Nursery Industry Environmental and Technical Research and Extension 2012/2013

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Nursery & Garden Industry Australia (NGIA)

Project Number: NY12001

NY12001

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Nursery & Garden Industry Australia

Final Report
HAL Project: NY12001
Completion Date: 31 August 2013

Nursery Industry Environmental and Technical Research and Extension 2012/2013

Project Leader: **Dr. Anthony Kachenko**
Nursery & Garden Industry Australia

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MEDIA SUMMARY

Project *NY12001 – Nursery Industry Environmental and Technical Research and Extension 2012/2013* provided the Australian nursery industry with the capacity to address several environmental and technical research and development issues that were aligned to the Nursery Industry Strategic Investment Plan 2012–2016. Each issue was developed through consultation with whole of industry which involved all State/Territory Associations, an industry needs assessment process and industry technical committees.

The national Environment Committee funded through this project met twice on 8 November 2012 and 6-7 June 2013 and provided technical input and strategic direction into this project as well as input on future research, development and extension opportunities for the Australian nursery industry.

The Industry Development Officer (IDO) network was an important contributor to this project in representing the Australian nursery industry at a regional level on key national environmental and technical issues such as biosecurity and quarantine. This ensured the nursery industry was adequately represented in key areas, namely biosecurity, that may have impacted on its long term sustainability.

Outcomes relating to this project included:

- Linkage with three university student projects that addressed key industry issues whilst educating tomorrow's future industry leaders.
- Development of six minor use permit applications to the Australian Pesticide and Veterinary Medicines Authority (APVMA) for industry access of key pesticides.
- Update of the National Plant Labelling Guidelines for clarity and technical correctness.
- Development of www.plantsafely.com.au to provide guidance to consumers on safe gardening practices.
- Consultation on the draft Australian Standard for Specifying Trees for Landscape use.
- Update of the Best Practice Manual for Pesticide Application in the Nursery and Garden Industry.
- Development of www.pestid.com.au to provide guidance on pest and disease management.
- A review of organic amendments in containerized plant production, to assess their utility to this sector.
- Development of video extension clips on how to undertake:
    - Import/End Point and In-line Inspections
    - Site Surveillance
    - Crop Monitoring
    - Vehicle Inspections
    - Water Testing

TECHNICAL SUMMARY

This project funds research, development and extension (RD&E) activities for the Australian nursery and garden industry (NGI). The direction of RD&E has been identified in the Nursery Industry 2010–2015 Strategic Plan, which has been used to develop this project.

Key areas of focus that were identified within the industry strategic plan relate to:

- the impact of climate change and drought/water shortages on markets
- biosecurity risks including biosecurity policies of state/territory governments that can severely impact on plant movements
- the risk of exotic plant pest incursions
- the lack of national standards for plant production.

As these issues are interconnected, a holistic approach where these issues are addressed under a single project is required. This approach has occurred for a number years under earlier projects (e.g.NY08002, NY09010, NY10005 and NY11000). To achieve this, several RD&E oriented sub-projects relating to these interconnected issues have been identified, discussed and included in this overarching RD&E project. Several tools were developed under this project including an online pest and disease ID tool.

As part of this project, a series of new extension resources focussed on visual modes of communication were developed. This comprised a series of short 'how to' video clips addressing fundamental aspects of nursery production in relation to Import/End Point/In-line Inspections, Site Surveillance, Crop Monitoring, Vehicle Inspections and Water Testing. An aspect of this project also synthesised international and national guidelines on specifying and growing trees and summarised the data into a draft Australian Standard for Specifying Trees for Landscape. Another aspect of this project investigated the current international availability and efficacies of organic amendments used in plant production and developed recommendations about their application in plant propagation, production and management for the Australian production nursery sector.

Six Industry Minor Use Permits for key agrochemicals were developed as part of this project providing growers with new and often safer chemistries that would otherwise be unavailable to industry. Another key aspect of this project was the development of collaborative RD&E projects with academic institutions across Australia to better leverage the capacity for the industry to invest in research projects. This also stimulates greater research, development and training opportunities for the industry and delivers key outcomes to whole of industry. Other objectives relating to this project included:

1. The operation of the National Environment Committee to provide the Australian NGI with the relevant leadership, support and guidance on key RD&E areas as identified within the Nursery Industry 2010–2015 Strategic Plan. The committee met twice on 8 November 2012 and 6-7 June 2013 during this project.
2. The update of National Plant Labelling Guidelines and development of a Plant Safely website (www.plantsafely.com.au) to ensure the industry's value and contribution to the public good is realised.

3. The adherence of NGIA to statutory obligations as a signatory to the Emergency Plant Pest Response Deed (EPPRD) including participation on emergency plant pest categorisation and consultative committees.

4. The representation of the Australian NGI at key meetings, forums and conferences to improve interaction with external stakeholders.

INTRODUCTION

In 2010, NGIA endorsed the Australian NGI Strategic Plan 2010-2015. In developing this plan, it was acknowledged that the Australian NGI was facing challenging times. The challenges, which are broadly-based across the production, supply and marketing chain, include the need to:

1. Increase the sales value of nursery products and services through marketing and promotion;
2. Enhance the capacity and efficiency of the industry's resources through upgrading industry skills, knowledge and practice;
3. Build industry support through shaping government, public and related industry understanding of the industry's benefits, and enhance these benefits through collaboration;
4. Invest in nursery product/service development to enable the industry to respond to growth opportunities and challenges; and
5. Support the industry through services and resources that enhance its capacity to respond to issues, capture opportunities and achieve the vision of this strategic plan.

These objectives do not occur in isolation and it is recognised that substantial change can only occur with effective communication, collaboration and co-investment all acting collectively. In particular, this is relevant to Research, Development and Extension (RD&E) and consequently, the Australian NGI has invested annually on activities to address key industry issues and challenges.

Historically, the industry has worked with the following agencies to facilitate RD&E activities:

- Horticulture Australia Limited (HAL)
- Australian Government
- government research providers from around Australia (Note – there is no lead agency for nursery RD&E identified in the National Horticultural Research Network, NHRN)
- private sector research providers
- Academia (through industry research linkages funded through the Nursery Levy)

Each of these agencies has a commitment and role to invest in, sponsor or conduct research that aligns with the Australian NGI Strategic Plan 2010-2015. In working with these agencies, the Australian NGI has maintained a proactive position when addressing key challenges through the development of on-farm best management programs (NIASA, EcoHort and BioSecure *HACCP*) that fall under the banner of Farm Management System. Other resources include technical nursery papers, training workshops, grower tools and resources (e.g. Nursery Footprint – Carbon Calculator).

Key areas of focus that are identified within the industry strategic plan relate to the impact of climate change and drought/water shortage on markets, biosecurity risks including biosecurity policies of state/territory governments that can severely impact on plant movement, the risk of exotic plant pest incursions and a lack of national standards for plant production. These aforementioned priority areas align with the National Rural Research and Development Priorities outlined by Department of Agriculture, Fisheries and Forestry (DAFF) and address the four objectives of the HAL Strategic Plan 2010–2015. Indeed, it is important to note that a prerequisite for co-investment is a shared vision between collaborators and this has been considered when developing this project and its individual sub-projects.

This project funds research, development and extension (RD&E) activities for the Australian nursery and garden industry (NGI) during 2012-2013. Key areas of focus that were identified within this plan and addressed by this project relate to:

- the impact of climate change and drought/water shortages on markets;
- biosecurity risks including biosecurity policies of state/territory governments that can severely impact on plant movements;
- the risk of exotic plant pest incursions;
- access to safe, reliable and efficacious pesticides to meet grower needs whilst being mindful of the environment; and
- the lack of national standards for plant production.

MATERIALS AND METHODS

Several environmental and technical research, development and extension (RD&E) sub projects were undertaken in this project. The approach followed has been detailed previously (see NY11000). This project builds on the work completed and reported on over the past 5 years under projects NY07006, NY08002, NY09010, NY10005 and NY11000.

The National Research and Market Development Manager (NY12014), formerly the National Environmental & Technical Policy Manager (NY10001) led this project with collaboration from the Regional Industry Development Officer (IDO) network (NY09010/NY12006).

The national Environment and Technical Committee operating as a sub-committee to the NGIA Board provided leadership and independent direction in addressing all components of this project. The Committee was tasked in evaluating current environmental and technical issues and monitored the future R&D direction of the Australian Industry in relation to the NGI 2010 – 2015 Strategic Plan and 2012-2016 Strategic Investment Plan. The Environment Committee consisted of 4 industry representatives and NGIA representatives (Dr Anthony Kachenko, Robert Prince, NGIA CEO and Chris O'Conner, NGIA Technical and Policy Officer). The committee was chaired by NGIA Board Director Simon Smith.

At the time of the report, the Committee had the following members:

- Simon Smith (Chairman), Managing Director, The Plantsmith Nursery, NGIA Board Member, , Northern Territory;
- John Bunker, Managing Director, Redlands Nursery Pty Ltd, Queensland;
- Steve Burdette, Business Development & Nursery Manager, Agriexchange, Renmark, South Australia; and
- Peter Douglas, Manager, Scotsburn Nurseries, Victoria.

This project funded two national Environment and Technical Committee meetings (8 November 2012 and 6-7 June 2013). A total of $10,000 was allocated to facilitate these meetings.

Each sub project was assessed following a rigorous and transparent process to ensure whole of industry had input into the industry RD&E direction (Appendix 1).

The skills and knowledge base of the regional IDO network was utilised through this project to assist with the extension of outcomes and to ensure industry was suitably represented at a national level. This ensured industry was represented with key environmental issues, most notably in the area of biosecurity. Where an IDO represented industry at an event (e.g. meetings, conferences, workshops etc.), a meeting report was submitted to the NETPM summarising the nature of the event, outputs arising from the event and future direction which were then circulated to all State and Territory Associations. A total of $20,000 was allocated to this project in order to cover conference/meeting attendance costs including travel and accommodation.

An additional $30,000 was allocated to Nursery & Garden Industry Queensland (NGIQ) to fund human resource support for the QLD Industry Development Manager (IDM) which recognised the added responsibility the Queensland IDM had in relation to maintaining the NGIs biosecurity commitments which includes attendance to all meetings associated with the Emergency Plant Pest Response Deed (EPPRD).

The remaining sub projects funded through this project are discussed below:

1. Update of the National Plant Labelling Guidelines and development of the 'Plant Safely' consumer website

This sub-project funded the printing and distribution costs associated with updating the National Plant Labelling Guidelines which were developed in 2007 to help the industry provide clear and accurate information on plant labels. The update included results from the Weed Risk Assessment Project and a general update on intellectual property. A new website was also developed (www.plantsafely.com.au) to provide guidance to consumers on safe gardening practices. Funds of $5,000 were allocated to cover the copy editing, layout and printing of the revised National Plant Labeling Guidelines. An additional $10,000 was allocated to develop the Plant Safely website.

2. Nursery and garden industry affiliate and research linkage program

This sub project funded several student research projects in Australian Universities to address key industry research issues whilst enhancing research linkages between industry and academia. Furthermore, this project also enhanced industry capacity for innovation and made a positive contribution towards the education of tomorrows industry professionals and leaders.

All projects funded through this sub project were developed in consultation with whole of industry. In addition, the relevant academic institution had to show progress of innovation relevant to industry needs in alignment with the NGI 2010 – 2015 Strategic Plan. This approach continued the direction of the NGI over the past four years where funds allocated to this project were used to exclusively support the costs associated with research overheads to enable successful fulfilment of the research objectives. This sub project was undertaken by three universities across Australia and valued at $60,000.

The following research projects were undertaken during this project:

1. **Living roofs for healthier living: Impacts of vegetated roofs on employee stress, engagement, well-being and performance** by Kate Lee, University of Melbourne. Kate is completing her PhD under the supervision of Dr Kathryn Williams.

2. **Climbing plant selection & green facades** by Annie Hunter-Block, University of Melbourne. Annie is completing her PhD in under the supervision of Dr Stephen Livesley. She is in her second year with this project having commenced under NY11000.

3. **Effect of vermicompost leachate on plant growth, nutrient uptake and microbial diversity in the rhizosphere** by Arian Moshefi, Faculty of Agriculture and Environment, The University of Sydney. Arian is completing his Honours degree under the supervision of Dr Rosalind Deaker.

In addition to these projects, NGIA undertook a mail out to 300 research bodies in December 2012 to promote the industry affiliate and research linkage program.

3. Development of an Australian Standard relating to tree production and specification

This project reviewed international and national guidelines on specifying and growing trees and summarised the data into a draft Australian Standard. This draft was submitted to Standards Australia in March 2012 and was approved to undergo further consultation and development in order to develop an Australian Standard for Specifying Trees for Landscape Use. A NGIA National Tree Standard Steering Committee (NNTSSC) has been developed to engage with industry and consolidate industry views to ensure consensus and balance in the development of the proposed Australian Standard. The function of the

NNTSSC was also to be used as a platform to commutate key outcomes of the NNTSSC to growers as and when required. Membership of the NNTSSC included:

- Alpine Nurseries
- Andreasen's Green Nurseries
- Benara Nurseries
- Flemings Nurseries
- Greenstock Nurseries
- Speciality Trees
- Warner's Nurseries
- Nationwide Trees

Members would also be 'advocates' of the proposed Australian Standard during the development. A total of $15,000 was allocated to this project in order to facilitate the NNTSSC meetings.

4. Review of current international availability and efficacies of organic amendments used in plant production

Dr Sally Stewart-Wade Consulting was contracted to undertake this review to investigate the current international availability and efficacy of organic amendments used in plant production. The project grouped the different types of organic amendments and documented research regarding their application in plant propagation, production and management, including their dosage and cost. Scientific research was summarised that relates to the various claims on the benefits to the production of horticultural plants. This enabled the assessment of their worth to the nursery and garden industry. A total of $15,000 was allocated to this project.

5. Online pesticide spray diary and best management practice (BMP) toolbox

Shane Holborn from BioScience Australia was contracted to update the content of the Best Practice Manual for Pesticide Application in the Nursery and Garden Industry for wider penetration with the production industry. A web resource including the updated guidelines and a pesticide spray diary will be created and housed on www.ngia.com.au. A total of $20,000 was allocated to this project.

6. Web based pest and disease management tool

The 'Integrated Pest Management in Ornamentals: Information Guide' and the pocket sized handbook 'Pests, Diseases, Disorders and Beneficial's in Ornamentals: Field Identification Guide' were converted to a SD card format in 2009. This sub-project funded the conversion of the current electronic tool into a web based information source accessible to industry via the internet. The resource provided a platform from which updates with new images/pests can be provided in a cost effective and real time manner. A total of $20,000 was allocated to this project.

7. A series of visual extension resources addressing key grower issues

NGIA contracted NGIQ to develop visual extension resources videos of key industry procedures to support raise awareness of on farm biosecurity measures and key procedures associated with BioSecure *HACCP*.

Each of these resources was developed in digital high resolution and loaded onto YouTube for industry uptake and use.

A total of $60,000 was allocated to this project in order to cover filming, voiceover and editing of each video.

8. Provide access to six Minor Use Permits (MUP) for industry

This sub project invested in the development of six MUP following consultation with growers for priority products that were submitted to Australian Pesticide and Veterinary Medicines Authority (APVMA) under the MUP program for nursery stock. This sub project has been in operation for the past four years to enable the registration of MUP required by the NGI with APVMA. A total of $20,000 was allocated to this project to facilitate this process. The following products were submitted to APVMA as part of this sub project by Peter Del Santo, AgAware consulting.

Permit ID	Description
PER12543	Movento (spirotetramat) / Nursery stock (non food) / Aphids, scale insects and whitefly
PER13382	Durivo (chlorantraniliprole + thiamethoxam) / Nursery Stock (non-food) / Diamond Black Moth, Cabbage White Butterfly, Heliothis, Loopers, Leafhoppers, Aphids, Thrips & Whitefly
PER13459	Aero (metiram + pyraclostrobin) / Nursery stock / Alternaria, Phytophthora, Colletotrichum, Powdery mildew & Downy mildew
PER13942	Suscon Maxi Insecticide (imidacloprid) / Nursery stock / Various insects
PER13953	Confidor 200 SC (imidacloprid) / Propagation Nursery Stock / Silverleaf Whitefly
PER14225	Copper oxychloride, Mancozeb & Triforine / Ornamentals & Non-fruit bearing plants of the Myrtaceae family / Myrtle rust

RESULTS AND DISCUSSION

The Environment and Technical Committee met on 8 November 2012 and 6-7 June 2013. The minutes arising from these meetings were circulated to whole of industry through the IDO network and State/Territory Associations to enable awareness of key issues discussed. A copy of the minutes from both meetings is provided in Appendix 2.

During May/June 2013, HAL and NGIA tendered for Preliminary R&D Proposals for new research concepts, ideas and technologies to meet the priorities listed in the Nursery & Garden Industry Strategic Investment Plan (SIP) 2012-2016. This process was introduced in order to cast a wider net to engage with researchers from across Australasia in order to address industry needs. This approach was also instigated to address the current ad hoc and opportunistic investment in nursery industry R&D.

An Expression of Interest (EOI) calling for Preliminary R&D Proposals was placed in the Tender section of the Weekend Australia (18/19 May; Appendix 3) and on the Horticulture Australia Website. The EOI was open from 18 May to 14 June. A total of 24 Preliminary Proposals were received during this period. These have been reviewed by HAL and NGIA with 6 encouraged to submit a more detailed project in November 2013. A schedule outlining this process is presented in Appendix 1.

During the reporting period, Grant Dalwood (South Australian IDO) joined the National Viticulture Biosecurity Committee on behalf of industry. The first meeting was held on 1 February 2013. A copy of the meeting report is provided as Appendix4. There were no meetings that required Industry Development Officer (IDO) representation on key industry environmental and technical issues.

The Australian nursery industry was represented by John McDonald (Queensland IDO responsible for biosecurity) through his involvement on all Consultative Committee on Emergency Plant Pests and Emergency Plant Pest Categorisation Group Meetings. A total of 221.5 hours were spent on these activities. During the reporting period, John also participated in 'Exercise Tortrix' which was a simulation covering the early stages of an emergency plant pest response for false codling moth. This process was proven to be a beneficial drill in disaster response management and risk mitigation for all parties involved. The nursery industry also released Version 3 of the Industry Biosecurity Plan for the Nursery Industry. This plan provides a framework to coordinate biosecurity activities and investment for Australia's nursery and garden industry. It also provides a mechanism for industry, governments and stakeholders to better prepare for and respond to, incursions of pests that could have significant impacts on the nursery and garden industry. A copy is available through the NGIA website.

1. Update of the National Plant Labelling Guidelines and development of the 'Plant Safely' consumer website

After an extensive consultation process with industry, Version 2 of the National Plant Labelling Guidelines was developed. A copy of these is provided as Appendix 4.

Key changes in Version 2 include;

- An updated explanation of PBR and trademark use;
- Revised warnings for plants which pose potential health risks;
- A revised list of plants potentially harmful to health ;
- Changes to the recommended wording for plants with weed potential;

- An updated list of references and links ; and
- Inclusion of information on barcode compliance with GS1.

A copy of these guidelines is also available on the NGIA website. A mail out to NGIA members was completed during March 2013.

The Plant Safety website www.plantsafety.com.au accompanies these guidelines to educate consumers about gardening safely. This resource provides useful resources including reference to a variety of existing levy funded resources such as Grow Me Instead as well as positive information on the benefits of green life linking through to Plant/Life Balance and levy funded research.

2. Nursery and garden industry affiliate and research linkage program

Three research projects were undertaken across Australian universities and research institutions during this project. Each project was developed in consultation with the NGI and the relevant academic institution and coordinated through the NETPM. Each project had to show progress of innovation relevant to industry needs in alignment with the NGI 2010 – 2015 Strategic Plan. The following projects were successfully commissioned:

1. **Living roofs for healthier living: Impacts of vegetated roofs on employee stress, engagement, well-being and performance** by Kate Lee, University of Melbourne. Kate is completing her PhD under the supervision of Dr Kathryn Williams. Expected project completion of December 2013.
2. **Climbing plant selection & green facades** by Annie Hunter-Block, University of Melbourne. Annie is completing her PhD in under the supervision of Dr Stephen Livesley. She is in her second year with this project having commenced under NY11000. Expected project completion of August 2015.
3. **Effect of vermicompost leachate on plant growth, nutrient uptake and microbial diversity in the rhizosphere** by Arian Moshefi, Faculty of Agriculture and Environment, The University of Sydney. Arian is completing his Honours degree under the supervision of Dr Rosalind Deaker. Expected project completion of December 2013.

Each of these reports will be developed into Posters for presentation at the 2014 Nursery & Garden Industry conference in Sydney.

3. Development of an Australian Standard relating to tree production and specification

A proposal submitted to Standards Australia in March 2012 was approved for the development of a proposed Australian Standard for Specifying Trees. Kylie Goodwin from Standards Australia was allocated as project manager. An industry NGIA National Tree Standard Steering Committee (NNTSSC) was developed to engage with industry and consolidate industry views to ensure consensus and balance in the development of the proposed Australian Standard for Specifying Trees. The function of the NNTSSC was also to be used as a platform to commutate key outcomes of the NNTSSC to growers as and when required. Members would also be 'advocates' of the proposed Australian Standard during the development.

NGIA is drafting the proposed Australia Standard through Standards Australia Committee EV-018 – Arboriculture, the same committee involved in the publication of "Protection of trees on construction sites". The first meeting of EV-018 was held on 14 March in Sydney. The drafting phase is complete with the proposed Australian Standard moving to public consultation in late September to late November 2013. The next EV-018 – Arboriculture meeting is scheduled for Thursday 5 December in Sydney.

4. Review of current international availability and efficacies of organic amendments used in plant production

A literature review was completed that collated the scientific literature on the use of organic amendments in containerized plant production, to assess their utility to this sector. The main organic amendments that were reviewed were: composts, based on plant residues, animal manures and municipal and industrial waste material; compost teas (aerated and non-aerated); meat, blood and bone meals; fish emulsions; seaweed extracts; organic waste materials (uncomposted); bioinoculants including mycorrhiza and plant growth-promoting bacteria; biochar; vermicomposts (solids and liquid teas); humic extracts; uncomposted plant parts; and amino acids and organic acids. Their efficacy was evaluated; their benefits and drawbacks discussed; their approximate costs outlined, their application rates considered and their practical relevance examined. The following recommendations were developed based on the review of the literature:

1. Evaluate the efficacy and optimal application rate of emerging organic amendments for containerized production

2. Evaluate the shelf life of organic amendments

3. Determine the optimal base level nutritional benchmarks for all nursery crops.

4. Match nutrient charting and responsive fertilizer applications to nutrient release from organic amendments

5. Investigate using blends and sequential application of organic amendments matched to crop requirements.

A copy of the review is provided as Appendix 5.

5. Online pesticide spray diary and best management practice (BMP) toolbox

The Best Practice Manual for Pesticide Application in the Nursery and Garden Industry was updated. Key elements updated included reference to new national work, health and safety legislations and reference to new technologies and innovations within horticulture. A final draft of the Best Practice Manual is provided as Appendix 6. The document will be housed on the NGIA website.

6. Web based pest and disease management tool

The web based pest and disease tool provides a paid subscription service to a secure website area that allows users to search for and read information on pests and diseases. The website allows a large and growing resource of information to be made available to members of the public. Searching for and viewing information on pests, maintaining the pest data, purchasing a subscription to a secure area of the website and maintaining the subscriptions and pricing information are key components of the website. The website is hosted through Zang IT and available at www.pestid.com.au.

7. A series of visual extension resources addressing key grower issues

Videos developed included how to undertake:

1. Import Inspections

2. End Point Despatch Inspections

3. In-line Despatch Inspections

4. Site Surveillance
5. Crop Monitoring
6. Vehicle Inspections
7. Water Testing

These videos will be housed on the NGIA website.

8. Provide access to six Minor Use Permits (MUP) for industry

Six MUPs were lodged with APVMA. The following permit was issued:

Permit ID	Description	Date Issued	Expiry Date	Permit holder
PER12543	Movento (spirotetramat) / Nursery stock (non food) / Aphids, scale insects and whitefly	28-Jun-13	31-May-15	NGIA / AgAware
PER13382	Durivo (chlorantraniliprole + thiamethoxam) / Nursery Stock (non-food) / Diamond Black Moth, Cabbage White Butterfly, Heliothis, Loopers, Leafhoppers, Aphids, Thrips & Whitefly	28-Aug-12	31-May-15	NGIA / AgAware
PER13459	Aero (metiram + pyraclostrobin) / Nursery stock / Alternaria, Phytophthora, Colletotrichum, Powdery mildew & Downy mildew	14-May-13	31-May-15	NGIA / AgAware
PER13942	Suscon Maxi Insecticide (imidacloprid) / Nursery stock / Various insects	05-Feb-13	31-May-15	NGIA / AgAware
PER13953	Confidor 200 SC (imidacloprid) / Propagation Nursery Stock / Silverleaf Whitefly	01-Mar-13	31-May-15	NGIA / AgAware
PER14225	Copper oxychloride, Mancozeb & Triforine / Ornamentals & Non-fruit bearing plants of the Myrtaceae family / Myrtle rust	28-Jun-13	30-Sep-18	NGIA / AgAware

Copies of these permits are provided in Appendix 7.

TECHNOLOGY TRANSFER

Two considerations were critical to the success of this project. Firstly, this project was developed following full consultation with the nursery industry utilising an industry needs assessment ranking process combined with skilled committee input. Secondly, all projects were aligned to the Nursery & Garden Industry Strategic Investment Plan (SIP) 2012-2016.

NGIA with State/Territory Associations will be tasked in communicating the outputs of this project to whole of industry. The IDO network will be instrumental in this process through on farm extension of outputs as well as authoring technical Nursery Papers and articled for industry publications.

This Final Project report will be available through the NGIA National Research & Development Database. Currently, 355 Final Project Reports available for download through this database. NGIA communications including NGIA website (www.ngia.com.au), NGIA Facebook page (http://www.facebook.com/nurseryandgardenindustry) and Blog (http://yourlevyatwork.com.au) will also be utilised to further communicate this project outputs to industry and relevant stakeholders.

All resources are available from the NGIA website including copies of the National Plant Labelling Guidelines. The Plant Safety website can be accessed at www.plantsafety.com.au and the Pest and Disease Management Tool can be accessed at www.pestid.com.au. When the proposed Australian Standard for Specifying Trees is completed, it will be available to purchase from SAI Global.

The Minor Use Permits are available on the Australian Pesticides and Veterinary Medicines Authority website (www.apvma.gov.au).

RECOMMENDATIONS

The success of this project is attributed to its holistic nature in bringing together various sub projects that are related to address key industry issues. This approach should continue in the development of future research, development and extension projects. Industry consultation through NGIA, State/Territory Associations and technical committees is desirable to ensure sufficient input into priority research, development and extension areas.

Future projects should consider the appropriateness of including IDO representation as this sub project is more closely aligned with NY12006.

Projects including industry affiliate and research linkage program, minor use provision program and biosecurity commitments should continue as core programs in future research and development activities undertaken by the Australian nursery industry. These projects provide industry with enhanced capacity on all three fronts.

Communication of project outputs will be fundamental in the next phase of this project. A variety of tools will be used to ensure outputs from this project are adopted widely across industry.

APPENDICES

The following appendices relate to the outcomes of the project:

1 Nursery industry RD&E planning schedule.

2 Minutes of NGIA Environmental Committee meetings held 8 November 2012 and 6-7 June 2013.

3 Expression of Interest (EOI) calling for Preliminary R&D Proposals.

4 Version 2 of the National Plant Labelling Guidelines.

5 Review of current international availability and efficacies of organic amendments used in plant production.

6 Best Practice Manual for Pesticide Application in the Nursery and Garden Industry.

7 Minor Use Permits.

Appendix 1

2012/13 Research, Developments and Extension Project Schedule

Date	Item	Purpose	Responsibility
January 2011 – 8/8/2011	State SNAC or Environment & Technical Committee meetings	Monitor, discuss and plan RD&E needs relevant to whole NGI	State SNAC or Environment & Technical Committees
11/8/2011	State RD&E proposals submitted to NGIA	Provide State NGIs with input into national RD&E direction	IDOs to submit State RD&E proposals to NETPM
Late August 2011	IAC meeting	Define Industry priorities, and future RD&E direction in alignment with NGI Strategic Plan	Outcomes from IAC relayed to NETPM and State CEO'S/Board
1/9/2011	A summary RD&E proposals to be forwarded to IDO network for evaluation by SNAC or State Environment & Technical Committee	Provide State NGI with input into national RD&E direction in line with NGI Strategic Plan	NETPM to circulate list of RD&E proposals to IDO network
29/9/2011	IDO network to rank all proposals based on urgency, importance, impact and success	Provide State NGI with input into national RD&E direction in line with NGI Strategic Plan	IDOs to submit State RD&E rankings to NETPM
1/10/2011	Evaluation of RD&E proposals submitted to NGIA	Ranked RD&E proposals highlight key RD&E priorities for Industry	NETPM to synthesis rankings
Mid October	Combined Board/Presidents/ CEOs meeting	Present RD&E priorities for future Industry levy investment	NETPM
3/11/2011	National Environment & Technical Committee meeting	Evaluate ranked proposals and ascertain if gaps exist in RD&E direction	National Environment & Technical Committee
16/11/2011	National RD&E projects submitted to HAL by NETPM	HAL evaluate National RD&E projects and make recommendations to IAC	NETPM/HAL
February 2012	IAC planning meeting	IAC evaluate and approve/reject National RD&E projects	IAC
July 2012	***Approved RD&E projects commence and communicated to whole of industry by NETPM***		

RD&E – Research, Development and Extension
IDO – Industry Development Officer
SNAC – State NIASA Advisor Committee
NETPM – National Environment & Technical Policy Manager
HAL – Horticulture Australia Limited
IAC – Industry Advisory Committee

Industry Call for RD&E projects in 2012/13

How to develop a proposal

Introduction

The goal of a research proposal is to show that the problem/issue proposed for possible investigation is significant enough to warrant the investigation. Is the method suitable and feasible, and are the results likely to prove fruitful for Industry? Will this proposal make an original contribution?

When developing proposals, make sure you consider the following:

1. Are outcomes clearly defined?
2. Are benefits to whole of industry adequately identified?
3. Is there existing research that can address this need?
4. Does this proposal address *market failure* adequately?
5. Is the method adequately defined?
6. Has a budget and time frame been proposed?
7. Linkages identified with NGI 2010-2015 Strategic Plan?

What is market failure?

Market Failure: Market failure applies where industries cannot adequately appropriate the benefits of research funding. The matching funds mechanism that HAL provides in the case of Voluntary Contributions, applies to an area of research where there is insufficient incentive for funding. This may arise from:

- no clearly identified alternate source of funds,
- significant obstacles in place restricting access to alternate research funds,
- a prolonged period of return on investment anticipated.

What is an R&D project?

R&D Project: the systematic experimentation or analysis in any field of science, technology, economics or business carried out with the object of acquiring knowledge that may be of use for the purpose of improving any aspect of the production, processing, storage, transport or marketing of horticultural products or applying knowledge for the purpose of improving any aspect of the production, processing, storage, transport or marketing of horticultural products.

Define the issues

A successful proposal begins by clearly and succinctly stating the purpose of the study. That is, what is the key research question being asked? The research question(s) is expressed in terms of the broader context of the study.

For example:

1. To quantify the impact of an Emissions Trading Scheme

2. Evaluate the presence of agrochemicals in irrigation water

It is important to establish a context for this intended research and demonstrate the need for it. A key question to ask yourself when developing a research proposal is ***DO you want to know or do you NEED to know?***

******Why does it matter? To whom? What use will it be?******

Novel issues that have not been previously researched or require further research to benefit whole of Industry are sought. **It's important to note that Levy Investment does not support commercial research by individual companies. In other words, the project must address *Market Failure.***

If you are well advanced in your thinking about the issue, you could speculate on possible outcomes of your research and their significance (see below).

Background

The aim of the background is to show that the proposed research will meet the ***need***. In other words, it is important to provide background information relating to the research question being asked. This may include reference to a 'gap' in the research literature, to the need for Levy investment in this study of the significance of this topic to Industry.

This is not expected to be extensive for the proposal. Essentially a few sentences are sufficient detail to justify the need for the research. It is important to shape the background around the argument for your proposal.

For example:

The imminent introduction of an Emissions Trading Scheme (ETS) is likely to impact on the sustainability of the Australian nursery Industry. An ETS is anticipated to have a significant economic impact on growers including a rise in inputs such as fuel, fertilizer and energy. Data is required to determine the financial burden growers will face with the introduction of an ETS. This project will require an economist for a period of 9 months for successful completion of this project. A tentative budget of $75,000 is required.

Does the proposal reflect Industry?

It is important that each proposal remains objective i.e. the use of 'I' or 'in my view' does not reflect objectivity and the needs for Industry.

Outcomes

When developing a proposal, it is important to focus on and take an approach of critical inquiry. It is also important to consider what will this proposal mean for Industry or the broader community? Consideration should also be given with regards to the likelihood of achieving a desirable outcome for Industry.

External Agencies (i.e. Universities)

Industry supports collaboration with state and federal research agencies; however it is important that the collaboration is mutually beneficial. External agencies do have a tendency of promoting their own agenda and in some cases, their agenda has little or no relevance to Industry. When discussing proposals with external agencies make sure you revert back to ***DO you want to know or do you NEED to know?***

It's also important that any conflict of interest is communicated in the development of the proposal.

Is the proposal achievable?

In developing a proposal, some consideration should be granted to the likelihood of addressing the research question. Is there an external agency that is resourced to facilitate the research? More often that not, a timeframe of 12 months is granted for the research to ensure outcomes are promptly made available to Industry. However, larger projects can be continued for a further 12 or 24 months pending the outcomes and 'gaps' in knowledge from the initial proposal.

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29-Aug-13

Appendix 2

MINUTES

Nursery & Garden Industry Australia

Environment and Technical Committee Meeting

Date:	Thursday 08 November 2012
Time:	9.30 am – 12.30 pm
Location:	NGIA Office, Unit 58, Quantum Corporate Park, 5 Gladstone Road, Castle Hill 2153
Attendees	Simon Smith (Chair), John Bunker, Steve Burdette, Robert Prince, Anthony Kachenko, Chris O'Connor
Apologies	

ITEM TOPIC

1 WELCOME AND APOLOGIES

S Smith opened the meeting at 0930am via teleconference. A Kachenko noted that S Burdette would be late as he was in transit and may need to put in as an apology. If needed, A Kachenko can brief S Burdette in relation to meeting outcomes. R Prince would be late in joining the meeting due to meetings with external agencies in the lead up to project submissions to HAL.

2 CONFIRMATION OF MINUTES – 28 JUNE 2012

S Smith asked the committee if there were any issues with the tabled minutes of 28 June 2012.

J Bunker asked if there was an issue with quorum. A Kachenko noted that there was no formal meeting procedure with quorum, noting that the committee is not a voting committee and that there were representatives from industry with NGIA as ex offico.

It was resolved that the minutes of the Environmental Meeting of 28 June 2012 be accepted.

Moved by J Bunker, seconded by S Smith. Carried unanimously

3 MATTERS ARISING FROM LAST MEETING

S Smith asked A Kachenko to review the action list from the last meeting. A Kachenko said that all action items were completed with the exception of the state of the industry report.

A Kachenko added that with the current market research project it may not be wise to bombard industry with survey requests. A Kachenko also said the Market Data report may cover more detail than the State of Industry Report.

A Kachenko advised that this action point will be kept on the Action list until an opportunity arises to reinitiate it.

ITEM	TOPIC

Further discussion regarding the action items and other general items:

A Kachenko noted that he would look at options for teleconference and venue locations for future meetings.

A Kachenko then noted that one item that was on the list for a while was investigating contacts in the mining industry and the possibility of sourcing funds. He noted that contacts for minerals council supplied by J Bunker had unfortunately stalled. A Kachenko also investigated contacts through the CRC for Contaminant Assessment and Remediation of the Environment and BHP. These proved to be fruitless, as they had grants and own projects, thought they did support the industry position. A Kachenko asked for direction if he was to leave this or continue working on these contacts.

S Smith noted that the key players in the mining industry should be kept in the loop as there may be opportunities in the future relating to carbon farming.

A Kachenko noted that this could be an area to promote iTree, and reengage with them. At the time of discussion with these parties the software was not ready for Australia wide application.

S Smith noted that there may be options through NUFA and via partnerships noting the potential for valuing re-forestry around mine sites. J Bunker suggested partnering with service providers doing on site environmental assessments, for sites such as mining, rail corridor easements or gas pipelines.

R Prince joined meeting at 0940 am.

S Smith noted that Melioidosis was something that should be discussed in the risk matrix noting that one of their growers did have it but was cleared.

A Kachenko noted that the details of major political parties' biosecurity policies summary have not been sent to the committee. A Kachenko noted that there may be opportunities to put message forward especially on urban forest and biosecurity front in the lead up to the 2013 Federal Election.

J Bunker noted that it is vital to build relationships with all government and opposition groups noting the recent change in government in QLD. J Bunker noted that in QLD there is a big focus on food producers which fails to identify with the nursery industry with supplying the starter plant material. J Bunker advised that he has been appointed to an industry development committee for DAFFQ which is again now a standalone ministry. J Bunker said that one of the aims of the Government is to double food production by 2050 and that there is a horticultural employment category looking at training opportunities and streamlining the seasonal workforce.

R Prince stated that at a recent meeting that Growcom noted that getting people to training was difficult following workshops on cyclone training in key horticultural areas that suffered from Yasi/Larry.

S Smith asked the question if we have an issue being aligned to Lifestyle horticulture in QLD. J Bunker replied what is Lifestyle horticulture and commented on the size of the industry, noting that in this light he is from nursery production rather than lifestyle horticulture. S Smith stated it would be interesting to look at what tonnage of food is produced via home gardens?

S Smith noted that we need to keep government & opposition abreast of developments in our industry and lobby both groups. J Bunker noted the history of positive relationships in previous years with government aided them and that this is vital in all states in order to keep relevant.

R Prince noted that as we represent industry we need to be aware of our stance with both political parties. J Bunker agreed noting that regardless if there will be a change or not we should embrace both sides at all times and keep relationships strong wether we agree with them or not.

A Kachenko noted that at the next meeting we should be fully aware of the policy directions of all Federal parties and provide an update on what we have done to ensure they are aware of the NGI issues.

S Smith suggested sending out a précis of key parties' policy to members, but noted that any information sent to growers should be apolitical and the facts must be correct.

R Prince stated that whilst political parties may change, the bureaucrats remain and these are the ones that provide input into policy and can filter information through to the ministers who control funding.

S Smith asked A Kachenko about carbon farming.

A Kachenko reported that case studies are being collected to demonstrate to Canberra the depth and benefits of the iTree tool. A Kachenko advised that he is in the process of arranging a meeting with Arboriculture Australia in Canberra, which will probably be in the New Year.

R Prince noted that response back from Government (Department of Climate Change) is that trees in the Urban Environment were aesthetic; hence the reason to obtain case study information, compared to forestry is vital – mono culture.

J Bunker asked about a replacement environment committee member. A Kachenko replied that he had approached Daniel Mansfield, but he declined due to time limitations. Daniel appreciated offer.

A Kachenko asked these committee members whom they would recommend as a suitable replacement.

S Smith called for nominations to go out to states seconded by J Bunker.

ACTION: A Kachenko will forward a copy of the major political parties policies to (who), including an update for next Environmental meeting on what NGIA have done to inform key political parties on issues/ideas and success in policy that will benefit the NGI.

ACTION: A Kachenko to keep mining industry key players abreast of developments regarding itree/urban reforestation.

ACTION: A Kachenko will approach the State and Territory Associations for nominations for a replacement member of the Environment committee.

4 MATTERS ARISING NOT ADDRESSED IN AGENDA

A Kachenko noted briefed the meeting on two external grants that he will be applying for;

1. Australian Research Council (ARC) linkage grant with Melbourne University to further Urban Forest knowledge, specifically water hydrology of street trees and links with urban tree sensitive design. Submissions are due by the end of November 2012. R Prince added that Top funding provided to PhD students in this investigation would need to be unmatched funding.
2. The second grant is through the Federal Department of Climate Change, investigating the extensions of resources to Not for Profit Associations who are looking at energy saving and reducing inputs and minimising footprints. Proposals are due 20 December 2012. Advice regarding the success of the project will be received in May 2013. The project would commence in late 2013.

J Bunker and S Smith expressed agreement with these submissions.

J Bunker asked for an update on the biosecurity levy.

R Prince replied that grower meetings have been conducted and reported that the voting overwhelmingly supported the levy and PHA membership fees. R Prince indicated that an application for these new levies will be submitted to DAFF in the coming two weeks and should be in effect by June 2013. R Prince also added that there may be a review of the levy by a new government.

S Smith discussed alternative levy components addressing volumetric measurements of pots and potting media usage.

R Prince said that in relation to this committee, something that may be investigated in future is harmonisation of inputs, similar to the Dutch system where pots, media, transport etc. are harmonised to drive cost out of the industry.

S Smith said that he would like to see a project advanced, in the area of harmonisation, of anything in common usage.

R Prince said regarding transport, as smaller companies fail, customers will dictate transport terms e.g. Bunnings and Masters. J Bunker discussed the use of standard shipping pallets and trollies.

A Kachenko said that harmonisation may be addressed via the national tree specifications standard which has yet to commence as he is awaiting confirmation from Standards Australia.

5 NATIONAL ENVIRONMENTAL PROJECT UPDATE

5.1 SUMMARY AND STATUS OF CURRENT GOVERNMENT ENQUIRIES

A Kachenko advised that regarding industry's response to the federal biosecurity legislation (The Act), there were three key areas for comment;

1. Opportunity for recourse for importers
2. Process of risk assessment not having independent scrutiny
3. Powers assigned to the Inspector General of biosecurity

R Prince said that this legislation will be actioned before Christmas with a view to this becoming law in February 2013.

It has to be remembered that there will be an opportunity to provide comment on the regulations but no further comment will be taken on The Act.

R Prince added that the agreed arrangements component of the act could allow major retailers an opportunity to establish supply chain arrangements with Asia. He cited the cut flower industry and highlighted government to government applications.

A Kachenko said that the regulations will have an important part to play, but could also have a positive influence on domestic market access issues.

J Bunker asked about a risk matrix for importers. R Prince said there is a risk matrix which is influenced by locations sourced diseases and end market use and noted company's use of moving product to alternate countries.

He said that DAFF quarantine has moved to a user pays system for imports and has consolidated their operations to central location in Melbourne.

A Kachenko said DAFF is looking at full cost recovery for its operations and this includes items which should be considered to be in the public good i.e. ancillary staff office space in

Canberra etc. A Kachenko indicated that he will attend a forum to provide input into DAFF's cost recovery guidelines on 15 November.

A Kachenko noted increased fees for export over the years and what impact this will have on imports. J Bunker said that there is potential for export, but fees are uneconomic. This was supported by R Prince who also noted value of Australian dollar and the impact it has on export.

A Kachenko then discussed the voluntary code on Chemical Security through by the Attorney General's Department.

The voluntary code is currently being drafted and said that this code is a watering down version of the original intent. There are a number of chemicals used in our industry that would be affected. He also said that this voluntary code should be available for release by July 2013. Once released A Kachenko will communicate with industry. R Prince said that the chemicals listed are wide ranging and if this code was mandatory it would have implications for industry, however indicated that some aspects are covered through NIASA and Chemcert requirements. S Smith said that this code may also lend credence to alternative chemicals that do not have a terrorism risk.

5.2 RIRDC WEEDS RISK ASSESSMENT PROJECT UPDATE

A Kachenko presented at the recent Australasian Weeds Conference where positive feedback for industry was received. A Kachenko said that the RIRDC weed risk assessment tool should be finished for launch in January 2013. A launch at MIFGS will also be considered.

A Kachenko said that if RIRDC weed risk assessment tool is finalised by January 2013, he would liaise with NGIV and the Hort. Media Association for an opportunity to launch at MIFGS.

5.3 URBAN FOREST

A Kachenko said that he will be presenting more trees please, key messages about the importance of urban forest, the iTREE tool & National Urban Forest Alliance (NUFA) at the upcoming Thriving Neighbourhood's conference.

He said that NGIA had maintained activity with articles on urban forest with various industry publications.

He indicated that the NUFA draft business plan was provided and some of this had been incorporated into a project proposal for submission to HAL. A Kachenko asked for feedback on these issues. S Smith and J Bunker noted that this was very comprehensive and well done.

A Kachenko needs to discuss carbon framing initiatives and next steps for iTREE after the rollout of training with Craig Hallam. Approximately 150 people attended itree training workshops nationally.

J Bunker suggested speaking with the Planning Institute of Australia is important as this will help to pick up all three tiers of Government.

ACTION: A Kachenko to approach Planning Institute of Australia regarding the iTREE tool and the importance of the urban forest.

ACTION: A Kachenko will maintain dialogue with Standards Australia regarding National Tree standards.

5.4 NURSERY PRODUCTION FMS UPDATE

A Kachenko provided an operating plan for FMS which is a $125,000 project split into nine key strategies. There will be a meeting on 09 December 2012 to review the plan. S Smith noticed a mistake in the budget figures. A Kachenko will amend the error. The induction tool box should be $10,000 not $20,000.

A Kachenko advised that a guide has been developed for induction of IDOs and strategies are on target. A Kachenko also said that funding will be half the current value over 2 years, based on feedback of the current strategic investment plan (SIP) however suggested that impact of this will be low due to tools having been established with the bulk of funding to maintain governance and key growth with markets.

6 OPERATIONAL ISSUES

6.1 REVIEW OF R&D 12/13 ANNUAL OPERATING PLAN

A Kachenko updated the committee on the Annual Operating Plan for the 2012/2013 Environment and Technical Policy and Extension.

Projects under strategy 3 will commence in the New Year.

A Kachenko indicated that all projects under strategy 4 were underway. He noted that one PhD project was currently funded through University of Melbourne investigating green facades. A Kachenko indicated that he would draft a flyer to send out to universities to advise them of opportunities for funding and research work with industry in early January.

S Smith asked where the budget allocation for travel will be used. Meetings by Skype will amount to this saving of funds. A Kachenko replied that unspent funds could be used to top up other areas of projects or those funds if they remain unspent would be returned to HAL, R Prince also said that a variance to the contract will have to be done. R Prince suggested that relevant researchers could be asked to present at environmental meetings. The meeting attendees agreed this was a good opportunity. J Bunker told the committee of an idea being floated regarding international grouping of chemical producers to ensure volumes of product and how this could be used in relation to minor use permits.

ACTION: A Kachenko to look at ideas for presenters for the next meeting.

ACTION: A Kachenko to draft a flyer to training institutes advertising the University Linkage Program.

ACTION: J Bunker to forward to committee details on production international region groups in relation to minor use permits.

6.2 PLANT LABEL GUIDELINES

C O'Connor provided an update on the progress of the Plant Label Guidelines. It is anticipated that this guideline, after legal review, will be disseminated by the end of November 2012.

S Burdette joined the meeting at 11.25 am.

7 RESEARCH PROPOSALS AND OPPORTUNITIES

7.1 Review of projects for submission to HAL

A Kachenko advised the committee that due to time constrictions, submissions for projects to HAL had already been ritten based upon submissions and recommendations from the IDO network. A Kachenko updated the committee on the inclusions of project NY13003 'Environmental and Technical Research, Development and Extension'. There were several projects that ranked in the top ten projects that were not included as they were being submitted by a third party (e.g. Myrtle Rust Liaison Officer) or they were not addressing a market failure (e.g. Occupational Health and Safety). All other top ten projects had been written into NY13003 for review including; 1 – water disinfection treatment comparisons; 2- crop monitoring and surveillance methodologies across different cropping systems; 3 - waste audit and gap analysis of Australian production nurseries. A Kachenko indicated that the IAC will review these in February 2013.

A Kachenko asked the committee for feedback or input on the submissions.

S Smith had no concerns with NY13003. J Bunker liked the approach seeking feedback from around the country. J Bunker asked about the researchers involved in these projects. A Kachenko said that with the closure of Redlands other options for research providers will have to be investigated. Those options could include Government departments, Private laboratories and Universities.

There was general discussion regarding the process of project selection and the need for the projects to address market failures.

In relation to the crop monitoring project, industry has to develop an agreed methodology or accept the current government methods, which may not be adequate.

J Bunker added that the standardisation from industry to inspectors would be good to have, as there is variability between inspectors.

R Prince briefly discussed the process of selecting research proposals, with A. Kachenko noting that there are limited ideas being put forward but the ideas selected would return the most value to industry as well.

S Burdette advised that he was comfortable with the process and the project submissions.

J Bunker asked that at the next meeting there should be time set aside to look at future issues, with a view to future proofing the industry. A Kachenko advised that the next meeting will be a larger meeting. Planning for the future and options for presenter presentations by allied researchers should allow a more robust discussion.

R Prince said there will be an approach to the state committees with a view to looking at some blue sky projects noting options for automation. J Bunker agreed that here may be some gaps where we can build our knowledge. J Bunker asked for confirmation on the committee name – is it Environment or Technical and Environment? R Prince advised that the committee covers both areas. S Smith said the committee should be Environment and Technical.

ACTION: A Kachenko to formalise the committee name to Environment and Technical

A Kachenko discussed project NY13002 which relates to the urban forest alliance. He discussed the inclusion of a report, based upon the top 20 key cities in Australia ranking their canopy cover, with a view to playing city against city. Also included were facilitation costs for training for iTree. S Smith said it is a strong project and is comfortable with the city vs. city angle.

J Bunker asked if there was IP on iTree. A Kachenko replied that there is no IP as the tool was developed by the US Government and is freely accessible.

All meeting attendees were in agreement with the project.

A Kachenko discussed the study tour project proposal, with the view to the project's investigation of the urban forest and extension science in the US. Links to include the key drivers of the urban forest, policy and linking in with regulators, how iTree is used in the US, successes and failures and linking in with extension research facilities in the states.

S Smith asked who would be included in the tour and how they would be chosen. A Kachenko said that would be industry levy payers and at this stage he is unsure but would perhaps be by ballot, including an NGIA representative, a Board Director and IAC representative and those driving this area or emerging young leaders in the industry. J Bunker asked about levy funding figures. R Prince replied that levy funds are down by 7-8%. J Bunker asked if this would mean there may be prioritisation or cuts to projects. R Prince said this is a possibility. S Smith said the situation would have to be monitored.

7.2 Environmental Risk Matrix

Updates to the matrix were discussed. S Smith advised that Melioidosis has become more of an issue for the public in the north of the country. The disease is active during the wet season, but with the nursery industry having irrigation year round it may present a higher risk to nursery workers.

S Smith suggested that we should include this on the matrix to inform members. Further information should be sourced.

R Prince said that a nursery paper or fact sheet for industry covering Melioidosis, Legionella and other biological agents, should be considered. A story should also be published in the Hort Media. These measures providing public information would assist in protecting industry. J Bunker has advised that this issue has been in the news in QLD in conjunction with recent flooding.

S Smith asked for anything else in relation to the matrix. J Bunker commented on watering and restrictions of supply, and how government changes approaches in this area.

R Prince said that over the last few years water supply companies have alternate sources of water (class B), and they are now looking at having water supplied out in the community to support green infrastructure and to make money. J Bunker noted that price is the driving option with B grade water as there is sufficient potable water at cheaper prices.

R Prince noted that the Smart approved water mark committee's focus is to save water and save energy, i.e. it costs to pump water.

J Bunker said following the education of the public to save water getting consumers to change habits is difficult.

ACTION: A Kachenko will update the matrix to include Melioidosis, and to include energy implications, consumer education and conservation verses restrictions under the water heading

7.3 Future R&D Service providers.

A Kachenko said that the industry will have to look at who else will be able to support research and indicated that the approach Ausveg used could followed whereby they sent information to their service provider networks to collate a list of possible providers. This may be useful to find key providers and contacts. A Kachenko should keep in mind Ausveg's approach when he sends out a call in relation to student project opportunities in the new year. S Burdette asked if A Kachenko has contacts with any other Universities. A Kachenko replied that he has contact with Adelaide, Melbourne, Monash, Queensland, Southern Queensland, Macquarie, and Murdoch universities but there are no doubt others working in research relevant to our industry.

R Prince also noted that HAL has a list of PhD candidates, and also a number of contacts have been made via conferences or existing relationships. A Kachenko said that this engagement with students is important as they move into policy decision making or research roles in state /local government.

8 General Business

S Smith asked if there was any further business.

The committee Next meeting is scheduled for 6-7 June 2013, in Melbourne.

A Kachenko will keep the group updated of invitations for guest presenters.

S Smith asked for Craig Hallam Arboriculture Australia to be present at the next meeting.

The meeting closed at 12:18pm

MINUTES

Nursery & Garden Industry Australia

Environment and Technical Committee Meeting

Date:	06 June 2013 Day 1
Time:	9.00 am – 5.00 pm
Location:	Downtowner on Lygon - 66 Lygon Street, Carlton, Victoria
Attendees	Simon Smith (Chair), John Bunker, Peter Douglas, Steve Burdette, Anthony Kachenko, Chris O'Connor, Stephen Livesley (Melbourne University), Dong Chen (CSIRO), Marco Amati (La Trobe University)
Apologies	Robert Prince

ITEM	TOPIC

1 Welcome and Apologies

S Smith opened the meeting at 09:30am and thanked all for their attendance and noted a special welcome to P Douglas new member to the committee. A Kachenko stated that R Prince is to be noted as an apology. A Kachenko gave a brief overview of the committee for the benefit of P Douglas. All committee members introduced themselves and gave a personal background brief.

2 Confirmation of minutes – Nov 2012

A Kachenko asked P Douglas if he had any questions about the previous minutes, at this stage he did not. S Smith asked for confirmation of tabled minutes from the November 2012 meeting. Approval was motioned by John Bunker and seconded by Steve Burdette.

3 Matters arising from last meeting

A Kachenko discussed the action item list. He noted that the Skype or net based meeting has not yet been investigated fully for this committee. With the next meeting focused on discussion of research proposals it would probably be more suited for face to face but the mid-year meeting could be suitable for this format. S Burdette agreed and noted that the face to face would help facilitate this. S Smith asked that the Skype facility be available if a member could not make the meeting.

A Kachenko also noted that the point on working with the mining industry was still incomplete. This has been difficult to achieve and to date has not had any great success.

S Burdette advised that discussion with politicians may prove to be more fruitful to open doors to access funding and establishing connections. S Smith suggested that connections to mining via indigenous projects, employment and education through mine rehabilitation may be an avenue to explore providing triple bottom line results. General discussion on this area followed. J Bunker noted bioremediation for mines as being another avenue to investigate.

4 Matter arising not addressed in this agenda

A Kachenko introduced the Vision 202020 as the new stage of Plant Life Balance. This has potential apart from connections to large development groups and councils to include mining as a component through FIFO villages and improving mining towns green space.

A Kachenko gave brief background on the itree tool for the benefit of the committee and its purpose in supporting vision 202020. Noted was that Multiplex and Lend lease are keen to use this tool as were the major councils.

S Burdette questioned the demographics of Australia and its impact upon 202020. General discussion followed on the target audience for 202020. Issues surrounding consumers working hours, completion for discretionary spend was discussed and the importance of the influencers was noted for the impact it will have.

A Kachenko also discussed the carbon farming initiative and efforts taken to extend nursery into this area. At this stage CFI is very restrictive and there is limited opportunity for industry to engage with this scheme.

5 National Environmental Project Update

5.1 Summary and status of current government enquiries

Biosecurity Bill

A Kachenko discussed the National Biosecurity Bill written submission made to government on behalf of industry. Concerns were raised around the absence of the regulations, and lack of ability to appeal decisions on import lines. There were some good components of the bill however it needs review. The legislation may not be enacted due to the timelines before government goes into caretaker mode prior to the upcoming election.

Included was the Hansard transcript of R Princes representation at a senate hearing on the issue.

Discussion was had in reference to the Peak Industry Bodies in particular the senate inquiry into the citrus industry. S Burdette provided an overview of Senator Rushton’s past involvement with the Citrus Industry Boards.

S Burdette also noted the importance of biosecurity for industry noting experience with the citrus industry. S Smith also observed the concerns around biosecurity.

A Kachenko noted the launch of the 3rd Version of the Industry Biosecurity Plan through PHA at the recent joint NGIV/IPPS conference in Melbourne.

General discussion followed on issues of controlling pests with the view that government may take the approach that the pests become endemic through bureaucracy so avoiding the costs surrounding eradication. The new legislation promoting more industry involvement will allow for industry to self-police this, and may release some funds for research opportunities. General discussion on the biosecurity level and industries relationship with PHA followed.

A Kachenko noted that he is monitoring the policies of the major political parties in the lead up to the election. He also noted that both government and the opposition have been given copies of our policy statement in relation to biosecurity. At this stage this is a watch and brief.

Registration of businesses for biosecurity purpose was discussed as being of importance and a focus for industry. S Burdette noted that Pat Barkley may be a contact to utilise in this area. A Kachenko advised that he has been working with Pat Barkley in this area having worked with her on the CRC for Plant Biosecurity Board. He also noted that Citrus and Ausveg are also motivated to introduce property registrations for horticulture.

Draft National Code of Practice for Chemicals of Security Concern

A Kachenko briefed the committee on the Draft National Code of Security Concern which has been put forward by the Attorney Generals Department in Canberra with a view to increasing security of chemicals which could be used for terrorism purposes. 96 chemicals are noted in the document with 11 selected for incorporation into the Draft National Code. This was originally to be a regulatory instrument but has since been downgraded to a voluntary code only.

Most of the directions in this document are covered through best practice procedures within the nursery industry and that this area is a watch and brief if it becomes more onerous to industry.

S Smith noted that this subject comes back to the issue of property registration.

Horticulture industry Export Consultation Committee

A Kachenko discussed with the committee the recent increases in fees and charges for export and that DAFF were looking at an approved officer arrangement program. The idea is to give approved businesses the ability to self-certify, however internationally there are a number of major countries which do not recognize non –government approved officers.

Registration charges have increased from nil in the past to $5500. A Kachenko notes that he has broached the subject of self-certifying businesses without the registration fee by using the FMS package and will be continuing to work to this end. He also noted that John McDonald is undertaking a domestic interstate trial of a similar nature using BioSecure *HACCP*.

J Bunker stated that his business has stopped registering their property as the fees did not justify the amount of product exported. It is also prohibitive if a job did come up to include the fee charge in the costs to the client. Freight forwarders are not a viable option for large tree stock.

J Bunker raised the importance of moving towards electronic based certification for quarantine.

Post Entry Quarantine

C O'Connor briefed the committee on the recent PEPICC meeting and the upcoming changes to import. Noted was information on the upcoming build of the new Federal quarantine facility and the impacts that this may have. This new build will see existing facility capabilities merged into one site in Mickleham (Melbourne) and the current facility operations wound down and eventually closed. Pressure on this facility may arise from closure of state government facilities such as QLD Eagle Farm site and the WA Government facility, which is likely to undergo a rebuild. Retention of a plant quarantine capability here is not assured.

ICON alert changes were noted and included that to *P.ramorum*.

S Burdette questioned the number of detections at the borders. A Kachenko noted that we have received this information previously although had to ask for it. These numbers may not necessarily be detection but of consignments considered suspect. C O'Connor noted that this links back to the recent proposed Biosecurity Legislation and the lack of recourse that importers have to challenge decisions for destruction of non-high dollar value lines.

General discussion on quarantine matters followed. Concerns over the skill sets of quarantine employees was raised in light of a consolidated facility.

S Burdette asked about communications to industry about PEPICC. C O'Connor responded by noting communications to the state associations and via the Your Levy at Work Blog.

C O'Connor also discussed the PEPICC prioritisation process whereby industry can have a voice to influence DAFF and their resource allocation in relation to cases requested by industry. This will be via a ranking process of requested cases based upon industry importance.

S Burdette requested that the committee be included upon the circulation of PEPICC minutes.

Action: C O'Connor agreed that PEPICC minutes will be circulated to the Environment and Technical Committee following future PEPICC meeting.

APVMA Harmonisation

A Kachenko briefed the committee on the APVMA harmonisation initiative. There will be a review of products each ten years. There has been some concern over the potential cost of this from industry due to increased redtape. However as science evolves it may be good to have a structure for review rather than an adhoc basis.

5.2 Australian Standard for Trees / National Best Practice Guidelines

A Kachenko briefed the committee on the Australian Standard for trees and its progress to date. Covered were details of the standard committee members and an overview of the standard writing process.

S Smith asked that once the standard was completed what works need to be done to promote it or will it be adopted because it is an Australian Standard. A Kachenko replied that various industry bodies such as Australian Institute of Landscape Architects (AILA) are aware and supportive of the standard and will promote its use amongst their membership. He noted that if the proposed Standards is approved, Natspec will be superseded.

J Bunker enquired if palms were to be part of the standard. A Kachenko replied that they are not, citing limited science or practice available for specifying palms.

General discussion on the standard followed.

A Kachenko noted that updates on the standard will be regularly released.

5.3 Nursery Production FMS and AOP

P Douglas questioned if the standard would be incorporated into FMS/ NIASA as an appendix. A Kachenko replied by noting that it may be included and highlighted that there has been concern about not using NIASA as the standards. A Kachenko advised the committee that the standard is a specification for a tree not the process on how to get to that point. He did advise that NIASA/FMS was referenced in the standard e.g. for management of pests and diseases.

The need for market access to be a driver for FMS was briefly discussed.

A Kachenko stated that in the upcoming NACC meeting that one of the key points will be the discussion on how to expand the FMS program.

A brief discussion on water disinfestation followed noting that some in ground growers have cited this as a stumbling block to accreditation.

A Kachenko briefed this committee on his recent audit trip of New Zealand nurseries noting the variance amongst them, and the expansion of the program to New Zealand.

A Kachenko also advised the committee of the proposed name change to Nursery Industry Accreditation Scheme Australasia, and the updated Heads of Agreement.

The issues of obtaining hard data on FMS benefits rather than anecdotal evidence was discussed followed by general discussion on FMS.

A Kachenko will provide a copy of the Annual Operating Plan (AOP) at the next meeting but advised that the program has been accepted by HAL for the next two years.

ActionL A Kachenko to provide a copy of the FMS AOP at the next Environment and Technical meeting.

5.4 Industry market Development / Plant life balance

Discussion was carried out earlier in the agenda, covering Vision 202020.

6-9 Presentations

Presentations on current levy funded research activities were presented by

- Dr Macro Amati La Trobe University
  Carbon Pollution mitigation potential of Australia's Urban Forests

- Dr Dong Chen CSIRO
  Mitigating Heat Stress with Urban Vegetation

- Dr Stephen Livesley University of Melbourne
  Burnley Research update

Copies of the presentations are included with these minutes.

General discussion on the presentations followed.

9 Meeting closed 5pm

MINUTES

Nursery & Garden Industry Australia

Environment and Technical Committee Meeting

Date:	06 June 2013 Day 2
Time:	9.30 am – 5.00 pm
Location:	Downtowner on Lygon - 66 Lygon Street, Carlton, Victoria
Attendees	Simon Smith (Chair), John Bunker, Steve Burdette, Peter Douglas, Anthony Kachenko, Chris O'Connor
Apologies	Robert Prince

ITEM	**TOPIC**

1 WELCOME AND APOLOGIES

S Smith opened the meeting at 0900am.

2 RESEARCH PROPOSALS AND OPPORTUNITIES

A Kachenko walked the committee through the submission and prioritisation process for research projects. A Kachenko covered the recent call for expressions of interest through the Weekend Australian for research that could be of benefit to the nursery and garden industry either by growing the market for Greenlife or removing barriers to production nurseries. This advertisement was also displayed on the HAL website and distributed through their network of researcher contacts. One of the aims of this process is to find new researchers and beneficial projects to address industry needs.

A Kachenko will send through the proposals to the committee, the states and the IAC to review the projects, with final submission to HAL in November.

P Douglas asked about the origin of the projects submitted and if any had come from unexpected areas. A Kachenko noted that a number of projects came out of relationships developed by contacts through conferences and many other connections.

A Kachenko went through the current R&D project for the committee. Detailed were the requirements for full P&L reporting, noting that any remaining funds need to be returned at the end of the project. The salient points of the current program were then covered including:

A Kachenko noted that is likely to be a surplus from this current project which will go back to HAL.

General discussion on the 2013/2014 programs including the IDO project followed, with A Kachenko providing an overview of how projects work including the administrative and financial details and reporting requirements to both HAL and industry.

Noted was that all projects need to show positive change and value.

S Burdette asked if it would be of benefit for this committee to meet at the HAL offices for the November meeting. All agreed that it may be of benefit.

Action: A Kachenko to organise next meeting at HAL offices with meeting with key HAL staff.

J Bunker noted that we need to as an industry to look at more across industry projects. A Kachenko replied that at present Jon Lloyd (CEO HAL) has each year allocated 2% of all levy funds that are directed to across industry projects with a view to rising over the next few years. This presented powerful benefits to all of horticulture although we need to ensure that the benefits to our industry are still tangible.

J Bunker observed that there is potential for BioSecure *HACCP* to be moved across to other industries. S Burdette noted other industries which use Global Gap may be interested in BioSecure *HACCP*, and J Bunker noted that although our industry is focused on amenity horticulture there is scope to move much more focus across to the production side of industry especially in regards to starter crops in this area.

General discussion on biosecurity and risk management systems followed.

A Kachenko provided the committee with details about the BioSecure *HACCP* interstate product certification trial and opportunity for this to be exported to other horticultural industries.

C O'Connor noted that the DAFF international export system ICON is being updated to BICON however is delayed at present.

S Burdette observed that it may be a good idea to remind industry of what tools have been developed for their use, something quick and simple. J Bunker noted that the Your Levy at Work Blog is excellent means of communicating this information.

General discussion on the power and use of online technology followed, including Google analytics.

Input and brain storming on the proposed R & D projects to be sent through.

Action: A Kachenko to send full R&D proposals from the expression of interest call to the committee for input.

Action: Committee members to send their input on the R&D proposals through to a Kachenko

Action: C O'Connor to set up a permanent drop box for the committee for notes and items of interest.

Discussion on presentations from day 1 followed. A Kachenko noted the benefits for industries via these researchers included greater exposure of industry to government and the ability to leverage levy dollars to greater benefit.

P Douglas observed that of the presentation's he could see a lot of benefits with the presentations from Burnley and more practical applications to growers.

Noted in this was also concern for future media inputs with the potential decrease in pine bark media. P Douglas asked if there was potential to direct some funding towards researching alternatives. P Douglas also questioned how we get more NIASA businesses and questioned and asked if there is some scope for funding research into why the numbers have plateaued.

In relation to growing media A Kachenko stated that he would discuss the subject with Stephen Livesley and John Rayner to see if there is capacity and interest for research in this area.

ACTION: A Kachenko to contact S Livesley to determine interest and capacity in further research into growing media.

In relation to NIASA, A Kachenko noted that businesses engaged is always discussed and that the upcoming NACC meeting will discuss this issue in detail. Also cited was a survey of approximately 3 years ago. From this the major barriers reported were the cost of getting to a stage to comply with the program requirements and no market driver. Others saw the tool as being important for biosecurity & environmental perspectives. A Kachenko also discussed a recent cost benefit analysis a project which showed positive results for growers. Market drivers via BioSecure *HACCP* and getting the key retailers and councils to require FMS certified businesses are the key future drivers for FMS.

J Bunker asked could he get information as to market share of FMS certified businesses. S Smith suggested that the rollout of FMS to New Zealand is a great opportunity to get bench line and comparison data for before and after impact of FMS.

A Kachenko also noted that part of the IDO role is market development and looking at opportunities to promote the FMS program. S Smith stated the importance of audits and administering the FMS program to ensure the integrity of the program when promoting it to retailers and government and also internally for a program for growers to aspire to.

The need for a mandatory property/business registration scheme was discussed with focus on the biosecurity benefits it would create.

C O'Connor suggested that a biosecurity drill may be an idea to follow up for our Industry. A Kachenko noted that biosecurity drills have been undertaken in the past in conjunction with PHA and Government and perhaps this should be a discussion NGIA should have with DAFF.

A Kachenko suggested that eBay may be a large biosecurity risk to industry.

ACTION: A Kachenko to approach PHA to run a biosecurity drill.

ACTION: A Kachenko to investigate project for NGI producer list/database.

S Smith noted that the database could be a great opportunity to engage more NGI businesses.

S Smith inquired about Fire Ants. J Bunker related his experiences noting that with state funding being reduced for management there have been more incursions. This spread may also be linked to the recent large flood events.

J Bunker asked if there was a way that we could get case studies of NIASA businesses to help promote the FMS scheme via the blog. A Kachenko replied that we have already done this via Hort Journal and are in the process of collating the previous stories to utilise for the blog and that we are continuing the relationship with Hort Journal.

S Smith broached the subject of encapsulated controlled release pesticides, their increasing use in our industry and potential OHS issue around their use, especially in the tropics.

A Kachenko noted that this could be an ideal nursery paper to highlight awareness.

S Smith also asked about the potential of these pesticides and residuals with vegetable crops/seedlings/herbs especially those plants that are ready to eat for the retail sector. S Smith also noted the use of growth regulators for edible crops.

A Kachenko does not believe there is any legislated requirement for maximum residue levels for plants destined for retailers but there certainly is for vegetables going to supermarkets.

Discussion on pesticide requirements followed.

ACTION: A Kachenko will follow up on plugs going to vegetable production and look at what pesticide requirements they must follow.

ACTION: A Kachenko will review the draft for the Pesticide Best Practice manual and determine if some of the points raised during the discussion should be included.

S Smith broached the subject of water disinfestation in relation to in ground growers and asked if there should be some research to determine from a risk management perspective if there was anything else we could look at.

A Kachenko replied that he has already started investigating this, noting that it is on the agenda for the upcoming NACC meeting. A Kachenko noted that there is some data from QLD in relation to costs of disinfestation. J Bunker observed that in terms of in ground monitoring there is some advantages as monitoring is much easier than in container production.

A Kachenko relates that much of the water disinfestation relates to closed systems and the need to prevent the recirculation of pathogens and agrees that with in ground production this is difficult but the purpose is risk management and controlling the likelihood of pathogens entering the growing site. A Kachenko also noted that this is on the agenda for the NACC meeting and will work towards resolving this issue, in the next 12 months.

P Douglas asked about John McDonald’s water scheduling work. Both A Kachenko and J Bunker provided some information on this area.

Environmental Matrix

A Kachenko asked the committee if there were any new inclusions that need to be included on the environmental risk matrix, noting that melioidosis had been included after the last meeting.

From earlier discussions in the meeting A Kachenko suggested that sustainable growing media supply and pesticides residues in relation to the supply to the retail market should be included.

J Bunker suggested that energy especially in relation to costs should be included, noting that if energy costs go up so do water costs.

ACTION: C O’Connor to update the Environmental Risk Matrix.

Training

C O’Connor briefed the committee on the eLearning project currently underway and demonstrated the test site.

ITEM	TOPIC
	S Burdette noted the benefits of the site for onsite training and the flexibility of the system and a great tool for induction training and confirming competence in the workplace. S Smith noted that the potential for up skilling staff is substantial. A Kachenko highlighted the lost cost of the system.

ACTION: C O'Connor to send invite to committee to undertake and review the trial eLearning course when complete.

A Kachenko briefed the committee on the submission from Russell Cummings on an NGIA Learning Academy, as an addition to the HAL next gen program he offered.

Given the cost and limited penetration of the training the committee agreed that this submission is not viable.

S Smith thanked the committee for their attendance and closed the meeting.

The meeting was closed at 3:00pm

Appendix 3

Nursery & Garden Industry Australia

Funding Call for Nursery Industry Preliminary R&D Proposals

Review of Preliminary R&D Proposals

Nursery & Garden Industry Australia

Funding Call for Nursery Industry Preliminary R&D Proposals

Nursery & Garden Industry Australia (NGIA) is the peak industry body for the Australian nursery and garden industry and is responsible for overseeing the national development and coordination of R&D programs in consultation with Horticulture Australia Limited (HAL) and regional associations.

NGIA is inviting Preliminary R&D Proposals for new research concepts, ideas and technologies to meet the priorities listed in the Nursery & Garden Industry Strategic Investment Plan (SIP) 2012-2016.

The focus of the SIP is to accelerate the development of these research concepts, ideas and technologies, aiming to either:

- Grow the market for plants and greenlife in the urban environment.
- Overcome key technical barriers in the production sector.

Funding is available over a four-year period by research agencies, institutions or consultants who can demonstrate novel approaches to the two research themes, deemed to be critical to the success of the nursery industry.

Application Process: The application process comprises of two stages:

Stage 1: Applicants are encouraged to submit a Preliminary R&D Proposal for initial consideration by NGIA.

Stage 2: Should your Preliminary R&D Proposal be successful, applicants will be asked to submit a full proposal for final consideration by HAL and the Nursery Industry Advisory Committee (IAC).

Preliminary R&D Proposal will need to meet the guidelines outlined on the HAL website to progress to the next stage, which will require a detailed proposal to be lodged.

Timing of Application: Beginning this year, NGIA will have an annual Preliminary R&D Proposal Call. In 2013, Preliminary R&D Proposal can only be submitted in the four week window opening on Monday, 20 May 2013 and closing 5pm Friday 14 June 2013.

Acknowledgement: Preliminary applications will be acknowledged and recorded by NGIA. Applicants will be advised in writing of the success or otherwise of their preliminary proposal by NGIA.

Instructions to Complete Preliminary R&D Proposal Form: The Preliminary R&D Proposal form is available by contacting NGIA on the following email address - info@ngia.com.au or calling 02 8861 5100. The Preliminary R&D Proposal should be completed electronically, and sent to - anthony.kachenko@ngia.com.au

Should you require further information, please contact:

Dr Anthony Kachenko
NGIA Environmental and Technical Policy Manager
anthony.kachenko@ngia.com.au

All proposals must be received by 5pm Friday 14 June 2013

Nursery Industry National Research Development and Extension

Consultation Process

Purpose

This paper intends to communicate a new approach in developing industry Research, Development and Extension (RD&E) projects through greater engagement with national and international RD&E agencies. This proposal supplements the current RD&E Consultation and Planning Process that is largely driven through state and territory Associations through NGIA via the National Environment and Technical Committee (NETC) and the Industry Advisory Committee (IAC).

This paper is being presented to address current deficiencies in agencies willingness to invest in the nursery industry. Current RD&E capability ranges from non-existent to medium level investment on a region by region basis. Current investment in nursery industry RD&E is *ad hoc* and opportunistic.

This paper proposes an eight stage process to engage with national and international agencies utilising existing industry committees, structures and approaches to RD&E.

Eight Stage Process

Stage 1

NGIA will facilitate a funding call for R&D proposals. An advertisement will be developed that details industry priority areas for investment with links to the Nursery Industry Strategic Investment Plan 2012-2016. The advertisement will call for 'Expressions of Interest' and will be circulated via various mechanisms including national print media.

The funding call will run for six weeks from Mid-April through to May.

Agencies will be asked to draft a preliminary proposal (Expression of Interest) that address the following criteria:

1. Are outcomes clearly defined?
2. Are benefits to industry adequately identified?
3. Is there existing research that can address this need?
4. Does this proposal address market failure adequately?
5. Is the method adequately defined?
6. Has a budget and time frame been proposed?
7. Has project monitoring and evaluation been considered?
8. Linkages identified with NGIA 2012-2016 Strategic Investment Plan?

Stage 2

Each preliminary proposal received will be tabled at the mid-year NGIA Environment and Technical Committee meeting to review.

The NGIA Environment and Technical Committee will prioritise each proposal based on industry needs in relation to urgency, importance, impact and success against the eight aforementioned criteria (e.g. Linkages identified with NGIA 2012-2016 Strategic Investment Plan). NGIA will circulate the ranked preliminary proposals to each State Association for comment.

Stage 3

State Associations will provide NGIA with comment (if required) on each of the ranked preliminary proposal. NGIA will incorporate this feedback into the ranked proposals and recommend to the nursery Industry Advisory Committee (IAC) which projects should be developed into full proposals.

Stage 4

The IAC will advise NGIA which preliminary proposals should advance through to full proposals. NGIA will provide feedback to each successful agency who will be encouraged to work with NGIA in developing full project proposals for submission to HAL during the industry call in November.

Stage 5

Each proposal will be tabled at the end of year NGIA Environment and Technical Committee meeting to endorse and provide final feedback (if necessary).

Stage 6

Agencies will submit projects to HAL for review during November. HAL will provide a recommendation to the IAC.

Stage 7

Projects will then be considered by the nursery IAC using the NGIA 2012-2016 Strategic Investment Plan for reference. This will occur during the first meeting in 2014.

Stage 8

Successful projects will be communicated by NGIA to whole of industry.

A summary of this process follows.

Nursery & Garden Industry Australia

Flow Chart 1: The Research, Development & Extension Consultation and Planning Process Schedule.

Stage 1

April – May	NGIA engage with agencies to submit RD&E preliminary proposals aligned to the Nursery & Garden Industry Strategic Investment Plan

↓

Stage 2

June	NETC rank preliminary proposals. NGIA circulate ranked proposals to State Associations for comment

↓

Stage 3

July	State Associations provide NGIA with comment on ranked proposals. NGIA provide ranked preliminary proposals with comments to IAC

↓

Stage 4

Late August	IAC screen preliminary proposals to advance to full proposals

↓

Stage 5

November	NETC endorse full proposals and provide any further input

↓

Stage 6

Mid November	HAL evaluate project proposals and make recommendations to IAC

↓

Stage 7

February	IAC evaluate and approve/reject project proposals

↓

Stage 8

NGIA communicated approved projects to whole of industry

Appendix 4

National Plant Labelling Guidelines

Version 2 January 2013

Nursery & Garden Industry Australia

Nursery & Garden Industry Australia

GUIDELINES FOR LABELLING OF PLANTS

Introduction:

These guidelines for labelling plants have been developed by the Australian nursery industry in conjunction with the Tree & Shrub Growers Victoria, the wider industry and a legal team with a specialist interest in intellectual property within the nursery industry. They are recommended for adoption by all plant producers, suppliers of plant material, plant retailers and label manufacturers.

These guidelines have been developed to reduce confusion and provide clear guidance in relation to the content of labels used on plants, and how plant information is conveyed to the market. These guidelines also support the efforts of regulators to address market access, invasive plant and potentially harmful plant issues.

Objectives of the Guidelines:

Provide a standard of acceptable and recommended guidelines for the nursery industry to adopt in preparation of labels and marketing material.

In these guidelines the definition of a label is any tag, brand, mark or statement in writing or any representation or design or descriptive matter on or attached to or used in connection with or accompanying any plant or plant material. This covers labels attached to plants, barcodes, sleeves, bulb cards, seed packets, planting guides; plant lists catalogues, printed plant pots and electronic representation.

To assist in understanding the obligations of providing clear, unambiguous and accurate information on labels and to avoid the public or others in the plant trade from being misled and deceived.

It is not the aim of these guidelines to include everything that should be on every label produced. It is to provide guidance on how to correctly deal with issues including:

1. **Correct botanical names – nomenclature**
2. **Intellectual property – Plant Breeders Rights and Trademarks**
3. **Potentially harmful plants – health and environment**

Definitions:

1. **Botanical Names** - A botanical name is the actual scientific name for the plant. It is the only internationally unique identifier for the plant.

   1.1. **Species:** A wild or natural species is the smallest population which is, in human terms, distinct and distinguishable from all others. It is the primary taxonomic unit, and gene exchange within the species occurs freely, while exchange between species via hybridization is usually restricted or even impossible.

   The name of a species is <u>always</u> identified by a botanical name comprising two words; the genus name and a specific epithet or species name (e.g. *Grevillea rosmarinifolia*). A botanical name must be latinized, and validly published in a recognised international journal in order to be legitimate.

   1.2. **Hybrids:** If natural hybrids do occur, the name of a hybrid can be given as the two species names separated by a multiplication sign e.g. *Calystegia sepium* x *Calystegia silvatica*, or if an author wishes, a latinized binary name linked by the multiplication sign e.g. *Calystegia* x *lucana* (the same taxon as the last example)

   1.3. **[Botanical] Variety:** 'Variety' used in a taxonomic sense describes members of a species that differ from others of the same species, in a naturally occurring population, in minor but heritable characteristics. A variety is often a local or ecological race or ecotype.

   The botanical variety name must be published and is latinized. It is used in conjunction with the name of the genus and species with the added abbreviation 'var'. e.g. *Ceanothus gloriosus* var. *exaltatus.*

   Note. The recognition of a distinct variety also automatically means that there is a typical variety of the species i.e. *Ceanothus gloriosus* var. *gloriosus.* Using the name *Ceanothus gloriosus* does not imply the typical form and the user of the name may be unaware of the existence of varieties.

   1.4. **Cultivated plants:** When a naturally occurring species is domesticated and 'bred' to change its characteristics, new 'cultivars' are developed. The term cultivar and botanical variety cannot be used interchangeably (see above). Cultivars are of diverse nature e.g. clones, self-fertilized lines or lines of hybrid origin developed in cultivation. In Plant Breeder's Rights terms, a 'plant variety' or a 'variety' is the same as a 'cultivar'.

   Cultivar names can be associated with a genus name, a species name or a hybrid. They are not latinized, are written with an initial capital letter and in single quotation marks e.g. *Rubus idaeus* 'Malling Wonder', *Viburnum* x *bodnantense* 'Dawn', *Rosa* 'Crimson Glory'.

2. **Intellectual Property:** -Intellectual property represents the property of your mind or intellect. In business terms, this also means your proprietary knowledge.

   2.1. **Plant Breeders Rights:** Plant Breeder's Rights (PBR) are time-limited exclusive commercial rights, granted by IP Australia for a plant variety that has been bred (i.e. a cultivated plant), is new, distinct from all other know varieties, uniform and stable. In PBR terms, a 'plant variety' or a 'variety' is generally the same as a 'cultivar', not to be confused with the botanical variety described above. The rights are a form of intellectual property, like patents, trade marks and copyright, and are administered under the Plant Breeder's Rights Act 1994.

   2.2. **Trade marks:** A trade mark is used to distinguish the goods and services of one trader from those of another. A trade mark is a sign, for example a word or logo, which is used to indicate that ***a plant has been grown by a particular grower***. The use of trade mark is implying that the owner of the trade mark has control over trade in relation to that plant. The owner of a trade mark can license others to use the mark. This use can be subject to conditions which could be in relation to quality and origin of the end product and the class of product to ensure that the integrity of the trade mark is maintained. This would apply to plants grown under licence that are grown to a particular standard. Trade marks should not be used on plants if the trade mark owner has no control over the way it is used in relation to a product.

   2.3. **Copyright:** Copyright protects the original expression of ideas, not the ideas themselves. It is free and automatically safeguards your original works of art and literature, music, films, sound recording, broadcasts and computer programs from copying and certain other uses. Copyright is not registered in Australia but arises automatically when the work is created. Copyright can apply to labels, manuals, brochures, videos, photographs and other such works developed by a business.

   2.4 **Plant Patents:** '*A patent is a right that is granted for any device, substance, method or process that is new, inventive, and useful*' (IP Australia web site). Plant related patents may be obtained over a plant variety, a process for producing a plant variety or biological information (e.g. a DNA sequence). In Australia new plant varieties can be patented if they meet the criteria, but this should not be confused with a 'plant patent' granted in the United States. The latter is granted under a special section of the patent law (designed to meet UPOV requirements) which applies specifically to asexually reproduced plant varieties. In the USA, the Plant Variety Protection Act only covers sexually reproduced plants. Sexually and asexually reproduced plant varieties can also be the subject of a normal US utility patent if they meet the relevant patent criteria, as in Australia.

3. Potentially harmful plants:

Consumer Health – A potentially harmful plant is a plant that causes:

- Poisoning: that is a toxic reaction when put into the mouth or ingested, or
- A skin reaction, that is a rash, swelling, dermatitis, allergy, pain or infection when handled or when skin comes into contact with a plant part, or
- Respiratory problems as a result of exposure to pollen, perfume or sawdust.

Environment – An environmentally harmful plant is one that:

- Has been identified to have sufficient weed impacts as to warrant publication of national specific control recommendations.
- Is undergoing assessment for potential invasiveness utilising National Guidelines to variety or cultivar level and may need increased awareness re management, or disposal.
- An invasive plant has the ability to thrive and spread aggressively outside its natural range. A naturally aggressive plant may be especially invasive when it is introduced to a new habitat. An invasive species that colonizes a new area may gain an ecological edge since the insects, diseases, and foraging animals that naturally keep its growth in check in its native range are not present in its new habitat.

The Guidelines

It is recommended that a label be:

- in the English language,
- legible and prominent in distinct contrast to the background,
- indelible - must not fade or be able to be rubbed off under normal conditions, and
- true and correct regarding information (i.e. not false or misleading).

Required Information:

a. **The botanical name of the plant** is always written in italics with the first word or genus name having a capital letter and the species written in lowercase e.g. *Grevillea rosmarinifolia*. The name of a validly published natural variety is also written in italics and separated from the species name by the abbreviation var., e.g. *Ceanothus gloriosus* var *exaltatus* (compare with cultivated variety below).

b. **A cultivar name (cultivated variety)** is always written with a capital letter, single quotation marks and is not italicised e.g. *Grevillea rosmarinifolia* 'Nana'. If the cultivar name (referred to as the plant variety name in PBR terms) is subject to protection under the Plant Breeders Rights Act the PBR symbol can be used beside the cultivar name, e.g. ***Grevillea rosmarinifolia* 'Nana'**Ⓟ. Then somewhere on the label the full PBR text should be included.

Appendix 2 contains a copy of the PBR Industry Guidelines for the use of the PBR symbol and letters.

c. **The common name** for the plant (when this differs from the botanical name). This is not required to be written in any particular way and preferably **must not** be depicted in italics or in quotation marks or in any way to confuse it with the botanic or cultivar name.

d. **Plant cultural notes.** These provide guidance on the requirements for the plant to be successfully grown and should cover:

- Brief description
- Desirable characteristics
- Preferred aspect
- Preferred soil type
- Likely height and width at maturity
- Special uses (e.g. bird attraction, suitable for coastal conditions)
- Any necessary cautions (e.g. potentially harmful plants [health and environment], invasive tendencies or disposal guidelines).

This information may be provided by text or pictogram but must be easy to understand and accurate.

If a grower uses a trade mark as a commercial designator to identify the plant as ***originating from that grower*** the trade mark should also appear on the labels.

a. The trade mark is ***not to be used as the botanical or cultivar name of the plant*** or as a substitute for the botanical or cultivar name of the plant.

b. If a trade mark is used on the label it should be consistently used in the same way on all labels which bear that trade mark. Preferably it should be depicted in capital letters, fancy script, in bold print or a colour all of which are different to the way in which the botanical and cultivar names are depicted.

c. If the trade mark is registered the ® can be used in close proximity to the trade mark. If the trade mark is awaiting registration or is an unregistered trade mark the letters ™ can be used in close proximity to the trade mark until registration is achieved. The TM is normally in capital letters and 'raised' above the name/expression it is associated with. This is also the case with the ® symbol.

d. The trade mark should be followed with a noun or the botanical name, the cultivar name or the common name, e.g. EVERGREEN CASCADE ® Weeping Alder *Alnus jorullenesis* 'Pendula'. It is recommended that the botanical name be in a font size that is in proportion with the general label font and is legible.

License Names or Trade Marks:

a. Where a grower uses a cultivar name which is the subject of protection under the Plant Breeders Rights Act and the use of that name is licensed to the grower by the PBR owner, the grower should indicate that he/she is the licensee of the PBR protected variety. The label should be in accordance with this guide and any terms of use in the licence agreement.

b. Where a grower uses a trade mark under license from another party the grower should use the trade mark in accordance with this guide and also in accordance with the licence agreement with the other party. It is recommended that the grower indicates that the trade mark is used under license e.g. EVERGREEN CASCADE ® Weeping Alder *Alnusjorullenesis* 'Pendula' used under licence.

Other Notices:

a. Some growers may wish to include a "passing off" notice on their plant labels. Such a notice is appropriate and can be used when the grower has adopted a trade mark to identify the commercial origin for a plant and the trade mark has been used to such an extent (either as a registered or an unregistered trade mark) for a reputation to have developed in that trade mark. **[e.g. This plant has been promoted by XYZ Nursery in the course of their business. ANY PERSON PASSING OFF a plant or plants as being those of XYZ Nursery or their authorised distributor by using the name XXYYZZ or imitating this label will be liable to civil action.]** A "passing off" notice is not to be directed to the botanical name, cultivar name or common name of the plant. To date, many uses of the "passing off" notice have not been used in conjunction with the correct use of a trade mark. Growers must be careful in the correct use of any "passing off" notice(s).

A copyright notice may appear on the label if the grower is the owner of copyright in the artistic material or photographs appearing on the label, e.g. © Copyright 2005 – (XYZ Nursery).

b. It is recommended that the grower seeks legal advice to determine ownership of copyright.

Potentially Harmful Plants - Consumer Health

1. Introduction:

Australians are fortunate in having access to a wealth of plant species. Most of these are harmless. However, there is a level of public concern regarding the potential harm from some plants in the house and garden. These guidelines for labelling will ensure that the public is informed of potentially harmful plants.

Plants that are known to be harmless do not require a warning.

A list of potentially harmful plants that are harmful if eaten can be found in Appendix 1.

This list has been established as a guide only by Nursery and Garden Industry Australia (NGIA). It was developed from a combination of reputable international and local sources and contains the list of plants known to be potentially harmful. The list will be regularly reviewed and updated by the NGIA Board and relevant subcommittee(s) with input from external expertise. This list is restricted to potentially harmful plants that are commonly cultivated for sale, and excludes weeds of national significance e.g. *Lantana camara*.

The list of potentially harmful plants posted on the NGIA website will be considered to be the most up-to-date list.

Disclaimer:

While every effort has been made in preparing this list, Nursery and Garden Industry Australia, accepts no responsibility for any errors, omissions or inaccuracies. NGIA accepts no responsibility to persons who may rely on this document, in whole or in part, for whatever purpose. As new species are continually being discovered and commercialised they need to be verified by authoritative institutions such as State Herbariums.

2. Need for Referencing on the Label

The required wording for each potentially harmful plant is as per Appendix 1 and must be presented in such a way as to not be confused with the general text of that label (as per the definition of a plant label).

Potentially Harmful Plants - Environment

The Nursery and Garden Industry is an active participant in processes relating to invasive plant management. The correct identification of plants by their botanical name will ensure accuracy in plant identification. The diversity of plant lists and regional focus of plant producers make it essential that there is an agreed scientific process for risk assessment that is valid to variety or cultivar level. With this in mind, the Australian nursery industry has recently developed an invasive plant risk assessment tool which can ascertain the degree of invasive risk associated with plants. This can be accessed by visiting the NGIA website.

Plant producers are urged to adhere to the following recommendations:

- Be aware of the legislation relevant to plant production and trade in their area. All plants on the WONS list are banned from production, sale or trade in all jurisdictions in Australia. Details of the WONS list can be found by clicking HERE.
- Do not produce plants for sale if they are on the National Environmental Alert List and Noxious Weeds List. This list is jurisdiction specific and will impact on what may be sold in various regions. The label should state any restrictions to where the plant is grown.
- Review the degree of invasive risk associated with plants available for sale using the Australian nursery industry invasive plant risk assessment tool.
- Provide cultural guidelines re plant management if a plant MAY show invasive characteristics e.g. Remove seed heads after flowering, dispose of plant or fruit via burial or approved composting facility.

General Requirement for Industry:

A grower must take all reasonable steps to avoid using labels for ornamental plants which are misleading or deceptive or likely to mislead or deceive. To mislead someone may include leading them to a wrong conclusion, creating a false impression or making false and inaccurate claims.

Designing and printing labels can be a difficult, detailed and expensive operation if done incorrectly. NGIA would recommend that you seek independent legal advice in this area to check your labels for accuracy and compliance before printing. You should also ensure your label supplier is providing labels that conform to the guidelines.

If barcodes are used on labels then they should comply with standards set by GS1. A copy of these can be found on the GS1 Australia website.

Questions or Issues:

Any questions or complaints about the content of plant labels can be directed to the Nursery & Garden Industry Australia, 7129 Baulkham Hills BC NSW 2153 or your state or territory nursery industry association. The version of these guidelines located on the NGIA website is the latest and current version. The Guidelines will be reviewed every 3 years by the NGIA Board and relevant subcommittee(s).

References and Links:

Botanical Names database: www.ars-grin.gov/~sbmljw/istaintrod.html accessed October 2012.

Code of Recommended Retail Practice Relating to the Labelling and Display of Potentially Harmful Plants - Published for its members by The Horticultural Trades Association December 2005

Frohne, D. and Pfänder H. J. (2005). Poisonous Plants: A Handbook for Doctors, Pharmacists, Toxicologists, Biologists and Veterinarians. Manson Publishing, UK.

IP Australia (for PBR, Trademark and Patent information) www.ipaustralia.gov.au accessed October 2012.

McKenzie, R. (2012). Australia's Poisonous Plants, Fungi and Cyanobacteria, A Guide to Species of Medical and Veterinary Importance. CSIRO Publishing, Australia.

Noxious Weeds List by State Jurisdiction: www.weeds.org.au/noxious.htm accessed October 2012.

Plants and fungi poisonous to people in Queensland: Queensland Government Booklet 2005 – Queensland Health and Environmental protection Agency.

Primefact 359 – Garden Plants poisonous to people. NSW DPI: November 2006

The Plant List: http://www.theplantlist.org/ accessed October 2012.

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Griffith University, Queensland

SUMMARY AND EXAMPLES

The examples below indicate how these guidelines should be put into practice.

We have identified eight different kinds of names that now appear quite frequently on retail plant labels and here we show how the words “spring splendour” can be presented in different ways to indicate different kinds of names.

Botanical Name:

- The botanical name is the single unique identifier for the plant and should be placed somewhere on the label. It may be put on the back of the label when the front is used for strong promotion. Botanically this is the species name consisting of the genus and specific epithet.

  Grevillea rosmarinifolia

- If the plant is a botanical variety of this species it would be written:

  Grevillea rosmarinifolia var *exaltatus*

- If the plant is a cultivar of this species it would be written:

  Grevillea rosmarinifolia ‘Spring Splendour’

- In the above botanical name the words ‘Spring Splendour’ in single quotes are known botanically as the cultivar epithet and this kind of botanical name is often referred to as the cultivar name. As presented here the cultivar has no legal protection.

- Note: the terms ‘cultivar’ and ‘botanical variety’ refer to very different things and must not be used interchangeably. In Plant Breeder’s Rights terms, a ‘plant variety’ or a ‘variety’ is the same as a ‘cultivar’.

Synonym:

- Alternative or old names are placed in brackets after the botanical name.

  Corymbia citriodora (syn. *Eucalyptus citriodora*). In Plant Breeder’s Rights terms, a synonym is generally an alternative plant variety name that is included in the application for PBR.

- The synonym is placed immediately after or under the botanical name.

Trade Marks

- These are generally placed on the front of labels as promotional brand names.

- An unregistered common law trade mark:

  SPRING SPLENDOUR ™ *Grevillea rosmarinifolia*

- In this example the TM would indicate an unregistered trade mark, and that Spring Splendour is a brand of *Grevillea rosmarinifolia.*

- A registered trade mark:

  SPRING SPLENDOUR® *Grevillea rosmarinifolia*

- In this example the ® would indicate a registered trade mark and that Spring Splendour is a brand of *Grevillea rosmarinifolia.*

- The trade mark cannot be used as the botanical or cultivar name of the plant or as a substitute for those names.

- There are no absolute rules on writing trade marks. However, in general a plant trader's trade mark is given the letters ™ written beside it when it is found on packaging and advertising. The symbol™ is generally taken to indicate a pending registration or common usage, while the symbol ® indicates a registered trade mark with full legal protection. We recommend this usage even though it is not legally required.

- It is recommended that the trade mark be written in capital letters or possibly a fancy script or bold colour that is different from the botanical or cultivar names. If the trade mark is a logo, make sure that it is written in the form that it is registered.

- A particular trade mark should be used consistently in the same way on all labels

- Somewhere on the label the trade mark should be followed by the botanical and/or cultivar and/or common name, for example:

  EVERGREENEDGER® *Buxus sempervirens* 'Rotundifolia', Round-leaf Box

- Where a trade mark is used under licence from another party it should be used in accordance with the licence agreement and it is recommended that licensing be indicated on the label, for example:

EVERGREEN EDGER® *Buxus sempervirens* 'Rotundifolia', Round-leaf Box, trade mark used under licence.

- Sometimes a copyright notice may appear on the label to protect the literary, artistic material or photographs appearing on the label, for example:

  © Copyright 2005 – GreenGills Nursery

- Avoid genercising the trade mark, this is where the product becomes generic or commonly known by. Trade marks should be used as an adjective not a noun or a verb for example;

  SPRING SPLENDOUR™ grows to 2 metres is incorrect
  SPRING SPLENDOUR™ *Grevillea rosmarinifolia* grows to 2 metres tall is correct

Plant Breeder's Rights:

- A true cultivar name protected by PBR:

  Grevillea rosmarinifolia 'Spring Splendour'

- A plant protected by PBR under a PBR variety name:

  Grevillea rosmarinifolia 'SPRSPLEN'

- Where a PBR protected plant is used under licene from another party it should be used in accordance with the licence agreement and it is recommended that licensing be indicated on the label, for example:

  Grevillea rosmarinifolia 'Spring Splendour' is under licence

Note, it is advisable (but not mandatory) for all names protected under PBR legislation to carry the PBR symbol or the letters "PBR".

The PBR symbol or letters should not be applied to trade marks, only varieties can bear the PBR logo or letters.

Also, note that plant material sold for test marketing before the lodgement of an application for a PBR should be labelled to establish an intention and time frame for an application for PBR. The following words should be used:

"Eligibility of this plant as a registrable plant variety under Section 43(6) of the Plant Breeder's Rights Act 1994 will expire on <insert date>."

Note: The date nominated must not exceed 12 months from the date of first sale in Australia and not more than four years from the date of first sale overseas (or six years in the case of overseas sales of tree and vine varieties).

Common Names:

- Common names are "generic" and therefore cannot be used as trademarks or cultivar names: they are written without quotes or any other embellishment or symbol.

Potentially Harmful Plant Wording

If this plant was known to be potentially harmful we would recommend the following wording:

Amaryllis belladonna - CAUTION Harmful if eaten

Potentially Environmentally Harmful Plant Wording

If the plant is known to be a declared weed in another state we would recommend the following wording on the label:

Lavandula stoechas - This plant is a declared noxious weed in Victoria and Western Australia

Hedera helix - English Ivy is a declared weed in ACT and considered highly invasive. Ensure the plant is controlled if planted and dispose of appropriately.

Appendix – 1. Potentially Harmful Plants: Health

Potentially harmful plant genus - includes all species unless specified	Potentially harmful plant common name/s	Required warning
Abrus precatorius	Coral Pea, Crab's Eyes, Paternoster Beans	CAUTION Harmful if eaten
Acalypha	Red Hot Cat-Tail, Copperleaf, Chenille Plant	CAUTION Harmful if eaten/skin & eye irritant
Acokanthera	Dune Poison Bush, Wintersweet	CAUTION Harmful if eaten/skin & eye irritant
Aconitum napellus	Badger's Bane, Monkshood, Wolfsbane	CAUTION Harmful if eaten/skin irritant
Actaea	Doll's Eyes, White or Red Banberry, Snake Berry	CAUTION Harmful if eaten/skin irritant
Adenium	Desert Rose, Impala Lily, Sabi Star	CAUTION Harmful if eaten
Aesculus hippocastanum	Buckeye, Horse Chestnut	CAUTION Harmful if eaten
Aglaonema	Aglaonema, Painted Drop-Tongue	CAUTION Harmful if eaten/skin & eye irritant
Agapanthus praecox* ssp.*orientalis	African Lily, Lily-of-the-Nile	CAUTION Harmful if eaten/skin & eye irritant
Agrostemma githago	Common Corncockle	CAUTION Harmful if eaten
Ailanthus	Tree of Heaven	CAUTION Skin & eye irritant
Allamanda	Allamanda, Golden Trumpet	CAUTION Harmful if eaten/skin & eye irritant
Alocasia	Taro, Chinese Taro, Giant Taro, Cunjevoi, Spoon lily, Elephant's ear	CAUTION Harmful if eaten/skin & eye irritant
Alstromeria	Lily of the Incas, Peruvian Lily	CAUTION Skin irritant
Amaryllis belladonna	Belladonna Lily, Jersey Lily, Marach Lily, Naked Ladies	CAUTION Harmful if eaten
Anthurium	Anthurium, Flamingo Flower	CAUTION Harmful if eaten/skin & eye

		irritant
Apocynum cannabinum	Dogbane	CAUTION Harmful if eaten
Argemone	Mexican Poppies	CAUTION Harmful if eaten
Arisaema	Arisaema, Dragonroot, Green Dragon, Cobra Lily, Indian Turnip, Jack-in-the-Pulpit	CAUTION Harmful if eaten/skin & eye irritant
Arum	Lily	CAUTION Harmful if eaten/skin & eye irritant
Atropa belladonna	Belladonna, Log Fern,	CAUTION Harmful if eaten
Aucuba japonica	Japanese laurel, Spotted laurel	CAUTION Harmful if eaten
Baptisia	False indigos	CAUTION Harmful if eaten
Borago officinalis	Borage	CAUTION Harmful if eaten
Bowenia	Zamia 'fern', Byfield 'fern'	CAUTION Harmful if eaten
Brugmansia	Angel's Trumpet	CAUTION Harmful if eaten/respiratory irritant
Brunfelsia	Lady of the Night, Francisia, Yesterday-today-and-tomorrow	CAUTION Harmful if eaten
Caesalpinia	Brazilian Ironwood, Leopard Tree, Bird-of-Paradise Shrub, Barbados Pride, Peacock Flower	CAUTION Harmful if eaten
Caladium	Angel Wings, Elephant Ears	CAUTION Harmful if eaten/skin & eye irritant
Calla	Water Arum	CAUTION Harmful if eaten/skin & eye irritant
Calophyllum inophyllum	Beauty leaf, Alexandrian laurel	CAUTION Harmful if eaten/skin & eye irritant
***Capsicum annum* (ornamental cultivars)**	Pepper, Capsicum, Bell Pepper	CAUTION Harmful if eaten/skin & eye irritant
Caryota	Fish-tail palm	CAUTION Harmful if eaten/skin & eye irritant
Cascabela	Lucky nut	CAUTION Harmful if eaten/skin & eye irritant

Cassia fistula	Golden shower tree	CAUTION Harmful if eaten
Castanospermum australe	Black Bean, Moreton Bay Chestnut	CAUTION Harmful if eaten/skin, eye & respiratory irritant
Catharanthus roseus	Madagascar periwinkle, Cayenne jasmine	CAUTION Harmful if eaten
Cestrum	Night Shade, Orange cestrum, Green cestrum, Night-scented jessamine,	CAUTION Harmful if eaten/skin, eye & respiratory irritant
Chelidonium majus	Greater Celandine	CAUTION Harmful if eaten/skin & eye irritant
Clivia	Bush lily	CAUTION Harmful if eaten
Codiaeum variegatum	Croton	CAUTION Harmful if eaten/skin & eye irritant
Colchicum	Autumn Crocus, Meadow Saffron, Naked Ladies	CAUTION Harmful if eaten
Colocasia esculenta	Cocoyam, Dasheen, Taro	CAUTION Harmful if eaten/skin & eye irritant
Convallaria majalis	Lily of the Valley	CAUTION Harmful if eaten
Corchorus olitorius	Jute	CAUTION Harmful if eaten
Coriaria	Coriara	CAUTION Harmful if eaten
Cotinus coggygria	Smoke bush, Venetian sumac, Wig tree	CAUTION Skin irritant
Cotoneaster	Cotoneaster	CAUTION Harmful if eaten
Cycas	Cycas	CAUTION Harmful if eaten.
Cyclamen	Cyclamen, Alpine Violet, Persian Violet, Sowbread	CAUTION Harmful if eaten
Daphne	Daphne	CAUTION Harmful if eaten/skin irritant
Datura	Angel's Trumpet	CAUTION Harmful if eaten
Delphinium	Larkspur	CAUTION Harmful if eaten
Dianella	Dianella	CAUTION Harmful if eaten
Dicentra spectabilis	Lady's locket, Dutchman's breeches, Bleeding heart	CAUTION Harmful if eaten/skin & eye irritant
Dictamnus albus	Burning Bush, Dittany	CAUTION Skin irritant

Dieffenbachia	Dumb Cane, Mother-in-Law's Tongue, Tuftroot	CAUTION Harmful if eaten /skin & eye irritant
Digitalis	Foxglove	CAUTION Harmful if eaten
Dracunculus	Black Arum, Dragon Arum, Voodoo Lily, Snake Lily	CAUTION Harmful if eaten/skin & eye irritant
Duranta	Duranta, Golden Bead Tree, Golden Dew Drop, Pigeon Berry, Brazilian Sky Flower	CAUTION Harmful if eaten/skin & eye irritant
Echium	Echium, Paterson's Curse, Purple Viper's Bugloss, Blue Weed, Pride of Madeira	CAUTION Harmful if eaten/skin irritant
Epipremnum (E. aureum) (SynScindapsusaureus)	Centipede Tongavine	CAUTION Harmful if eaten/skin & eye irritant
Eriobotrya japonica	Loquat, Japanese medlar, Nispero, Japanese plum	CAUTION Harmful if eaten
Erythrina	Coral Tree	CAUTION Harmful if eaten
Erythrophleum chlorostachys	Ironwood	CAUTION Harmful if eaten
Euonymus europaeus	Burning Bush, Corkbush, Winged Spindle Tree, Strawberry Bush, Wintercreeper,	CAUTION Harmful if eaten
Euphorbia (except E. pulcherrima)	Euphorbia, Wood spurge	CAUTION Harmful if eaten/skin & eye irritant
Fatsia japonica	Formosan rice tree, Japanese fatsia	CAUTION Harmful if eaten/ skin & eye irritant
Gelsemium sempervirens	Carolina Jasmine, Yellow Jessamine	CAUTION Harmful if eaten
Ginkgo biloba	Maiden-hair tree	CAUTION Harmful if eaten/skin irritant
Grevillea	Grevillea	CAUTION Skin irritant
Hedera	Ivy	CAUTION Harmful if eaten/skin irritant
Heliotropium		CAUTION Harmful if eaten
Helleborous	Lenten Rose, Winter Rose	CAUTION Harmful if eaten/skin irritant
Hemerocallis	Day lily	CAUTION Harmful if eaten
Hippeastrum	Amaryllis, Knight's Star Lily	CAUTION Harmful if eaten/skin & eye

		irritant
Homeria (syn. Moraea)	Cape Tulip, Puerto Rico yellowseed	CAUTION Harmful if eaten
Hyacinthoides	Bluebells	CAUTION Harmful if eaten
Hyacinthus	Hyacinth	CAUTION Harmful if eaten/skin irritant
Hydrangea	Hydrangea	CAUTION Harmful if eaten/skin & eye irritant
Hyoscyamus	Henbane	CAUTION Harmful if eaten
Hypericum perforatum	St John's wort	CAUTION Harmful if eaten
Ilex	Holly	CAUTION Harmful if eaten
Ipomoea tricolor	Belle de Nuit, Moonflower, Cardinal Creeper Morning Glory, Spanish Flag	CAUTION Harmful if eaten
Iris	Iris	CAUTION Harmful if eaten
Jatropha	Peregrina, Coral Plant, Physic Nut, Spicy Jatropha, Gout Plant	CAUTION Harmful if eaten/skin & eye irritant
Kalmia	Sheep Laurel, Calico Bush, Mountain Laurel Eastern Bog Laurel, Swamp Laurel	CAUTION Harmful if eaten
Laburnum anagyroides	Laburnum, Golden Chain Tree	CAUTION Harmful if eaten
Lagenaria siceraria	Gourd	CAUTION Harmful if eaten
Lathyrus	Sweet Pea, Vetchling, Wild Pea	CAUTION Harmful if eaten
Lepidozamia	Wunu, Scaly Zamia	CAUTION Harmful if eaten
Leucaena leucocephala		CAUTION Harmful if eaten
Ligustrum	Privet	CAUTION Harmful if eaten
Lobelia (except L. erinus)	Lobelia	CAUTION Harmful if eaten
Lonicera	Honeysuckle	CAUTION Harmful if eaten/skin & eye irritant
Lupinus	Russell lupin, Lupine	CAUTION Harmful if eaten
Macrozamia	Burrawang	CAUTION Harmful if eaten
Mandevilla	Chilean jasmine	CAUTION Harmful if eaten

Mandragora	Mandrake	CAUTION Harmful if eaten
Manihot esculenta	Cassava	CAUTION Harmful if eaten
Melia	Persian Lilac, White Cedar	CAUTION Harmful if eaten
Mirabilis	Four O'Clock Flower, Marvel of Peru, Vieruurtjie	CAUTION Harmful if eaten/skin irritant
Monstera deliciosa	Fruit Salad Plant, Swiss Cheese Plant, Mexican Breadfruit	CAUTION Harmful if eaten/skin & eye irritant
Moraea	Cape tulip	CAUTION Harmful if eaten
Muscari	Grape hyacinth	CAUTION Harmful if eaten
Narcissus	Daffodil, Jonquil	CAUTION Harmful if eaten/skin irritant
Nerine	Spider lily	CAUTION Harmful if eaten
Nerium	Oleander	CAUTION Harmful if eaten/skin & respiratory irritant
Nicotiana	Tobacco	CAUTION Harmful if eaten
Ornithogalum	Chincherinchee, Star of Bethlehem	CAUTION Harmful if eaten
Papaver	Opium Poppy	CAUTION Harmful if eaten
Parthenocissus	Virginia creeper	CAUTION Harmful if eaten
Pedilanthus	Devil's Backbone, Zig-zag plant, Slipper flower	CAUTION Harmful if eaten/skin & eye irritant
Phaleriaclerodendron	Rosy Apple	CAUTION Harmful if eaten
Philodendron	Philodendron,	CAUTION Harmful if eaten/skin & eye irritant
Phytolacca	Poke, Pokeberry, Pokeweed, Bella Sombra Tree	CAUTION Harmful if eaten
Physalis alkekengi	Chinese lantern, Winter cherry	CAUTION Harmful if eaten
Pimelea		CAUTION Harmful if eaten
Plumeria	Pagoda Tree, White Frangipani, Frangipani	CAUTION Skin & eye irritant
Podophyllum	May Apple	CAUTION Harmful if eaten
Polygonatum	Solomon's seal	CAUTION Harmful if eaten
Polyscias	Aralia, Malaysian Aralia, Geranium	CAUTION Harmful if eaten/skin irritant

	Aralia, Ming Aralia	
Primulaobconica	German Primrose, Poison Primrose	CAUTION Skin irritant
Prunus laurocerasus&lusitanica	Cherry Laurel, Laurel Cherry Portugal Laurel, Portuguese Laurel	CAUTION Harmful if eaten
Rhamnus	Italian Buckthorn, Coffeeberry, Redberry Common Buckthorn, South African Dogwood	CAUTION Harmful if eaten
Rhus	Rhus Tree	CAUTION Harmful if eaten/skin & eye irritant
Ricinus communis	Castor Bean Plant, Castor Oil Plant	CAUTION Harmful if eaten/eye & respiratory irritant.
Robinia psuedoacacia	Black Locust, False Acacia	CAUTION Harmful if eaten
Ruta graveolens	Common Rue, Herb of Grace, Rue	CAUTION Skin & eye irritant
Sambucus	Elder, Elderberry	CAUTION Harmful if eaten
Schefflera	Umbrella Plant	CAUTION Skin irritant
Scilla	Bluebell, Squill	CAUTION Harmful if eaten
Scindapsus		CAUTION Harmful if eaten/skin & eye irritant
Solandra maxima	Chalice Vine	CAUTION Harmful if eaten
Solanum	Solanum	CAUTION Harmful if eaten
Sorbus aucuparia	Rowan, Mountain ash	CAUTION Harmful if eaten
Spathiphyllum	Peace Lily	CAUTION Harmful if eaten/skin & eye irritant
Symphytum	Comfrey, Knitbone	CAUTION Harmful if eaten
Synadenium grantii	African Milkbush, Grant's Milkbush	CAUTION Harmful if eaten/skin & eye irritant
Syngonium	Syngonium, Arrowhead Vine, Five Fingers vine	CAUTION Harmful if eaten/skin & eye irritant
Tabernaemontana	Crape Gardenia, Crape Jasmine, Pinwheel Flower, Milkwood	CAUTION Harmful if eaten
Taxus	Yew	CAUTION Harmful if eaten

Templetonia retusa	Cockie's tongue, Bullock bush	CAUTION Harmful if eaten
Thevetia (syn. Cascabelathevetia)	Lucky Nut, Yellow Oleander	CAUTION Harmful if eaten /skin irritant
Toxicodendron	Californian Poison Oak, Western Poison Oak	CAUTION Harmful if eaten/skin & eye irritant
Triunia	Spice Bush	CAUTION Harmful if eaten
Tulipa	Tulip	CAUTION Harmful if eaten /skin irritant
Veratrum	False Hellebore	CAUTION Harmful if eaten
Wisteria	Wisteria	CAUTION Harmful if eaten
Xanthosoma	Yautia, Tannia, Blue taro	CAUTION Harmful if eaten/skin & eye irritant
Zamioculcas zamiifolia	Zanzibar gem, Zee zee, ZZ plant, Money tree, Arum 'fern', Eternity plant	CAUTION Harmful if eaten/skin & eye irritant
Zantedeschia	Arum Lily, Calla Lily	CAUTION Harmful if eaten/skin & eye irritant
Zephyranthes	Wind flower, Fairy lily, Rain lily	CAUTION Harmful if eaten
Zigadenus	Death Camas, Zygadene	CAUTION Harmful if eaten

Appendix – 2. Industry guidelines for PBR labelling (from the IP Australia website)

Varieties covered by provisional or full protection under the ***Plant Breeder's Rights Act 1994*** should use the accepted form of the logo and warning as illustrated.

If several varieties of the same species under a brand name are listed, the PBR symbol should be displayed next to the protected varieties.

Note: It is no longer necessary to display application or grant numbers.

Labelling Seed Bags

This version of the logo prints either solid PMS 562 or Black onto seed bag packaging.

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Cap height of box = height of section of logo

Labelling Plants

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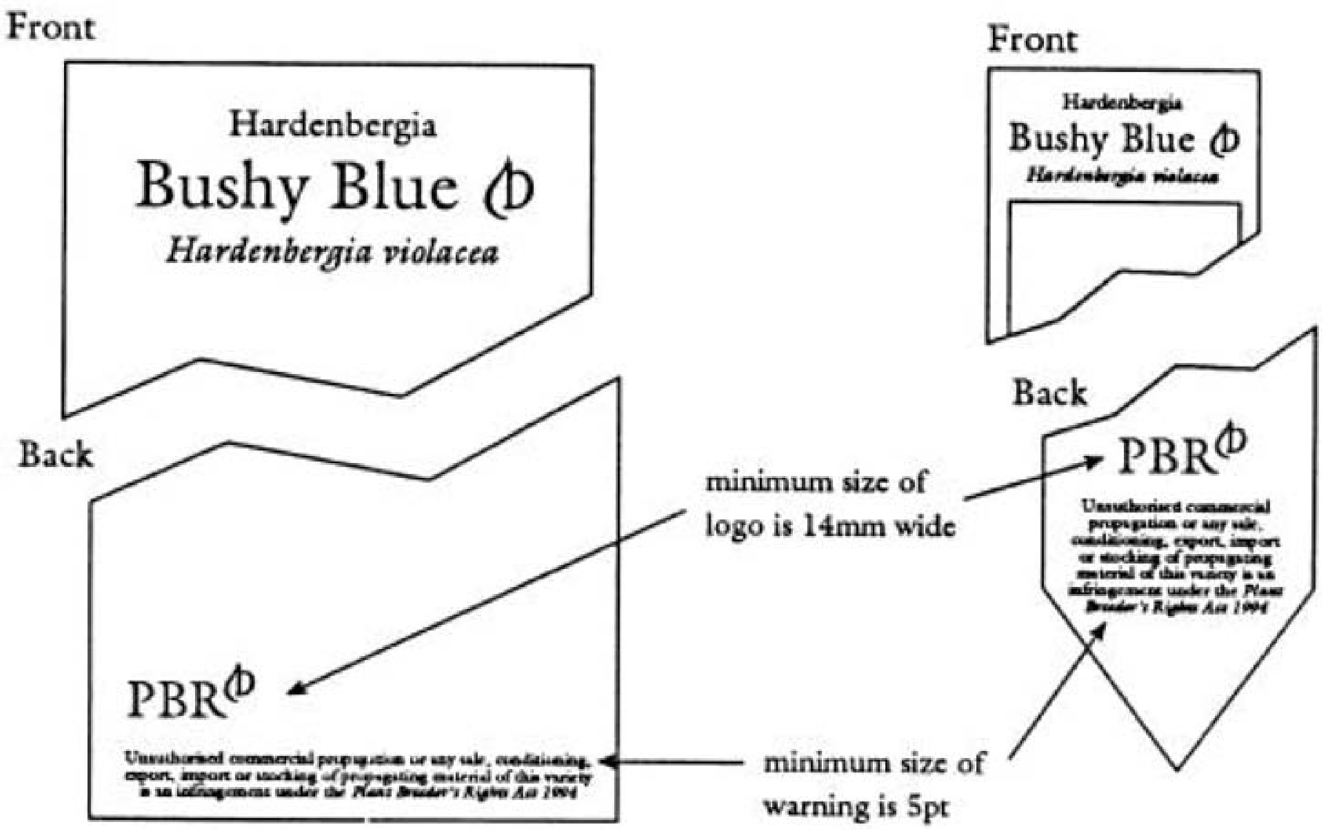

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eg. Asplenium antiquum **Victoria** ⦶
Acacia cognata **Green Mist** ⦶
Phaseolus vulgaris **Phoenix** ⦶

Appendix 5

Efficacy of Organic Amendments Used in Plant Production

Final Report

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1. Introduction

The efficacy of organic amendments, a broad collection of products sourced from naturally occurring organic materials that can be supplemented to growing media (or soil) for enhanced plant growth, requires assessment. To date, there has been relatively little scientific scrutiny of the many alleged gains to applying these organic amendments (Quilty and Cattle, 2011), particularly in containerized plant production. The aim of this report was to assemble and review the scientific studies on the use of organic amendments in containerized production horticulture, to assess their utility to this sector. The main organic amendments that were reviewed were: composts, based on plant residues, animal manures and municipal and industrial waste material; compost teas (aerated and non-aerated); meat, blood and bone meals; fish emulsions; seaweed extracts; organic waste materials (uncomposted); bioinoculants including mycorrhiza and plant growth-promoting bacteria; biochar; vermicomposts (solids and liquid teas); humic extracts; uncomposted plant parts; and amino acids and organic acids. Their efficacy was evaluated; their benefits and drawbacks discussed; their approximate costs outlined, their application rates considered and their practical relevance examined. The following recommendations have been formulated to attempt to outline what is required to fill the current gaps in the knowledge: 1) evaluate the efficacy and optimal application rate of emerging organic amendments for a wide range of crops in containerized production for which there is currently very limited information; 2) examine the shelf life of organic amendments under normal storage conditions; 3) determine the optimal base level nutritional benchmarks for all nursery crops so that organic amendments can be identified that can supply or partly supply these nutrients; 4) match nutrient charting and responsive fertilizer applications to nutrient release from organic amendments to determine the precise application timing of organic amendment products for optimal efficacy; and 5) investigate using blends and sequential application of organic amendments matched to crop requirements for optimal plant production.

1.1 Background

While the Australian Standard for potting mixes (AS3743-2003) outlines the physical, chemical, and biological requirements for potting mixes packaged for retail sale, it can be used as a guide for bulk use in production nurseries. According to the standard, the growing medium can be composed of any materials (other than glass or any other sharp objects), provided that specific physical and chemical requirements, as appropriate, are met. As such, this standard can also be used as a guide for the addition of organic amendments, though careful consideration must be given to any human health implications since these are not addressed by this standard. The Australian Standard for composts, soil conditioners and mulches (AS4454-2012) outlines the requirements for organic products and their mixtures used to amend the physical and chemical properties of growing media and soils. It specifies physical, chemical, and biological requirements for composts, mulches, soil conditioners and related products (including vermicomposts, with extra requirements if not thermogenically composted) for bagged and bulk use in all market sectors, but does not apply to organic fertilizers such as blood and bone, liquid organic wastes or liquid seaweed products. (Pertinent requirements include a minimum pH of 5.0, a maximum electrical conductivity of 10 dS/m (but gives maximum product application rates above this), certain human pathogen indicator levels, and specifies a compost maturity index).

Organic amendments are a diverse group of products derived from naturally occurring organic materials that can be added to growing media or soil, with the ultimate goal of improving plant production. They include biochars; bioinoculants; meat, blood and bone meals; composts; compost teas; fish emulsions; humic extracts; seaweed extracts; and vermicomposts (Quilty and Cattle, 2011). Such organic amendments are used commercially in plant production systems, both field- and container-based, in Australia and worldwide (Quilty and Cattle, 2011). There are many alleged gains to applying organic amendments during plant propagation, production and management. Their purported benefits include providing nutrients to plants; stimulating plant growth and enhancing flowering; controlling diseases and pests; increasing beneficial microbial biomass; and increasing tolerance to water stress (Gamliel *et al.*, 2000; Litterick *et al.*, 2004; Quilty and Cattle, 2011). They can also be useful for the partial replacement of growing media that have excellent production properties but some disadvantages associated with them, such as peat (Baran *et al.*, 2001; Bustamante *et al.*, 2008; Garcia-Gomez *et al.*, 2002; Papafotiou *et al.*, 2004). Whilst the claimed benefits of organic amendments are numerous, there is a relative paucity of scientific assessment of their efficacy (Quilty and Cattle, 2011).

Organic amendments are thought to have great potential to improve plant growth but their effects have been generally inconsistent (Bonanomi *et al.*, 2007; Bonanomi *et al.*, 2010). An organic amendment that improves plant production at one locale, may not do so in other regions with a different climate, plant materials and cultural conditions (Chong, 2005). In some cases, they have negative effects which limit their use (Bonanomi *et al.*, 2007). The value of some organic amendments has been questioned. The effects of liquid fertilizers derived from natural products, such as seaweeds, vegetables, animals or fish, on crop and pasture production in the field was reviewed (Edmeades, 2002). Though there was no reference to containerized studies, this review examined 28 products and 810 treatment effects, and found there was no evidence to show that any of them were effective at improving the yield of any crops. Edmeades (2002) stated their “observed effects...on a wide range of crops were normally distributed about zero with an equal number of positive and negative ‘responses’”; “the frequency of statistically significant events...was consistent with probability theory, assuming that the products are ineffective” and “the range of observed effects are...consistent with the normal variability associated with field trial experimentation”. He asserted that, when applied as recommended, there were inadequate amounts of nutrients, organic material or plant growth promoting compounds to enhance plant growth (Edmeades, 2002); and that studies with negative results were rarely published (Bonanomi *et al.*, 2007; Cassan *et al.*, 1992), creating a bias towards drawing the conclusion from the published scientific literature that they were effective. Edmeades (2002) conceded that it was possible that these products could improve plant growth if applied at much higher rates, though it was unlikely to be economically viable for field crops. The high value horticultural market may have the potential to sustain such application rates in containerized production.

1.2 Objectives

Containerized production poses unique challenges when considering organic amendments to growing media as compared to their addition to broadacre agriculture and horticulture. Organic amendments need to be compatible and supportive of the growth of plants in these systems, where roots are restricted to small volumes of growth substrates, which need to supply nutrients, water and oxygen and support the growth of plants throughout the crop production cycle (Kuo *et al.*, 2004; St. Martin and Brathwaite, 2012). In terms of supplying nutrients, synchronizing the mineralization of nutrients from organic amendments with the demand of the plants remains one of the greatest challenges (Treadwell *et al.*, 2007). Also, shifts in time and source can lead to inconsistency in the constitution of a specific organic amendment and variation in characteristics of the resultant growing media (Hicklenton *et al.*, 2001). This can be amplified in container production due the limited volume of the container. The nursery, garden and horticultural production industries demand a consistent, vigorous finished plant on a tight timetable and such media variability must not interfere with the uniform rate of growth, plant nutrition or its form and aesthetics (Hicklenton *et al.*, 2001; Jack *et al.*, 2011; Sterrett, 2001). Some growers produce plants in-ground, and the use of organic amendments in broadacre systems has been reviewed recently by Quilty and Cattle (2011), albeit with an agricultural focus. As such, in this report, there is only passing reference to such work where appropriate. Instead, the purpose of this report was to collate the scientific literature on the use of organic amendments in containerized plant production, in an effort to evaluate their value to this sector.

2. Types of Organic Amendments

Composted pine bark, produced from *Pinus radiata* Don, is the principal component of potting media in Australia (Carlile, 2008; Handreck and Black, 2002). Peat is also extensively used (Abad *et al.*, 2001) and is mostly imported from the Northern Hemisphere, with negligible amounts from the limited Australian resources of sphagnum peats and sedge peats, which generally have less desirable characteristics (Anonymous (1994) cited in Handreck and Black, 2002; Offord *et al.*, 1998). However, peat can be expensive, scarce and environmentally unsustainable (Baran *et al.*, 2001; Castillo *et al.*, 2004; Heiskanen, 2013). Transportation costs, in particular, have increased its cost (Heiskanen, 2013). Peat is harvested from highly sensitive wetlands ecosystems of high ecological and archaeological importance (Bustamante *et al.*, 2008). In Australia, the small, scarce freshwater peatlands from which peat is mined are fragile ecosystems, often containing rare or threatened species (Offord *et al.*, 1998). Besides causing environmental degradation, mining and subsequent use of this non-renewable resource results in the liberation of carbon dioxide (due to aerobic decomposition of the peat), an important greenhouse gas (Benito *et al.*, 2005; Bustamante *et al.*, 2008; Termorshuizen *et al.*, 2004). Peat bogs constitute important carbon dioxide sinks (Bustamante *et al.*, 2008). Mineralization of a cubic metre of peat emits 247 kg of fossil carbon dioxide (Smith *et al.*, 2001). Replacement of this amount of peat with an organic amendment such as compost, would equate to a saving of about 362 kg of carbon dioxide per tonne of compost. This beneficial effect in terms of carbon dioxide liberation, combined with peat bogs serving as a substantial sink for atmospheric carbon dioxide, the avoidance of emissions from landfills as a result of recycling materials to produce organic amendments such as compost, and the potential reduction in the need for fertilizers, all make for a strong case for decreasing the proportion of peat used in growth substrates by supplementing it with various organic amendments (Smith *et al.*, 2001; Termorshuizen *et al.*, 2004).

Whilst total substitution of peat with other organic matrices, such as compost, is restricted by a lack of homogeneous characteristics, potentially high levels of soluble salts and the risk of phytotoxic compounds (Ceglie *et al.*, 2011), partial substitution would be a satisfactory compromise (Baran *et al.*, 2001; Bustamante *et al.*, 2008; Garcia-Gomez *et al.*, 2002; Papafotiou *et al.*, 2004). In particular, substitution using locally sourced products that are waste products from other processes and industries, would be the ideal solution, environmentally, economically and politically (Heiskanen, 2013). The high nutrient content and potential presence of growth promoting substances in organic amendments, such as composts, are benefits of such substitution. However, establishing the correct proportions is essential, since if amendment rates overcome a favourable threshold, there may be negative effects of factors such as high salt concentrations and alkaline pH on plant growth (Ceglie *et al.*, 2011). In Australia, commonly employed alternatives include composted eucalypt bark, hardwood sawdust and various agronomic, industrial and municipal wastes (Handreck and Black, 2002).

In container production, if the aim is to partially replace existing growing media, then the real test is whether organic amendments can deliver plants of equivalent quality and productivity to those expected from conventional production methods. For instance, Zhai *et al.* (2009) compared the growth of greenhouse tomatoes in combinations of peat-based substrates amended with composts from various feedstocks (domestic garden waste, swine manure, or spent mushroom substrate) and liquid fertilizers (fish- or plant-based), to growth in the peat-based substrate with conventional hydroponic fertilizer. Yields of tomatoes grown in some treatments of 50% spent mushroom compost or domestic garden waste compost, with an organic liquid feed plus either plant-based or fish-based liquid feeds to provide N and P, were equivalent to those of the hydroponic control. Spent mushroom compost combined with a low rate of the plant-based liquid fertilizer was the most productive organic treatment. However, care is required as higher rates of fish-based or plant-based liquid fertilizers induced *Fusarium* crown and root rot, which severely reduced yield. Generally, organic-produced tomatoes had a lower postharvest decay index indicating better shelf life than their conventional counterparts. While microbial activity and numbers of bacterial- and fungal-feeding nematodes were greater in compost/liquid fertilizer treatments than in the hydroponic control, the diversity of the bacterial populations did not differ (Zhai *et al.*, 2009). Similarly, Rippy *et al.* (2004) found that numerous combinations of 15% vermicompost-amended pine bark or peat/pine bark media plus organic liquid feeds based on seaweed extracts produced tomato yields equivalent to those of the conventional production system. These are two examples of how equivalent growth can be achieved using organic amendments, but growers must be aware of potential trade-offs such as higher disease incidence.

The combination of an ever-expanding population, intensive farming practices and industrial practices used worldwide leads to a tremendous amount of organic wastes that require careful disposal to mitigate an environmental hazard (Atiyeh *et al.*, 2000c; Kuo *et al.*, 2004). Taking the view of Raviv (1998) that these organic wastes are 'resources out of place', the container plant production industry, with its perpetual need for growth substrates, is well placed to utilize such recycled wastes as the basis for organic amendments (Kuo *et al.*, 2004). Several countries have created their own national inventory of organic wastes with potential for use in the growing media for containerized ornamental plant production (Abad *et al.*, 2001). In Spain, of 105 waste products examined, 63 showed potential for use as container media amendments, with most having physical, physicochemical and chemical properties which were either acceptable or easily improvable. Examples of properties that were commonly outside the optimal or acceptable range included particle size, air capacity, total water holding capacity, total organic matter, pH and electrical conductivity (Abad *et al.*, 2001). Organic amendments including composts; compost teas; meat, blood and bone meals; fish emulsions; and vermicomposts can all be based on organic waste materials.

2.1 Composts

Composted pine bark, produced from *P. radiata*, is the major constituent of potting media in Australia today (Carlile, 2008; Handreck, 1986). However, compost can be produced from any plant or animal matter.

Composting is the breakdown of organic matter by microorganisms, including bacteria, fungi and actinomycetes, under aerobic conditions into beneficial, stable end products. The end product is termed compost, or thermogenic compost to distinguish it from other similar products derived from other composting processes, such as vermicomposts (Azcona *et al.*, 2011; Kuo *et al.*, 2004; Litterick and Wood, 2009; St. Martin and Brathwaite, 2012). Some of the organic matter is mineralized to carbon dioxide, ammonia, and water and the remainder is converted into humic substances (Hoitink and Fahy, 1986; Kuo *et al.*, 2004; Rynk *et al.*, 1992). Composting is comprised of an active composting (mesophilic) phase, characterized by microbial breakdown of carbon sources generating heat, encouraging the growth of thermophilic bacteria (thermophilic phase), and a cooling and maturation phase (Atiyeh *et al.*, 2000c; Avery *et al.*, 2012; Kuo *et al.*, 2004; St. Martin and Brathwaite, 2012). During this final curing phase, mesophilic microbes recolonise the compost from the outer low-temperature layer, which is critically affected by moisture content (Hoitink *et al.*, 1997). Compost production has been reviewed recently by St. Martin and Brathwaite (2012). For use in container media, composts must be stable and mature to avoid secondary biodegradation, leading to oxygen and nitrogen deficiencies in the rhizosphere and the presence of phytotoxic compounds (Raviv, 2005). The quality and performance of composts should be reproducible and predictable (Inbar *et al.*, 1993), though this is a challenge given the range and variability of feedstock sources.

Composts derived from waste materials or by-products from other industries may be useful as an ingredient in container media in ornamental, nursery crop and vegetable transplant production systems (Epstein, 1997; Fitzpatrick, 2001; Sterrett, 2001). Whilst there may be some reluctance to use some of these composts for food crop production, due in part to a negative perception by society of the source feedstock (for example, sewage sludge biosolids and municipal solid waste), these composts may find more acceptance for the production of non-edible crops such as ornamentals, forest and garden trees, and shrubs (Alexander, 2001; Farrell and Jones, 2009; Raviv, 1998; Raviv, 2005; Raviv, 2008).

Variation in physical, chemical and biological parameters across and within compost types, sources and batches has hindered its widespread use as an organic amendment (St. Martin and Brathwaite, 2012). Factors such as starter feedstock type; production methods including pre- and post-processing methods; level of compost maturity and stability; and the resulting chemical, physical and biological attributes of the compost impact the efficacy of compost to improve plant growth and/or suppress disease (Fitzpatrick *et al.*, 1998; Litterick and Wood, 2009; Nkongolo *et al.*, 2000). Such attributes (with their optimal values or acceptable ranges) include the carbon:nitrogen ratio (<20); nutrient (especially nitrogen) content; cellulose and lignin content (for plant residues); particle size (0.25-2 cm), bulk density (<0.4 g/cm^3), total porosity (>85%) and air-filled porosity (5-30%); various gas exchange indices; water holding capacity (20-60%); electrical conductivity (soluble salts content; <2.5 dS/m); moisture content; pH (5-7.6); cation exchange capacity (ability to retain nutrients), the presence of toxic compounds including pesticides; and a wide diversity of microflora (including bacteria, fungi and actinomycetes) and microfauna (such as nematodes, springtails and mites) (Abad *et al.*, 2001; Bezdicek *et al.*, 2001; Fitzpatrick *et al.*, 1998; Hoitink and Fahy, 1986; Kuo *et al.*, 2004; Litterick and Wood, 2009; Nkongolo *et al.*, 2000; Rynk *et al.*, 1992; Rynk, 2001; Verdonck, 1988).

When producing compost from plant residues for use as a horticultural growing medium, the choice of the starting feedstock is crucial in terms of both nutritional quality and structural quality (Dresbøll and Thorup-Kristensen, 2005; Dresbøll and Magid, 2006). Root development and proliferation is influenced by the physical structure and stability of the medium (Dresbøll and Thorup-Kristensen, 2005). Feedstocks with different lignin and cellulose contents, and different morphological properties, such as tissue arrangement, affect the features of the final compost product. The geometry and surface characteristics of particles and the resultant pores created determine the water retention properties and the air and water availability to roots (Dresbøll and Thorup-Kristensen, 2005).

Production methods can influence the efficacy of compost as an organic amendment in terms of disease suppression. Biphasic composts can be prepared whereby starter feedstocks are composted to the end of the thermophilic phase, and then this partially stabilized compost is amended with extra organic matter, inducing a second thermophilic phase (Labrie *et al.*, 2001). Labrie *et al.* (2001) showed that biphasic composts utilizing shrimp waste significantly reduced the incidence of cucumber damping-off caused by *Pythium ultimum* Trow. compared to that of a commercial brand of compost based on shrimp waste. Shrimp waste amendment at the end of the first thermophilic phase altered the resident microbial populations of the biphasic compost, promoting the proliferation of Gram-positive bacteria antagonistic to oomycete plant pathogens such as *P. ultimum* (Labrie *et al.*, 2001).

The influence of the level of compost maturity and stability on its efficacy in terms of disease suppression was demonstrated by Kuter *et al.* (1988). Municipal sewage sludge composts were added to a container medium that was conducive to both *Pythium* and *Rhizoctonia* damping-off. Compost cured for 4 months consistently suppressed damping-off caused by *Pythium* spp. but not that caused by *Rhizoctonia* *solani* Kühn. Storing media amended with the 4-month cured compost for an additional 4 weeks, rendered it suppressive to both diseases. Media amended with 25% (v/v) municipal sewage sludge compost and stored induced disease suppression levels that avoided plant losses in greenhouse and nursery crops due to damping-off over 5-month (*R. solani*) and 2-year (*Pythium* spp.) production cycles (Kuter *et al.*, 1988).

Compost can also be deliberately inoculated with antagonists to improve its suppression of certain plant diseases (Postma *et al.*, 2003; Termorshuizen *et al.*, 2004; Zhang *et al.*, 1998). Compost derived from a mixture of vegetable and animal market wastes, sewage sludge and domestic garden wastes was naturally suppressive of *Fusarium* wilt of tomato, and was compared to a peat mix that was highly conducive (Cotxarrera *et al.*, 2002). Amendment of the peat mix with the compost rendered it more suppressive. Comparing the peat mix, the compost and the compost-amended peat mix, the peat mix was acidic with a low electrical conductivity, the compost was basic with a high electrical conductivity, and the compost-amended peat mix had a similar pH to the compost but the electrical conductivity was approximately halved. Such abiotic properties can play a role in disease suppression. The high pH may have limited the availability of micronutrients to the pathogen, restricting its growth, and the high electrical conductivity can reduce pathogen survival. The compost-peat mix was amended with *Trichoderma asperellum* Samuels, Lieckf. & Nirenberg isolates or a non-pathogenic isolate of *Fusarium oxysporum* Schlecht. emend. Snyder & Hansen. The non-pathogenic isolate of *F. oxysporum* was highly suppressive to *Fusarium* wilt of tomato, giving significantly greater suppression than that caused by the compost-peat mix alone or the *Trichoderma*-amended compost (Cotxarrera *et al.*, 2002). It has been proposed that composts can suppress plant diseases by inducing systemic acquired resistance (SAR) (Zhang *et al.*, 1998), for example, in cucumber against anthracnose caused by *Colletotrichum orbiculare* (Berk. & Mont.) Arx and *Pythium* root rot caused by *P. ultimum*, and in *Arabidopsis* against bacterial speck caused by *Pseudomonas syringae* Van Hall pv. *maculicola*, likely via high populations of microorganisms (Lievens *et al.*, 2001; Zhang *et al.*, 1998).

It is important to determine optimal compost conditions for maximal colonization of the compost by antagonists and inoculate accordingly. For example, mature composted hardwood tree bark removed from various temperature zones within the compost pile and incorporated into a growing medium for a radish bioassay affected the ability of *Trichoderma hamatum* (Bonorden) Bainier to suppress *Rhizoctonia* damping-off (Chung and Hoitink, 1990). However, Postma *et al.* (2003) found that the maturation stage or the location of the compost sample in the compost pile did not affect antagonist survival in the pathosystems they studied.

Therefore, it can be seen that it is not feasible to draw general conclusions about the positive or negative effects of compost as media amendments for the growth of nursery species, due to the wide array of organic substances used as starter feedstocks and the myriad of composting processes employed (Heiskanen, 2013). This exacerbates the problem of inconsistent performance (Bonanomi *et al.*, 2007; Bonanomi *et al.*, 2010), real or perceived, which has hampered adoption. Reviewing studies on the responses of annual, perennial and woody ornamental plants in container production to increasing amounts of compost incorporated into the growing medium, Moore (2005) deduced that there were five potential growth outcomes: no response, increase then plateau, linear increase, bell curve or decrease. Therefore, it is essential to test any new compost-amended growing medium before widespread production use (Heiskanen, 2013). For example, Paplomatas *et al.* (2005) found great variability in suppression of *Verticillium* wilt of eggplant among eleven compost amendments. In a model pathosystem, the authors found that, compared to the control, only five composts displayed significant suppression, while three showed equivalent disease severity, and three exhibited greater disease severity (Paplomatas *et al.*, 2005). Compost is generally cheaper than peat and other growth substrates, so in container production, as long as amending the substrate with compost does not compromise the consistency and vigour of the final product, it can make production more cost effective (Klock-Moore and Fitzpatrick, 2000). Production costs may also be reduced if the compost is disease suppressive, obviating the need to sterilize growing media and reducing fungicide use (Hoitink and Fahy, 1986; Stephens and Stebbins, 1985), and due to slow release of nutrients, reducing fertilizer inputs (Rynk *et al.*, 1992). If it improves plant growth in any aspect, that is a further benefit.

Potential long term reductions in production costs are an incentive to utilize organic amendments such as compost, especially if they have an effect on more than one production issue. For example, composts have been used as top dressings for turf and have consistently suppressed numerous fungal diseases including both foliar and root pathogens, in comparison with untreated turf or turf dressed with sand or topsoil (Litterick and Wood, 2009; Nelson and Boehm, 2002). While short term disease control was often not as effective as that afforded by fungicides, in the long term, disease control and turf quality due to compost top-dressing surpassed that provided by fungicides. This reinforces that a long term, holistic, sustainable approach is required to containerized plant production.

2.1.1 Plant Residues

2.1.1.1 Tree barks

Composted pine (*P. radiata*) bark is the main ingredient of potting media in Australia today, and it is widely used internationally, particularly in the USA, western Europe and the UK (Carlile, 2008; Handreck and Black, 2002). It can be produced with a range of particle sizes to optimize air-filled porosity, has excellent water holding capacity, minimal slumpage, provides ballast, retards evaporation of water, has desirable cation exchange capacity, a low decomposition rate and can suppress pathogens (Carlile, 2008; Handreck and Black, 2002). In general, composted tree barks have been combined with peat (often 4:1 v/v) or replaced peat as media for container crops because of their disease suppressive effects (Daft *et al.*, 1979; Hoitink, 1980; Hoitink and Fahy, 1986; Hoitink *et al.*, 1991; Kuter *et al.*, 1983; Spring *et al.*, 1980). Their use has eliminated the need to sterilize media and has reduced the use of fungicides to control soil-borne diseases of containerized nursery crops (Hoitink, 1980). The tree species from which the bark is obtained and the wood content (affected by the debarking process) can influence disease suppression. Both softwoods, such as pine, and hardwoods, such as eucalypts, have been used.

Mature composted hardwood bark (CHB) significantly suppressed *Rhizoctonia* and *Pythium* crown and root rot of poinsettia (Daft *et al.*, 1979), damping-off caused by *R. solani* in celosia and radish bioassays (Nelson and Hoitink, 1982; Nelson and Hoitink, 1983; Stephens *et al.*, 1981) and *Fusarium* wilt of chrysanthemum (Chef *et al.*, 1983), but this suppression was eliminated by heating or exposure to gamma radiation (Nelson and Hoitink, 1983). Suppression was re-established by adding 10% unheated mature CHB or *Trichoderma harzianum* Rifai originally isolated from mature CHB (Nelson and Hoitink, 1983). Media amended with immature CHB were only slightly suppressive and heating had little or no effect on this suppressive effect (Chef *et al.*, 1983; Nelson and Hoitink, 1983). These results indicate that the suppressive ability of mature CHB is due to microbial activity, whilst the lower level suppression due to immature CHB may involve chemical inhibitors. Further to support this latter claim, leachates from fresh (<11-week-old) CHB suppressed *Phytophthora* root rot of lupine *(Lupinus angustifolius* L.) seedlings, due to substances in the leachate inhibiting sporangium formation and lysing zoospores and cysts (Hoitink *et al.*, 1977). The microbial activity in CHB responsible for suppression of *Rhizoctonia* damping-off includes members of numerous genera of fungi, particularly *T. hamatum* and *T. harzianum* (Nelson *et al.*, 1983). Disease suppression is dependent on populations of these antagonistic microbes, as well as unspecified factors to do with compost maturity. Therefore, consistent suppression of *Rhizoctonia* damping-off requires the isolation and reintroduction of such antagonists into an environment favourable for their growth to optimize antagonistic activity, such as mature CHB (Nelson *et al.*, 1983).

Composted eucalypt bark (CEB) significantly suppressed root rot disease caused by five different *Phytophthora* species in container-grown waratah (*Telopea speciosissima* L.) and banksia (*Banksia occidentalis* R.Br.) plants, compared to those in steamed (inactivated) CEB or a commercial nursery mix (Hardy and Sivasithamparam, 1991; Hardy and Sivasithamparam, 1995). This suppression seemed to be due to specific fungal and actinomycete isolates, and there is potential for these isolates to be mass produced and added back into CEB to enhance root rot control in nursery species (Hardy and Sivasithamparam, 1995).

Norway spruce (*Picea abies* (L.) Karst.) seedlings were grown in peat amended with forest-nursery waste compost at 25%, 50% or 100% (v/v) in the greenhouse, prior to transplantation to the field (Veijalainen *et al.*, 2007). The forest-nursery waste was comprised, not of tree bark, but of bare root and container tree seedlings, peat and weeds, which was composted for 4 years. In the greenhouse in the first 12 weeks of growth, compost amendment significantly decreased seedling height, diameter and shoot and root dry mass, except root dry mass in 25% compost, which was equivalent to that in peat alone. Foliar nutrient concentrations were optimal in all the seedlings, except the nitrogen content, which decreased with increasing compost amendment. Compost amendments had no effect on the root-egress potential, that is, the growth of roots from root plugs into the surrounding soil, which was tested prior to outplanting. Following transplantation to the field, seedlings that had been grown in peat grew significantly more than the other seedlings during the first season. Thereafter, compost amendments generally did not affect growth, except in 100% compost amendment, which had significantly lower final height and stem diameter (Veijalainen *et al.*, 2007).

Whilst composted pine bark is the mainstay of containerized media in Australia and its benefits are well-established, a variety of plant residues can be composted to produce beneficial amendments for plant growth, and these are presented below in alphabetical order.

2.1.1.2 Apple Pomace

Apple pomace is a by-product of the juice and cider industry. In one brief report, four nursery species, silverleaf dogwood (*Cornus alba* L.), euonymus (*Euonymus fortunei* (Turcz.) Hand. -Mazz.), Andorra juniper (*Juniperus horizontalis* Moench) and Emerald cedar (*Thuja occidentalis* L.), were transplanted into a commercial growing medium amended with 25%, 50%, 75% or 90% apple pomace (Chong, 1992). All four species grew well in the amended media, with equivalent shoot dry weights compared to those in the standard medium, except Andorra juniper which grew better, having significantly higher shoot dry weight with 75% or 90% pomace. However, these high rates of apple pomace caused significant shrinkage of the medium, and so were unsuitable (Chong, 1992), but the lower rates may have potential. If apple pomace is an inexpensive waste product in close proximity to container production facilities, it may be worthwhile testing other plant species for their response to low rates of media amendment with this compost, but this is unlikely to be an amendment with widespread application.

2.1.1.3 Coffee Waste

Coffee pulp is a waste product of processing coffee cherries for the beverage industry. Tomato seedlings grown in commercial growing media amended with 10% coffee pulp compost had significantly higher aerial biomass, were 20% taller and had more nodes per plant compared to those in the standard medium (Berecha *et al.*, 2011). This was partly due to improvements in the physicochemical properties of the medium. However, in a separate study, coffee waste compost (the precise composition and composting conditions of which were not specified) did not improve the growth of spinach (*Spinacia oleracea* L.), radish (*Raphanus sativus* L.) and Chingensai (*Brassica campestris* L.) (Ebid *et al.*, 2008). When these species were grown in soil amended with coffee waste compost, tea leaves compost, kitchen garbage compost or inorganic N fertilizer as a control, spinach leaf and radish root dry matter yield was significantly lower in coffee waste compost than all the other treatments, whilst radish leaf and Chingensai leaf dry matter yield was significantly lower in coffee waste compost than both tea leaves compost and the inorganic N fertilizer control (which were equivalent). The varying effect of coffee waste as an amendment on plant growth may be due to different compost starter feedstock despite them both being based on coffee waste, different composting conditions, different base media or the different plant species studied. Given the minimal production of coffee in Australia, the paucity of research on coffee pulp compost and its inconsistent efficacy, this cannot be considered as a useful organic amendment for containerized plant production.

2.1.1.4 Cotton Waste

Cotton waste compost has been studied as an amendment to potting media for the production of ornamental plants. Cotton waste compost did not generally have any negative effects on the growth of foliage ornamentals such as croton (*Codiaeum variegatum* (L.) A. Juss.), ficus (*Ficus benjamina* L.), poinsettia (*Euphorbia pulcherrima* Willd. ex Klotzsch) and *Syngonium podophyllum* Schott, when it replaced 50-65% of the peat component in the peat-perlite growing medium (Papafotiou *et al.*, 2001a). When it replaced 25%, 50% or 75% of the peat component in the peat-perlite growing medium, plant height, leaf number, and leaf size of croton did not change, but foliage colour was altered, and root dry weight was increased in 25% amended media (Papafotiou *et al.*, 2007). Plants grown in media amended with cotton waste compost had more areas coloured red in their leaves, with the red coloration increasing as the rate of cotton waste compost amendment increased. When cotton waste compost replaced 50% of the peat component in the peat-perlite growing medium, croton plants were of similar quality to those grown in the unamended medium. Increasing amendment rate of cotton waste compost level caused a concomitant increase of nitrogen, phosphorus, and potassium concentrations in the media; an increase in the electrical conductivity (which reduced to levels equivalent to that of the control medium after 50 days of culture); and an increase in the pH (Papafotiou *et al.*, 2007). Similarly, Jackson *et al.* (2005) found that ficus (*F. benjamina*) and lantana (*Lantana camara* L.) plants grown in pine bark substrate amended with 40%, 60% or 100% cotton waste compost significantly increased root growth (the only parameter measured) compared to those in the unamended substrate.

The tropical foliage species Asian bell tree (*Radermachera sinica* (Hance) Hemsl.) and Australian umbrella tree (*Brassaia actinophylla* Endl.) were grown in different peat-bark proportions amended with 25%, 50%, 75% or 100% composted cotton waste (Wang, 1991). Asian bell tree grew adequately in media amended with 25% or 50% composted cotton waste but dry weight was reduced in compost-amended media with a 50% bark component. The dry weight of Australian umbrella tree was reduced in media amended with 50% or more composted cotton waste. Australian umbrella tree grew best, and Asian bell tree grew poorest in the medium comprised of 25% composted cotton waste, 50% bark and 25% peat. Growth response to composted cotton waste amendments appeared to be species dependent (Wang, 1991).

The ornamental plant *Coleus* x *hybridus* Voss. was grown in pine bark amended with 20%, 40%, 60%, 80% or 100% composted cotton waste (Owings, 1993). Coleus grown in 20-40% composted cotton waste were significantly taller, while those in 100% composted cotton waste were significantly shorter, 25 days after potting compared to plants in unamended media. By 42 days after potting, coleus in 20-80% composted cotton waste were of equivalent height to those in unamended media, but those in 100% cotton waste were still significantly shorter. Coleus grown in 40% composted cotton waste were significantly heavier than those in unamended media, while those in 100% composted cotton waste had significantly lower dry weights. Coleus in media containing 20-60% cotton waste had equivalent visual quality ratings to those grown in unamended media, but quality was significantly decreased in 80-100% composted cotton waste (Owings, 1993). Media amendment at 20-60% was considered suitable for coleus production.

Chrysanthemum (*Dendranthema grandiflora* Tzvelev.), oleander (*Nerium oleander* L.), lantana (*L. camara*) and zonal geranium (*Pelargonium zonale* L.) were grown in media containing cotton waste compost, rice hulls, peat and perlite in various ratios (Papafotiou *et al.*, 2001b). Replacing 60% of the peat component in the peat:perlite (1:1) standard growing medium with cotton waste compost, caused a slight reduction in plant height in all species, except in geranium, increased the number of flowers in all species, except in chrysanthemum, and accelerated flowering in all species, except oleander. Plant height and flower number was similar in plants grown in media where 50% or 100% of the perlite component was replaced with rice hulls, compared to plants grown in the standard medium. This was not the case in chrysanthemum, where the number of flowers, and the stem length of a cut flower variety, was reduced, which would be commercially unacceptable; and in lantana (only in 100% rice hulls), where plants were shorter but this gave a more favourable appearance to the plant. Plant height of all species (except geranium) was reduced in media containing cotton waste compost, peat and rice hulls. Reduction in plant height is a positive effect in potted ornamentals, since plant growth retardants are used to control plant size for the commercial market (Papafotiou *et al.*, 2001b).

For example, compact potted chrysanthemum plants were grown in a peat:perlite 1:1 mix and sprayed with the plant growth retardant daminozide to control plant size. Replacing half the peat in the growing medium with cotton waste compost restricted shoot elongation, mainly retarding the internodal length (Papafotiou and Vagena, 2012). This resulted in a smaller plant size combined with a compact shape, which is the effect induced by low rates of daminozide application and demanded commercially. Replacing half the peat in the growing medium with cotton waste compost and applying a low rate of daminozide (2000 mg/L) retarded shoot growth similar to that induced by high rates of daminozide (3000-3500 mg/L). Cotton waste compost or high rates of daminozide reduced leaf size but did not affect flower head size. Application of daminozide or use of cotton waste compost accelerated flowering, but did not alter final flower number. This study showed that in this production system, partial growing medium substitution with cotton waste compost allowed a reduction in the rate of daminozide required to achieve commercial quality chrysanthemums, with numerous economic and environmental gains (Papafotiou and Vagena, 2012). The authors proposed that the cotton waste compost amendment decreased the total porosity and water availability, which decreased aeration in the rhizosphere, reducing plant growth.

Poinsettia (*E. pulcherrima*) rooted cuttings were grown in peat and/or composted pine bark media containing 25%, 50% or 75% composted cotton burrs (Wang and Blessington, 1990). Plants grown in media amended with any rate of composted cotton burrs were slightly shorter and narrower, with lower dry weights and 10% smaller inflorescences, compared to those grown in unamended peat:composted pine bark (1:1). However, the number of branches and bracts, days to bloom, and plant grade after 30 days were not influenced by composted cotton burr amendment and so this waste product can be used to produce plants of excellent post-production quality. Media amended with 50% composted cotton burrs maintained acceptable levels of electrical conductivity and stable pH during the culture period (Wang and Blessington, 1990).

The ornamental plant gerbera (*Gerbera jamesonii* H. Bolus) grown in compost obtained from a mixture of cotton waste and olive husk, mixed with rice hulls and peat (1:1:1 by volume), gave equivalent shoot dry matter and flower production compared to those in the standard medium (100% peat) (Caballero *et al.*, 2009).

Seeds of lettuce (*Lactuca sativa* L.), radish and spinach were sown in compost derived from cotton waste and mixed with soil at 20%, 40%, 60%, 80% or 100% (Khah *et al.*, 2012). The mean plant height and number of leaves per plant was significantly higher for all three species grown in 100% compost than in the peat control. In general, plants were significantly taller, had more leaves and were heavier when the major component of the growing medium was compost compared to those in the peat control. The effect of compost amendment of soilless growing media was not tested.

The use of cotton waste compost as an organic amendment for containerized production of ornamentals appears to have benefits when used at 20-60%, though the effect was species dependent. With Australia’s large cotton industry generating ample cotton waste which requires disposal, there is plenty of scope for the use of this presumably inexpensive feedstock for the production of compost and its use in containerized production. Further studies are required to determine its effect on the growth of vegetable transplants, and the physical and chemical characteristics of amended growing media. There was no mention of any pesticide residues in the cotton waste compost in any of the studies above, and thorough composting should obviate any risk of these remaining, but composts should be analysed for such contaminants to avoid any undesirable effects (Bezdicek *et al.*, 2001; Rynk, 2001), given the extensive use of pesticides in cotton production.

2.1.1.5 Grape Marc

Grape marc, the solid remains (skin, pulp and seeds) of the grape after pressing, is a wine-making by-product which can be composted to recycle these residues and lessen their environmental impact (Bustamante *et al.*, 2008; Carmona *et al.*, 2012). There is usually an imbalance of nutrients, with high potassium but low calcium, magnesium, copper and zinc, and unleached, it can have high electrical conductivity (Handreck and Black, 2002), so these issues must be considered.

The ornamental plant hypostases (*Hypostases phyllostagya*) grown in peat amended with 25% or 50% composted grape marc had equivalent shoot dry weights compared to those in the standard medium (100% peat). This was confirmed by analysis of the physical and chemical properties of the amended media, with lower rates of amendment having more suitable characteristics (Baran *et al.*, 2001). Ficus (*F. benjamina*) plants were grown in peat amended with 50% or 100% (v/v) composted grape marc and compared to standard media of peat, and peat plus 20% vermiculite (Chen *et al.*, 1988). Plant growth parameters such as dry weight, stem diameter, height and leaf colour were significantly improved in 50% compost amended media, compared to those in the standard media. In another study, the ornamental plant gerbera (*G. jamesonii*) grown in 100% composted grape marc gave greater shoot dry matter and equivalent flower production compared to those in the standard medium (100% peat) (Caballero *et al.*, 2009).

Marigold (*Tagetes patula* L. *nana*) plants were grown in a peat-based substrate amended with composted grape marc (or composted olive marc) at 20%, 50%, 90% or 100% (Tosi *et al.*, 1989). Physical and chemical properties of the composts (not compost-amended media) included a carbon:nitrogen ratio of 25.2 for grape marc compost (and 59.5 for olive marc compost), a pH near 7, a high free porosity, a water retention capacity lower than that of peat, and an unbalanced nutrient content. None of the amendments improved plant growth compared to the unamended substrate; a 20% composted grape marc amendment was the only medium in which plants had growth parameters equivalent to the unamended substrate. Only when zeolite, a mineral with high ionic exchange capacity (which can immobilize phytotoxic compounds) and nutrient content, was added to all media was plant growth improved, but still none of the amendments in combination with the zeolite medium improved plant growth beyond that of those in unamended zeolite peat-based substrate. However, marigolds grown in 90% grape marc plus 10% zeolite had some growth parameters equivalent to the unamended peat-based substrate, and so this medium may have potential as a substitute for peat-based substrates (Tosi *et al.*, 1989).

Plug seedlings of lettuce, pepper, melon and tomato grown in peat amended with 33%, 50% or 100% grape marc generally had equivalent growth across a range of germination and vegetative parameters (though in some instances, some parameters were reduced) compared to those in the standard medium (100% peat) (Carmona *et al.*, 2012). The physical properties of the grape marc-amended media were suitable, except they had lower total available water content, which can be ameliorated by mixing with other substrates or irrigation management. The chemical properties were also suitable, with no phytotoxicity or nitrogen immobilization. In another study, tomato plants were grown in peat amended with 25%, 50%, 75% or 100% (v/v) composted grape marc and compared to a commercial peat mixture (Reis *et al.*, 1998). The growth of tomato plants in media amended with 25-50% composted grape marc was generally similar to or better than that in the commercial peat mixture, whereas higher levels of composted grape marc reduced plant growth (Reis *et al.*, 1998).

In an earlier study, pepper, tomato and cucumber seedlings were grown in peat amended with 50% or 100% (v/v) composted grape marc and compared to standard media of peat, and peat:vermiculite:perlite (1:1:1 v/v) (Inbar *et al.*, 1986). Compost-amended media had high total porosity, low bulk density (more desirable than the extremely lightweight peat in terms of plant anchorage), adequate air and water capacity, neutral pH, low electrical conductivity, high cation exchange capacity, and high phosphorus and potassium concentrations. Plants of all three species grown in 50% and 100% compost-amended media had significantly greater shoot dry weights than those in the standard media (except shoot dry weight of peppers in the 50% amendment which, while greater than peat only, was equivalent to that in the peat:vermiculite:perlite medium). Shoot dry weight of tomatoes and cucumbers in 50% and 100% compost-amended media, and peppers in 100% compost-amended media were approximately double that in the standard media. Consequently, the seedlings reached transplanting size faster, reducing the production period by 6-10 days (Inbar *et al.*, 1986).

In a study combining grape marc with animal manure prior to composting, lettuce, chard, and broccoli (*Brassica oleracea* L.) grown in peat amended with 25% or 50% composted grape marc/cattle manure, and coriander grown in peat amended with 25% composted grape marc/cattle manure, had equivalent or greater aerial biomass fresh and dry weights compared to those in the standard medium (100% peat) (Bustamante *et al.*, 2008). With respect to physical, physicochemical and chemical characteristics, the amended media generally had suitable physical properties within optimal ranges, but higher than optimal pH and slightly higher electrical conductivity, which were the main limiting factors for their use, and should be monitored carefully.

Such amendments can also aid in disease suppression. Cress (*Lepidium sativum* L.) grown in peat amended with 20% composted residues from a viticulture and enological factory suppressed damping-off caused by *P. ultimum* and *R. solani*, but did not suppress damping-off caused by *Sclerotinia minor* Jagger (Pane *et al.*, 2011). Mandelbaum *et al.* (1988) also found that grape marc compost suppressed *Pythium* damping-off in cucumbers. Media amended with grape marc compost were suppressive to *Fusarium* wilt of tomatoes caused by *Fusarium oxysporum* f. sp. *lycopersici* Snyder & Hansen (Borrero *et al.*, 2004; Borrero *et al.*, 2006). Containerized media containing composted grape marc suppressed diseases caused by *R. solani* and *Sclerotium rolfsii* Sacc. (Gorodecki and Hadar, 1990). The severity and build-up of damping-off of radish, and the incidence of root rot of the ornamental plant pothos, both caused by *R. solani*, was reduced in media containing 67% composted grape marc, compared with that in peat-based media. Media containing 67% composted grape marc suppressed disease caused by *S. rolfsii* in chickpeas and beans. The presence of antagonistic microbes in the compost was proposed as the likely mechanism of disease suppression.

Therefore, this low cost, widely available, waste product can be transformed into a high nutrient amendment that could be utilized to at least partially replace peat in horticultural production in the greenhouse, but its effect needs to be verified for particular species, especially for long term containerized crops. Differing plant growth responses to the different rates of amendment may be due to numerous variables including variation in the original feedstock (e.g. grape cultivars and processing methods), composting conditions and experimental methodology. Further work is required to determine the optimal procedures to produce consistent, efficacious grape marc compost before a recommendation of widespread utility would be possible.

2.1.1.6 Green Wastes

Green waste compost can be produced from any wood and vegetable residues and has been assessed as an amendment to soilless growing media for horticultural production (Burger *et al.*, 1997; Ceglie *et al.*, 2011; Hartz *et al.*, 1996; Mugnai *et al.*, 2007; Spiers and Fietje, 2000; van der Gaag *et al.*, 2007). Amendment rates up to 30% by volume are generally recommended, as higher rates may cause toxicity due to high soluble salt levels, but this will be dependent on the source (Spiers and Fietje, 2000). Other potential issues with green waste compost include high nitrogen drawdown rate, high pH, high ammonium concentration, and slumpage due to rapid breakdown of woody waste (Handreck and Black, 2002). In a fitting continuum of the production cycle, green waste compost can be derived from horticultural greenhouse crop waste, which can then be used as substrate amendments for containerized production (Mazuela and Urrestarazu, 2009; Urrestarazu *et al.*, 2001). Tomatoes grown in peat (with 10% perlite) amended with 20%, 45%, 70% or 90% green waste compost (from olive tree prunings, broccoli cropping residues, lawn clippings and wood chips) were significantly taller, and had increased stem, leaves and total fresh and dry weights compared to those in unamended media (Ceglie *et al.*, 2011). This was despite the amended media generally having significantly higher pH and electrical conductivity than the unamended medium. The 20% and 45% treatments gave the greatest improvement in plant growth. This was partly supported by the work of Prasad and Maher (2001) and Maher and Prasad (2004) who found that satisfactory growth of tomatoes was achievable in media containing up to 25% composted green waste, but 50% caused reductions in growth likely due to high electrical conductivity and nitrogen immobilization.

Two ornamentals, *Photinia* x *fraseri* Dress. and *Viburnum tinus* L., were grown in peat-based substrates amended with 25%, 50%, 75% or 100% composted green waste derived from municipal waste (Mugnai *et al.*, 2007). The effect of composted green waste on the growth of ornamentals was species-specific; it increased *Viburnum* growth (when added at a low rate), but decreased *Photinia* growth. *Viburnum* grown in 25% compost-amended media generally grew better than those grown in unamended media, with significantly increased dry weight, width, and leaf area. *Viburnum* grown in 50% or 75% compost-amended media was generally equivalent to those grown in unamended media, but those in 75% compost-amended media had more compact canopies. *Viburnum* growth was significantly and unacceptably reduced in 100% composted green waste (Mugnai *et al.*, 2007). This was generally supported by the work of Guérin *et al.* (2001) on *Viburnum*. *Photinia* grown in any of the compost-amended media had significantly lower dry weights and reduced leaf area compared to those grown in unamended media (Mugnai *et al.*, 2007). *Photinia* grown in 75% or 100% compost-amended media were significantly shorter, with thinner shoots than those grown in the unamended media, and were of unacceptable quality. This was due to 75% and 100% compost-amended media having a pH ≥7, which is higher than optimal for these species and led to immobilization of micronutrients such as iron and aluminium. Although the EC values increased with compost amendment, this was tolerated by both species. Also, high rates (75% or 100%) of composted green waste increased the susceptibility of plant species to water stress (Mugnai *et al.*, 2007).

Seven ornamentals: three bedding plant species - marigold (*Tagetes* spp. L.), vinca (*Catharanthus roseus* Don.) and petunia (*P. hybrida* Vilm.); rooted cuttings of chrysanthemum (*D.* x *grandiflorum*); and three shrubs - sweet mock orange (*Pittosporum tobira* Ait.), photinia (*Photinia* x *fraseri*) and juniper (*Juniperus sabina* L.); were grown in peat-based substrates amended with 25%, 50%, 75% or 100% composted green waste (CGW; feedstock was ground municipal domestic garden and landscape waste) (Burger *et al.*, 1997). When grown in 100% CGW, seed germination and young seedling parameters (plant height, stem and root fresh and dry weights) were lowest compared to these parameters in other media, likely due to high air-filled porosity, low water holding capacity and high electrical conductivity. Adequate growth and development of most plants was achievable in 25% or 50% CGW-amended media, since blending minimized these deficiencies and the variability of these physicochemical properties. Plants were better able to grow in media with higher CGW content, once they were transplanted into larger containers (Burger *et al.*, 1997). However, users must be aware of the variation of such compost. Over a 5 month period, three CGW samples collected from each of two composting operations had physicochemical (such as macronutrient contents) and biological properties that varied widely, both between operations, and among samples from the same operation (Hartz *et al.*, 1996). Tomato (*Lycopersicon esculentum* Mill.) and marigold (*Tagetes erecta* L.) plants were grown in perlite amended with either 50% CGW or 50% peat (v/v) under varying fertigation regimes. Despite the variation, plant growth in CGW-amended media was equivalent or superior to peat-amended media; and while CGW contributed to crop macronutrient nutrition, optimum growth was only achieved with the highest fertigation rate. This is likely due in part to net nitrogen immobilization in compost-amended media (Hartz *et al.*, 1996).

The growth of vinca (*C. roseus*), verbena (*Verbena hybrida* L.) and shantung maple (*Acer truncatum* Bunge) in 100% domestic garden waste compost was compared to that in traditional media of 75% pine bark and 25% peat moss (Sloan *et al.*, 2010). Growth response in 100% domestic garden waste compost varied with species. Biomass production was equivalent for vinca, significantly less for verbena and growth rate (stem thickness and height) was significantly decreased for shantung maple in the compost medium compared to that in the traditional medium. These decreases may have been due to lower than optimal total porosity and container capacity water content, and higher than optimal electrical conductivity of the 100% domestic garden waste compost.

Azalea (*Rhododendron indicum* (L.)) and variegated pittosporum (*P. tobira*) plants were grown in a pine bark-based substrate amended with 20%, 40%, 60% or 80% composted domestic garden waste, consisting of leaves, grass and ground tree components (Beeson Jr, 1996). Shoot growth of plants in compost-amended substrates was equivalent to or better than that of plants in unamended media. However, as the amendment rate increased, air porosity of the medium and root growth decreased, while water holding capacity increased. Both species grew best in the pine bark-based substrate amended with 40% composted domestic garden waste (Beeson Jr, 1996).

Rooted cuttings of chrysanthemum (*D.* x *grandiflorum*) and fuchsia (*Fuchsia magellanica* Lam.) were transplanted into peat-perlite media amended with 20%, 50% or 80% composted domestic garden waste (consisting mainly of woody waste) and top-dressed with nil, 1x or 2x slow release fertilizer (Hummel *et al.*, 2001). Domestic garden waste compost amendment improved the growth of both species. In all media, growth of fuchsia increased with increasing rate of slow release fertilizer. In all media except that amended with 80% domestic garden waste compost, growth of chrysanthemum increased with increasing rate of slow release fertilizer (Hummel *et al.*, 2001).

Postharvest residues from bluegrass seed production, including leaves, stems, thrashed panicles, seeds, empty seed heads and chaff, were used raw; ground or not ground and composted alone; or composted with cattle manure or alfalfa seed screenings; and used as a 50% amendment to equal proportions of peat and perlite (Manning *et al.*, 1995). Bluegrass plus alfalfa compost-amended media had suitable physical and chemical properties for plant growth. Tomato plants grown in bluegrass plus alfalfa compost-amended media had significantly greater shoot dry weight (up to 3.5-fold more), leaf area (up to 4-fold more), leaf dry weight and stem diameter than those grown in any other media, and plant height equivalent to those grown in the control medium.

Compost amendment can improve the disease suppressive properties of a potting medium (van der Gaag *et al.*, 2007), but suppression varies with the type of compost and pathosystem (Termorshuizen *et al.*, 2006). Peas grown in sterilized sand amended with 5% or 15% domestic garden waste compost, and cucumbers grown in peat-based potting media amended with 50% domestic garden waste compost, suppressed disease caused by *P. ultimum* compared to those in the standard medium (Bruns and Schüler, 2000). However, the absence of production details of the composts from the report detracted from the study.

The disease suppressive effects of twelve green waste composts of various composition were tested in three bioassay pathosystems: *Phytophthora cinnamomi* Rands-lupin (*Lupinus albus* L.), *Cylindrocladium spathiphylli* Schoulties-*Spathiphyllum* Schott, and *R. solani*-cauliflower (*Brassica oleracea* L.) (van der Gaag *et al.*, 2007). Plants were grown in peat-based substrates amended with 20% of one of twelve composts. None of the composts suppressed *P. cinnamomi*, three of the composts significantly suppressed *C. spathiphylli* (though not high levels of suppression), and nine of the composts significantly suppressed *R. solani*, which was mostly due to the low pH of the medium. The disease suppressive effects of three green waste composts were tested against *Fusarium* wilt, caused by *F. oxysporum* f. sp. *cyclamini* in *Cyclamen persicum* Mill. and caused by *Fusarium foetens* Schroers, O'Donnell, Baayen et Hooftman in *Begonia elatior* in two experiments. These two plants are moderately salt sensitive, like most ornamentals (van der Gaag *et al.*, 2007). None of the three composts had a significant effect on *Fusarium* wilt of cyclamen. Two and three composts significantly suppressed *Fusarium* wilt in begonia in the first and second experiments, respectively. Begonia plants grown in compost-amended or unamended media grew similarly in both experiments. In the second experiment, cyclamen plants grown in compost-amended media had a significantly lower number of flowers than those grown in unamended media. None of the composts stimulated disease.

These findings were similar to a very large study by Termorshuizen *et al.* (2006) that tested eighteen composts for seven different plant pathogens. Composts originated from different source materials including green and domestic garden waste, straw, bark, biowaste and municipal sewage; more than half of them had green waste as a component. The suppressive ability of compost-amended (20% v/v) peat-based potting media was determined against *Verticillium dahliae* Klebahn on eggplant, *R. solani* on cauliflower, *Phytophthora nicotianae* Breda de Haan on tomato, *P. cinnamomi* on lupin and *C. spathiphylli* on *Spathiphyllum* sp., and of compost-amended loamy soil (20% v/v) against *R. solani* on *Pinus sylvestris* L. and *Fusarium oxysporum* f. sp. *lini* Snyder & Hansen on flax. Composts differed in their ability to suppress disease for different pathosystems. Of 120 bioassays, 54% showed significant disease suppression, while only 3% showed significant disease enhancement. No single compost significantly suppressed disease caused by all pathogens, and the pathogens were not affected similarly by all composts. Generally, parameters derived from the compost mixes were better at predicting disease suppression than those derived from the pure composts. The authors concluded that compost amendment generally has a positive or nil effect on disease suppression, and only rarely stimulates disease (Termorshuizen *et al.*, 2006) and that composts should be tested in individual production systems.

In a comparable study, Scheuerell *et al.* (2005) examined the suppressive ability of 36 composts to diseases in three pathosystems, *P. ultimum* and *Pythium irregulare* Buisman/cucumber and *R. solani*/cabbage. Composts were derived from different source materials including ground plants/recycled soilless media, domestic green waste, bark, manure, vermicompost, spent mushroom compost, and seafood processing waste; about half of them had green waste as a component. When mixed with a commercial peat-based substrate (1:1 v/v), composts varied in their ability to suppress the three diseases; 67% of composts significantly reduced *P. irregulare* damping-off of cucumber, 64% reduced *P. ultimum* damping-off of cucumber, but only 17% reduced *R. solani* damping-off of cabbage. Only 11% of composts significantly suppressed all three diseases (including only one of the green-waste-based composts). None of the compost-amended media stimulated disease caused by *Pythium* spp., but 44% of the compost-amended media had significantly more damping-off caused by *R. solani* compared with the infested peat-based standard; that is, more were stimulatory than suppressive (Scheuerell *et al.*, 2005). This again highlights the need for thorough testing of each compost with each pathosystem in the production system.

Other types of compost that have been suggested as a component of soilless growing media include pruning waste compost. Pruning waste has adequate levels of organic matter and a high cation exchange capacity, but has a high pH, a high carbon:nitrogen ratio (both greater than optimal values) and low nutrient content. As a result of the high pH, it may not be appropriate for use with alkaline-sensitive plants, and the authors suggested mixing it with a more nutrient-rich material such as spent mushroom compost (Benito *et al.*, 2005; Benito *et al.*, 2006).

With councils country-wide collecting green waste from residential and commercial properties, and other sources of green waste, there is an abundance of material available for composting. Variation in the original feedstock, not only with content but also proportions, can have a substantial effect on green waste compost attributes, and consequently, plant growth. The challenge is to produce a reliable, predictable product from such heterogeneous material, and this may only be possible by using green waste from a more consistent point of supply than, for example, council collections. Identifying the source ingredients to produce a consistent product for specific crops in a production nursery environment requires further work. Generally, 25-50% amendment with green waste compost has a positive effect on plant growth parameters, but response is species specific; and on disease suppression, but response is pathosystem dependent.

2.1.1.7 Olive Wastes

Composted olive-mill waste has been studied for its use as an amendment to potting media for the production of foliage ornamentals. Plants were grown in media with olive-mill waste compost replacing 25%, 50% or 75% of the peat component in standard peat-perlite (1:1) growing medium (Papafotiou *et al.*, 2004; Papafotiou *et al.*, 2005). Increasing amendment with olive-mill waste compost increased the bulk density and the electrical conductivity (the latter decreasing to be equivalent to that of the control in the first month of the 5-10-month culture period), and decreased the total porosity and readily available water (Papafotiou *et al.*, 2005). Yet, olive-mill waste compost did not reduce plant marketability parameters of foliage ornamentals such as croton (*C. variegatum*). and ficus (*F. benjamina*), when it replaced up to 75% of the peat component in the peat-perlite growing medium, or *S. podophyllum* when it replaced up to 25% of the peat component in the peat-perlite growing medium (Papafotiou *et al.*, 2005). Similarly, in another study, increasing replacement of peat by olive-mill waste compost increased the electrical conductivity, but this was rapidly reduced during the 4-month culture period of poinsettia (*E. pulcherrima*) (Papafotiou *et al.*, 2004). Olive-mill waste compost amended at 50% and 75% decreased the total porosity and the easily available water. Increasing amendment rates induced a gradual decrease of the plant height, bract number and node number where the first bract was initiated of poinsettia. Only poinsettia plants grown in media with 25% of the peat replaced with olive-mill waste compost produced commercially acceptable plants equivalent to those grown in the standard medium. Plant height and node number where the first bract was initiated were significantly reduced in the 25% olive-mill waste compost medium, although this was regarded as a positive effect since plant growth retardants are used to control plant size for the commercial market, and the restriction of vegetative growth occurred only during the first month of culture (Papafotiou *et al.*, 2004).

Olive waste composts are also useful for vegetable production. Tomatoes grown in peat (with 10% perlite) amended with 20%, 45% or 70% olive waste compost (from olive tree prunings, olive cake (pomace), lawn clippings and wood chips) were significantly taller, and had increased stem, leaves and total fresh weights compared to those in unamended media (Ceglie *et al.*, 2011). The 20% amendment gave the greatest improvement in plant growth.

Nine composts derived from wastes and by-products of the olive oil (leaves, wastewater, press cake), wine (grape marc), and mushroom (spent waste) industries were incorporated at 25% with peat and assessed for their suppression of soil-borne and foliar pathogens of tomato, and their physicochemical attributes (Ntougias *et al.*, 2008). All compost amendments suppressed *Phytophthora nicotianae* in tomato when incorporated immediately after curing (81–100% decrease in disease incidence), but were less effective when used 9 months after curing (55–100% decrease in disease incidence). Suppression of *Fusarium oxysporum* f. sp. *radicis-lycopersici* Jarvis & Shoemaker was lower and there was substantial variation among composts (8–95% decrease in disease incidence when used immediately and 22–87% decrease in disease incidence after 9 months storage). Induced systemic resistance against the foliar pathogen *Septoria lycopersici* Speg. was conferred by three of the nine composts (Ntougias *et al.*, 2008). Other compost-amended substrates have reportedly suppressed other foliar pathogens of tomato (Aldahmani *et al.*, 2005). There were no determining biotic or abiotic characteristics of suppression of the soil-borne and foliar pathogens among the nine composts, highlighting the complexity of the phenomenon and the importance of individual evaluation of compost products for specific uses (Ntougias *et al.*, 2008).

From the very limited studies available, a 20-25% amendment rate seems most useful for containerized plant production, but plant response is species specific. Given the small size of the domestic olive industry, only if olive processing facilities are nearby to container production facilities, then olive waste compost may find a local, niche market, but further testing of the response of a wider variety of plant species would be required.

2.1.1.8 Rice Hulls

Various media amendments or replacements based on rice hulls, a by-product of the rice milling process, that have been composted have been studied. However, composted rice hulls have a severe, albeit short-lived level of nitrogen drawdown (Handreck and Black, 2002) which presents a significant issue for their widespread use. Rice hulls mixed with corn cobs (1:1) or rice hulls:corn cobs:grape stalks (2:1:2) were composted and used as media for the growth of three bedding plants: salvia (*Salvia splendens* Sellow ex J.A. Schultes), verbena (*V.* x *hybrid*) and marigold (*T.*

patula nana) (Accati *et al.*, 1996). In general, plants grown in rice hulls:corn cobs compost had equivalent or improved growth and quality parameters compared to those grown in the peat medium. This was in part due to the high, readily available water and the suitable air-filled porosity of the compost medium. However, the addition of grape stalks had a toxic effect due to the presence of polyphenols and tannins, and increased the pH; consequently, plants grew poorly.

Azalea (*Rhododendron* sp.), Japanese holly (*Ilex crenata* Thunb.), juniper (*Juniperus* sp.) and indian hawthorn (*Raphiolepsis indica* (L.) Lindl.) were grown in a pine bark-based medium amended with composted rice hulls at 50% or 100% (v/v) (Laiche Jr and Nash, 1990). In general, plant growth in the rice hull-amended media was equivalent to that in unamended pine bark medium. Any effects on the physical and chemical properties of the media were not reported

Begonia (*Begonia* x *semperflorens*), impatiens (*Impatiens walleriana* Hook. f.), salvia (*S. splendens*), and vinca (*C. roseus*) were grown in peat-vermiculite media amended with 10%, 20%, 30%, 40% or 50% composted or fresh rice hulls (Dueitt *et al.*, 1993). Rice hull amendment led to equivalent plant heights for all species, though begonia plants in fresh rice hull-amended media were generally shorter (though not statistically) and impatiens were generally taller compared to the unamended control. Rice hull amendment generally led to equivalent plant weights for begonia and impatiens, though in salvia plants amendment usually led to a significant reduction in weight, and all vinca had significant weight reductions compared to the unamended control (Dueitt *et al.*, 1993).

The harvested residues of pea seedlings, grown on a bed of rice hulls as a vegetable were composted with the rice hulls to form pea and rice hull compost (Chang *et al.*, 2010). Growth, yield and cut flower quality of anthurium (*Anthurium andreanum* Linden) plants grown in a standard medium receiving pea and rice hull compost amendment were equivalent to those receiving a nitrogen-equivalent controlled release fertilizer or a chemical nutrient solution.

Given the localization of the rice industry and inherent challenges of the material such as the severe nitrogen drawdown, broad use of this inexpensive amendment is unlikely. Since the response of only ornamental species has been examined, testing of vegetable transplants would be a welcome addition to the data set.

2.1.1.9 Spent Mushroom Waste

Spent mushroom waste, also called spent mushroom substrate, spent mushroom compost or fresh mushroom compost, is the composted organic substrate that is discarded after mushroom production is complete (Chong, 2005; Fidanza *et al.*, 2010). Various organic wastes are used as raw materials for the substrate such as wood wastes (e.g. sawdust), paper products, cereal straws (including those that have already been used for horse bedding and so also have valuable manure deposits), grain hulls including spent brewer's grain, corn cobs, coffee waste, tea leaves, sugarcane bagasse, seed and nut hulls, and soya bean meal, and can be combined with other supplements such as poultry litter, gypsum, urea or ammonium nitrate. The raw materials are composted prior to mushroom production (Chong *et al.*, 1991; Chong, 2005; Stamets, 2000). In some studies, the spent mushroom compost was used fresh, while in others, the spent mushroom compost was put through a second composting stage. After examination of the nutrient content, bulk density, particle size distribution and carbon:nitrogen ratio, fresh mushroom compost was considered suitable as an amendment, with physical and chemical properties that generally were comparable to or better than those of composted bark (Chong and Rinker, 1994; Chong, 1999; Fidanza *et al.*, 2010). The pH and the soluble salt content tend to be high, at least initially, and must be monitored. In reviewing the following studies, the spent mushroom compost was fresh, unless specified otherwise.

The growth of numerous woody nursery crops was equivalent or better in media containing spent mushroom compost than that in unamended media, with growth generally increasing as the proportion of spent mushroom compost in the medium increased from 25% to 100% (v/v) (Chong *et al.*, 1991; Chong *et al.*, 1994; Chong and Rinker, 1994; Chong, 1999). However, shrinkage of the growing medium also increased with increasing compost level. Also, there was little difference whether freshly spent (high salt level), leached (low salt level) or aged/weathered (intermediate salt level) composts were used, and in any case, salts were leached rapidly from containers under normal irrigation regimes (Chong *et al.*, 1991; Chong and Rinker, 1994; Chong, 2005). The authors suggested that the amended media should never be allowed to dessicate, since this increases the risk of phytotoxic effects, and it should only be used in smaller containers, due to slow or no salt leaching from large containers (Chong, 1999). Also, spent mushroom compost can be phytotoxic to certain species, such as rhododendrons (*Rhododendron* spp.) and azaleas (*Azalea* spp.), due to initial high salts and high pH (Chong, 2005). The salt level of growing media amended with spent mushroom compost should be monitored, particularly in the first two weeks after planting.

Deutzia (*Deutzia gracilis* Siebold & Zucc.), dogwood (*C. alba*), forsythia (*Forsythia* x *intermedia* Zab.), ninebark (*Physocarpus opulifolius* (L.) Maxim), potentilla (*Potentilla fructicosa* L.), privet (*Ligustrum vulgare* L.) rose (*Rosa* L.) and weigela (*Weigela florida* (Bunge) A.DC.) were grown in pine bark amended with 33%, 67%, and 100% (v/v) of each of three sources of spent mushroom compost: unweathered (high salt), weathered (intermediate salt), and unweathered compost leached with water (low salt) (Chong *et al.*, 1991). Weathered spent mushroom compost was spent mushroom compost left to weather and compost naturally for 2 years. Although different species varied in their growth response to compost sources and rates, most grew equally well or better in the compost-amended media than in 100% pine bark and were influenced slightly, or not at all, by initial or prevailing elevated salt levels due to compost amendment. Increasing compost rates led to increased shoot and root dry weights for dogwood, forsythia, ninebark, rose, and weigela for all compost sources, and increased shoot dry weights for deutzia and potentilla for the weathered source only. Increasing compost rates led to decreased shoot and root dry weight of privet and root dry weights of weigela and potentilla for all compost sources. All shrubs were of marketable quality at harvest, regardless of compost source or rate, except privet which exhibited leaf chlorosis in all compost-amended media (Chong *et al.*, 1991).

In a later, similar study by Chong *et al.* (1994), cotoneaster (*Cotoneaster dammeri* C. K. Schneid.), dogwood, forsythia and weigela grown in pine bark or peat amended with 25% or 50% (v/v) of each of two sources of spent mushroom compost, grew equally well (cotoneaster) or significantly better in compost-amended media compared to those in the unamended media. Grown under trickle fertigation, the initially high, potentially toxic salt levels in all compost-amended media were leached rapidly, within 14 days of planting and were not detrimental to the species tested, similar to earlier studies (Chong *et al.*, 1994). Three of these plant species were then used in a study directly comparing three waste-derived composts: spent mushroom compost (SMC), municipal waste compost (MWC) and turkey litter compost (TLC) (Chong, 2004). Dogwood, forsythia and weigela were grown in each compost at 25%, 33% and 50% (v/v), mixed respectively with 50%, 33% and 25% paper mill sludge, plus, 25%, 33% and 25% of a supplemental ingredient, bark or sand. Plants were also grown in two control media: 100% bark and the nursery mix of 80% bark, 15% peat and 5% topsoil (v/v). Growth response varied with plant species. Dogwood grew best in SMC-amended substrates, and had less but equal growth in MWC and TLC. Dogwood grew best with bark as the supplement and there was no response to compost rate. Weigela grew best in MWC-amended substrates, and had less but equal growth in SMC and TLC. Weigela growth increased with increasing rates of all composts when supplemented with sand but not bark. Forsythia grew equally well in SMC and MWC, which were both better than TLC. Forsythia growth increased with increasing rates of SMC with sand, or of MWC with bark. Despite variation in the species response to compost amendment, all plants were at least of marketable size at harvest (i.e. at least comparable to growth in 100% bark; larger if growth was at least comparable to that in the nursery mix). High soluble salts due to amendment with all composts declined rapidly after the first irrigation to acceptable levels (Chong, 2004).

Four cultivars of chrysanthemums and two cultivars of Easter lilies (*Lilium longifolium* Thunb.) were grown in a commercial growing medium amended with 50%, 66% or 100% spent mushroom compost (Dallon Jr, 1987). In general, the highest commercial quality plants, including the highest bud count, for all cultivars of both species were produced in the commercial medium amended with 50% spent mushroom compost. The shortest plants were produced in 100% spent mushroom compost. Similarly, the ornamental plant gerbera grown in 50% spent mushroom compost mixed with peat had increased shoot dry matter and equivalent flower production to those grown in the standard medium (100% peat) (Caballero *et al.*, 2009).

Cucumber and tomato seedlings were grown in vermiculite amended with 50%, 67%, 75% or 80% spent mushroom compost, or perlite amended with 67%, 75%, 80% or 83% spent mushroom compost, and their growth compared to that in 1:1 peat:perlite (v/v) (Zhang *et al.*, 2012). The best growth of both species was found in vermiculite amended with 67% spent mushroom compost, and perlite amended with 80% spent mushroom compost. In these substrates, plant height, leaf area, fresh and dry weights, and index of seedling quality of both species, was equivalent to, or significantly greater than these parameters in the standard peat:perlite medium. Tomato seedlings grown in vermiculite amended with 75% spent mushroom compost, and cucumber seedlings grown in perlite amended with 83% spent mushroom compost, also had equivalent or slightly increased growth parameters compared to those grown in the standard peat:perlite medium, while those grown in all other media showed poorer performance in some parameters (Zhang *et al.*, 2012). The physical and chemical properties of the mixtures were suitable for tomato and cucumber seedling growth, except vermiculite amended with 50% spent mushroom compost and perlite amended with 67% spent mushroom compost, which had higher than optimal total porosity, air porosity and pH. In this study, the spent mushroom compost underwent a second composting for 21 days, and then 'matured', but the time period of the maturing phase was not specified.

In another study, three vegetable species, tomato, zucchini (*Cucurbita pepo* L.) and pepper (*Capsicum annum* L.), were grown in peat-based media amended with spent mushroom compost of *Agaricus bisporus* (Lange) Imbach (SMS-AB), *Pleurotus ostreatus* (Jacq.) P. Kumm. (SMS-PO), or a 1:1 mixture of both (SMS-50), at 25%, 50%, 75% and 100% v/v (Medina *et al.*, 2009). Generally, the addition of SMS to the growing media increased the pH, salt content, macro- and micro-nutrient concentrations and air capacity, and decreased water holding capacity compared to peat. Generally, peat-based media could be amended up to 75% with spent mushroom compost without a significant decrease in seed germination of the three species. However, in contrast to the findings of Zhang *et al.* (2012), the fresh weight of tomato plants was significantly reduced in all the media amended with spent mushroom compost compared to that in the unamended media. The differences in results were likely due to the spent mushroom compost in this study being used fresh (i.e. not undergoing a second composting) and simply dried for 48 hours. Overall, zucchini and pepper grown in media amended with SMS-AB or 25% SMS-PO or SMS-50 had equivalent fresh weights compared to those in the unamended media, but reduced fresh weight when grown in all other amended media (Medina *et al.*, 2009). Further studies are required to examine the effect of the mushroom species grown as the previous mushroom crop on the efficacy of spent mushroom compost as an organic amendment for a range of plant species in containerized production.

Similarly, Maher (1991; 1994) found that tomato plants grown in peat-based media amended with spent mushroom compost at 5% up to 30% (in 5% increments), had reduced growth compared to those in the unamended media, likely due to the high level of soluble salts. The author found that the spent mushroom compost was a good source of potassium and phosphorus, but a poor source of nitrogen, and so would need to be supplemented with nitrogen to achieve growth equivalent to a fertilized peat substrate (Maher, 1991; 1994). In these studies, the spent mushroom compost underwent a second composting for 2 months.

Lettuce, tomato, cucumber (*Cucumis sativus* L.) and marigold (*T. patula*) were grown in peat-vermiculite substrate amended with fresh or aged spent mushroom compost at 0%, 25% or 50% (v/v), leached or unleached (Lohr *et al.*, 1984a). To create aged spent mushroom compost, fresh compost underwent 6 weeks of aerobic aging by placing it in 200 L drums with holes at the base and the lid ajar, and turning the compost into a new drum every 3 days (Lohr *et al.*, 1984b). The bulk density, total pore space, total water at saturation and air space in both fresh and aged compost was suitable for plant growth. Both had very high soluble salt levels, which could be easily leached, and acceptable levels of metals. Fresh compost had high shrinkage and high concentrations of nitrogen in the ammonium form, which likely led to higher pH than aged compost, and this could negatively affect plant growth (Lohr *et al.*, 1984b). Not surprisingly, plants grown in media amended with fresh spent mushroom compost were generally smaller, had symptoms of ammonium toxicity, and, for marigold, took longer to flower (Lohr *et al.*, 1984a). Plants grown in media amended with 0% or 25% spent mushroom compost were larger than those in media amended with 50% spent mushroom compost, likely due to high soluble salt levels in the media with the higher amendment. Flowering in marigolds grown in media amended with

50% spent mushroom compost was delayed. Leaching generally increased plant yields by reducing the soluble salt levels. Overall, media amended with 25% aged spent mushroom compost (leached or unleached) yielded high quality plants comparable to those in the unamended media; leached media amended with 50% aged spent mushroom compost yielded plants of reduced but acceptable quality (Lohr *et al.*, 1984a).

The growth and nutrient status of two nursery species, forsythia and weigela and two turfgrass species, creeping bentgrass (*Agrostis palustris* Huds.) and Kentucky bluegrass (*Poa pratensis* L.) hydroponically grown in liquid waste products were compared to those grown in traditional and commercial hydroponic solutions (Michitsch *et al.*, 2007). The liquid waste products tested were a water extract of spent mushroom compost, a water extract of municipal solid waste compost, or wastewater from anaerobically digested municipal solid waste, and each of these three amended with N, P and/or K to equate nutrient levels to those in the traditional hydroponic solution. Plants grown in the amended spent mushroom compost extract grew best overall. Assessing biomass production, visual quality ratings and growth indices, plants in amended spent mushroom compost extract grew marginally better or at least as well as those in the traditional hydroponic solution, the commercial hydroponic solution, or the other amended liquid waste product solutions. Issues with using liquid waste products, such as salinity (spent mushroom compost extract had the highest EC of all liquid waste products at 2.1 dS/m), pH fluctuations, nutrient imbalances, and the roots of plants being coated with a mucus-like slime (thought to be an accumulation of root exudates, not microbial growth), need monitoring to ensure they do not negatively affect plant growth.

Incorporation of fresh spent mushroom compost into growing media can not only improve plant growth, but also suppress plant disease (Romaine and Holcomb, 2001). Spent mushroom compost, finely sieved, has desirable physical and chemical attributes including excellent aeration porosity, water holding capacity and nutrient contents. Tomato seedlings were grown in vermiculite amended with 50% or 100% spent mushroom compost screened to produce a coarse, fine or unsieved product. Growth of tomatoes was greatest in vermiculite amended with 50% or 100% of fine spent mushroom compost, compared to growth in the unamended medium. Tomato seedlings grown in perlite amended with 25%, 50%, 75% or 100% spent mushroom compost and inoculated with *P. ultimum* (the causal fungal pathogen of damping-off) had significantly greater survival compared to those in unamended media, and equivalent to uninoculated seedlings. The high soluble salt content of spent mushroom compost was overcome adequately by leaching via standard irrigation practices (Romaine and Holcomb, 2001). More studies testing the effect of various particle sizes of spent mushroom compost on the physical and chemical properties of media and the knock-on effects on plant growth and disease suppression using other plant species are warranted.

Ten agricultural waste products were compared as growing media for cabbage (Huang and Huang, 2000). Cabbages grown in spent forest mushroom compost had significantly greater shoot dry weights compared to all other media, including the standard commercial medium. (In this study, the spent forest mushroom compost was spent mushroom compost that had been used to grow the forest mushroom *Lentinus edodes* Singer, and then underwent a second composting for 12 weeks). Cabbage grew well in spent forest mushroom compost (75%) combined with carbonized rice hull (25%), shrimp and crab shell meal (0.5%), blood waste (0.2%) and lime (0.3%) and this medium was suppressive to damping-off caused by *R. solani*. This suppression was likely associated with both microbial activity and chemical inhibitors (Huang and Huang, 2000). In an earlier study, cabbage was grown in a commercial growing medium amended with one of five organic compounds: 1) spent forest mushroom compost, fish meal, blood waste, lime, and allyl alcohol; 2) *Bacillus subtilis* (Ehrenberg) Cohn isolate 1; 3) *B. subtilis* isolate 2; 4) fermented liquid fertilizer containing fish meal, molasses, and yeast extracts; or 5) *B. subtilis* isolates 1 and 2 (Shiau *et al.*, 1999). Four of the five amendments (except the fish meal-based product) suppressed damping-off. Of these, amendment with the spent mushroom compost-based compound at just 0.1% was most effective in controlling damping-off, significantly reducing disease incidence compared to the unamended control, and enhancing the growth of cabbage (Shiau *et al.*, 1999). Additional studies examining the effect of such low rates of incorporation of spent mushroom compost in other pathosystems and elucidation of the mechanisms involved would be of interest.

The addition of non-composted waxed cardboard to immature compost derived from spent mushroom compost and/or pulverized wood wastes was tested for its efficacy to improve the growth of four container-grown woody nursery shrubs (Raymond *et al.*, 1998). Deutzia, silverleaf dogwood, red-osier dogwood (*Cornus sericea* L.) and ninebark grew better in immature composts containing waxed cardboard, spent mushroom compost and/or pulverized wood wastes than in compost without cardboard. In media amended with cardboard-containing compost, the growth of three of the four species (not ninebark) was equivalent to or greater than that in the standard nursery mix. This was despite the immaturity of the compost media and high initial soluble salts (mainly due to the spent mushroom substrate), which leached from the media within 14 days after planting. In fact, the authors suggested that such high initial soluble salt levels may play a role in stimulating the growth of some container-grown nursery crops, and that the waxed cardboard may somehow reduce the availability and so, toxicity of souble salts in the media (Raymond *et al.*, 1998). Supplementary work investigating the mechanisms at work would be worthwhile.

With most of the mushroom growers in Australia located near the capital cities, they are near to many production nurseries and the regular turnover of spent mushroom compost can be put to good use as an economical organic amendment for containerized production. It appears there is data to support the efficacy of spent mushroom compost over a range of plant species, but studies addressing annual bedding plants is lacking. There is a balance to be struck between amendment level for improved plant growth and disease suppression, and high soluble salt and pH levels and media shrinkage. Container size and irrigation regimes with respect to leaching of high soluble salt levels and the phytotoxicity to some species should be considered.

2.1.1.10 Various

A variety of plant-derived organic matter has been composted and tested for its efficacy as an organic amendment for containerized plant production.

In the growth room, tomato seeds were sown in field soil amended with 2%, 4% or 8% spearmint (*Mentha spicata* L.) or sage (*Salvia fruticosa* Mill.) compost (Chalkos *et al.*, 2010). In general, the abundance of bacterial and fungal soil microbes increased, the population of nitrifying bacteria were maintained and tomato growth was stimulated, with increasing rate of both composts compared to those in the standard medium. The highest bacterial density, the highest fungal density, the tallest tomato plants (3x taller), the greatest plant biomass and the best weed suppression was associated with the 8% spearmint compost. Such amendments would need to be assessed in soilless growing media to establish their utility in containerized production horticulture.

Tomato, broccoli, and onion (*Allium cepa* L.) plants were grown in a peat-based commercial substrate or pure peat amended with 33%, 67% or 100% compost derived from a combination of sweet sorghum bagasse, pine bark, and either urea (compost A) or brewery sludge (compost B) as a nitrogen source (Sánchez-Monedero *et al.*, 2004). All substrates had suitable physical, physicochemical and chemical properties for plant growth, with the exception of high levels of electrical conductivity. Compost A, amended at a rate of 67% or 100%, caused a substantial and significant reduction in tomato seed germination, and at 100% caused a slight but significant reduction in broccoli seed germination compared to that in the commercial substrate. Broccoli grown in the commercial substrate amended with either compost A or B at any rate had parameters equivalent to or better than those in the unamended commercial substrate. Broccoli grown in pure peat amended with either of the composts at 33% or 67% had equivalent shoot heights but reduced dry weights, compared to those in the commercial substrate. Generally, tomato plants grown in all media had growth parameters equivalent to those in the commercial substrate, except those in 100% compost A which had reduced dry weight and shoot height. Onions grown in 67% or 100% of compost A or B generally had significantly lower dry weights but equivalent shoot heights, and response was variable at 33%, compared to those in the commercial substrate. Overall, vegetable seedlings of acceptable size were produced in media amended with either compost at 33% (Sánchez-Monedero *et al.*, 2004).

Five ornamental species, cut-leaf daisy (*Brachycome multifida* DC), hibiscus (*Hibiscus rosa-sinensis* L.), bower vine (*Pandorea jasminoides* (Lindl.) K. Schum.), star jasmine (*Trachelospermum jasminoides* Lindl. Lem.) and african violet (*Saintpaulia* Wendl. sp.) showed equivalent growth in media amended with composted sugarcane bagasse as plants grown in peat moss or pine bark (Trochoulias *et al.*, 1990). Sugarcane bagasse and molasses, as well as two other treatments of tea compost or flower compost (unspecified), increased significantly the numbers of desirable free-living nematodes when applied to naturally infested flower beds before planting carnation, compared to unamended beds (Langat *et al.*, 2008). Free-living nematodes play an important role in nutrient cycling; any effect on plant parasitic nematodes was not discussed. Sugarcane bagasse is readily available as a feedstock for composting, but while some nurseries use it, its application is not widespread (Handreck and Black, 2002).

Cucumbers were grown in peat-vermiculite media amended with various concentrations of liquorice (*Glycyrrhiza glabra* L.) root compost that had been inoculated with the damping-off pathogen *Pythium aphanidermatum* Edson (Fitzp.) (Hadar and Mandelbaum, 1986). All liquorice compost-amended media significantly suppressed disease compared to those in the standard medium, with suppression increasing with increasing amendment level. When inoculated media were incubated for 3 weeks before planting, suppression increased in the amended media, while disease increased in the peat only media. This trend was the same for other hosts tested, namely tomatoes, peppers and melons. Both immature compost and sterilized mature compost were not disease suppressive, indicating that microbial populations in mature compost facilitated suppression. With only a small number of liquorice plantings in Australia, there is little potential for the amendment of containerized media with liquorice root.

Shredded *Miscanthus* straw, composted with ammonium sulphate, urea or pig slurry as a nitrogen source, has been investigated as an alternate substrate for the growth of ivy (*Hedera helix* L.) and Japanese aralia (*Fatsia japonica* (Thunb.) Decne. & Planch.) (Kresten Jensen *et al.*, 2001). While shoot length of ivy grown in shredded *Miscanthus* straw composted with urea or pig slurry was equivalent to that in the fertilized peat control, dry matter production was significantly reduced in all *Miscanthus* media compared to the fertilized peat control. Plant height and dry matter production of Japanese aralia was greatest in the fertilized peat control compared to all other media. Since *Miscanthus* is not grown as a crop in Australia, its use as containerized media amendment can be discounted.

The lack of published studies for each of these various plant-based amendments and their absence or limited availability means that their potential as media amendments can be disregarded.

2.1.2 Animal Manures

Animal manures have long been used as an initial feedstock for compost production, mainly for field use. The utility of manure-based composts as amendments for container production is less studied. Animal manures can be used alone or mixed with other organic substances to produce compost for use in container crops. They are especially useful for co-composting due to the large, diverse populations of microorganisms, which accelerate and enrich the composting process (Raviv, 2008). Livestock manures also contain microorganisms which can infect humans such as *Escherichia coli* (Migula) Castellani and Chalmers, *Listeria monocytogenes* (Murray *et al.*) Pirie and *Salmonella* spp., but thorough thermogenic composting destroys these organisms (Grewal *et al.*, 2007; Grewal *et al.*, 2006).

2.1.2.1 Cattle Dung

Cattle dung, composted alone or co-composted with other organic materials may provide a useful amendment for container crops. (Composting for 3 days at 55°C destroyed the human pathogens *E. coli*, *Salmonella* and *Listeria* that were present in the cattle manure (Grewal *et al.*, 2006)). Ficus (*F. benjamina*) plants were grown in peat amended with 50% or 100% (v/v) composted separated cattle manure and compared to standard media of peat, and peat plus 20% vermiculite (Chen *et al.*, 1988). Plant growth parameters such as dry weight, stem diameter, height and leaf colour were significantly improved in 50% compost-amended media, compared to those in the standard media. Similarly, pepper, tomato and cucumber seedlings were grown in peat amended with 50% or 100% (v/v) composted separated cattle manure and compared to standard media of peat, and peat:vermiculite:perlite (1:1:1 v/v) (Inbar *et al.*, 1986). Compost-amended media had high total porosity, low bulk density (more desirable than the extremely lightweight peat in terms of plant anchorage), adequate air and water capacity, neutral pH, high electrical conductivity which was quickly leached to low levels, high cation exchange capacity, and high phosphorus and potassium concentrations. Plants of all three species grown in 50% and 100% compost-amended media had significantly greater shoot dry weights than those in the standard media; shoot dry weight of tomatoes and cucumbers were approximately doubled. Consequently, the seedlings reached transplanting size faster, reducing the production period by 6-10 days (Inbar *et al.*, 1986).

Such amendments can also aid in disease suppression. Cress (*L. sativum*) grown in peat amended with 20% composted cow manure had reduced incidence of damping-off caused by *P. ultimum*, *R. solani* and *S. minor* (Pane *et al.*, 2011). Mandelbaum *et al.* (1988) also found that separated manure (unspecified) compost suppressed *Pythium* damping-off in cucumbers. Composted cow manure incorporated into soil in pots prior to transplanting tomato seedlings significantly reduced soil-borne disease severity caused by *Pyrenochaeta lycopersici* R. Schneider & Gerlach and *Verticillium albo-atrum* Reinke & Berthold (measured by an increase in root fresh weight) and increased fruit yield (Giotis *et al.*, 2009). There was also an increase in soil biological activity due to amendment indicating that increased competition from the saprophytic soil biota may be a mechanism for reducing disease and increasing fruit yield (Giotis *et al.*, 2009). Containerized media containing composted separated cattle manure suppressed diseases of various plants caused by *R. solani* and *S. rolfsii* (Gorodecki and Hadar, 1990). The severity and build-up of damping-off of radish (*R. sativus* (radicula group)), and the incidence of root rot of the ornamental plant pothos (*Epipernum aureum* L. (Engl.)), both caused by *R. solani*, was reduced in media containing 67% composted separated cattle manure, compared with that in peat-based media. Media containing 67% composted separated cattle manure suppressed disease caused by *S. rolfsii* in chickpeas (*Cicer arietinum* L.) and beans (*Phaseolus vulgaris* L.). The presence of antagonistic microbes in the compost was proposed as the likely mechanism of disease suppression (Gorodecki and Hadar, 1990).

Raviv *et al.* (1998a) examined the effect of replacing a portion of the peat in a peat-based medium with cattle manure compost (30%) on the growth of lettuce, cabbage (*Brassica oleracea* L.), tomato and basil (*Ocimum basilicum* L.) transplants. Conventional, commercially grown transplants are often not uniform in quality and have unacceptable rates of mortality in the first weeks after transplanting. Lettuce and cabbage seedlings grown in compost-amended media, not only had significantly increased fresh and dry weights, but when transplanted to the field, had lower disease incidence caused by *P. aphanidermatum*, than transplants grown in the standard medium. Processing tomato transplants grown in compost-amended media had significantly increased fresh weights, heights and final fruit yields compared to those grown in the standard medium. Sweet basil plants grown in compost-amended media had significantly reduced disease severity caused by *F. oxysporum* f. *basilici* and increased fresh weight compared to those grown in the standard medium. These increases in plant growth are likely due to improved nutrient availability in the media.

Separated cow manure can be composted with other organic substances and used to amend growing media. Tomato plants grown in sand amended with 10%, 25% or 50% compost derived from separated cow manure and either grape marc, wheat straw or orange peels, generally had lower root galling indices and fewer eggs of the nematode *Meloidogyne javanica* (Treub) Chitwood than those grown in unamended sand (Raviv *et al.*, 2005). The greatest reduction in these parameters was in sand amended with 50% separated cow manure-wheat straw compost and 50% separated cow manure-orange peels compost. The three composts also controlled *Fusarium* crown and root-rot disease in tomato and suppressed, to varying levels, *Fusarium* populations added to the media. In addition, tomato plants grown in 100% of each compost were taller and generally had higher yields compared to those grown in the standard peat medium. The physical and chemical properties of the compost and their mixtures were generally suitable for use as growing media (Raviv *et al.*, 2005). However, effects are not always desirable. Dairy cattle dung was mixed with tea leaves (tea beverage factory waste) and sawdust (a by-product of mushroom cultivation) and then composted (Chang *et al.*, 2010). When then added as an amendment to a standard growing medium, it retarded the growth of anthurium (*A. andreanum*) plants (cultivated for cut flower production) due to manganese toxicity and poor carbon assimilation resulting from insufficient nitrogen.

While there seems to be some positives from using cattle dung compost in terms of growth improvements and disease suppression, further work is required to establish its utility on a range of containerized crops. There is no doubt that it is readily available, inexpensive amendment. However, the industry would require reassurance of the safety of manure-derived composts from a human health perspective.

2.1.2.2 Swine Waste

Compost produced from swine waste has been used as an amendment in greenhouse plant production. Potting media amended with 20% composted swine waste suppressed *Pythium* damping-off of cucumber and damping-off of impatiens by *R. solani*, while fresh or uncomposted swine waste was conducive to disease (Diab *et al.*, 2003). This suppressive medium containing composted swine waste had more diverse microbial populations, and was comprised of more fluorescent pseudomonads, heterotrophic fungi, endospore-forming bacteria and oligotrophic bacteria than a less suppressive medium containing composted swine waste produced by a different compost management practice (Diab *et al.*, 2003). In a later study, 20% composted swine waste was combined with aluminium-amended potting mix and artificially inoculated with *Phytophthora parasitica* Dastur., the causal agent of soil-borne damping-off of many horticultural bedding plants (Fichtner *et al.*, 2004). The compost/aluminium-amended medium suppressed populations of *P. parasitica*, with abiotic suppression (due to aluminium) occurring initially, followed later by biotic (compost-mediated) suppression.

A range of human and animal pathogens can be present in swine waste, including bacteria such as *Salmonella enteric* serovar *typhimurium* and *L. monocytogenes* that cause human food-borne illnesses (Grewal *et al.*, 2007). Thermogenic composting of swine waste reduces the levels of these pathogens. Swine waste, which interestingly had no detectable levels of these two organisms, was inoculated with 10^6 CFU/g of each organism and composted at 55°C. The mean MPN/g of *S. typhimurium* and *L. monocytogenes* in the 55°C compost after 3 days had significantly decreased to 44 and 489, respectively (MPN=most probable number; a standard method for enumerating such bacteria). Detectable (but very low) levels of both pathogens persisted up to 56 days in 55°C compost. Composting at a lower temperature (25°C), simulating cooler parts of the compost, can still result in substantial pathogen reduction, although at a slower rate (Grewal *et al.*, 2007).

As for compost derived from cattle dung, of paramount importance is the absence of harmful levels of human and animal pathogens from composted swine waste, and stringent quality assurance parameters would be required to ensure that this was not compromised. Similarly, there are ample supplies of this resource, but much additional testing is needed to establish efficacy over a larger spectrum of plant species. It may find application as a minor feedstock component for co-composting with woody plant waste.

2.1.2.3 Poultry and Turkey Litter

Compost produced from poultry and turkey litter can be used as a media amendment in container crops, including various deciduous ornamental shrubs, woody nursery species and bedding plants (Chong, 2005; Marble *et al.*, 2008; Marble *et al.*, 2011). It generally has high initial salt levels, an high pH and, if it is not properly aged, it may contain high levels of ammonium, which is potentially phytotoxic (Chong, 2005; Handreck and Black, 2002). As a result, use at high rates is often phytotoxic, but use at low rates can stimulate growth, as was found for lettuce grown in media amended with poultry manure compost (Hammermeister *et al.*, 2006). In the same study, poultry manure compost applied at a high rate to orchardgrass (*Dactylis glomerata* L.) was initially phytotoxic, but all rates significantly increased shoot and root dry weights compared to those in the standard medium due to high nitrogen supply; showing that response is species-specific.

Poinsettia cultivars were grown in a peat-perlite substrate amended with 25%, 33% or 50% compost derived from one of six sources: poultry litter, crab offal, domestic garden waste, municipal solid waste, lime dewatered biosolids, or polymer dewatered biosolids (Ku *et al.*, 1998). Most of the compost-amended substrates produced compact, commercial quality plants. Poultry litter, domestic garden waste and municipal solid waste composts amended up to 50%, and polymer dewatered biosolids and crab offal composts amended up to 25% resulted in high quality plants (Ku *et al.*, 1998).

Composted poultry litter has also been evaluated at various rates as a fertilizer for the growth of annual bedding plants *Petunia* Juss. spp. and *Verbena hybrida* in raised beds (Marble *et al.*, 2011). Plants grown in beds amended with composted poultry litter were equivalent in quality, and equivalent to or larger than plants grown in beds fertilized with conventional inorganic fertilizer. With inorganic fertilizer costs increasing, composted poultry litter may be able to be used to reduce the use rates of conventional fertilizers.

Besides improving plant growth, poultry manure compost amendments can suppress plant disease. Lupin (*L. albus*) seedlings were grown in potting mix amended with composted or uncomposted chicken, cow, sheep or horse manure (25% v/v), and inoculated with the root rot pathogen *P. cinnamomi* (Aryantha *et al.*, 2000). Composted or uncomposted chicken manure were the only amendments to consistently and significantly reduce pathogen survival and the development of disease symptoms on lupins compared to those in unamended potting mix. While all composts increased organic matter content, total biological activity, and populations of actinomycetes, fluorescent pseudomonads, and fungi, only chicken manure-based amendments stimulated endospore-forming bacteria, which was strongly associated with seedling survival. Rooted cuttings of *Thryptomene calycina* (Lindl.) Stapf. grown in sand-peat potting mix amended with commercially available composted chicken manure (15% v/v) had significantly greater survival than those in unamended potting mix. However, amendment of potting mix with ≥5% (v/v) chicken manure compost was strongly phytotoxic to young *Banksia spinulosa* Sm. plants and so, is not suitable as an amendment for phosphorus-sensitive plants (Aryantha *et al.*, 2000).

Composted turkey litter can also be a useful amendment in container production. Cotoneaster (*C. dammeri*) and daylilies (*Hemerocallis* L. sp.) were grown in pine bark substrate amended with 4%, 8%, 12% or 16% (v/v) composted turkey litter (Tyler *et al.*, 1993). In general, plants of both species grew as well in the compost-amended media as in the unamended media. In daylily plants, root dry weight decreased with increasing compost rate, but compost amendment had no effect on leaf dry weight. In cotoneaster plants, increasing the compost rate increased the leaf and stem dry weights, but decreased the root dry weight. Based on the growth responses of the plants, the authors concluded that the composted turkey litter substituted for the dolomitic limestone, micronutrients and macronutrients that were added to the unamended substrate (Tyler *et al.*, 1993). This work was supported by a later study examining the growth of cotoneaster and another nursery species, *Rudbeckia fulgida* Ait. in pine bark substrate amended with 8% (v/v) turkey litter compost (Kraus and Warren, 2000). These authors found that the compost acted as a slow release fertilizer, particularly as a source of phosphorus, having a greater impact on plant growth than when phosphorus was added as conventional fertilizer (Kraus and Warren, 2000).

Turkey litter compost leachate has been studied as an amendment in fertigated production systems. Common ninebark (*P. opulifolius*) was grown in 100% composted pine bark and fertigated with recirculated unamended turkey litter compost (TLC) leachate, nutrient-amended TLC leachate (to match a control complete nutrient solution), unamended municipal solid waste compost (MSW) leachate, or nutrient-amended MSW leachate (Gils *et al.*, 2005). Of the leachate solutions, ninebark grew well with only unamended TLC, showing no nutrient toxicity or deficiency symptoms and similar growth to those fertigated with the non-recirculated control solution. Poorer growth in the other leachate solutions was mainly due to excess salts and/or nutritional imbalances. However, growth in the any of the leachate solutions was less than in the recirculated control complete nutrient solution.

Poultry manure can be composted with other organic matter to produce valuable amendments. Four composts, one produced from cow and chicken manure and peat; two produced from cow, chicken and sheep manure and peat; and one produced from pig manure, straw, sawdust and bark; were used as an amendment to field soil (soil: compost 2:1, v/v) to grow tomatoes in pots in the growth room (De Brito Alvarez *et al.*, 1995). Tomatoes grown in the three cow/chicken manure-based compost amendments had significantly improved plant growth (higher shoot and root dry weights), while those grown in the pig manure-based compost amendment had significantly reduced plant growth, compared to those in the standard medium. The compost amendments did not increase the number of microorganisms in the rhizosphere compared to the control, but altered the species composition. The cow/chicken/sheep compost amendments increased the incidence of plant growth promoting bacteria antagonistic to some pathogens, such as *F. oxysporum* f. sp. *radicis-lycopersici*, *Pyrenochaeta lycopersici*, *Pythium ultimum* and *R. solani* (De Brito

Alvarez *et al.*, 1995). These results may not translate to the growth of plants in soilless growing media.

In a later study, a poultry manure-based compost was compared to other amendments for their effect on the growth of tomatoes. Tomato plants were grown in container culture using compost derived from poultry manure and cranberry presscake; sewage-sludge biosolids; or green waste (mostly leaves), either alone or mixed with peat, soil, or peat and soil (Hu and Barker, 2004). The poultry manure-based compost was a more nutrient-rich compost than the other two and so, media based on this substrate were the best for tomato growth, yielding larger plant mass, and higher nutrient concentrations and accumulation (Hu and Barker, 2004).

Farmyard manure (unspecified) was composted and amended at various rates to a peat-based substrate, and compared to various rates of amendment of household waste compost or uncomposted chicken manure for its effect on the germination of lettuce seeds and subsequent growth (Eklind *et al.*, 2002). The lowest rate (12%) of farmyard manure compost was the most suitable of the tested substrates for the propagation of lettuce, in terms of seed germination rate, plant dry weight, height, number of leaves and root development. Factors such as low net nitrogen mineralization and high electrical conductivity in these media can pose issues for plant propagation (Eklind *et al.*, 2002).

Issues with composted poultry and turkey litter including high and variable salinity, high pH and potential ammonium phytotoxicity are of concern for its use in containerized plant production. It may be best suited as a feedstock constituent to be co-composted with woody waste or sawdust to ameliorate these characteristics. There is ample, on-going supply.

2.1.3 Municipal and Industrial Waste Material

2.1.3.1 Municipal Solid Waste

Municipal solid waste (MSW) (or biowaste) compost, usually made from the organic fraction of residential kitchen and domestic garden waste, has been substituted into soilless container media in various proportions for horticultural production of numerous species in the greenhouse (Radin and Warman, 2011). Plant growth has generally been equivalent to or better than plant growth in containers with standard mixes, as long as MSW compost comprised 50% or less of the container medium (Chong, 2005; Shiralipour *et al.*, 1992). Rates greater than 50% can lead to decreases in plant growth and productivity, mainly due to phytotoxicity as a result of the high electrical conductivity (salt concentration) of MSW compost (Gils *et al.*, 2005; Radin and Warman, 2011; Shiralipour *et al.*, 1992).

Stem cuttings of nine evergreen landscape shrubs were rooted in peat or perlite media amended with 15%, 30%, 45%, 60% or 75% MSW compost (which had increasing levels of soluble salts) (Chong, 2000). The taxa tested were *Buxus sempervirens* L., *Juniperus chinensis* L. (three cultivars), *J. horizontalis* (two cultivars), *J. sabina*, *Taxus* x *media* Rehd. and *T. occidentalis*. Four taxa, two cultivars of *J. horizontalis*, *J. sabina* and *T. occidentalis* were tolerant (rooting positively influenced or unaffected) of the salt levels caused by incorporation of MSW, whilst the other five taxa were intolerant (rooting adversely affected to varying degrees) (Chong, 2000). This indicates that increased soluble salt levels are not always detrimental to plant propagation and production, and is species dependent.

Tomatoes were grown in a sand-topsoil mix amended with MSW compost at a low or high rate (Radin and Warman, 2011). Plants grown in MSW compost had significantly lower tomato fruit yields compared to plants treated with conventional or organic fertilizer. However, in a second experiment in the same study, this time with better quality field soil, increased compost rates, and the MSW compost treatments tested in factorial combination with compost tea derived from the MSW compost, the yields improved. Plants grown in the various MSW compost and MSW compost tea combinations had equivalent fruit yields to those treated with the conventional fertilizer, with significantly greater yields from plants grown in MSW compost at the low rate combined with a weekly spray of MSW compost tea (Radin and Warman, 2011).

Cuttings of cotoneaster were grown in peat amended with 25%, 50%, 75% or 100% source-separated MSW or spruce bark compost (standard medium) in each of two consecutive years (Hicklenton *et al.*, 2001). Despite the MSW being sourced from the same commercial composting facility both years, it varied in its chemical composition, bulk density, soluble salt content or pH. The soluble salt content was initially high in media amended with MSW, but declined to suitable levels within one month of potting. Growth of cotoneaster in MSW-amended media was equivalent to, or greater than that in the standard peat-bark media, and was similar for both years, despite the inherent variability in the MSW compost. Poorest growth was observed in 100% MSW and 100% bark.

Geranium (*Pelargonium* x *hortorum* Bailey) was grown in pots containing a peat-based medium amended with 10%, 20%, 30%, 40% or 50% MSW compost (v/v) (Ribeiro *et al.*, 2000). As the rate of MSW compost amendment increased, the electrical conductivity of the medium increased. Substrate amendment with MSW compost at 10% or 20% significantly improved plant growth (in terms of shoot dry weight, number of leaves per plant, number of flower stems per plant and number of flowers per flower stem) compared to plants grown in the unamended medium, but additional nitrogen and phosphorus are required. Amendments >20% reduced plant growth due to the high level of salts and are not recommended (Ribeiro *et al.*, 2000). Siminis and Manios (1990) also found that a peat-based medium amended with 20% MSW compost (v/v) gave the best growth of ficus (*F. benjamina*), though no data were presented, only the physical and chemical properties of the media which were suitable for plant growth.

Six ornamental species were grown in pine bark substrates amended with 25%, 50%, 75% or 100% MSW compost; a further three species were grown in pine bark substrate amended with 25% MSW compost (Lu *et al.*, 2005). The physical and chemical properties of 100% MSW compost were all in acceptable ranges, except the high initial electrical conductivity, which could be reduced quickly by flushing with water after potting and overhead irrigation. Two species, common sweetshrub (*Calycanthus floridus* L.) and ‘Cameo’ quince (*Chaenomeles* x *superba*), had improved plant growth in media amended with 25% MSW compost compared to growth in unamended media. Four species had equivalent plant growth in media amended with 25-50% MSW compost compared to growth in unamended media. All other plants grown in amended media had equivalent or reduced growth compared to those in unamended media. There was no linear trend for either increased or decreased plant growth as the rate of MSW compost increased and the response was species-specific. For example, while the growth of some species was adversely affected with 50% MSW compost, other species, such as dwarf nandina (*Nandina domestica*) and dwarf yaupon holly (*Ilex vomitoria* Sol. ex Aiton) had equivalent growth in 100% compost as compared to the unamended control (Lu *et al.*, 2005).

The growth and development of tomato seedlings in 30% MSW compost in a peat-based substrate was similar to, and in some parameters, better than, that in the unamended medium (Castillo *et al.*, 2004; Herrera *et al.*, 2008); however, 65% MSW had detrimental effects due to high pH and high soluble salts (Herrera *et al.*, 2008). Lievens *et al.* (2001) found that cucumber transplants germinated in potting soil amended with compost derived from source separated household waste had significantly greater shoot dry weights than those germinated in unamended potting soil.

Two bioassay species, cress (for germination) and spring barley (*Hordeum vulgare* L.) (for growth) were assessed in peat or composted pine bark amended with 25%, 50% or 75% (v/v) MSW compost (Cendón *et al.*, 2008). Physical and chemical properties of the MSW compost were evaluated, but not the compost-amended media. The physical properties of MSW compost were generally within recommended ranges. MSW compost had higher electrical conductivity, pH, cation exchange capacity and nutrient levels (the latter two being highly desirable) than peat or composted pine bark. The high electrical conductivity would decrease when mixed with peat or composted pine bark. Whilst there was poor germination and growth in 75% compost-amended media, there was greater germination and better growth in 25% MSW compost-amended media than that in the unamended media.

The possibility of undesirable constituents, such as heavy metals and pathogens, being present in MSW compost must be considered (Castillo *et al.*, 2004; Diener *et al.*, 1993). Carballo *et al.* (2009) found that the levels of heavy metals in the MSW composts they used were acceptable, except the lead (Pb) level which exceeded their national upper limit. However, the concentrations of all heavy metals were low in the teas made from these MSW composts. Also, there may be limited transfer of heavy metals from the growing medium to the plants, at least for some species. Castaldi and Melis (2004) grew tomatoes in media comprised of raw or composted beached seagrass *Posidina oceanica* (L.) Delile, a known bioaccumulator of heavy metals. They found no significant difference in the growth, fruit yields or the heavy metal concentrations in fruits or leaves of tomato plants grown in these media compared to those grown in the control medium (Castaldi and Melis, 2004). Also, with respect to pathogens, human, animal and plant, as long as lethal temperatures and adequate exposure times are achieved during the composting process, pathogen levels will be reduced to below disease-causing thresholds (Avery *et al.*, 2012; Noble and Roberts, 2004; Noble *et al.*, 2009).

There are other potential issues with using MSW compost as a media amendment. There are regulatory hurdles with respect to their production, quality standards and use (Harrison and Richard, 1992). In part, this relates to risk assessment of the potential health hazards to the consumer and general public, as well as occupational health and safety of compost production workers (Gillett, 1992). This stems from the risk of contaminants such as heavy metals and organic pollutants and physical risks from sharps (glass, metal, plastic) (Farrell and Jones, 2009). The presence of non-compostable contaminants, such as plastic and glass, can mean that extra screenings may be required for safety and aesthetic reasons. Quality control can present challenges with different batches potentially having different characteristics due to lack of uniformity of source ingredients. The presence of high salt levels or certain nutrients may potentially cause phytotoxicity; this can be ameliorated by wet-sieving. An inappropriate pH may induce micronutrient deficiencies and so would need adjustment. There may be unpleasant odours, however these are somewhat diluted in the substrate mixtures. Finally, as for most organic amendments, there may be differential plant species response, so MSW compost should be tested in individual production systems (Castillo *et al.*, 2004; Chong, 2005; Diener *et al.*, 1993; Farrell and Jones, 2009; Giotis *et al.*, 2009).

MSW compost amendments can also aid in disease suppression. Cress grown in peat amended with 20% composted organic fraction of either differentiated or undifferentiated MSW suppressed damping-off caused by *P. ultimum* and *S. minor*, but did not suppress damping-off caused by *R. solani* (Pane *et al.*, 2011). In another study, composted MSW incorporated into soil in pots prior to transplanting tomato seedlings significantly reduced soil-borne disease severity caused by *P. lycopersici* and *V. albo-atrum* (measured by an increase in root fresh weight) and increased fruit yield and number per plant compared to unamended soils (Giotis *et al.*, 2009). Whether this translates to soilless growing media is unknown.

Cucumber was grown in a peat-based substrate amended with 20%, 40% or 60% MSW compost, produced using MSW that had been wet-sieved prior to composting, and inoculated with *P. ultimum* (Veeken *et al.*, 2005). Wet-sieving MSW prior to composting increased the organic matter and decreased the salt content of the compost, which meant that higher amendment rates than the usual 20% (up to 60% v/v compost) could be tolerated without detrimental effects on cucumber growth. Increasing the rate of compost amendment from 20% to 60% resulted in an increase in suppression of *Pythium* damping-off from 31% to almost complete suppression (94%). The consistency and predictability of disease suppression also increased, which is important to negate the perception of compost amendments as being unreliable and inconsistent (Veeken *et al.*, 2005).

Rhizoctonia solani is a pathogen of numerous woody ornamental plants, causing rot of cuttings (Tuitert *et al.*, 1998). Cucumber was used as a substitute plant in a bioassay and grown in a peat-based medium amended with 20% composted MSW that was freshly delivered, matured on-site for an extra month, or matured on-site for an extra 5-7 months, before inoculation with *R. solani*. Freshly delivered compost and 5-7-month matured compost suppressed growth of *R. solani* , yet 1-month matured compost stimulated pathogen growth. Freshly delivered compost had greater microbial activity than compost that was matured for an extra period, and this may have contributed to its suppressive ability. The 5-7-month matured compost had high populations of cellulolytic and oligotrophic actinomycetes which may play a role in suppressing *R. solani* (Tuitert *et al.*, 1998). This same compost, amended to sterilized field soil in pots at 1% (w/v), suppressed *Pythium* root rot in iris (*Iris xyphium*) (van Os and van Ginkel, 2001).

In a similar study, sand was amended with 10% or 30% composted MSW, and artificially infected with *P. ultimum* or *R. solani* (Schueler *et al.*, 1989). Compost amendment reduced the incidence of disease in beetroot and beans. Under low disease pressure, fresh matter yield of plants in compost-amended media was equivalent to that in non-infested controls. Under high disease pressure, the compost was still suppressive, though the fresh matter yield of plants in compost-amended media was reduced (Schueler *et al.*, 1989).

Different mixtures of MSW compost, dry sewage sludge, grape marc, rice hull and pine bark, used to replace 50% of the peat content in a standard growth substrate produced equivalent final quality oleander, rosemary (*Rosmarinus officinalis* L.) and cypress (*Cupressus sempervirens* L.) plants as those grown in the standard substrate (Ingelmo *et al.*, 1998). The resulting substrates generally had suitable physical and chemical properties for plant growth, with increased microporosity (which improves rewettability of substrates due to higher water holding capacity and reduced drainage), increased pH and higher electrical conductivity (which reduced over the period of the study due to leaching). Such amendments reduced the cost of the substrates by 20-40%, while not diminishing the quality of plants produced, and using similar amounts of water and nutrients (Ingelmo *et al.*, 1998). This was supported by a modelling study demonstrating that peat could be successfully substituted with a mixture of MSW compost and composted pine bark, but due to high salt content, could not be used on its own (Moldes *et al.*, 2007).

Australia currently has numerous facilities for the production of MSW compost (Oakes, 2009) and, of course, a continual supply of feedstock. The cost of commercially produced MSW compost is about \$35-41/m^3 plus transport costs (2006 prices), which for a production nursery that is 100 km from the compost production facility would cost approximately \$41-46/m^3 (Anonymous, 2006). The feedstock, and consequently the resultant product, is highly variable and quality issues need resolving to ensure the production of a consistent, reliable product. Particular challenges include high soluble salt levels (further work to assess the efficacy of wet-sieving to reduce these levels would be useful), heavy metals and sharps. Testing of annual bedding species and more vegetable transplant species is highly desirable.

2.1.3.2 Sewage Sludge

Using compost made from raw sewage sludge or treated (digested) sewage sludge (biosolids) as an amendment in containerized production of horticultural and forestry plants is not a new idea (Gouin, 1993; Guerrero *et al.*, 2002; Sanderson, 1980). Being rich in plant nutrients, it can supply many of the nutrient needs of plants, depending on the plant species and the amount used (Gouin, 1993). However, two main drawbacks of most composts derived from sewage sludge are deleteriously high soluble salt concentrations if used at high amendment rates (Gouin, 1993), and manganese binding causing deficiency symptoms in sensitive plants (Broschat, 1991).

In addition, the wastewater treatment procedures employed prior to composting can affect the efficacy of the compost for enhancing plant growth (Fitzpatrick, 1986). For example, dwarf schefflera (*Schefflera arboricola (*Hayata) Kanehira) and spathiphyllum were grown in sewage sludge composts that differed in the processes used to treat the initial wastewater: one was heat-treated, the other was polymer-stabilized; or in a commercial peat-pine bark-growing medium. At the end of the 26-week production period, both species grew significantly better in the heat-treated sewage sludge compost, compared to growth in the commercial medium, with the scheffleras 6 weeks ahead in growth indices and spathiphyllums 8 weeks ahead. The growth of both species in the heat-treated sewage sludge compost was 3 weeks ahead of growth in the polymer-stabilized sewage sludge compost. The polymer-stabilized sewage sludge compost had pore space percentages and electrical conductivity outside the suggested ranges (with electrical conductivity almost twice that of the heat-treated sewage sludge compost and the commercial medium) which may have contributed to its poorer performance compared to the heat-treated sewage sludge compost. Such faster production times achieved with the heat-treated sewage sludge compost, combined with the generally lower cost of compost compared to commercial media, is of economic significance (Fitzpatrick, 1986).

Similarly, chrysanthemum plants were grown in a peat-sand medium amended with 50%, 60% or 67% (v/v) sewage sludge compost derived from one of two sources – either lime-dewatered raw sludge and woodchips; or polymer-dewatered digested sewage sludge and woodchips (Gouin, 1985). Either compost source was a useful amendment up to 60% for producing marketable chrysanthemums when top-dressed initially with a complete or even a nitrogen-only slow release fertilizer, having comparable growth to those in a commercial peat-based medium with a complete fertilizer. The number of flower buds that developed was decreased when the compost amendment was increased to 67% (Gouin, 1985).

Marigolds were grown in vermiculite (50% v/v) amended with 10%, 20%, 30%, 40% or 50% compost derived from sewage sludge, and the remainder comprised of peat (Bugbee and Frink, 1989). Three other composts tested in the same study were each derived from pharmaceutical fermentation residues, cranberry wastes, or food flavouring wastes. Shoot dry weight of marigolds was significantly greater in sewage sludge-amended media compared to that in the unamended substrate. Without supplemental fertilizer, plant growth in substrates amended with the other composts was equivalent to or greater than that in unamended media, except in media amended with 40% or 50% composted food flavouring wastes. Plant growth was improved with supplemental fertilizer due to increased levels of plant nutrients, except in media containing 50% composted pharmaceutical fermentation, 50% composted residues cranberry wastes, or 40% or 50% composted food flavouring wastes where growth decreased due to excess nitrogen in the ammonia form, unsuitable pH or high soluble salts (Bugbee and Frink, 1989).

An earlier study testing marigolds showed that digested sewage sludge compost could provide many of the nutrient needs of the plants. The marigolds were grown in a peat-based substrate amended with 33%, 66% or 100% compost derived from digested sewage sludge (Chaney *et al.*, 1980). The recommended fertilizer supplements to the peat-based substrate (nitrogen, phosphorus, limestone and trace elements) were deleted one at a time, all, or all except nitrogen. The compost provided 33% nitrogen, 100% phosphorus and 100% trace elements, but the compost-amended media had a pH of ≥6.7 which could reduce microelement availability to plants and so, may require acidifying. Soluble salts limited yield somewhat in media amended with 67-100% of compost. Growth of marigolds in media amended with 33% compost with the addition of only potassium nitrate was equivalent to that in the standard peat-based substrate with its recommended fertilizer supplements (Chaney *et al.*, 1980).

Particle size of sewage sludge compost can affect the efficacy of the compost to improve plant growth. Wandering jew (*Tradescantia fluminensis* Vell.) was grown in perlite amended with 40%, 60%, 80% or 100% composted raw sewage sludge comprised of coarse, medium, fine or very fine particles (Marcotrigiano *et al.*, 1985). Top dry weights of plants were greatest in media amended with low rates of composted raw sewage sludge and/or compost with coarse particles, which resulted in media with low soluble salt levels and high levels of air-filled pore space. In a second trial, wandering jew, Swedish ivy (*Plectranthus australis*), piggyback (*Tolmiea menziesii* (Pursh) Torr. & Gray) and star sedum (*Sedum lineare* var. *variegatum*) were grown in perlite amended with 40% very fine particle composted raw sewage sludge or 80% coarse particle composted raw sewage sludge, and compared to the same species grown in three commercial media. All species grew well in the commercial media but growth response to the compost-amended media varied with species. Only wandering jew in either of the compost-amended media, and star sedum grown in the 80% coarse particle compost-amended media had equivalent growth to those in the commercial media (Marcotrigiano *et al.*, 1985).

In a similar study examining the effect of particle size, marigold, zinnia (*Zinnia elegans* Jacq.) and petunia were grown in vermiculite amended with 25%, 50%, 75% or 100% fine, medium, coarse or a size blend of composted digested sewage sludge (Wootton *et al.*, 1981). As compost particle size increased, growth decreased, so shoot dry weights of plants were greatest in media containing higher proportions of small compost particles. Plants grown in compost-amended media had greater shoot dry weights than those in the standard peat-based medium. As compost particle size increased, air-filled pore space percentage increased, available water decreased and shoot dry weight decreased. Since nutrients were not at optimal levels or in the correct balance for plant growth, the addition of fertilizer increased plant growth. No toxicity symptoms due to soluble salts or heavy metals were observed due to compost amendment (Wootton *et al.*, 1981).

Impatiens, marigold and coleus plants were grown in a peat-vermiculite medium amended with 10%, 20% or 40% composted raw sewage sludge that had been cured for 4, 6, 8 or 10 months (Vega-Sanchez *et al.*, 1987). Increasing compost amendment rates decreased plant top dry weight and visual quality, and increased electrical conductivity, pH, ammonium, nitrate, nitrogen dioxide and extractable nitrogen, phosphorus and potassium. Despite this, impatiens and marigold plants grown in 10% or 20% compost-amended media were marketable, regardless of compost curing time. Increasing compost curing time decreased soluble salt levels, pH and extractable nitrogen and potassium of the media at transplanting, resulting in increased dry weight of impatiens and marigold plants. Coleus plants were stunted and unmarketable in all compost-amended media (Vega-Sanchez *et al.*, 1987).

Impatiens were grown in soil in pots amended with composted sewage sludge/pine bark; composted sewage sludge/straw; or composted pig manure at 30%, 50% or 70% (v/v) (Vabrit *et al.*, 2008). Impatiens grown in media containing either of the composted sewage sludge amendments had equivalent or superior growth to those in unamended soil. Plants grown in media amended with composted pig manure generally grew poorly, likely due to high souble salt concentration, poor porosity and poor aeration.

The growth of vinca, verbena and shantung maple in 50% wastewater biosolids and 50% pine bark was compared to that in traditional media of 75% pine bark and 25% peat moss (Sloan *et al.*, 2010). Growth response in biosolids-amended media varied with species. Biomass production was significantly greater for verbena, significantly less for vinca and growth rate (stem thickness and height) was significantly increased for shantung maple in the biosolids-amended medium compared to that in the traditional medium.

Raw or treated sewage sludge is often co-composted with another organic material prior to media amendment. Cucumber, tomato, strawberry (*Fragaria vesca* L.) and gerbera were grown in a peat-rice chaff medium amended with 25% (v/v) compost, derived from sewage sludge and poplar bark (1:2), or peat amended with 50% compost (Pinamonti *et al.*, 1997). Media amended with compost generally had suitable physical and physicochemical properties; there was an increase in heavy metal concentrations but they fell within acceptable limits and did not accumulate in plants. Both media amended with compost generally improved plant nutrition, vegetative growth and increased the quantitative and qualitative characteristics of production for all species tested, compared to those grown in unamended media.

Cuttings of poinsettia and seedlings of lettuce, cabbage, sweet william (*Dianthus barbatus* L.) and pansy (*Viola* x *wittrockiana* Gams.) were grown in a peat-perlite medium amended with 25%, 33% or 50% new or aged compost, derived from polymer-dewatered sewage sludge co-composted with processed municipal solid waste (Purman and Gouin, 1992). 'New' compost referred to 7 days of 'vertical site' composting, followed by 30 days in windrows, while 'aged' compost referred to 7 days of 'vertical site' composting, followed by 90 days in windrows. Plant growth of all species was not influenced by compost age. Growth of lettuce, cabbage and pansy plants in compost-amended media was generally equivalent to that in a commercial medium (Sunshine mix), while growth of sweet william was somewhat reduced (but was equivalent to that in the unamended peat-perlite medium). Growth of poinsettia cuttings in compost-amended media was less than that in the commercial medium (but was equivalent to that in the unamended peat-perlite medium). However, the number of inflorescences was generally equivalent, and the bract diameter was equivalent or greater than that in the commercial medium. Although the plant growth response to the two composts was similar, aged compost caused less media shrinkage, was a more appealing colour and lacked unpleasant odours, compared to fresh compost (Purman and Gouin, 1992).

Compost made from sewage sludge, biowaste, peat and woodchips was tested as an amendment at 10%, 20% or 30% to peat-based container media for the growth of Norway spruce (Heiskanen, 2013). Whilst the amendment at any level did not increase the growth of Norway spruce and the plants grew best in peat only, it also did not decrease seedling growth nor affect growth in the first summer after outplanting. However, at 20-30% amendment, there was a slightly higher proportion of seeds that did not germinate and a slightly higher seedling mortality, and this may have been due to their higher pH and salt content. Otherwise, the physical and chemical properties of the compost-amended media were generally suitable.

Petunia, marigold, geranium, cabbage, carrot and turnip plants were grown in media amended with 25%, 50%, 75% or 100% compost produced from dewatered activated sludge cake/straw mixtures, while coleus and begonia plants were grown in media amended with 33%, 50%, 75% or 100% compost (Lopez-Real *et al.*, 1989). The growth of the ornamental and vegetable plants was, in general, not greatly affected by amending the growth substrate with different rates of compost. The number of flowers did not differ between any of the treatments for any of the plant species. Generally, shoot weights of plants grown in compost-amended substrates were greater than those of plants grown in either 100% peat or 100% compost. The inferior physical and chemical characteristics of sewage sludge compost compared to peat, particularly the bulk density, moisture holding capacity, cation exchange capacity and potential presence of heavy metals, means that it can only be used a partial amendment to growing media (Lopez-Real *et al.*, 1989).

In another study, compost was made from a mix of sewage sludge and sugarcane trash (SSC) and tested as an amendment at 40% to peat container media for the growth of lettuce (Jayasinghe *et al.*, 2010). It was also combined at 40% or 60% with synthetic aggregates (SA, made from soil, paper waste and starch waste) and peat. Lettuce plants grown in any of the SSC-amended media had significantly higher fresh and dry shoot and root weights compared those in the peat control, with the mix of 40% SSC, 20% SA and 40% peat giving maximum growth and biomass yield. The physical and chemical properties of the amended media were generally within published ideal limits (even for heavy metal contents) with the only notable exception being electrical conductivity values of SSC-amended media, which were as high as 1.02 dS/m, but this did not negatively affect plant growth.

In a Spanish study, the shrub (*Pistacia lentiscus* L.) was grown in peat or a pine bark-peat mix amended with 40% compost derived from either sewage sludge and pruning waste (1:3), or municipal solid wastes and pruning waste (1:1.5) (Ostos *et al.*, 2008). Plants grown in the compost-amended substrates generally had greater shoot and root dry weights, were taller and had enhanced nutrient contents, particularly for the sewage sludge-based compost, compared to those in the unamended, commercial peat medium. This was despite the compost-amended substrates having pH, electrical conductivity and organic matter values outside acceptable limits (Ostos *et al.*, 2008).

Compost made from a 1:4 mix of sewage sludge and green waste was amended at 25%, 50%, 75% or 100% to a peat-based medium to test its effect on the growth of begonia, *Mimulus* (*Mimulus* “Magic x hybridus”), salvia, and marigold (Grigatti *et al.*, 2007). In the 25% compost-amended medium, all species grew as well as or better than those in the unamended medium, in terms of plant height, number of flowers per plant and dry weight. Assessing these same parameters in 50%, 75% and 100% compost-amended media, growth of begonia was equivalent to or better than that in the unamended medium. In 50% compost-amended media, all species grew as well as or better than those in the unamended medium, except salvia was shorter and had less flowers, and marigold had less flowers. In 75% and 100% compost-amended media, growth of salvia, *Mimulus* and marigold was reduced in at least two of the three parameters compared to that in the unamended medium. These reductions in growth for some species at higher compost amendment rates was likely due to higher than optimal pH and electrical conductivity, and reduced water holding capacity of the amended media (Grigatti *et al.*, 2007).

Tomatoes were grown in peat-vermiculite media amended with biosolids:domestic garden waste (1:4) compost at 18%, 35%, 52% or 70% (Ozores-Hampton *et al.*, 1999). One of three compost batches used had high initial electrical conductivity, but generally this was reduced to optimal levels by amendment with the peat-vermiculite media. Other chemical and physical properties were variable among batches. Despite this, tomato seedlings grown in media amended with the compost had significantly increased leaf area, shoot and root dry weight and stem diameter (assessed 35 days after seeding), compared to those grown in the standard unamended medium. In general, there was no effect of compost rate on tomato parameters. The compost provided a slow release nutrient source that produced tomato plants with higher quality characteristics than those grown in the standard medium. In general, once transplanted to the field, any advantage due to compost addition disappeared, and fruit size and yield was similar among all treatments.

In an earlier study, impatiens were grown in three different compost-amended media: 1) composted biosolids and domestic garden waste (SYTP): 20% biosolids, 44% domestic garden waste, and 36% mixed paper 2) composted refuse fuel residues with biosolids and domestic garden waste (RYT): 74% refuse-derived fuel residuals, 10% biosolids, and 16% domestic garden waste; and 3) composted municipal solid waste, 100% (MSW) (Klock and Fitzpatrick, 1997). Plants were transplanted into a standard pine bark/peat-based substrate amended with 30%, 60% or 100% compost. Shoot dry weight of plants grown in SYTP increased, grown in MSW decreased and grown in RYT were unchanged, with increasing substrate amendment. Number of flowers on impatiens plants grown in SYTP and RYT increased, and grown in MSW were unchanged, with increasing substrate amendment. Initial medium soluble salt concentrations in MSW media were more than double concentrations measured in SYTP and RYT media. Impatiens plants showed superior growth in 100% SYTP and 100% RYT compared to 100% MSW, likely due to the relatively higher level of compost maturity in SYTP and RYT, as indicated by lower carbon:nitrogen ratio and soluble salt concentrations.

A sub-tropical perennial plant, cat whiskers (*Orthosiphon stamineus* Benth.) was grown in a peat-based substrate amended with 25%, 50%, 75% or 100% (v/v) compost derived from biosolids/domestic garden waste (ratio and compost production parameters unspecified) (Krumfolz *et al.*, 2000). As compost amendment rate increased, nitrogen and carbon concentrations, pH, electrical conductivity and bulk density increased, while initial moisture content decreased. Plant growth was slightly reduced when grown in peat-based media amended with high rates of compost (75% or 100%) compared to those in unamended media, but plants from each treatment were considered marketable.

Many studies have investigated the efficacy of a compost made from a 1:1 mix of biosolids (treated sewage sludge) and domestic garden (yard) trimmings (mainly woody waste) termed SYT. SYT was compared to a compost made from a 1:4 mix of used greenhouse substrates (peat, bark, polystyrene, bedding and pot plant remains) and domestic garden trimmings (chipped wood waste) (GHC) for its effect on the growth of begonia and impatiens plants (Klock-Moore, 1999b). Plants were transplanted into a standard peat-based substrate amended with 30%, 60% or 100% compost. Begonia and impatiens plants grown in SYT-amended substrates were significantly larger than those grown in GHC-amended substrates (though these plants were still commercially acceptable), probably due to higher initial substrate nutrient concentrations (including a lower carbon:nitrogen ratio and so, reduced net nitrogen immobilization). Shoot dry weight and plant size of begonias and impatiens increased with increasing substrate amendment with SYT, but not for GHC (Klock-Moore, 1999b). Similarly, salvia plants were grown in a standard peat-based medium amended with either SYT or a 1:1 seaweed: domestic garden trimmings compost at 30%, 60% or 100% (Klock-Moore, 2000). Salvia grown in SYT-amended media had significantly greater shoot dry weights and more flower spikes than those grown in seaweed/domestic garden waste compost-amended media or the unamended control, despite high initial electrical conductivity levels. As the SYT amendment rate increased from 0% to 60%, the shoot dry weight and flower number of salvia plants increased, but then decreased at 100%. Growth of plants in seaweed/domestic garden waste compost-amended media was equivalent to those in the unamended control, and all plants grown in all media were of marketable quality (Klock-Moore, 2000).

In two earlier studies, snapdragon (*Antirrhinum majus* L.), impatiens (Klock, 1997a), dianthus (*Dianthus chinensis* L.) and petunia (Klock, 1997b) were grown in the same SYT-amended media. Shoot dry weight, size, and height increased with increasing substrate amendment with SYT to 100% for both impatiens and snapdragon (Klock, 1997a), and increased with increasing substrate amendment with SYT to 60%, then decreased at 100% for dianthus and petunia (Klock, 1997b). This was likely due to the high soluble salt levels in 100% SYT: 28 times greater than in 0% SYT and 2 times greater than in 30% or 60% SYT. Still, growth of dianthus and petunia in media amended with 100% SYT was greater than that in unamended standard peat-based substrate. All plants grown in SYT-amended media were larger than those in unamended standard peat-based substrate (Klock, 1997a; Klock, 1997b).

The influence of particle size of SYT has been studied. SYT was passed through two different sized screens (13 mm or 19 mm) to create two products differing in final particle size and incorporated into media at 30%, 60% or 100% (v/v) (Klock-Moore, 1999a). When impatiens were grown in any of the amended substrates, final plant size and shoot dry weight were significantly increased in the 13 mm SYT-amended media compared to those in the 19 mm SYT-amended media, but both products at 100% amendment produced larger plants compared to those grown in unamended media. The different particle sizes did not create substantial differences in pore space, moisture content, air-filled porosity and water holding capacity, which could have led to differences in plant growth (Klock-Moore, 1999a).

Similarly, 13 mm SYT has been studied for its effect on the growth of a range of perennial nursery crops. Mexican heather (*Cuphea hyssopifolia* H. B. K.) was grown in coir- or peat-based substrates amended with 13 mm SYT at 25%, 50%, 75% or 100% (Wilson *et al.*, 2001a). Plants grown in media with high SYT amendment rates (75% or 100%) showed reduced growth compared to those in unamended controls. However, all plants were deemed marketable after 8 weeks, irrespective of SYT concentration or base media composition (i.e. coir or peat). As SYT amendment increased, the carbon:nitrogen ratio and percent moisture decreased and media stability, nitrogen mobilization, pH, electrical conductivity and bulk density increased (Wilson *et al.*, 2001a). Bolivian sunset (*Gloxinia sylvatica* (HBK) Wiehler), Brazilian plume (*Justicia carnea* Lindl.) and golden globe (*Lysimachia congestifolia*) were grown in the same SYT amended at the same rates to peat-based substrates, and the effect on plant growth and development varied with species (Wilson *et al.*, 2002). When grown in SYT-amended media, *Gloxinia* were generally smaller with reduced flower development, compared to those grown in unamended media, but plants were of acceptable colour and quality. When grown in SYT-amended media, *Justicia* were equivalent in size or smaller compared to those grown in unamended media, but flower development was not affected. However, the visual colour and quality of the plants decreased when grown in 100% SYT. The growth parameters of *Lysimachia* grown in SYT-amended media were equivalent or slightly reduced compared to those grown in unamended media, with some reduction in flower development, but plants were still of acceptable visual colour and quality. Compost-amended media had increased values for pH, electrical conductivity, bulk density, particle density and total porosity, compared to peat-based media. The high electrical conductivity of 75-100% SYT-amended media may have played a role in decreased plant growth in these substrates (Wilson *et al.*, 2002).

Three *Salvia* species were grown in 13 mm SYT amended at 50% or 100% to peat-based substrates and irrigated using ebb-and-flow, drip or manual systems (Wilson *et al.*, 2003). Plants grown in SYT-amended media were generally equivalent or slightly smaller than those grown in unamended media, and were of marketable quality, regardless of the medium and irrigation system. Amendment of peat-based substrates with SYT significantly increased the pH, electrical conductivity, bulk density, total porosity, particle density, and many nutrient concentrations (Wilson *et al.*, 2003).

The effect of incorporating 13 mm SYT into a commercial peat-based mix at 20%, 40%, 60%, 80% or 100% on the growth of cauliflower was studied (Kahn *et al.*, 2005). Seedling emergence was delayed when higher rates of SYT amendment were used, and this was likely due to increasing electrical conductivity of the media, but only 100% SYT reduced the final number of plants. In ≥40% SYT amendment, seedling height and dry weight decreased. Only a 20% SYT amendment rate gave growth similar to the commercial peat-based mix (Kahn *et al.*, 2005).

Three woody shrubs (pineland privet (*Forestiera segregata* var. *pinetorum* (Small) M.C. Johnst.), Simpson's stopper (*Myrcianthes fragrans* (Sw.) McVaugh), and Walter's viburnum (*Viburnum obovatum* Walter) were grown in 6.4 mm SYT amended at 40% or 100% to pine bark-based substrates (Wilson *et al.*, 2006). SYT-amended media had lower initial moisture, pH, total porosity, and container capacity; and higher bulk density, particle density and concentrations of many nutrients including nitrogen, phosphorus and potassium; than the other media. SYT amendment did not affect plant height or shoot dry weight, and after transplantation to the field, original container medium did not influence subsequent plant height, growth index, stem parameters, or visual quality.

Wilson and Stoffella (2006) used the same 6.4 mm SYT compost as a media amendment. Seven ornamental wetland and flatwood species were grown in a commercial peat-pine bark-sand mix (standard), the standard mix amended with SYT at 40% (to replace the peat portion) or 100% SYT. Parameters such as height, leaf colour, shoot and root dry weight, and number of flowers were assessed. Plants grown in 40% or 100% SYT had equivalent or significantly greater growth parameters compared to those grown in the standard mix. In particular, plants grown in 40% or 100% SYT had equivalent (2 species) or greater (5 species) shoot dry weights compared to those grown in the standard mix. Two species grown in 40% or 100% SYT were taller compared to those grown in the standard mix. The growth parameters of one species, Carolina petunia (*Ruellia caroliniensis* (J.F. Gmel.) Steud.), grown in 40% or 100% SYT were all significantly greater than those grown in the standard mix (except leaf colour which was equivalent), with height more than doubled, 4.5 times more flowers, and shoot dry weight tripled (Wilson and Stoffella, 2006). In a separate study, blanketflower (*Gaillardia pulchella* Foug.) was grown in the same media as above at the same rates (Danielson *et al.*, 2004). Plants grown in 40% or 100% SYT were taller and had greater shoot dry weights than those grown in the standard mix, while all other parameters were equivalent. After transplantation to the field, there were no differences in any parameters, including flower and visual quality ratings, due to initial container medium used (Danielson *et al.*, 2004).

In an earlier study, four ‘hammock’ (hardwood forest) species were tested using the same protocol (Wilson *et al.*, 2004). Plants grown in 40% or 100% SYT had equivalent or significantly greater growth parameters compared to those grown in the standard mix. Plants grown in 40% or 100% SYT were significantly taller (except one species which was equivalent in height), had significantly greater shoot dry weights, and significantly greater root dry weights (except one species which was equivalent in weight) compared to those grown in the standard mix. Two species grown in 40% or 100% SYT had double or triple the number of flowers compared to those grown in the standard mix. This was despite initial analyses of the medium that indicated that compost alone had a high pH and high electrical conductivity, but may have been due to high concentrations of many nutrients including nitrogen, phosphorus and potassium (Wilson *et al.*, 2004). Even earlier work reported in a non-peer reviewed growers’ magazine indicated that SYT (size not specified) could be a partial alternative to peat for the containerized production of herbaceous perennials (Wilson *et al.*, 2001b). Ten species were grown in peat-based or perlite-vermiculite media amended with 25%, 50%, 75% or 100% SYT. The effect of media amendment on plant growth and development varied with plant species. Eight of the ten species grown in 25% or 50% SYT-amended media had equivalent shoot dry weights to those grown in unamended media. Regardless of SYT rate, three of these eight species had equivalent shoot dry weights compared to those grown in the unamended peat-based medium. Another three of these eight species grown in media amended with SYT of 75% or less had shoot dry weights equivalent to those grown in the unamended peat-based medium, but at 100%, shoot dry weight was significantly reduced. The remaining two of these eight species could tolerate SYT amendment of 50% or less, with shoot dry weights equivalent to those grown in the unamended peat-based medium, but higher rates caused a significant reduction in shoot dry weight. Flower development, colour and visual quality of some species was unaffected by SYT amendment (even when biomass was reduced) while in other species it was unacceptably reduced (Wilson *et al.*, 2001b).

Composted raw or digested sewage sludges (biosolids) have received much attention for their use as an organic amendment for containerized production. It is important to note the effect of the treatment procedure and particle size on efficacy, and the issues such as high soluble salt levels, potential heavy metal content and differential species response. The average cost of dry biosolids is $34 per tonne (2012 prices) (Darvodelsky, 2012). Beneficial effects in many species would indicate that there is much scope for using biosolids as an amendment in production nurseries, and further testing of species responses in warranted.

2.1.3.3 Paper Mill Waste

Pulping, papermaking and paper recycling operations result in a solid waste from the treatment of effluent called paper mill sludge (Chong, 2005), which can be composted (Bellamy *et al.*, 1995). Paper mill sludge should be tested for phytotoxic heavy metals and organic contaminants like dioxins and polychlorinated biphenyls (PCBs), though depending on the type of paper production, these may be found at only very low, acceptable levels (Bellamy *et al.*, 1995; Chong, 2005; Tripepi *et al.*, 1996). Composting can reduce the high carbon to nitrogen ratio to a more plant-friendly 30:1, help stabilize the material, and minimize shrinkage of amended media (Bellamy *et al.*, 1995; Tripepi *et al.*, 1996). Jackson (1998) found that paper mill sludge from a Tasmanian paper mill was nutrient poor, requiring substantial amounts of nitrogen, potassium and phosphorus to initiate composting. Various horticultural plant species were grown in perlite amended with different rates of composted paper mill sludge. Media amended with 60-90% (v/v) paper mill sludge compost had excellent air-filled porosity and water holding capacity, but required an increase in pH, a reduction in the calcium to magnesium ratio, and a slow nutrient-releasing fertiliser to enable satisfactory germination and growth. Paper mill sludge compost as a constituent of soilless growing media was deemed a ‘potentially profitable and an environmentally acceptable method of utilising this organic waste’ (Jackson, 1998).

Lilac (*Syringa vulgaris* L.) plants, amur maple (*Acer tataricum* L. ssp. *ginnala* (Maxim.) Wesm.) plants, and cistena plum (*Prunus* x *cistena* Hansen) cuttings were grown in a pine bark-sand mix amended with 25% or 50% composted paper sludge or peat, or sand amended with 75% composted paper sludge (Tripepi *et al.*, 1996). Plants of all three species grown in compost-amended media grew as well as or better than those in peat-amended media, even in 75% composted paper sludge. Lilac plants in 25% compost-amended media had almost double the shoot dry weight and were 80% taller than those in the unamended bark-sand medium or those in the 25% peat-amended medium. Maple plants in 50% compost-amended media had at least 33% greater shoot dry weight than those in peat-amended media. Plum cuttings in 25% compost-amended media grew at least 53% taller than those in peat-amended media. While most of the physical and chemical properties of compost-amended media were suitable for plant growth, including no observable shrinkage, the cation exchange capacity and the nitrate levels require monitoring (Tripepi *et al.*, 1996).

Three tropical landscape crops, orange-jessamine (*Murraya paniculata* L. Jack), Cuban royal palm (*Roystonea regia* (Kunth) O. F. Cook) and dwarf oleander were grown in 100% pulp and paper mill waste compost, mixed MSW compost, or mixed MSW and dewatered sewage sludge compost (Fitzpatrick, 1989). Plant heights and total dry weights of both orange-jessamine and Cuban royal palm in all three compost-amended media were equivalent to those in the unamended peat-pine bark-based control medium. Plant height and total dry weight of dwarf oleander in compost-amended media was equivalent to (in mixed MSW and dewatered sewage sludge compost) or greater than (in pulp and paper mill waste compost) that in the unamended medium. (Dwarf oleander grown in mixed MSW compost were equivalent in height but had greater total dry weight than those in the unamended medium) (Fitzpatrick, 1989).

Examination of the response of other plant species including vegetable transplants, annual bedding species and shrubs would add to the scant knowledge on the effect of composted paper mill waste on plant growth. Monitoring of the levels of heavy metals and organic contaminants would be essential.

2.1.3.4 Brewing Waste

Brewing waste (a mixture of yeast and residual malt) can be used as an organic amendment for containerized plant production. Brewing waste was combined with lemon tree prunings, composted and then amended at 25%, 50%, 75% or 100% with either peat or a commercial substrate based on composted grape marc (Garcia-Gomez *et al.*, 2002). When peat was amended with up to 75% brewing waste-based compost or when the commercial substrate was amended with up to 50% brewing waste-based compost, the growth and development of calendula in these media was generally equivalent to that in the respective unamended media. Higher amendment rates led to reduced growth due to physical properties of the media such as low total pore space, and high electrical conductivity. When peat or the commercial substrate was amended with up to 50% brewing waste-based compost, the growth and development of calceolaria (a more salt-sensitive species) in these media was generally equivalent to (or sometimes greater than) that in the respective unamended media; higher amendments with higher electrical conductivity restricted growth (Garcia-Gomez *et al.*, 2002). The compost acted as a slow release fertilizer, providing mainly nitrogen and potassium.

Given the waste generated by the sizable brewing industry, additional work on the efficacy of this amendment on a broad range of containerized crops, including those with longer culture periods, would be justifiable. Also, establishing the physical and chemical characteristics of brewing waste-amended media would be worthwhile

2.1.3.5 Olive Mill Wastewater

Olive mill wastewater is another agroindustrial waste that can be recycled. Olive mill wastewater combined with olive leaves was composted and then amended at 25%, 50%, 75% or 100% with either peat or a commercial substrate based on composted grape marc (Garcia-Gomez *et al.*, 2002). When peat or the commercial substrate was amended with up to 50% olive mill wastewater-based compost, the growth and development of calendula was generally equivalent to that in the respective unamended media. When peat or the commercial substrate was amended with up to 25% olive mill wastewater-based compost, the growth and development of calceolaria (a more salt-sensitive species) was generally equivalent to that in the respective unamended media (Garcia-Gomez *et al.*, 2002). The compost provided nutrients for plant growth but the high salt levels meant that compost could only be amended at low rates.

Given the small size of the domestic olive industry, only if olive processing facilities are nearby to container production facilities, then olive mill wastewater may find a local, niche market, but further testing of the response of a wider variety of plant species would be required.

2.1.3.6 Food residuals

Compost was made from either pre-consumer food residuals mixed with domestic garden waste (primarily leaves) as a bulking agent, or from used straw horse bedding (Clark and Cavigelli, 2005). Seeds of lettuce and tatsoi (*Brassica rapa*) were sown in peat-based media amended with 50% or 100% compost. Seed germination of both species in 50% or 100% food residuals compost was equivalent to that in the peat-based control medium supplemented with synthetic fertilizer. Subsequent plant growth in terms of height and marketable yield in 100% food residuals compost was statistically similar to that in the peat-based control medium supplemented with synthetic fertilizer, but height and yield in 50% food residuals compost was significantly reduced. Germination and growth of both species in 50% or 100% horse bedding compost was very poor and commercially unacceptable. Though the two composts were similar in terms of physical properties including total nitrogen content, carbon:nitrogen ratio and bulk density, the net nitrogen mineralization was high in the food residuals compost, but there was net nitrogen immobilization in the horse bedding compost, possibly due to high salinity, and this is likely to have resulted in the different responses of the plants. The food residual compost was slightly more expensive than the standard peat-based control medium, but this was partly due to the scale and mechanization of the composting procedure, which could be refined for improved efficiency. If used as part of an organic production system, the cost may be able to be passed onto the consumer (Clark and Cavigelli, 2005).

Whilst the availability of food residuals would be plentiful, production efficiencies would require improvement to lower its cost. Also, there are concerns that the composition of the feedstock would be highly variable, leading to an inconsistent product. Further testing of more plant species to ascertain the utility of such an amendment would be needed. The cost of composts is highly variable depending on the feedstock, but they are (adjusted to current prices) approximately \$7-\$840/t or \$105-\$525/t for pelletised products (Quilty and Cattle, 2011).

2.2 Compost Teas

Compost tea is made by placing compost of known properties directly in water, or more usually, in a porous container (e.g. a bag suspended in water or on a screen with water running through) and leaving it to ferment or ‘brew’ for a defined time period (Anonymous, 2003; Anonymous, 2004; Ingham, 1999a; Krishnamurthy, 2011; St. Martin and Brathwaite, 2012). This is opposed to a compost extract, which is when compost is mixed with a solvent, usually water, but is not fermented (Scheuerell and Mahaffee, 2002). Compost tea production has been reviewed recently by St. Martin and Brathwaite (2012). Compost often comprises 10-25% of the tank volume, but can range from 0.1% to 50% and should be experimentally derived, and can be amended with numerous other supplements at 0.001-0.01%, before or after fermentation (Brinton *et al.*, 1996; Krishnamurthy, 2011; Litterick and Wood, 2009; Mahaffee and Scheuerell, 2006; Scheuerell and Mahaffee, 2002; St. Martin and Brathwaite, 2012).

Supplements often added during the fermentation include molasses, yeast extracts, sucrose, grains, fish emulsions, malt, peptone, starches, nutrient broths, algal powders such as soluble kelp, humic extracts and rock dust; designed to promote growth and enhance diversity of microbes (as reviewed by Anonymous, 2003; Anonymous, 2004; Litterick and Wood, 2009; Mahaffee and Scheuerell, 2006; Pant *et al.*, 2009). However, the addition of nutrients during non-aerated compost tea production can lead to offensive odours (Scheuerell and Mahaffee, 2002). There are also proprietary food packets that contain mixtures of 80% organic and 20% natural minerals derived from sulfate of potash-magnesia, feather meal, soy meal, cottonseed meal, mycorrhiza, kelp and alfalfa meal (DeBacco, 2011). However, published scientific evidence to support efficacy claims made regarding compost tea, various recipes and proprietary additives is scarce (Litterick and Wood, 2009; Mahaffee and Scheuerell, 2006; Scheuerell and Mahaffee, 2004; Scheuerell and Mahaffee, 2006). Optimal combinations of additives for use in specific situations should be the subject of further studies (Litterick and Wood, 2009).

The positive or negative effects of compost tea on plant growth and disease suppression depend on the quality of the initial compost feedstock and its formulation (as for compost); the tea production conditions, such as the ratio of compost to water, aeration, duration, temperature and pH; application decisions such as the dilution ratio, equipment, tank mixing with fertilizers, timing, frequency, storage and adjuvants; and the environmental conditions during application and use (Carballo *et al.*, 2009; Ingham, 1999b; Litterick and Wood, 2009; Scheuerell and Mahaffee, 2002). As for compost, the quality of the initial compost feedstock including its level of maturity and stability (Scheuerell and Mahaffee, 2002) can influence its efficacy. Compost teas produced from unstable compost are more phytotoxic due to the continued decomposition of the organic matter in the immature, uncured compost, the simultaneous production of toxic metabolites, yielding a compost with low pH and a high ammonium levels (Carballo *et al.*, 2009). Also the quality of the initial compost feedstock can be reduced if it is contaminated by residual herbicides. There have been some instances of contaminated compost having detrimental effects when used on desirable plants (Bezdicek *et al.*, 2001; Rynk, 2001), but mixing with other ingredients would dilute any residuals and thorough composting should degrade them (Handreck and Black, 2002).

The source of the compost is an important factor in the efficacy of the resultant compost tea to inhibit pathogen growth and suppress disease. Non-aerated compost teas produced from either chicken manure, sheep manure, bovine manure, shrimp powder, or seaweed, all significantly inhibited the mycelial growth of *Botrytis cinerea* (DeBary) Whetzel *in vitro*, and in greenhouse tests, suppressed grey mould (caused by *B. cinerea*) on tomato plants (Koné *et al.*, 2010). However, sheep manure compost tea was consistently the most effective, giving the greatest inhibition of mycelial growth and the highest disease suppression (>95% disease reduction) for up to 9 weeks. In the same study, the compost teas also inhibited the growth of *Alternaria solani* Sor. and *Phytophthora infestans* (Mont.) de Bary *in vitro*, and although they reduced disease development, they did not adequately control powdery mildew of tomato caused by *Oidium neolycopersici* L. Kiss (Koné *et al.*, 2010). However, there are some microbial safety issues to consider with the application of these non-aerated compost teas, as those prepared from chicken manure compost and interestingly, seaweed compost consistently showed the presence of coliforms. Similarly, Haggag and Saber (2007) tested compost teas made from each of three different plant residues, chicken manure, or 2:1 mix of each plant residue:chicken manure, for their ability to suppress early blight of tomato and purple blight of onion in the greenhouse. All compost teas significantly reduced disease severity compared to unsprayed controls. The three plant residue:chicken manure mixtures gave the greatest reduction in disease severity. All chicken manure-based compost teas had high bacterial populations, but the levels of potential human pathogens or indicator species were not measured.

Teas prepared from composts cured in windrows for 3, 5, 10, or 16 months all significantly reduced the severity of bacterial spot of tomatoes (Al-Dahmani *et al.*, 2003). Palmer *et al.* (2010b) found that inhibition of *B. cinerea* (in bean leaflet bioassays) by aerated compost teas produced from various feedstocks varied significantly among compost ages (Palmer *et al.*, 2010b). Aerated compost teas prepared from immature (28- to 32-day-old) compost inhibited *B. cinerea* growth in the bean leaflet bioassay and *B. cinerea* conidial germination *in vitro*, and had more culturable bacteria than fungi. However, it should be noted that the shortest compost age (3 months) in the Al-Dahmani *et al.* (2003) study was equivalent to the longest compost age in the Palmer *et al.* (2010b) study, and different pathosystems were studied. Palmer *et al.* (2010b) found that bacterial and fungal diversity was higher at an early stage in the compost cycle (28 days after windrow initiation), than at later stages (up to 87 days), and it seemed diversity rather than abundance was a more important factor for disease suppression, at least in this pathosystem. *B. cinerea* inhibition declined as the internal windrow temperature decreased below 51°C.

Similarly, Scheuerell and Mahaffee (2002) and Weltzien (1991) stated that the efficacy of compost tea for plant disease suppression was mainly due to the very rich and varied microbial populations, potentially the total population and/or the diversity (specific sub-populations); but the total culturable bacterial population did not seem to correlate to suppression (Palmer *et al.*, 2010b; Scheuerell and Mahaffee, 2002; Scheuerell and Mahaffee, 2004; Scheuerell and Mahaffee, 2006). Manipulation of many of the factors described above will impact on the growth and diversity of microorganisms in the final compost tea, and hence its efficacy (Scheuerell and Mahaffee, 2002).

Compost teas may be aerated or non-aerated. Aerated compost tea is achieved by bubbling air into the water, which also helps to reduce dissolved chlorine in the water if only chlorinated water sources are available (Krishnamurthy, 2011; Litterick and Wood, 2009). Aeration of the tea is designed to encourage optimal growth of beneficial microorganisms, which requires a minimum dissolved oxygen concentration of ~6 ppm (Krishnamurthy, 2011). Aerated compost teas usually start with compost to water ratios of 1:10-50 v/v and ferment for only 12-24 hours, and can be expensive to produce with a wide range of compost tea 'brewers' available (Mahaffee and Scheuerell, 2006). Non-aerated compost tea is characterized by no active aeration, or only minimal aeration apart from the initial mixing stage (Litterick and Wood, 2009). This may include stirring every 2-3 days (Brinton *et al.*, 1996). Non-aerated compost teas usually start with compost to water ratios of 1:3-10 v/v and ferment for 1-120 days, though 7-14 days is typical, and are cheap to produce (Mahaffee and Scheuerell, 2006). The final product of either production method has soluble nutrients and a variety of microorganisms derived from the compost (Anonymous, 2003). After brewing, the compost tea should be used as soon as possible and not stored; its microbial activity is reportedly halved within 12 hours (Hutchinson, 2008).

There have been conflicting claims regarding both the efficacy in terms of plant disease control and the phytotoxicity of aerated versus non-aerated compost teas (Mahaffee and Scheuerell, 2006). Brinton *et al.* (2004) found that, at least for small-scale production of compost tea, there was equivalent growth of desirable microbes in both aerated and non-aerated systems. Scheuerell and Mahaffee (2000; 2004; 2006) directly compared the effect of aeration during production of compost teas from a range of feedstocks (with and without additives) and found no significant difference in control of powdery mildew of rose, grey mold of geraniums, or *Pythium* damping-off of cucumber, or any phytotoxicity. Al-Dahmani *et al.* (2003) directly compared the effect of aeration by producing aerated, non-aerated and anaerobic compost teas (the latter produced in an anaerobic jar with O_2 absorbers and CO_2 indicators) and observed no differences in control of bacterial spot of tomato, or phytotoxicity. Mahaffee and Scheuerell's (2006) review of these studies and other relevant literature indicated that aeration has no effect on disease control or phytotoxicity.

A later study by Haggag and Saber (2007) compared aerated compost teas and non-aerated compost teas from a range of feedstocks in the greenhouse and in the field for their effect on suppression of early blight of tomato and purple blight of onion. In the greenhouse trial, the authors claimed that while both aerated and non-aerated compost teas decreased severity of both diseases, 'non-aerated compost teas displayed the highest reduction in disease incidence', and 'there were differences in disease control afforded by aerated compost teas and non-aerated compost teas when using the same compost source' (Haggag and Saber, 2007). However, closer examination of the methods showed that 1) only disease severity was measured, not disease incidence; 2) the so-called aerated compost tea was not actively aerated and was, in practice, a comparison of fermentation period of non-aerated compost teas of 24 h versus 6 d; and 3) the aerated and non-aerated treatments could not be compared statistically, as they were analysed separately. Furthermore, in the field trial, no statistical measures were provided for comparing the effect of aerated and non-aerated compost teas on disease severity (Haggag and Saber, 2007). These issues raise doubts about the findings of this study.

Carballo *et al.* (2009) tested the effect of aeration (and other production conditions) on the phytotoxicity of compost teas. They found that, in general, non-aerated teas were more phytotoxic that aerated teas, as measured by a commonly used germination test and a growth test. Whilst the authors acknowledge the phytotoxicity of the compost teas, they also proposed that the germination test was too stringent for the determination of compost tea phytotoxicity and that the growth test was a more reliable indicator. The authors suggested that the greater phytotoxicity of non-aerated compost teas could be due to a higher dissolved salt concentration or the presence of organic acids produced by microorganisms in the anaerobic environment. (Carballo *et al.*, 2009).

Xu *et al.* (2012) compared the efficacy of aerated and non-aerated compost tea, and a compost extract, all based on the same pig manure/rice straw compost. In laboratory tests, the compost extract and teas significantly inhibited the *in vitro* growth of the soil-borne pathogenic fungi *Fusarium oxysporum* f. sp. *niveum*, *Fusarium* *oxysporum* f. sp. *cucumerinum*, *Fusarium oxysporum* f. sp. *cubense*, and *Fusarium oxysporum* f. sp. *melonis*, but not *R. solani*. In greenhouse tests using soil naturally infested with root knot nematodes, tomato plants treated with compost extract or compost tea had significantly higher fresh root biomass (1.25-5.67 times higher) and significantly lower number of egg masses (up to 88% less) and nematodes (up to 51% less) than plants treated with a water control. In addition, the compost extract and teas displayed low phytotoxicity to lettuce and cress when diluted to 25% or less, but generally the two compost teas were more phytotoxic than the compost extract. All compost products showed high phytotoxicity when applied without dilution. These authors found that while microbial populations in general were the most important factor related to pathogen inhibition, bacterial community diversity was not significant. Overall, there was no difference in the efficacy of the aerated compost tea, the non-aerated compost tea and the compost extract.

Compost teas can be applied using existing irrigation and fertigation systems, or using pesticide application equipment (Anonymous, 2003), without the need for expenditure on additional infrastructure. Prior to application, compost tea should be filtered to prevent injectors, lines, emitters and sprayer nozzles becoming blocked. Having said this, filtering out suspended particles from the compost tea that can contain bound microbial populations may decrease the efficacy of the compost tea (Anonymous, 2003; Bess, 2000). Equipment should be thoroughly cleaned after use to avoid unintentional microbial growth in the system apparatus. Adjuvants can be added prior to application to increase leaf coverage (spreaders), improve adherence to plant surfaces (stickers), protect microbes from stressors (protectants) or support microbial growth and extend survival (nutrients) (Anonymous, 2003; Litterick and Wood, 2009; Mahaffee and Scheuerell, 2006; St. Martin and Brathwaite, 2012). Optimal combinations of adjuvants for use in specific situations should be the subject of further studies (Litterick and Wood, 2009).

Efficacy of the final compost tea is influenced by the dilution and application rate, usually diluted 1:2 -1:10 with water (Krishnamurthy, 2011), although Scheuerell and Mahaffee (2004) showed that a dilution of 1:9 significantly reduced suppression of *Pythium* damping-off of cucumber, and even dilutions of 1:1 and 1:4 reduced disease suppression, though the effect was inconsistent. An application rate equivalent to 50 L/ha every 14 days is advised, but the rate, frequency of application, sprayer type and pressure, and nozzle size can all affect efficacy and require optimization for specific production systems (Hutchinson, 2008; Krishnamurthy, 2011; Scheuerell and Mahaffee, 2002).

Application of compost tea to plants alters their microbial populations, by supplying exogenous microbes present in the tea, but also by supplying nutrients to support the growth and survival of endogenous microorganisms in the phyllosphere and rhizosphere (Ingham, 1999a). Tränkner (1992) found that 1 hour after applying non-aerated compost tea to bean plants in the glasshouse, the total number of microorganisms on the leaves increased 10^3 CFU/cm^2. Furthermore, when the plants were kept under moist conditions (not specified), this population level of microorganisms was maintained for 5 days. The glasshouse environment of most containerized production systems may provide similar conditions supporting the persistence of microbes beneficial to plant growth and/or disease suppression.

Such microbes can inhibit the growth of plant pathogens, in part by secreting siderophores. Siderophores are small, high affinity iron-chelating compounds, which effectively kidnap iron, making it unavailable to the pathogen for normal growth and function (Diánez *et al.*, 2006a; Diánez *et al.*, 2006b). Aerated compost tea, produced from grape marc compost over 1 day, 1 week or 2 weeks, inhibited the growth *in vitro* of eight plant pathogens: *R. solani, F. oxysporum* f. sp. *radicis-lycopersici,* two races of *F. oxysporum* f. sp. *lycopersici*, *F. oxysporum* f. sp. *radicis-cucumerinum, V. dahliae, P. aphanidermatum,* and *Phytophthora parasitica*; and the mycopathogen, *Verticillium fungicola* (Preuss) Hassebrauk. Inhibition increased with increasing production time. Growth inhibition was mainly via the production of siderophores, though other undetermined biological mechanisms were at work (Diánez *et al.*, 2006a; Diánez *et al.*, 2006b).

Compost tea production parameters, including initial compost feedstock, aeration, nutrient additives, duration of production, periodic stirring, tea depth and adjuvants were assessed in one comprehensive study for their effect on one pathosystem - grey mold of geranium caused by *B. cinerea* (Scheuerell and Mahaffee, 2006). Most compost teas did not significantly suppress disease; of 104 batches of non-aerated compost teas, only 31% significantly reduced disease. For non-aerated compost teas, chicken manure compost or domestic garden trimmings compost and longer production times (14 days versus 7 days) gave the most consistent, significant disease suppression; periodic stirring (every 2-3 days), the initial addition of nutrients, tea depth (tea obtained from 15 cm deep rather than the surface) or aeration had little or no effect. For aerated compost teas, application with adjuvants that increased dispersal and adherence of tea droplets significantly reduced disease. The initial addition of nutrients, though increasing the populations of culturable bacteria, did not consistently improve disease suppression, which was also found by Scheuerell and Mahaffee (2004). Residual nutrients from such initial additions may, in fact, support saprophytic growth of the pathogen, thwarting suppression (Scheuerell and Mahaffee, 2004; 2006). Despite this, the most consistent formulation for suppression of grey mold of geranium and *Pythium* damping-off of cucumber was aerated compost tea produced with kelp and humic acid additives, so particular additives can be effective in certain pathosystems (Scheuerell and Mahaffee, 2004; 2006).

Compost extraction ratios may also influence the efficacy of compost teas. Teas prepared at extraction ratios of 1:1, 1:3, and 1:5 (compost:water, v/v) all significantly reduced the severity of bacterial spot compared with the water control (Al-Dahmani *et al.*, 2003). Teas extracted with similar ratios of 1:3, 1:10 and 1:30 (compost:water w/v) also suppressed disease symptoms caused by *B. cinerea* in bean leaflet bioassays, but these authors tested a much greater range of extraction ratios, and found that the lowest extraction ratio of 1:1 or a very high extraction ratio of 1:100 gave significantly less suppression (Palmer *et al.*, 2010b).

Compost teas are usually extracted using water only, but other extractants can be used, such as whey (Pane *et al.*, 2012), which can act as a food source for increasing microbes with disease-suppressive qualities from the compost (Line and Ramona, 2003). Five composts, four produced from feedstocks containing various levels of tomato residues and one produced from biowaste feedstock, were extracted in either water or whey (Pane *et al.*, 2012). (Biowaste is the organic fraction of municipal solid waste that has been collected separately (Veeken *et al.*, 2005)). The ten teas suppressed growth (*in vitro*) and reduced disease symptoms (*in vivo*) of three fungal pathogens of tomato: *B. cinerea*, *Alternaria alternata (*Fr.) Keissl. and *P. lycopersici* (Pane *et al.*, 2012). The populations of bacteria and fungi varied little across the ten teas, and bacterial numbers were 10^3 CFU/mL, at least three orders of magnitude lower than what has been proposed as the threshold limit for disease suppression by compost teas (determined in the cucumber-*P. ultimum* pathosystem (Scheuerell and Mahaffee, 2004). Disease suppression was significantly affected by the extractant used but varied with the pathogen. Grey mould caused by *B. cinerea* was controlled significantly better with water-extracted tea; there was no substantial difference in early blight caused by *A. alternata* with water- or whey–extracted tea; and corky root caused by *P. lycopersici* was controlled significantly better with whey-extracted tea (Pane *et al.*, 2012). The whey-extracted tea required extra dilution to avoid phytotoxicity due to high salt concentrations and a low pH. Given the variation with pathosystems, the effect of the extractant should be investigated for specific situations.

Compost teas may contribute to negative effects on plant growth. Tomatoes grown in a sand-topsoil mix drenched with MSW compost tea (non-aerated) every two weeks, every week, or every four days (or amended with MSW compost at a low or high rate) had significantly lower tomato fruit yields compared to plants treated with conventional or organic fertilizer (Radin and Warman, 2011). However, in a second experiment in the same study, this time with better quality field soil, compost tea applied as a foliar spray every two weeks or every week, increased compost rates, and the MSW compost tea and compost treatments tested in factorial combination, the MSW treatments gave equivalent or significantly greater tomato fruit yields than those treated with the conventional fertilizer (Radin and Warman, 2011). This highlights the need to optimize organic amendment application parameters and tailor them to individual production systems.

Also, compost tea made from MSW inhibited root length of germinating lettuce seeds, however only very high tea concentrations inhibited the growth of lettuce and barley seedlings (Carballo *et al.*, 2009). Aerated teas produced at low temperatures from stable MSW compost generally caused less phytotoxicity than non-aerated teas produced at higher temperatures from unstable MSW. Greater phytotoxicity due to non-aerated teas could be due to a higher dissolved salt concentration or the presence of organic acids produced by microorganisms in the anaerobic environment. Greater phytotoxicity of compost teas produced at higher temperatures may be due to a higher concentration of phytotoxic compounds due to greater extraction efficiency. Greater phytotoxicity of compost teas produced from unstable compost is likely due to the continued decomposition of the organic matter in the immature, uncured compost, with the concomitant production of toxic metabolites, resulting in a compost of low pH with a high concentration of ammonium (Carballo *et al.*, 2009).

Very little attention has been given to the interaction of compost teas with other inputs to plant production, but there is potential for positive effects. The conjunctive use of reduced rates of each of compost tea (derived from empty fruit bunch, presumably from palm oil, and chicken manure) and conventional inorganic fertilizer significantly and synergistically increased the vegetative growth, yield and bioactive components of the ethnomedicinal herb *Centella asiatica* (L.) (Siddiqui *et al.*, 2011). Since compost tea will always be just one of the many inputs in containerized production, further studies are required in this area. Given this, it is also important that the use of compost tea can be integrated into the existing production system, and this seems feasible. This includes its application via existing irrigation/fertigation infrastructure, tank-mixing with other compatible inputs (e.g. other organic amendments such as seaweed extracts, fish emulsions and humic extracts) for application with conventional pesticide application equipment, and application timing with respect to other inputs that may be incompatible (e.g. pesticides).

With the inherent variability in compost tea, coming from inconsistent feedstocks, it is difficult to produce a reliable, consistent product (Bonanomi *et al.*, 2007; Bonanomi *et al.*, 2010). This, combined with a myriad of tea production conditions that can be manipulated and numerous application decisions, means it is challenging to make general recommendations that would be suitable for all production systems. Striking a balance between efficacy of disease suppression and phytotoxicity via the application of compost tea can be challenging. From studies directly comparing the efficacy of aerated and non-aerated compost teas, it seems unnecessary to invest in expensive aeration production systems. It is important to tailor compost tea products to specific production systems and their particular pathosystems. Further work on integrating compost tea applications with other inputs would be worthwhile. If these issues can be addressed, it is practical to apply compost teas in a production nursery environment. The cost is comprised of the cost of the compost, and depending on aeration, costs for non-aerated teas are negligible, while costs for aerated teas can range from $250-$2000 for the brewer. There may also be extras such as starter ingredients.

2.3 Biodynamic Products

Biodynamic products are used in biodynamic farming, where the farm is viewed ‘as an organism, a self-contained entity’ (Diver, 1999). A complete holistic approach is taken to the integration, health and wellbeing of crops, livestock and the farmer, the recycling of nutrients and soil maintenance, and their association with higher, non-physical realms (cosmic and terrestrial forces) are embraced. Biodynamic products include two preparations that are made from materials packed into cow horns and buried in the soil for 6 months at a specific time of the year, and then applied as a spray; and six preparations from particular plant parts that are exactingly used in homeopathic quantities to produce compost. These preparations are used to ‘moderate and regulate biological processes as well as enhance and strengthen the life (etheric) forces on the farm’ (Diver, 1999). Given that biodynamic products are so entwined to the farming system, to use them in containerized plant production outside of such an approach, goes against the fundamental tenets of the holistic system.

2.4 Meat, Blood and Bone Meals

Wastes from animal slaughterhouses can be recycled into secondary products. Whilst they are widely used in field applications (Quilty and Cattle, 2011), documentation of their use in containerized plant production is scarce. They are usually sold in solid form as pellets or granules. They are also available as liquid products for application as a drench, via fertigation or as a foliar spray (Quilty and Cattle, 2011). Blood meal, the dehydrated powder form of the blood of animals (Chan *et al.*, 2007b) can be resuspended to make a liquid fertilizer. In the liquid fertilizer, to avoid solids blocking nozzles and valves, a microwave-enhanced advanced oxidation process is required to solubilise these solids and release nutrients (Chan *et al.*, 2007b).

2.4.1 Solid

Ideally, organic amendments would release a low, relatively constant nutrient level for the entire cropping cycle in containerized production (Williams and Nelson, 1992). The pattern and term of nitrogen release of seven organic materials was established and their suitability as slow release, low rate fertilizers for the production period (10 to 12 weeks) of chrysanthemum was examined and compared to a standard slow release fertilizer and a weekly liquid fertilizer control. The organic materials were 1) unsteamed bone meal, 2) a mixture of two bacteria, *Bacillus licheniformis* (Weigmann) and *B. subtilis*, plus the fungus *Aspergillus niger* (van Tieghem) in a non-viable state, 3) an activated microbial sludge from wastewater treatment, 4) sludge from a poultry manure methane generator, 5) an amino acid producing bacterium *Brevibacterium lactofermentum* (Okumura *et al.*), 6) aged pine needles, and 7) poultry feathers. The organic materials released high levels of nitrogen during the first 2-3 weeks, which tapered off to almost nil at 6 to 7 weeks, and this could not be extended by increasing application rates. Despite this, plants grown in the bone meal and *Br. lactofermentum* amendments had equivalent growth to the standard slow release fertilizer and a weekly liquid fertilizer control by 12 weeks (Williams and Nelson, 1992).

Blood meal or meat meal mixed into a peat-compost growing medium significantly increased the shoot dry weight of tomato transplants in the greenhouse compared to unfertilized plants (Gagnon and Berrouard, 1994). In a greenhouse study, blood and meat wastes (unspecified) incorporated into soil at 1% or 5% reduced plant parasitic nematode populations, reduced disease symptoms and improved the growth of pigeon pea plants compared to that in unamended soil (Akhtar and Mahmood, 1995). Given that these two studies were reported only as short communications, the latter lacking details of the amendments and using soil, further work would be required to verify their outcomes, determine the effect on the physical and chemical properties of the media, and evaluate the ability of solid blood and meat meal to improve the growth of other plant species. Approximate costs (adjusted to current prices) are \$840-\$1260/t (Quilty and Cattle, 2011).

2.4.2 Liquid

Blood meal is used as a liquid fertilizer component of some organic hydroponic greenhouse operations in BC, Canada (Chan *et al.*, 2007b). There is a scarcity of research into blood meal as a liquid fertilizer for containerized production, but approximate costs (adjusted to current prices) are \$11-\$32/L (Quilty and Cattle, 2011).

2.5 Fish Products

2.5.1 Fish Meal

Fish meal is the dried protein derived from various fish species which is mainly used for animal feed, for example for pigs, other fish, but has also been used as a soil amendment in the field production of vegetables (Abbasi *et al.*, 2006; Blatt and McRae, 1998; Conniff, 2012; Gagnon and Berrouard, 1994). Various species of fish are used including menhaden (which, incidentally, is the Native American word for fertilizer (Conniff, 2012)), ocean perch, mackerel, tuna and carp. In a greenhouse study, fish remains (unspecified) incorporated into soil at 1% or 5% reduced plant parasitic nematode populations, reduced disease symptoms and improved the growth of pigeon pea plants compared to that in unamended soil (Akhtar and Mahmood, 1995).

Fish waste compost can be produced by co-composting ground bottom-fish waste with a mixture of western hemlock and coarse Douglas-fir sawdust (Hummel *et al.*, 1993; Hummel *et al.*, 2000). Market quality blueberry (*Vaccinium corymbosum* L.) and juniper were grown successfully in Douglas-fir bark amended with 25% fish waste compost plus 240 mg of supplementary nitrogen fertilizer per container (Hummel *et al.*, 1993). In other studies, different amendment rates of this same compost were tested for the growth of rhododendron (Kuo *et al.*, 1997), marigolds and geraniums (Hummel *et al.*, 2000). Rhododendrons were grown in Douglas-fir bark amended with 25%, 50%, 75% or 100% fish waste compost plus different nitrogen fertilizer rates under overhead sprinkler irrigation (Kuo *et al.*, 1997). The best growth in terms of root and shoot growth indices was generally in the medium amended with 50% fish waste compost. Overhead sprinkler irrigation leached much of the inorganic nitrogen present in the compost, regardless of amendment rate, in the first 2-3 weeks, so its beneficial effect was short-lived and regular nitrogen fertilizer application was required to sustain commercially acceptable plant growth and quality (Hummel *et al.*, 2000; Kuo *et al.*, 1997). Drip irrigation would minimize such nitrogen leaching, retaining as much as possible for plant use (Kuo *et al.*, 1997). Marigolds and geraniums were grown in Douglas-fir bark amended with 50% or 100% fish waste compost plus nil, 1x or 2x supplementary nitrogen fertilizer (Hummel *et al.*, 2000). The 100% fish waste compost medium provided sufficient inorganic nitrogen to produce high quality marigolds in 7 weeks (as large and of as high quality as any that received supplementary nitrogen) and marketable quality geraniums in 9 weeks. The 7-week-old marigolds did not benefit from supplemental nitrogen fertilizer. In the 9-week-old geraniums, supplemental nitrogen fertilizer did increase shoot growth and quality indices (though did not affect dry weight or inflorescence number), and so was unnecessary as they were already attractive and of marketable quality. In the 50% fish waste compost medium, marigolds responded to supplemental nitrogen at 7 weeks and geraniums at 5 weeks, when plants in the 2x nitrogen treatment were larger than those in the nil nitrogen treatment (Hummel *et al.*, 2000).

A compost derived from sawdust:soil:fish:shrimp:crab waste (4:1:1:1:1 v/v) (no further details provided), was one of 36 composts tested for its ability to suppress seedling damping-off caused by three different pathogens (Scheuerell *et al.*, 2005). The fish-based compost had no effect on damping-off of cucumber caused by *P. irregulare* or *P. ultimum,* and significantly increased damping-off of cabbage caused by *R. solani*.

Composted fish waste, combined with an additional nitrogen source, would need to be tested on a wide range of nursery species to determine its applicability in production systems, with particular attention paid to the possibility of an increase in plant disease. An assessment of its effect on the physical and chemical properties of soilless growing media is also required.

2.5.2 Fish Emulsions

The production of fish meal yields liquid byproducts known as fish emulsions (Abbasi *et al.*, 2006). Fish emulsions, also called fish hydrolysates or fish soluble nutrients, are prepared by squeezing excess liquid from the processed fish, removing the oil and some of the water, and acidifying with sulphuric acid to stabilize the product (Abbasi *et al.*, 2003). The main use of fish emulsions has been as fertilizers for house, garden and greenhouse plants (Aung and Flick Jr, 1980) or as preplanting soil amendments for the control of fungal diseases (Abbasi *et al.*, 2002; Abbasi *et al.*, 2006). Fish emulsion acts directly by providing nutrients for plant growth, but also indirectly, by acting as a nutrient base for the growth of plant growth promoting rhizobacteria (El-Tarabily *et al.*, 2003). Such bacterial and actinomycete isolates produce plant growth regulators such as auxins, gibberellins and cytokinins, which can aid plant growth, and seem to use the fish emulsion as a source of nutrients and precursors for production of these compounds (El-Tarabily *et al.*, 2003).

Container-grown tomatoes in the greenhouse were treated with fish emulsions at various rates and frequency intervals and their growth compared to those fertilized with a complete inorganic nutrient solution (Aung and Flick Jr, 1980). Tomatoes treated with fish emulsions applied at weekly or biweekly intervals had comparable growth and fruit yields as plants fertilized with full strength Hoagland's nutrient solution. The fish emulsion treatment stimulated vegetative production but delayed flowering and fruit ripening by 5-8 days, depending on the application rate and frequency (Aung and Flick Jr, 1980). In a study evaluating sawdust waste as a growing medium constituent, fish emulsion added at 1% (v/v) enhanced the effect of sawdust waste as a 30% or 100% amendment to soil in pots in the greenhouse for increasing the yield of tomato (Cheng, 1987).

Fish emulsions have also been applied to various container grown ornamental and vegetable plants in the greenhouse: marigold, calendula (*Calendula officinalis* L.), peperomia (*Peperomia obtusifolia* (L.) A. Dietr.), chrysanthemum, coleus, pepper and tomato (Emino, 1981). Plants were treated with 1) fish emulsion (NPK 5:0.44:0.44), 2) fish emulsion amended with seaweed, sugarcane extracts, urea, phosphoric acid and potassium sulphate (NPK 5:1.7:3.3) or 3) a complete inorganic fertilizer solution (NPK 20:8.8:16.6) at equivalent rates of nitrogen at weekly intervals. Growth parameters of plants of all species treated with fish emulsion or amended fish emulsion were equivalent to those plants treated with the complete inorganic fertilizer. Additionally, there were no differences in the visual quality of plants and no phytotoxicity due to the fish emulsion treatments (Emino, 1981).

Fish emulsion has both nutritive and disease suppressive properties (Abbasi *et al.*, 2002; Abbasi *et al.*, 2004). Studies have shown that fish emulsions can promote the growth of plants and suppress diseases such as damping-off of seedlings caused by *R. solani* and *P. aphanidermatum* (Abbasi *et al.*, 2002; Abbasi *et al.*, 2004). Abbasi *et al.* (2002; 2004) found that 4% fish emulsion, incorporated into pathogen-infested, peat-based substrates 7 days prior to planting radish or cucumber seeds, suppressed 70-80% of seedling damping-off. Similarly, equivalent levels of disease suppression were achieved if lower concentrations of fish emulsion (1 or 2%) were incorporated for longer, namely 28 days prior to planting seeds. The authors included an equivalent inorganic fertilizer as a control treatment, which did not suppress disease, suggesting that disease suppression by the fish emulsion was not due to improved plant nutrition. In addition, plant growth was increased by a factor of 2-3 by the addition of 4% fish emulsion (measured by fresh and dry plant weights) compared to that in unfertilized peat, which was equivalent to plant growth achieved using an equivalent inorganic fertilizer.

In a later study, the incidence and severity of *Verticillium* wilt of eggplant was reduced by adding 0.5% or 1% fish emulsion to infested soil in pots in the greenhouse 2 weeks prior to planting (Abbasi *et al.*, 2006). The higher rate also significantly increased plant growth, doubling the fresh and dry plant weights (Abbasi *et al.*, 2006). The fish emulsion had no immediate or direct effect on the pathogen tested (Abbasi *et al.*, 2004; Abbasi *et al.*, 2006). These authors proposed that one of the mechanisms to explain the disease reduction may be a toxic effect of the volatile fatty acids, particularly acetic acid and formic acid, which are present in the fish emulsion, on the pathogen (Abbasi *et al.*, 2006). Fish emulsions also increase the biological activity in the substrate and increased numbers of culturable bacteria and fungi have been reported (Abbasi *et al.*, 2004). In fact, fish emulsions have been used to propagate plant-growth-promoting rhizobacteria (El-Tarabily *et al.*, 2003). Fish emulsions do not act as the source of suppressive microbes *per se*, but increase the microbial carrying capacity of the substrate (Abbasi *et al.*, 2004). However, Giotis *et al.* (2009) found that the commercial fish emulsion-based liquid fertilizer had no positive effect on soil-borne disease incidence caused by *P. lycopersici* and *V. albo-atrum* or on the number (per plant), size or yield of tomato fruit (Giotis *et al.*, 2009). Given that the studies by Abbasi *et al.* (2004) and Giotis *et al.* (2009) used soil, the situation in soilless growing media is undetermined.

Fish emulsions can also be applied as a foliar spray to reduce the severity of bacterial spot of tomatoes and peppers (Abbasi *et al.*, 2003). Tomato and pepper plants, grown in pots in the greenhouse, were sprayed with a 0.5% aqueous suspension (v/v) of fish emulsion, applied twice at 1-week intervals, one application before and one after inoculation with *Xanthomonas campestris* (Pammel) Dowson pv. *vesicatoria*. Plants sprayed with fish emulsion showed significantly less disease symptoms than those sprayed with water, and there were no phytotoxic effects.

Basil grown in the greenhouse in a commercial peat/perlite/compost medium were fertilized with either an organic liquid fertilizer comprised of hydrolysed fish emulsion, fermented poultry litter, kelp extracts and soft rock phosphate; or a conventional fertilizer (Succop and Newman, 2004). Yields were generally equivalent under either regime. Interestingly, taste test panellists could detect flavour differences between basil grown with the two different fertilizer regimes, though they showed no preference.

Fish emulsion has also been used for seed pre-hydration to improve the seed vigour of peas (Andarwulan and Shetty, 1999). Pre-hydration treatment of pea seeds with 0.2% mackerel by-product fish emulsion enhanced the production of phenolics, which generally improved seed vigour which translated into the average plant height and weight increasing by 9% and 15%, respectively, though this was not significantly different to the control (pre-hydrated in water).

Given that treatment with fish emulsion resulted in some taste differences in basil (Succop and Newman, 2004), its application to edible crops is likely precluded; but there is still scope for application to ornamental species. Information on the comparative benefits of applying fish emulsions as a soil drench or a foliar spray is required. Also, testing of different plant species and fish emulsions sourced from different fish species would be a relevant endeavour. Its practical applicability in a production nursery environment is feasible, with costs (adjusted to current prices) at approximately $16-$26/L (Quilty and Cattle, 2011).

2.5.3 Source of Fish Products

Fish meal and fish emulsions are usually produced from the bones and offal from fish processing industries. The sustainability of manufacturing fish-based liquid fertilizers has been questioned, since they may be contributing to supporting unsustainable fishing practices (Giotis *et al.*, 2009). This can be avoided by manufacturing the product from the processing of feral fish species, which not only preserves natural fish populations, but targets pest species that have numerous ecological effects (Anonymous, 2013). One example of this is a product called Charlie Carp which is made from whole European Carp, an invasive pest fish species causing major environmental damage, particularly in the Murray-Darling basin.

2.6 Seaweed Extracts

For thousands of years, humans have utilized seaweeds to enhance plant production (Craigie, 2011). First, collected seaweed was spread, later it was dried and milled to produce seaweed meal and, more recently, liquid seaweed concentrates have been produced (Crouch and Van Staden, 1994). The main species used to obtain commercial products include *Ascophyllum nodosum* (L.) Le Jolis, *Ecklonia maxima* (Osbeck) Papenfuss., *Laminaria* spp., *Sargassum* spp. and *Durvillaea* spp. (Craigie, 2011). Manufacturing methods are commonly proprietary and rarely published, but are either chemical (by alkali or acid treatment) or physical (milling or high pressure disruption). Crouch and Van Staden (1994) alleged that the effect of dry seaweed meals on plant growth can take months, as the carbohydrates need to be broken down by soil bacteria to be available to plants. By comparison, it was claimed that the effect on plant growth due to liquid preparations, which have their components in a more readily usable form, are much more rapid (Crouch and Van Staden, 1994), and likely makes them more suitable for use in containerized production. They are usually applied as a foliar spray, or less commonly, as a root flush (Verkleij, 1992).

The claimed beneficial effects of seaweeds on plant growth include enhanced germination, root growth, rooting of cuttings, chlorophyll synthesis, general plant vigour, biomass and yield; reduced transplant shock; increased nutrient uptake and plant nutritional quality; induction of early flowering and fruit ripening, fruit production and improvement of marketable qualities of fruit (uniformity, shelf life); suppression of disease via pathogen resistance; increased resistance to pest attack (insects, nematodes); and augmentation of tolerance to abiotic stresses such as salinity and frost (as reviewed in Abetz, 1980; Craigie, 2011; Crouch and Van Staden, 1994; Khan *et al.*, 2009; Metting *et al.*, 1990; Zodape, 2001). Cassan *et al.* (1992) claims that some effects have been reported only anecdotally by commercial organizations, with negative results rarely reported (Bonanomi *et al.*, 2007; Cassan *et al.*, 1992), and

Edmeades (2000; 2002) questioned their value in field production, conceding that it was possible that these products could improve plant growth if applied at much higher rates. Notwithstanding this, there seems to be evidence in the above reviews to support the efficacy of some seaweed extracts on the growth of some plant species in containerized production. The level of response in plant growth parameters cannot be explained by the amount of mineral nutrients in commercial preparations (Crouch and Van Staden, 1993). The effects are likely due, in part, to plant growth regulators, such as cytokinins, auxins, abscisic acid and similar compounds, other low molecular weight organic compounds such as betaines (that help alleviate osmotic stress), and larger polymers (Craigie, 2011; Crouch and Van Staden, 1993; Crouch and Van Staden, 1994; Khan *et al.*, 2009; Stirk and Van Staden, 1997). Also, the production of terpenes and phenols by some seaweeds have the potential to inhibit the growth of fungal plant pathogens (Peres *et al.*, 2012). Apart from direct effects, seaweeds can also influence the physical, chemical and biological properties of growing media, which in turn affect plant growth (Khan *et al.*, 2009). For instance, seaweeds can improve the water holding capacity of media and promote the growth of beneficial microorganisms.

Chemical processing methods, such as alkali treatment, can form novel compounds in the extracts (Craigie, 2011). The nature and quantity of these novel compounds will depend on the parent seaweed composition and the manufacturing conditions used. Application of alkaline, neutral and most acidic extracts from five seaweed species significantly increased dry matter yields of mung beans, with plants treated with the alkaline extracts having the highest yields, while acidic extracts significantly enhanced root formation (Sharma *et al.*, 2012). Also, carbon, nitrogen, lipid, polysaccharide, mineral and cytokinin concentrations of seaweed species can alter with season and likely, with growth stage (Sharma *et al.*, 2012; Stirk and Van Staden, 1997; Verkleij, 1992). Consequently, various commercial seaweed extracts, and therefore their biological activity and their effect of plant growth, can vary greatly (Craigie, 2011; Verkleij, 1992). Presumably this is adequately addressed in the quality assurance of the products.

Dry powder of three seaweed species was incorporated individually into soil in pots in the screenhouse, planted with sunflower or tomato plants and inoculated with one of the causal agents of fungal diseases: *Macrophomina phaseolina* (Tassi) Goid., *R. solani* or *Fusarium solani* Mart., or the nematode *M. javanica* (Sultana *et al.*, 2011). All three seaweeds significantly reduced infection of sunflowers by *M. phaseolina* and *F. solani*, and increased plant height, while only one seaweed, *Spatoglossum variabile* Figari & De Notaris, reduced infection by *R. solani* and increased fresh root weight, compared to the unamended control. All three seaweeds significantly reduced infection of tomatoes by *R. solani*; *S. variabile* and one other seaweed reduced infection by *F. solani*; and no seaweeds reduced infection by *M. phaseolina*. Only the seaweed *S. variabile* increased plant height, shoot weight, root length and root weight compared to the unamended control. In both hosts, the disease reductions were equivalent to reductions achieved by applying a chemical fungicide, and control of nematode infection was equivalent to that of a chemical nematicide (Sultana *et al.*, 2011). The effect of dry powdered seaweeds in soilless growing media has not been determined.

Liquid preparations of seaweed concentrates are more commonly used than dry powder forms, and the products are formulated as liquid concentrates or soluble powders. Rayorath *et al.* (2008) developed three standard rapid bioassays using the model plant *Arabidopsis thaliana* to test the bioactivity of *A. nodosum* extracts, comparing a liquid concentrate and a soluble powder of this same seaweed. They found that both extracts promoted root and shoot growth in comparison to untreated controls. They were generally as effective as each other, although this was dependent on which of the three bioassays were used. Furthermore, using molecular techniques, they found evidence that the enhanced plant growth may, in part, be due to components of the commercial extracts modulating the concentration and localisation of auxins. The authors proposed that such bioassays could be used for quality control purposes to ensure levels of bioactive compounds were consistent and effective, despite variation in factors such as geographic area of collection, season and growth stage (Rayorath *et al.*, 2008).

The liquid seaweed extract *A. nodosum*, marketed as Maxicrop in numerous formulations, has shown some positive effects on plant growth and pest/pathogen suppression in some studies (of which some of the reports have deficiencies), but has also had no effect in others. In fact, the efficacy of all Maxicrop products has been questioned. In a legal case in New Zealand, after hearing evidence from more than 40 scientists from around the world, the High Court ruled that Maxicrop products did not promote plant growth (Edmeades, 2000; 2001). Court-supplied evidence showed that, when applied according to manufacturer's instructions, Maxicrop provided levels of macro- and micro-nutrients three to four orders of magnitude less than that compared to plant requirements and typical fertilizer nutrient amounts, and low levels of plant hormones whose practical significance was doubtful (Edmeades, 2000). The judgement was that Maxicrop (all product formulations including a product for 'indoor' (home) use) 'cannot and does not work', supported by a lack of efficacy in more than 140 field trials. No glasshouse trials were specifically discussed, so there remains the possibility that Maxicrop may have some effect in certain situations, though this is questionable.

Maxicrop was reported to significantly suppress the populations of two-spotted red spider mites on strawberries grown in high polythene tunnels, as compared to untreated controls (Hankins and Hockey, 1990). The authors proclaimed that the mites on the treated plants seemed 'less settled' (no quantitative measurements were made) and that appeared to affect their feeding and so, their fecundity. The precise mechanism was unclear, but the authors proposed that the extract may contain chelated metals that can reduce mite fecundity (Terriere and Rajadhyaksha, 1964), or may not have a direct insecticidal effect, but indirectly alter plant growth such as toughening the cuticle or producing a more viscous sap, which could alter the mites feeding preference (Abetz, 1980; Stephenson, 1966). None of these proposed mechanisms were investigated by the authors (Hankins and Hockey, 1990). Plant hormones IAA and cytokinins have been identified in Maxicrop and similar products, and so may play an indirect role in pest suppression (Sanderson and Jameson, 1986; Sanderson *et al.*, 1987; Zhang and Ervin, 2004). Cytokinins have been positively identified in other seaweed products including Seasol (made from Tasmanian giant bull kelp, *Durvillea potatorum*) (Tay *et al.*, 1985; Tay *et al.*, 1987) and Seamac 600, a cytokinin-rich extract of *Ascophyllum*. Seamac 600 sprayed onto greenhouse roses produced 14-47% more "bottom breaks" - sprouting of renewal canes from the base of the plant - in the roses, compared to the controls (Raviv, 1986). Two commercial seaweed extracts based on *A. nodosum* increased the fresh and dry shoot weights of aromatic coleus (*Coleus amboinicus* Lour.) by 18% compared to the untreated control; however, details of the methodology were missing in this brief conference paper, so the validity of the findings could not be determined (Morales-Payan, 2006).

Maxicrop has also been tested hydroponically, though it was in spring barley (Steveni *et al.*, 1992). Plants grown in a hydroponic solution amended with Maxicrop Triple grew faster and had a 56-63% increase in growth parameters compared to those grown in the control hydroponic solution. Plants grown in the control hydroponic solution and sprayed with Maxicrop Triple grew faster and had a 35-38% increase in growth parameters compared to those grown in the control hydroponic solution and sprayed with water.

Foliar application of a *A. nodosum*-based seaweed extract, Goëmar GA 14, to spinach seedlings in pots in a growth cabinet increased significantly the total fresh and dry matter production compared to the untreated control (Cassan *et al.*, 1992). It was proposed this was due to plant growth regulators in the extract altering photosynthate partitioning to improve the sink capacity of the leaves. The absence of some details in the methodology means that such results should be interpreted with care. Another *A. nodosum*-based seaweed extract, Marinure, had no positive effect on soil-borne disease incidence caused by *P. lycopersici* and *V. albo-atrum* or on the number (per plant), size or yield of tomato fruit (Giotis *et al.*, 2009).

Using a seed priming technique, which is intended to provide physiological improvement to seeds, pepper seeds were soaked in the following dilutions of Maxicrop: 1:1, 1:5, 1:10, 1:25, 1:50, 1:100, 1:250, 1:500 and 1:1000 for 1, 2 or 3 days (Sivritepe and Sivritepe, 2008). None of the Maxicrop treatments gave a significantly increased germination rate or decreased germination time compared to priming in water (although the authors did not emphasize this point). In general, among the Maxicrop dilutions, total germination rate decreased and mean germination time increased with increasing seaweed concentration and decreasing soaking duration (Sivritepe and Sivritepe, 2008).

A commercial product based on an *A. nodosum* extract, humic acids, ascorbic acid and thiamine was evaluated for its effect on the growth and flowering of marigold (Russo *et al.*, 1994). In the greenhouse, the product, applied as a 1% drench, stimulated earlier germination, and led to transplants with increased root lengths and shoot heights, compared to untreated plants. These plants flowered earlier when treated with the product combined with fertilizer, though their shoot height and diameter were equivalent compared to plants receiving fertilizer only. When transplanted to the field, these plants were taller, had more flowers and flowered earlier when treated with the product combined with fertilizer, compared to plants receiving fertilizer only. The authors proposed that the product led to an increase in the lumen area of the xylem, enhancing permeability to water and nutrients, leading to improved growth (Russo *et al.*, 1994), though they provided no data to support this hypothesis.

Tomato plants were treated with a drench of seaweed products based on *A. nodosum*, and marketed as commercial systemic resistance/plant growth promotion inducers (Vavrina *et al.*, 2004). The seaweed products did not improve the plant growth parameters tested (stem length and diameter, leaf area, dry shoot and root weight, true leaf number) compared to the untreated control. In only two of six trials, the seaweed products significantly reduced the severity of bacterial spot (caused by *X. campestris* pv. *vesicatoria*) in inoculated tomato plants. Plants grown in soil infested with root knot nematodes (*M. incognita*) and treated with the seaweed products had equivalent disease and growth to the untreated control. The authors stated that the timing of treatment application with respect to the physiological age and status of the plant requires better understanding to improve the consistency of this and other systemic resistance/plant growth promotion inducing products (Vavrina *et al.*, 2004).

In a brief research note describing work with Norwegian seaweed treatments (species not specified but presumably *A. nodosum*), Aitken and Senn (1965) claimed that the seaweed treatments applied to poinsettia plants produced a greater number of flowers per plant, improved flower quality and increased weight compared to untreated controls. However, the same treatments applied to geraniums reduced total fresh and dry weights of roots and tops, and decreased the number and size of flowers compared to untreated controls. Given that the methodology was not described and that no data were presented, this can only be considered as anecdotal information.

Kelpak is an extract made from the seaweed *E. maxima* produced in South Africa using a patented ‘cold cellburst’ manufacturing process to release growth hormones (Featonby-Smith and Van Staden, 1983), which reportedly stimulate rapid growth in plants. It has been shown to promote root growth via the presence of auxins (Crouch and van Staden, 1991; Crouch *et al.*, 1992). There have been a number of studies testing its effect on vegetables, ornamental nursery species, *Pinus* spp. and *Eucalyptus* spp. in pots in the glasshouse. In an early study, tomato plants had significantly greater shoot, root and fruit fresh and dry weights after applying Kelpak as a foliar spray at regular intervals or as a one-off soil drench at transplanting, compared to the control (Featonby-Smith and Van Staden, 1983). Tomatoes treated with Kelpak showed increased root growth and reduced root knot nematode infestation compared to the control, and it was proposed this may be due to cytokinins contained in Kelpak (Featonby-Smith and Van Staden, 1983). In a later study, Kelpak applied as a soil drench (0.2%, 0.4% or 1%) significantly improved the growth of tomato seedlings, but application as a foliar spray (0.4%) had no effect on young plants (Crouch and Van Staden, 1992). However, foliar-applied Kelpak had greater effects of fruit yield than when applied as a soil drench. Kelpak-treated plants showed early fruit ripening, a total fruit fresh weight increase of 17%, and an increase in the number of harvested fruit by about 10% (Crouch and Van Staden, 1992).

Applications of Kelpak to seedlings of marigold, cabbage (Aldworth and Van Staden, 1987) and tomato (Crouch and Van Staden, 1992) increased root size and vigour and consequently, reduced transplant shock compared to untreated plants. In tomato seedlings, this enhanced root growth translated into improved root:shoot ratios and biomass accumulation (Crouch and Van Staden, 1992). In addition, the plants set more flowers earlier, probably due to robust plant growth, and had increased fruit yield, producing larger-sized fruits, compared to untreated plants (Crouch and Van Staden, 1992).

Pepper plants were treated with 0.4% Kelpak by dipping at transplanting, by three foliar spray applications at 21 d intervals after transplanting, or both (Arthur *et al.*, 2003). None of the treatments had a significant effect on the growth of pepper plants in terms of plant height, root:shoot ratio, the total plant biomass or the number of fruit. However, the combined treatment of dipping at transplanting followed by three foliar sprays caused a significant increase in both the number and the size of marketable fruit (Arthur *et al.*, 2003).

A brief research note by Beckett *et al.* (1994) indicated that Kelpak did not affect shoot or root mass of tepary bean plants, but significantly increased yield in the form of bean weight rather than bean number, suggesting Kelpak acted as a biostimulant. In another study, the yield of lettuce (grown in sand in pots) receiving an adequate supply of nutrients was significantly increased (by 14%) after an additional treatment with Kelpak (Crouch *et al.*, 1990). Also, the concentration and amount of nutrients in the lettuce leaves was increased greatly by Kelpak treatment, suggesting that the yield increase may be in part due to increased nutrient uptake induced by Kelpak. Increased nutrient uptake was also observed for other seaweed products (Maxicrop, Proton and Algipower), when foliar application increased macro- and micro-element uptake at optimum or higher nutrient element conditions, but only increased copper uptake by grapevines in nutrient deficient media (Turan and Köse, 2004). However, Kelpak applied to tomatoes had little effect on the uptake of foliar-applied trace elements such as copper, manganese and zinc when typically supplied with macro-nutrients (Beckett and Van Staden, 1990).

The ability of Kelpak to relieve nutrient stress was tested when okra (*Abelmoschus esculentus* (L.) Moench) seedlings were grown without nitrogen, phosphorus or potassium but were treated with a 0.4% Kelpak solution three times a week in the greenhouse for 8 weeks (Papenfus *et al.*, 2013). Kelpak treatment significantly increased seedling vigour under nitrogen, phosphorus and potassium deficiency, and improved most seedling growth parameters under phosphorus and potassium deprivation. The nutrients supplied by Kelpak itself were insufficient to relieve nutrient stress, so the increased growth and seedling vigour is attributable to plant growth regulators, such as auxins and cytokinins, improving the absorption capacity of available nutrients. It was proposed that this may also in part be due to the presence of polyamines acting in synergy with the plant growth regulators (Papenfus *et al.*, 2013).

Kelpak has also been tested as an additive to the nutrient solution in the aeroponic culture of ginseng (*Panax ginseng* Meyer) (Kim *et al.*, 2012). Growth generally improved due to Kelpak amendment, with leaf area and root weight of ginseng significantly increased when Kelpak was added, as compared to those in the unamended nutrient solution. Kelpak may provide some advantage for the production of the purported bioactive compounds, ginsenosides.

Kelpak was added to *in vitro* culture medium at 0.25%, 0.5% or 1% for the micropropagation of potato plantlets and 0.5% was applied as a leaf/soil drench immediately after transplanting (Kowalski *et al.*, 1999). Kelpak included at the low concentration of 0.25% into the culture medium enhanced plantlet quality and translated to better establishment in the greenhouse, resulting in larger plants with increased root development. Increasing the concentration did not improve plant growth. An extra application of Kelpak as a leaf/soil drench to transplants had an adverse effect on plant parameters (Kowalski *et al.*, 1999). Similarly, other seaweed extracts (from *Gracilaria edulis* (S.G.Gmelin) P.C.Silva and *Sargassum wightii* Greville) used in tomato tissue culture improved seed germination and induction of multiple shoots from explants, induced the shooting and rooting of cultures *in vitro*, and increased survival of plantlets transferred from the growth chamber to the greenhouse (Vinoth *et al.*, 2012). Likewise, Kelpak applied as a soil drench following transplantation of *in vitro* grown plantlets of the nursery species *Scilla krausii* Bak. and *Kniphofia pauciflora* Bak. aided in acclimatization, significantly increasing root growth and inducing early rooting (Lindsey *et al.*, 1998).

Providing further evidence that seaweed products can reduce transplant shock and improve seedling vigour, Kelpak was applied as a root dip to cabbages, and as a foliar spray or a root drench to marigolds at transplanting (Aldworth and Van Staden, 1987). Root and shoot growth of both species increased, and in marigolds, the number of flowers increased and the time to flowering was significantly reduced. For marigolds, soil applications had a more pronounced effect on plant growth parameters than foliar applications, though both methods resulted in improvement (Aldworth and Van Staden, 1987).

In a later study, Kelpak was applied to *Pinus pinea* L. seedlings as a foliar spray or a root drench at different concentrations up to three times prior to transplanting (Atzmon and Van Staden, 1994). Foliar application generally increased plant weight mainly by increasing seedling height: shoot length and weight increased and root to shoot ratio decreased. Root application did not increase plant weight but accelerated root growth and increased the dry weight of laterals, with the greatest improvements in those treated three times with the highest Kelpak concentration. Application of Kelpak as a root drench enhanced seedling quality and increased survivorship at transplantation (Atzmon and Van Staden, 1994). The absence of important details from the methodology, such as the amount of Kelpak applied, makes it difficult to assess the robustness of the research.

Testing its effect on another *Pinus* species, Kelpak (1%, 10% or 50%) was applied to the base of cuttings of *Pinus patula* Schiede ex Schltdl. & Cham. for 1, 6, 12 or 24 h in summer or autumn (Jones and Van Staden, 1997). Dipping cuttings into 10% Kelpak for 1 to 12 hours in autumn were the most effective treatments, producing up to 70% rooting, which were significantly better than cuttings dipped into water only. These treatments also improved rooting quality, developing a vigorous, functional root system with numerous lateral roots. The seasonality effect should be noted and is likely due to changes in endogenous auxin levels (Jones and Van Staden, 1997). Similarly, dipping cuttings of the ornamental plants *Callistemon citrinus* Skeels, *Evolvulus glomeratus* Nee & Mart, *Vitex agnus-castus* L. and *Impatiens auricoma* Baill. into 10% Kelpak for 18 hours significantly increased rooting in terms of both root number and mean root dry weight (Crouch and van Staden, 1991). Numerous Kelpak concentrations were tested from 0.1% to 100% but 10% gave optimal rooting response.

Kelpak was applied to the cut stem-base of cuttings of pelargonium (*Pelargonium peltatum* L'Her) and three weeks later to the roots at 0.5%, 1% or 2% (Urbanek Krajnc *et al.*, 2012). Treatment with Kelpak caused a significant increase in shoot fresh weight compared to untreated controls. Treatment with 2% Kelpak caused maximum increases in chlorophyll content, which translated into highest root fresh weight, highest shoot:root ratio and the most leaves. It was concluded that Kelpak both reduced the stress of inserting the cuttings into soil and stimulated plant growth. Similarly, in a preliminary study, Kelpak and another seaweed extract product Wuxal Ascofol, applied to trees prior to taking cuttings, increased the number and weight of shoots and the weight of cuttings of hawthorn (*Crataegus pinnatifida* Bunge) and *Prunus marianna* (Szabó and Hrotkó, 2009). The commercial biopreparation Algaminoplant, comprised of extracts from the seaweed genera *Sargassum*, *Laminaria*, *Ascophyllum* and *Fucus*, applied to cuttings of two dogwood cultivars improved rhizogenesis by increasing the percentage and degree of rooting, compared to control cuttings (Pacholczak *et al.*, 2012).

Three rates (0.5, 1 or 2 mL per plant) of Kelpak were applied as either a foliar spray or a root drench at transplanting of marigolds (Van Staden *et al.*, 1994). Kelpak application improved the vegetative and reproductive growth of marigolds, with the 1 mL application rate giving the best overall results. Plants treated with 1 mL of Kelpak by either method had significantly greater fresh and dry shoot weights, significantly longer stems, produced significantly more flowers and had significantly more seeds per flower head than untreated plants. The number of seeds per plant increased in plants treated with any rate of Kelpak by either method. Plants treated with other rates improved some parameters compared to untreated plants, but were more inconsistent (Van Staden *et al.*, 1994). This report, however, was only a brief research note, with some details of the methodology absent and some inconsistencies in the statistical analysis, so it is difficult to scrutinize these results.

The growth of seedlings of three *Eucalyptus* species (*E. nitens* H.Deane & Maiden., *E. macarthurii* H.Deane & Maiden. and *E. grandis* W. Hill ex. Maiden.) was significantly increased by foliar application of Kelpak compared to water only controls (Van Staden *et al.*, 1995). For the first two species, Kelpak was applied at 0.2%, 1% or 10%, at 2, 4, 8 and 10 weeks after planting, with harvest at 12 weeks. For *E. grandis*, Kelpak was applied at 20%, 30% or 50% at 2 weeks (one application), at 2 and 6 weeks (two applications) or at 2, 6 and 10 weeks (three applications), with harvest at 12 weeks, to see if costs could be reduced by applying more but only one time. Both foliar sprays and root flushes (0.2%, 1% or 10% at the same timing as the foliar sprays) significantly increased root and shoot growth of *E. grandis*, indicating that either method could be used. All foliar applications improved growth, with the authors recommending one early foliar application at 20%. One early root flush application of 10% Kelpak was the most effective root flush treatment. An extra application of Kelpak after transplantation to the field did not consistently improve growth parameters and was deemed unnecessary (Van Staden *et al.*, 1995).

The effect of storage on seaweed concentrates was examined in a study by Stirk *et al.* (2004). Two seaweed concentrates, derived from the seaweeds *E. maxima* and *Macrocystis pyrifera* Bory using the cell burst method were analysed for their auxin and cytokinin contents before and after being stored at 54°C for 14 days to provide an indication of product shelf life. The total cytokinin content for both seaweed concentrates increased, while the auxin content decreased after their storage at an elevated temperature. Auxins are known to be heat sensitive, so their degradation under high temperature conditions was expected. The large increase in the cytokinin levels, which are generally more robust compounds, may have been due to the high temperature breaking down the remaining particulate matter present in the seaweed concentrate, releasing bound cytokinins from the membranes and the vacuoles. This technique of 'accelerated ageing' at elevated temperatures, whilst somewhat artificial, is an accepted method used to evaluate the shelf life of a product (Stirk *et al.*, 2004). Whether products were still efficacious after accelerated ageing was not examined.

Seaweeds can also be composted and non-aerated compost teas produced from these composts. Non-aerated compost tea from seaweed significantly inhibited the mycelial growth of *B. cinerea*, *A. solani* and *P. infestans in vitro*, and in greenhouse tests, suppressed grey mold of tomato (caused by *B. cinerea*) and reduced disease development of powdery mildew of tomato (caused by *Oidium neolycopersici*) (Koné *et al.*, 2010). However, there were some microbial safety issues to consider with the application of seaweed-derived non-aerated compost tea, as they consistently showed the presence of coliforms (Koné *et al.*, 2010).

Many of the studies reported here, with the exception of those that had deficiencies in their methodology as indicated, show positive effects of liquid seaweed extracts on plant growth and it is likely that at least some of these effects are genuine. This must be qualified by reiterating that negative results are rarely reported (Bonanomi *et al.*, 2007; Cassan *et al.*, 1992), which creates a bias towards drawing the conclusion from the published scientific literature that they are effective (Edmeades, 2002) and that the New Zealand High Court found that Maxicrop 'cannot and does not work' (Edmeades, 2000). Further work is required to establish ideal rates; optimize application method, timing (with respect to plant growth stage) and frequency; study the interaction with other organic amendments; and examine the effect of different production batches to detect any seasonal differences; on various plant species in containerized production horticulture. In a production nursery environment, the application of seaweed extracts is possible, with costs (adjusted to current prices) at approximately $11-$32/L (Quilty and Cattle, 2011).

2.7 Organic Waste Materials (Uncomposted)

Various municipal, industrial and agronomic waste materials have been studied for their utility as amendments to more traditional media for containerized production of horticultural plants. Temporal and source variations can alter the physical and chemical properties of organic amendments from waste materials (Hicklenton *et al.*, 2001) and so, they should always be assessed for local characteristics (Maňas *et al.*, 2009).

2.7.1 Municipal Waste

Sewage sludge, activated sewage sludge or composted sludge with municipal solid waste (MSW) were added at 25% to paper mill sludge (25%), and either peat or pine bark (50%) (Maňas *et al.*, 2009). The seed germination, physical parameters and morphological attributes of Maritime pine (*Pinus pinaster* Ait.) grown in these various media were compared to those of plants grown in 25% paper mill sludge/75% peat or pine bark as the control media. Generally, these media had excellent water retention capacity but had difficulty releasing it, causing root asphyxiation issues. Despite this, the greatest germination occurred in sewage sludge treatments and the pine bark control medium. Plants grown in the activated sewage sludge treatments had the best physical parameter values overall (which included height, stem diameter, aerial dry weight, root dry weight and total dry weight), generally greater than those in the unamended control. Composted sludge treatments combined with municipal solid waste were the most useful amendments for morphological attributes, which indicate good survival potential in the field after transplanting. Therefore, whilst different media favoured different parameters, the best all round media were those containing activated sewage sludge, and any containing peat to achieve a good balance of desirable plant attributes (Maňas *et al.*, 2009).

Tomatoes were grown in soil in pots amended with anaerobically digested biosolids or raw biosolids at 2.5% or 5% (w/w). Their growth was compared to those in unamended soil plus urea, or soil amended with immature domestic garden waste compost, or ground fresh corn stovers (stalk, leaf, husk and cob residue). Normal green healthy tomato plants grew in digested biosolids-amended soil, equivalent to urea-fertilized control plants (Hue and Sobieszczyk, 1999). However, amendment with raw biosolids, or the other organic materials immobilized nitrogen leading to nitrogen-deficient plants.

A more unusual organic amendment is human hair and wool waste (Zheljazkov, 2005). In container experiments, the addition of wool or hair waste to soil generally increased yields of basil, thorn apple (*Datura innoxia* Mill.), peppermint (*Mentha* x *piperita* L.) and garden sage (*Salvia officinalis* L.), increased available nitrogen in the medium, increased total nitrogen in plant tissues and enhanced soil microbial biomass. The study found that wool and hair wastes decompose slowly under glasshouse conditions to act as a slow release fertilizer (Zheljazkov, 2005). It would be interesting to see the effect in soilless growing media.

Issues with such municipal wastes, including the risks of introducing plant and human pathogens, unpleasant odours, excessive water retention, nitrogen immobilization and a general repugnance at the idea, make their practical use in a production nursery environment implausible.

2.7.2 Industrial Waste

Raw paper mill sludge has been tested as an amendment (up to 20%) for growing container crops and can increase the growth of deciduous shrubs due to its high initial nitrogen content (Bellamy *et al.*, 1995; Chong, 2005). As mentioned earlier, paper mill sludge should be assayed for harmful levels of heavy metals and organic contaminants, though this is only an issue from certain paper production processes (Bellamy *et al.*, 1995; Chong, 2005; Tripepi *et al.*, 1996). Sludge-amended media should be monitored for electrical conductivity levels, which tend to be high, and shrinkage of media at high amendment rates (greater than 67%), which can be ameliorated by composting the sludge (Bellamy *et al.*, 1995). However, the main deterrents for the general use of sludge are the offensive odour; that different batches and sources of sludge can vary in their physical and chemical characteristics, and so, vary in their usefulness as an amendment; large variations in species response; and toxicities or deficiencies due to specific nutrients, particularly nitrogen due to immobilization (Bellamy *et al.*, 1995; Chong *et al.*, 1998; Chong, 1999; Chong, 2005).

Four deciduous ornamental shrubs, cotoneaster, dogwood, forsythia, and weigela were grown in pine bark or pine bark-peat amended with 15% or 30% (v/v) raw paper mill sludge from each of two sources, or both (Chong and Cline, 1993). All species grew equally well or better in the sludge-amended media than in the unamended media. Cotoneaster and forsythia grew more in media amended with sludge from one source (which incidentally had high initial electrical conductivity, more than 10x the level of the other sludge), compared to sludge from the other source, mainly due to a difference in available nutrients. Though the electrical conductivity was not monitored throughout the study, it was assumed based on other similar studies that the high initial salt levels were rapidly leached 10-14 days after planting to lower levels suitable for plant growth (Chong and Cline, 1993). This work was supported by other experimental trials (Bellamy *et al.*, 1995) and by later work by Chong and Purvis (2005) where dogwood, forsythia and weigela were grown in pine bark, or pine bark amended with 20%, 40% or 60% (v/v) raw paper mill sludge. Their growth was compared to growth in pine bark amended with the same rates of composted paper mill sludge or municipal waste compost, and also to the standard nursery mix of 8 bark:1.5 peat:0.5 topsoil. While growth of all three species was poorest in bark amended with raw paper mill sludge compared to the other amendments, it was generally comparable to growth in the nursery mix (Chong and Purvis, 2005).

Wastewaters from various sources are often nutrient-rich and can be used as a liquid organic amendment, as long as the macro- and micro-nutrient contents are analysed before and during use (Chong *et al.*, 2008). Wastewaters from a mushroom farm (washwater, operational run-off and leachates from compost piles) and an anaerobic digestion pilot plant (using mixed municipal solid waste as a feedstock to produce biogas for electricity generation) were diluted and applied as a recirculated fertilizer to three nursery species, namely silverleaf dogwood, common ninebark and spirea (*Spiraea* x *bumalda* Burvénich) (Chong *et al.*, 2008). These were compared to recirculated fertilizer stock solution with complete macro- and micro-nutrients and a traditional controlled release fertilizer. The dilutions of the wastewaters chosen for use were based on the nutrient analysis prior to use in an attempt to avoid nutrient imbalances and the fertigation was computer-controlled with a target electrical conductivity continuously monitored. Growth with all three recirculated treatments was similar and significantly higher than that obtained with the controlled release fertilizer, and the plants grew rapidly to a marketable size (within 9-12 weeks). There was no sign of nutrient deficiency or toxicity symptoms to the plants, but the high salt contents of the wastewaters led to small to moderate buildup of salts in the closed system, which were physiologically tolerated by the species tested, but may be unsuitable for salt-sensitive species (Chong *et al.*, 2008).

In a separate study, the wastewater from the anaerobic digestion pilot plant was compared to 'compost tea' and a nutrient solution for hydroponic plant propagation for its effect on the rooting of cuttings for plant propagation (Chong *et al.*, 2005). However, what the authors termed compost tea, was really compost extract - water poured over compost (derived from the same municipal solid waste as that used for anaerobic digestion) and filtered. Also, both the wastewater and the compost extract were stored at 4°C until used, but there was no indication of the time period this entailed. The rooting of cuttings of sage, currant (*Ribes odoratum* H. L. Wendl. F. G. Bartling & H. L. Wendland), euonymus and weigela was tested in the three nutrient sources, each diluted to four different soluble salt levels. Rooting was assessed by three criteria: percent rooting, root number and root length. Maximum rooting response to different soluble salt levels varied with species but was generally similar for nutrient solutions (e.g. euonymus rooting percent and root length increased linearly with increasing salt levels and was similar for all three sources, but weigela was unresponsive to salt levels or nutrient sources). Also, maximum rooting response to different soluble salt levels varied with the rooting criterion measured (e.g. euonymus root number was unresponsive to salt levels or nutrient sources). In conclusion, wastewater and compost extract can be used, with dilution, for the propagation of some species (Chong *et al.*, 2005).

Corn distillation products or condensed distiller's solubles, co-products of ethanol production by yeast fermentation of corn, have also been tested as organic amendments for various vegetables (Abbasi *et al.*, 2007). In greenhouse experiments, when condensed distiller's solubles were applied to soil as a pre-plant amendment for eggplants or potatoes, there was a decreased incidence of *Verticillium* wilt and increased plant biomass, and a reduction in scab severity, respectively, compared to those in unamended soil (Abbasi *et al.*, 2007). In the growth room, condensed distiller's solubles incorporated into *R. solani*-infested, peat-based substrates 7 days prior to planting radish seeds, significantly suppressed seedling damping-off. The authors speculated that the diseases were suppressed due to the condensed distiller's solubles stimulating microbial activity in the substrates.

Oil palm waste was mixed with coal fly ash-based synthetic aggregates and tested as an alternative container substrate (not an amendment) for the growth of French marigold (Jayasinghe *et al.*, 2009). Coal fly ash, a by-product of coal combustion, was mixed with paper waste and starch waste to form the synthetic aggregates (CSA), and these were combined with oil palm waste at ratios of 1:5 or 1:10. Marigolds grown in 1:5 or 1:10 CSA:oil palm waste had significantly greater growth and yield parameters compared to those grown in a standard container substrate, zeolite (hydrated aluminium silicate minerals). Marigold had maximum growth and yield parameters in the 1:10 CSA:oil palm waste medium, with 51% greater shoot fresh weight, 93% greater shoot dry weight, 54% greater root fresh weight, 150% greater root dry weight, were 19% taller and had 61% more flowers per plant, than those grown in zeolite. The 1:10 CSA:oil palm waste medium had enhanced physical and chemical properties which were in the established ideal substrate range.

The ornamental shrubs viburnum, weigela and abutilon (*Abutilon* cultivar) were grown in pots outdoors and sprinkler irrigated using treated sewage effluent or traditional well water (Gori *et al.*, 2000). Using the treated sewage effluent for irrigation posed no major problems, with a general positive effect on plant growth. Response was species specific; for example, viburnum and weigela irrigated with treated sewage effluent had significantly greater total dry mass than those irrigated with well water, while abutilon plants had equivalent total dry mass. The treated sewage effluent acted as a source of nutrients, was of medium salinity, very low in heavy metals (lower than the well water) and UV treatment reduced the high levels of microorganisms (Gori *et al.*, 2000). Similarly, a species-specific response to wastewater irrigation was also found by Fitzpatrick *et al.* (1986) and Wu *et al.* (1995).

The numerous issues detailed above (including differential plant species responses) with raw paper mill sludge, wastewaters and sewage effluent, and the lack of particular industries in Australia preclude these industrial wastes being considered any further as organic amendments for containerized plant production.

2.7.3 Agronomic Waste

Various agronomic wastes, both animal and plant, can be utilized as organic amendments. Dehydrated and pelleted hen manure was resuspended, filtered and applied as an organic fertilizer and compared to conventional fertilization for the growth of geranium plants in the greenhouse (Gravel *et al.*, 2009). Growth, flower production and the overall plant quality were not affected by the fertilization regime, however, the population of *Pythium* spp. (the causal agents of *Pythium* root rot) on the roots was significantly lower for all treatments fertilized with hen manure compared with those under conventional fertilization (Gravel *et al.*, 2009). Whilst this indicates that the organic liquid fertilizer played a role in the suppression of *Pythium* infection, such organic amendments and regimes should be tested carefully on horticultural crops (Gravel *et al.*, 2009).

Tomatoes grown in soil amended with uncomposted chicken manure at 2.5% or 5% produced normal green healthy plants, equivalent to urea-fertilized plants (Hue and Sobieszczyk, 1999). However, other amendments tested in the same study including raw biosolids, immature domestic garden trimmings compost and ground fresh corn stovers (stalk, leaf, husk and cob residue) immobilized nitrogen and led to nitrogen-deficient plants.

Rice hulls, a by-product of the rice milling process, have been used as an amendment to plant growing media. They can improve aeration but have limited water holding capacity and severe, albeit short-lived, level of nitrogen drawdown (Handreck and Black, 2002). In work done in the early 1970s, parboiled rice hulls were used as a component of the growing medium for the production of tulips for cut flowers by the rooting room method (Einert and Baker, 1973). Media containing rice hulls not only produced tulip plants equivalent to those grown in the standard media, but were also lighter in weight enabling easier handling using this production method, and allowed for easier harvesting. Rice hulls have been used alone, or combined with the stem core of kenaf (*Hibiscus cannabinus* L.), a highly productive annual renewable crop. *Pinus halepensis* M. seedlings were grown in 30 or 50% rice hulls-amended peat, 100% kenaf or 60% kenaf/20% rice hulls/20% peat (Marianthi, 2006). Seedlings grown in 30% rice hulls-amended peat had nursery and field performance similar to, or better than those grown in the peat control medium. Seedlings grown in media containing kenaf performed poorly, likely due in part to the lower organic matter content and volume shrinkage of kenaf-amended media. In addition, the rice hulls and kenaf amendments generally increased the total porosity and the total concentrations of most nutrients, and media amended with 30 or 50% rice hulls required frequent irrigation due to their lower water holding capacity.

Organic wastes such as feather meal, crab shells, cottonseed or dried whey sludge (a by-product of cheese production), each mixed into a peat-compost growing medium, significantly increased the shoot dry weight of tomato transplants in the greenhouse compared to unfertilized plants (Gagnon and Berrouard, 1994). In another pot experiment examining feather meal (as well as other amendments) added to soil, feather meal was phytotoxic to lettuce, particularly at high rates (equivalent to 400 and 800 kg total N/ha) (Hammermeister *et al.*, 2006). Feather meal applied at a high rate (equivalent to 800 kg total N/ha) to orchardgrass (*Dactylis glomerata* L.) was initially phytotoxic but in general, all rates significantly increased shoot and root dry weights compared to those in the standard medium due to high nitrogen supply. In another study examining cottonseed hulls as a media amendment, the growth of vinca, verbena and shantung maple in 35% cottonseed hulls and 65% pine bark was compared to that in traditional media of 75% pine bark and 25% peat moss (Sloan *et al.*, 2010). Growth of all species in cottonseed-amended media was inhibited. Growth of vinca was so poor that biomass production data could not be obtained, biomass production was significantly less for verbena and growth rate (stem thickness and height) was significantly decreased for shantung maple in the cottonseed-amended medium compared to that in the traditional medium.

Uncomposted manures would not be considered in a production nursery environment due to pathogen issues and the other agronomic wastes hold little potential, so will not be examined further.

2.8 Bioinoculants

Khan and Anwer (2011) defined bioinoculants as ‘microorganisms that induce stimulatory effects on plant growth and/or suppressive effects on pests or pathogens through a variety of mechanisms when applied in an ecosystem’. This would include biological control agents, making it a very broad topic, so for the purposes of this review, the definition of bioinoculants is narrowed to cover only mycorrhizal fungi and plant growth promoting bacteria and fungi (though some of these do have biological control properties) with a brief mention of other products. Khan and Anwer (2011) reviewed the use of fungal bioinoculants for the management of plant diseases. Bioinoculant formulations are often applied as drenches, spot treatments, or granules, and less commonly as foliar sprays. Storage of bioinoculant products presents a challenge, with various formulations such as pellets, granules, and powders being employed to preserve their biological properties, usually more successfully than liquid formulations (Khan and Anwer, 2011). Sodium alginate gel is a useful material for encapsulating liquid preparations of microorganisms to form a pellet, in which microbes can remain viable for many weeks (Fravel *et al.*, 1985). Some granules and powders, which can be based on inexpensive agricultural or industrial wastes or by-products, can enable viable bioinoculants to be stored up to 32 weeks at 25°C or at room temperature (Khan and Anwer, 2011). For example, bagasillo (fine fraction of bagasse from sugar cane processing) was better than peat, charcoal or coal as a carrier for two rhizobia species, maintaining the highest population after storage at 28°C for 6 months (Singh *et al.*, 2012).

2.8.1 Mycorrhizal Fungi

Inoculation of plants with mycorrhizal fungi may have many benefits (Siddiqui and Kataoka, 2011; Stewart and Pfleger, 1977), including improving plant growth; increasing tolerance to abiotic stresses; increasing resistance to pathogens; promoting earlier flowering and fruiting; increasing vase life of cut flowers; and reducing transplant shock and enhancing establishment (as reviewed by Chang, 1994; Corkidi *et al.*, 2008; Davies Jr, 2008). The response of plants to colonization by mycorrhizal fungi is often positive, but may be neutral or even negative (Corkidi *et al.*, 2008). For example, Raviv *et al.* (1998b) found that inoculation of lettuce in the glasshouse with mycorrhiza led to a slight inhibition of growth, likely due to competition with the roots for nutrients, when their availability may be a limiting factor. The authors suggested inoculation upon transplantation to the field would be more beneficial. Mycorrhizal fungi infectivity is not linearly correlated to effectiveness in terms of better plant growth, and the growth substrate can influence mycorrhizal fungi infectivity and so, effectiveness (Corkidi *et al.*, 2008). The most abundant and widespread symbiotic associations of plants are with arbuscular mycorrhizal (AM) fungi, and to a lesser extent, ectomycorrhiza fungi (Siddiqui and Kataoka, 2011).

Geranium plants were grown in a peat-based substrate with zero, low or high level of organic NPK fertilizer, and inoculated with or without a commercial AM fungus inoculum (Nowak, 2004). In unfertilized plants, mycorrhizal inoculation increased all plant growth parameters, but delayed flowering, though the number of flowers was unaffected. Under low level fertilization, mycorrhizal-inoculated plants had increased root and flower dry weights, increased nutrient acquisition, photosynthetic activity, transpiration and stomatal conductance. Under high level fertilization, mycorrhizal inoculated plants were taller, had increased root and flower dry weights, and increased photosynthetic activity, but took longer to flower, though the number of flowers was unaffected (Nowak, 2004). In a similar study, inoculation of container-grown bush morning glory (*Ipomoea carnea* N. von Jacquin ssp. *fistulosa* (K. Von Martinus ex. J. Choisy) D. Austin) with AM fungi enhanced growth and allowed a reduction in the amount of fertilizer used to produce marketable quality plants (Carpio *et al.*, 2005).

Marigold and zinnia seeds were sown in soil inoculated with the AM fungus *Glomus etunicatum* W.N. Becker & Gerd. (Aboul-Nasr, 1996). Mycorrhiza-inoculated plants flowered faster, had more flowers, were taller and had greater shoot and root fresh weights compared to uninoculated controls. In pots in the field, mycorrhizal inoculation of petunias, asters (*Callistephus chinensis* Cass) and impatiens with a consortium of indigenous AM fungi increased the number of flowers (three-fold in petunia, two-fold in asters and impatiens), flowered at least 15 d earlier, grew taller and increased the vegetative dry matter of the plants compared to uninoculated controls, which as comparable to the response due to chemical fertilizers (Gaur *et al.*, 2000).

In a later field (raised bed) trial, a consortium of indigenous AM fungi or a single culture of *Glomus intraradices* N.C. Schenck & G.S. Sm. was inoculated into soil into which five ornamental plant species, petunia, marigold, aster, poppy (*Papaver rhoeas* L.) and carnation (*Dianthus caryophyllus*) were transplanted (Gaur and Adholeya, 2005). Asters inoculated with mycorrhiza had more flowers (up to 39% more) and flowered earlier (up to 10 d earlier), but petunias and marigolds had fewer flowers (up to 30% less) and flowered later (up to 14 d later), compared to uninoculated controls. There was no effect of mycorrhizal inoculation on the flowering of poppies and carnations. Mycorrhizal colonization and propagule density varied with host and type of inocula, with petunias and marigolds having the greatest colonization due to the mixed mycorrhizal consortium. It was proposed that the negative effect on flowering was due to heavy root colonization coupled with high spore production, possibly causing a fungal carbon drain (Gaur and Adholeya, 2005). Mycorrhizal-inoculated asters had moderate root colonization and high P concentrations in the shoots, indicating an effective association. This study emphasizes that mycorrhizal inoculation can potentially enhance production of certain ornamental species, and highlights the need to test different mycorrhizal inocula on the species of interest to ensure the effect is beneficial. The negative effect on petunias in this study contradicted the positive effect in the authors' earlier study (Gaur *et al.*, 2000), but was not discussed by Gaur and Adholeya (2005), though differences included the growing conditions in terms of soil in pots compared to raised beds. Similarly, Russo (2006) found that inoculation of media with a mix of AM fungi (*Glomus aggregatum* (Schenck & Smith) emend. Koske, *G. intraradices* and *G. mosseae* Gerd & Trappe) had little effect on plant height and dry weight of pepper compared to untreated controls.

The effect of inoculation with AM fungi was examined on the growth and flower quality of the ornamental plant chrysanthemum (Sohn *et al.*, 2003). At transplanting, AM fungi inoculation significantly improved rooting rate, tap root length, number of lateral roots, and shoot and root growth compared to uninoculated controls. At 7 weeks post-transplanting, AM fungi inoculation significantly increased plant height, leaf area, root length, and fresh and dry weight of shoots, stems and roots compared to uninoculated plants. AM fungi inoculation significantly shortened flowering time and generally increased fresh weight, width and height of flowers and nutrient uptake compared to uninoculated plants (Sohn *et al.*, 2003).

Inoculation with AM fungi can be combined with the addition of other organic amendments for improved plant growth in containerized production. Pelargonium plants were grown in a peat-based substrate amended with 20% or 40% domestic garden waste compost and inoculated with or without one of three commercially available AM fungi inocula (Perner *et al.*, 2007). All inoculated plants had colonized roots (while control plants did not), and increased numbers of buds and flowers and shoot concentrations of P and K, but not shoot dry weight or shoot N, compared to control plants. (Increasing the compost rate, increased shoot dry weight and shoot nutrient concentrations). Flower development and the nutrient status of pelargonium plants were enhanced by mycorrhizal inoculation in combination with compost amendment (Perner *et al.*, 2007). Similarly, onion were grown in tubes containing a soil medium amended with 2% composted grape marc (CGM) or drenched with 20 mL per tube of diluted water extract of CGM, and inoculated with or without a commercial AM fungus (*Glomus intraradices*) inoculum (Linderman and Davis, 2001). While both the CGM-amended media alone increased onion shoot and root biomass (with the water extract being more effective), combined inoculation with the AM fungus synergistically enhanced growth, with the CGM extract particularly augmenting root colonization by the fungus.

Five ornamental plant species, marigold, germander (*Teucrium fruticans* L.), lavender (*Lavandula augustifolia* Mill.), zinnia and miniature rose (*Rosa* sp.), were grown in a peat-based medium amended with 15%, 30%, 45% or 60% coir and inoculated with or without a commercial AM fungus (*G. intraradices*) inoculum (Linderman and Davis, 2003). Mycorrhiza formed equally well or better in coir-amended media as in unamended media. Any increase in plant growth parameters due to mycorrhiza were small and were species dependent, with only the growth of marigold consistently enhanced. Mycorrhizal inoculation depressed growth of germander in the medium composed of 60% coir. With or without mycorrhizal inoculation, growth of lavender was depressed in all coir-amended media, compared to the unamended control (Linderman and Davis, 2003).

Chives (*Allium schoenoprasum* L.) were inoculated with AM fungus mix 1 (*G. intraradices* + *G. mosseae*) or mix 2 (*G. macrocarpum* + *G. mosseae*) and then transplanted into sand amended with 15% separated cow manure composted with either grape marc, wheat straw or orange peels; or low or high levels of phosphorus (Üstüner *et al.*, 2009). Chives inoculated with AM fungus Mix 1 and grown in sand amended with wheat straw-cow manure compost, or chives inoculated with AM fungus Mix 2 and grown in sand amended with orange peels-cow manure compost, had an equivalent number of leaves and harvested dry weights compared to those grown in phosphorus-amended sand. It was recommended to establish AM fungal colonization before transplantation into compost-amended media, as such rates of compost amendment would inhibit spore germination and subsequent root colonization.

AM fungi can also play a role in the suppression of plant disease. Poinsettia plants were inoculated with the AM fungus *G. mosseae*, with or without fertilizer (Stewart and Pfleger, 1977). Shoot weight of poinsettia plants inoculated with *G. mosseae* only was equivalent to that of plants receiving fertilizer only, and that of plants inoculated with *G. mosseae* and fertilizer. Also, the shoot weight of poinsettia plants inoculated with *G. mosseae* and then the root rot pathogens *P. ultimum* and *R. solani* 20 days later was equivalent to pathogen-uninoculated plants, indicating some mechanism of disease suppression (Stewart and Pfleger, 1977). Druege *et al.* (2006) found that rooting of poinsettia cuttings was enhanced by the AM symbiosis of the donor stock plants. Colonization of these stock plants by AM fungi reduced decay of excised cuttings under unfavourable postharvest storage conditions and generally promoted the formation of adventitious roots.

In the glasshouse, the AM fungus *G. aggregatum* was inoculated into the root zone of pyrethrum plants 3 weeks prior to inoculation with the root rot pathogen *R. solani* (Abdul-Khaliq *et al.*, 2011). Inoculation with the AM fungus suppressed root rot disease completely and increased shoot biomass by almost 40%. The authors proposed that root colonization by *G. aggregatum* may have altered the physiology of the pyrethrum plants leading to development of resistance to the root rot pathogen and disease control, and increased uptake of phosphorus leading to improved growth.

Cyclamen plants were inoculated with the AM fungus *Glomus fasciculatum* and the two pathogens *F. oxysporum*, the causal agent of *Fusarium* wilt, and *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc., the pathogen responsible for anthracnose of cyclamen (Maya and Matsubara, 2013). Plants inoculated with only the mycorrhizal fungus had significantly greater growth and biomass compared to the non-mycorrhizal controls. Plants inoculated with the mycorrhizal fungus and either of the pathogens had significantly less disease incidence compared to the pathogen-inoculated, non-mycorrhizal controls. *G. fasciculatum* induced resistance to these diseases by increasing the antioxidative activity in the plants (Maya and Matsubara, 2013).

Mycorrhizal fungi can also be combined with biological control agents for disease control and/or improved plant growth. Grey mold caused by *B. cinerea* in potted roses was suppressed and plant vigour was enhanced by the simultaneous use of the mycorrhizal fungus *G. mosseae* and the biocontrol fungus *Ulocladium atrum* (Preuss) Sacc., despite high disease pressure, harsh stress conditions and the otherwise disease-conducive greenhouse conditions applied (Møller *et al.*, 2009). In marigold, inoculation with the mycorrhizal fungus *G. mosseae* suppressed disease caused by the root rot pathogen *P. ultimum*, causing better plant growth in mycorrhizal plants, and co-inoculation with the fungal antagonist *Trichoderma aureoviride* Rifai synergistically increased plant biomass (Calvet *et al.*, 1993).

Cucumber seedlings were grown in soil in pots in the greenhouse with or without inoculation of AM fungi (either one strain of *Glomus caledonium* (Nicolson & Gerdemann) Trappe & Gerdemann or a consortium of *Glomus* spp. and *Acaulospora* spp.) and the wilt pathogen *F. oxysporum* f. sp. *cucumerinum* (Hu *et al.*, 2010). Cucumber plants inoculated with the pathogen without AM fungi had significantly less biomass, a higher incidence of *Fusarium* wilt and produced no cucumber fruit, compared to the pathogen-uninoculated controls. Cucumber plants inoculated with the pathogen and only the AM fungi consortium, not the single AM fungus strain, had greater plant biomass, a lower incidence of *Fusarium* wilt, and improved cucumber yields comparable to the pathogen-uninoculated controls. The AM fungi consortium suppressed *Fusarium* wilt of cucumber in the greenhouse (Hu *et al.*, 2010).

Asparagus seedlings inoculated with a mycorrhizal fungus (*Glomus* sp.) growing in soil containing 10% or 30% carbonized chaff, coconut charcoal or manure of coffee residue (descriptions of amendments were not given), were later inoculated with *F.* f. sp. *asparagi*, the causal agent of *Fusarium* root rot (Matsubara *et al.*, 2002). Root rot incidence and severity was significantly reduced in mycorrhizal inoculated plants in 10% or 30% coconut charcoal and 10% manure of coffee residue compared to the controls.

Ectomycorrhizal fungi form mutualistic relationships with a small number vascular plant genera, *Pinus* being one of them. The growth of Allepo pine (*P. halepensis*) seedlings was greatly enhanced by inoculation with the ectomycorrhizal fungus *Pisolithus* sp. in surface forest soil in pots (Ouahmane *et al.*, 2009). The fungus significantly altered the functions of soil microbial populations, favouring microorganisms potentially beneficial to plant growth, such as phosphate solubilizing bacteria.

Inoculation with mycorrhizal fungi can have many benefits including improved plant growth and disease suppression, but the plant response is species-specific, so thorough testing is required; in particular more information on the response of vegetable transplants and woody species is needed. Also, more research on the effect of inoculating with a single species or consortia, interaction with other organic amendments and the timing, method and rate of inoculation would be useful.

2.8.2 Plant Growth-Promoting Bacteria and Fungi

Colonization of plant roots or the rhizosphere by beneficial microbes such as plant growth-promoting bacteria (PGPB) or rhizobacteria (PGPR) and plant growth-promoting fungi (PGPF) can increase plant growth. PGPR applied to potting media can form stable populations in the rhizosphere that can survive transplantation to the field and persist throughout the growing season to have ongoing effects (Kokalis-Burelle *et al.*, 2006).

Inoculation of tomato roots with a PGPR, a strain of *B. subtilis*, increased root growth and some fruit quality aspects (Mena-Violante *et al.*, 2005; Mena-Violante and Olalde-Portugal, 2007). Tomatoes inoculated with *B. subtilis* had significantly increased root length, root dry weight, fruit yield per plant (up to 25% more), fruit weight and fruit length, and in some cases, marketable yield (up to 20% more), compared to uninoculated plants. The authors suggested these increases could be due to a combination of improved nutrient availability and the effect of phytohormones (Mena-Violante and Olalde-Portugal, 2007). Fruit texture was also improved, with firmer fruits obtained from inoculated plants, which could translate into a longer shelf life (Mena-Violante *et al.*, 2005; Mena-Violante and Olalde-Portugal, 2007).

Three species of PGPB (*Bacillus* spp.) were inoculated onto radish seedlings that were then grown under salinity stress in pots (Yildrim *et al.*, 2008). Inoculated seeds had increased germination percentage and faster germination compared to uninoculated seeds. Under salt stress, subsequent plant growth parameters of fresh and dry shoot and root weights were significantly increased in inoculated treatments, compared to uninoculated treatments. The authors proposed that bacterial inoculation of seeds ameliorated the deleterious effects of salt stress by enhancing chlorophyll content, photosynthetic activity and relative water content; modifying mineral uptake; and reducing membrane damage, hence inducing salt tolerance (Yildrim *et al.*, 2008). This may have application if an organic amendment causes increased soluble salt levels in the growing medium in containerized production; inoculation with such bacteria could mitigate the detrimental effects on the growth of plants. In a similar experiment, primula (*Primula vulgaris*) and begonia were grown in fertilized peat or composted bark amended with one of four microbial products: *Trichoderma viride* Pers.:Fr., *T. harzianum*, *Pseudomonas fluorescens* or *B. subtilis*; and grown under salinity stress in pots (Gruda *et al.*, 2008). However, in this study, there were no beneficial effects of the microbial additives.

Five PGPR and three PGPF were inoculated onto 4-week-old tomato seedlings to establish any promoting effect on plant growth under hydroponic conditions (Gravel *et al.*, 2007). Inoculation with *Pseudomonas putida* or *Trichoderma atroviride* Karst. stimulated growth, increasing fruit yields in rockwool and in an organic medium, compared to uninoculated controls. Both organisms produced indole acetic acid (IAA), and it is likely that this played a role in the improved reproductive growth. In another study, *Trichoderma*-inoculated cabbage seedlings had greater fresh weights than uninoculated seedlings, and it was proposed that this was due to improved uptake of nutrients (Raviv *et al.*, 1998b).

The effect on the growth and biomass production of one-month-old teak plantlets inoculated with each of twenty-three isolates of phosphate solubilizing bacteria (PSB) was studied in the nursery (Mohan and Radhakrishnan, 2012). All inoculated plantlets grew better than the uninoculated controls. A *B. subtilis* isolate and a *Ps. fluorescens* isolate showed the most potential for improving growth and biomass production of teak, and when combined, the two isolates synergistically enhanced the growth, biomass and quality of teak plantlets.

Some diazotrophs (nitrogen-fixing bacteria) form symbioses with some plants and have beneficial effects on plant growth. For example, inoculating a soil-based growing medium with a nitrogen-fixing bacterium (*Azotobacter chroococcum* Beijerinck) prior to seeding of aonla (an important plant in traditional Indian medicine) or planting of pomegranate cuttings, increased seed germination (aonla), seedling height (aonla), number of branches (pomegranate), leaf area and shoot dry weight (Aseri *et al.*, 2008; Aseri *et al.*, 2009). However, a combination treatment of the bacterium with the AM fungus (*G. mosseae*) was the most effective at improving these parameters, and also enhanced rhizosphere microbial activity; increased the concentration of various metabolites and nutrients in the plants; and helped the plants to establish better under harsh field conditions, with significant improvement in the plant height, plant canopy, fruit yield and other parameters (Aseri *et al.*, 2008; Aseri *et al.*, 2009). Also Russo (2006) found that inoculation of media with a mix of *Sinorhizobium* sp. bacteria (*S. meliloti* and *S. leguminosarum* biovar *trifolii*) increased plant height and dry weight of pepper compared to untreated controls.

The growth, quality and nutrient acquisition/use of *Casuarina equisetifolia* L. seedlings inoculated with bioinoculants under tropical nursery conditions was studied (Muthukumar and Udaiyan, 2010). Seedlings were inoculated with, individually or in combination, an AM fungus (*Glomus geosporum* (T.H. Nicolson & Gerd.) C. Walker), a species of phosphate solubilizing bacteria (*Paenibacillus polymyxa* (Prazmowski) Ash *et al.*) and a nitrogen-fixing actinomycete *Frankia*. Bioinoculant inoculation stimulated seedling growth (increased height, stem girth and biomass), improved nutrient uptake efficiency and enhanced seedling quality, but generally reduced the nutrient use efficiency. *P. polymyxa* or *Frankia* inoculation increased the degree of mycorrhizal colonization, increasing nutrient accumulation. Whilst dual inoculations of microbes improved parameters over individual inoculations, inoculation with all three microbes increased the growth response compared to dual or individual inoculations.

Plant growth-promoting microbes can also play a part in disease suppression. In the glasshouse, *Streptomyces* sp., *B. subtilis* and *T. harzianum* were each inoculated into the root zone of pyrethrum plants either simultaneously or 3 days after inoculation with the root rot pathogen *R. solani* (Abdul-Khaliq *et al.*, 2011). Simultaneous inoculation with *Streptomyces* sp., *B. subtilis* and *T. harzianum* gave 70%, 50% and 50% disease control respectively, while 3 days post-inoculation gave 50%, 50% and 25% disease control respectively, which was as effective as the standard fungicide treatment.

In the greenhouse, geranium plants were inoculated with either of the beneficial microbes *Ps. putida* or *T. atroviride*, a mixture of the two organisms, or the commercial product Rootshield (*T. harzianum*). Plants were then inoculated with the causal agent of *Pythium* root rot (*P. ultimum*) and fertilized with a filtered suspension of dehydrated hen manure or conventional fertilizer (Gravel *et al.*, 2009). Individual treatments of *P. putida* and *T. atroviride* increased shoot and root dry weight, while the mixture of the two increased root fresh and dry weight, compared with the control. Roots of plants inoculated with the *P. putida* and *T. atroviride* mixture had the weakest colonization by *Pythium* spp., regardless of fertilization regime. Growth, flower production and the overall plant quality were not affected by the fertilization regime, however, colonization of geranium roots by *Pythium* spp. was significantly lower for all treatments fertilized with hen manure compared with those under conventional fertilization (Gravel *et al.*, 2009).

In the greenhouse, four native bacterial strains (*Ps. putida*, *Serratia marcescens*, *Bacillus* spp. and *Ps. fluorescens*) and one commercial product (*Bacillus amyloliquefaciens* Priest *et al.*) were inoculated before sowing and after transplanting of cucumber, which was naturally infected by *F. oxysporum* f. sp. *cucumerinum* (Gül *et al.*, 2013). Plants inoculated with *P. putida* and *S. marcescens* had significantly higher fruit number and higher yields compared to the control plants. These two native strains were more effective at increasing plant growth and yield compared to the commercial product, probably because of their adaptations to local climatic conditions.

Tomato plants were treated with a drench of a bacterial suspension based on *B. subtilis* and two other *Bacillus* species, and marketed as Companion, a commercial systemic resistance/plant growth promotion inducer (Vavrina *et al.*, 2004). The bacterial suspension did not improve the plant growth parameters tested (stem length and diameter, leaf area, dry shoot and root weight, true leaf number) compared to the untreated control. In only one of six trials, the bacterial suspension significantly reduced the severity of bacterial spot (caused by *X. campestris* pv. *vesicatoria*) in inoculated tomato plants. It did not improve growth or suppress disease caused by root knot nematode (*M. incognita*). Timing of treatment application with respect to the physiological age and status of the plant requires better understanding to improve the consistency of this and other systemic resistance/plant growth promotion inducing products (Vavrina *et al.*, 2004).

An isolate of *Bacillus cereus* Frankland & Frankland (*Bc*) was grown on a mix of one-week-old fermented rape meal and compost pig manure for 10 days to produce a bio-organic fertilizer (Tong-Jian *et al.*, 2013). A known biocontrol bacterial strain of *B. thuringiensis* (*Bt*) and a biocontrol fungal strain of *T. harzianum* (*Th*) were fermented in the same way, to produce comparison products, and all three were combined to produced a mixed bio-organic fertilizer. Each bio-organic fertilizer was then assessed for its efficacy to suppress the effects of root knot nematodes (*Meloidogyne* sp.) on greenhouse-grown tomatoes. Tomatoes grown in the *Bc*-only fertlizer, the *Th*-only fertlizer or the mixed fertilizer media had significantly greater dry shoot and root weights than those grown in the control medium (no isolate inoculation), with those grown in the mixed fertilizer medium growing significantly better than any other media. Also, all of the fertilizer media significantly reduced the galling index, the number of egg masses in roots, the number of eggs per mass and the number of nematodes in the rhizosphere soil, with the *Bc*-only fertilizer and the mixed fertilizer media giving the greatest reduction in these parameters compared to any other media. This suppression was likely due to the production of nematicidal compounds by *B. cereus* (Tong-Jian *et al.*, 2013).

Eight of fifty PGPR strains tested significantly suppressed bacterial speck of tomatoes caused by *Pseudomonas syringae* pv. *tomato* (Ji *et al.*, 2006). The most effective strains, *Pseudomonas fluorescens* and *Bacillus pumilus*, were further trialled in field tests with foliar biological control agents, showing some disease suppression.

There are numerous PGPR/PGPB-based and other bacteria-based products which are available in Australia. Depending on the claims for use, some products require registration with the Australian Pesticides and Veterinary Medicines Authority (APVMA), and others do not. For example, biological control agents require registration since they are used as a pesticide (targeting a pest). However, other products, such as fertilizers, do not require registration. As long as the bacteria-based product is 'not claimed to have any effect as a regulator of plant growth', registration is not required (APVMA, 2013). Examples of such products include Ultra Boost+6, which contains six PGPB strains; and Bactivate and similar products, which contain five *Bacillus* species (by Bactigro Australia).

Further research on PGPR/PGPB should include assessment of the response of annual bedding plant species, the effect of single, dual or multiple inoculations, application timing with respect to host plant growth stage, and the potential for bacterial inoculants to ameliorate the effects of high salt levels, which may exist as a result of the application of other organic amendments, such as spent mushroom compost.

2.8.3 Other Products

There are registered commercial products available overseas based on species of the bacterium *Bacillus*. Three examples of such products registered in the USA are Sonata, Serenade and Kodiak. Sonata is a foliar spray based on *B. pumilus* for the control or suppression of many important plant diseases in greenhouse- and field-grown fruit and vegetable crops. Serenade is a soil drench based on *B. subtilis* for the control or suppression of many important plant diseases in field-grown fruit and vegetable crops. Kodiak Concentrate Biological Fungicide contains *B. subtilis* (though a different strain to Serenade) which colonizes the developing root system, suppressing disease organisms of a range of field crops. Given that these products are registered by the USA's national registration authority, their efficacy has been evaluated and demonstrated. *Bacillus* products such as these may have application as biological control agents for soil-borne damping-off and grey mould, which can be problematic in micropropagated plants in high-humidity fogging glasshouses (Li *et al.*, 1998). The only registered biological product in Australia, other than virus-based or bacterium-based biological insecticides, is Vinevax, a biological fungicide based on *T. harzianum* for the control of a fungal disease of grapevines.

The practical application of bioinoculants in a production nursery environment is feasible, with costs (adjusted to current prices) at approximately \$11-\$80/L (Quilty and Cattle, 2011).

2.9 Biochar

During the manufacture of gaseous and liquid biofuel products via pyrolysis, a biomass feedstock is heated rapidly in the absence of oxygen, and a granular, carbon-rich residue (charcoal) remains, called biochar (Dumroese *et al.*, 2011; Elad *et al.*, 2011; Huber *et al.*, 2006). There is growing use of biochar in agriculture, for improved soil health and also for carbon sequestration for mitigating carbon emissions, and its potential for horticultural field crops has been reviewed recently (Cox *et al.*, 2012). Whilst biochar application is an activity that does not count towards Australia's emissions target under the Kyoto Protocol, it is one of the eligible activities under the Australian Government's Carbon Farming Initiative and credits generated through its application can be sold on the voluntary market (Lines-Kelly, 2012).

Biochar may also have potential as an organic amendment in containerized nursery plant production (Cox and Van Zwieten, 2012). The starter feedstock and the pyrolysis conditions, particularly temperature, heating rate, oxygen level, pressure and residence time in the reactor, can affect the final characteristics of biochar (Elad *et al.*, 2011; Jenkins and Van Zwieten, 2012; Keiluweit *et al.*, 2010; Kookana *et al.*, 2011; Thies and Rillig, 2009), and so influence its performance as an amendment for plant growth (Chan *et al.*, 2007a; Chan *et al.*, 2008). Biochar amendment may improve the physical structure of the growing medium; neutralize acidic media; provide nutrients in a slow release form (Thies and Rillig, 2009; Van Zwieten *et al.*, 2012); increase the use efficiency of fertilizers; enhance root growth; suppress soil-borne diseases (Van Zwieten *et al.*, 2012); and promote resistance of plants to plant pathogens by altering microbial population size and community structure (Lehmann *et al.*, 2011; Thies and Rillig, 2009; Van Zwieten *et al.*, 2012) and increasing in the relative abundances of potential biocontrol bacteria (Kolton *et al.*, 2011). Biochar may also be useful as a carrier for inoculation of beneficial microorganisms such as diazotrophs (nitrogen-fixing bacteria) and mycorrhizal fungi (Lehmann *et al.*, 2011; Thies and Rillig, 2009). It may also bring environmental, social and economic benefits to growers in terms of carbon trading (Kachenko *et al.*, 2011). However, biochar may also decrease the efficacy of some pesticides (Downie, 2012; Kookana *et al.*, 2011), negatively affect the availability of nutrients (e.g. by immobilization), release bound toxicants such as heavy metals (Kookana *et al.*, 2011) and if allowed to dry out, become water repellent (Downie, 2012). There have been few studies focussing on the addition of biochar to potting mix and soilless media systems, and in relation to the Australian nursery industry, the number of studies has been negligible; further research is warranted (Cox and Van Zwieten, 2012; Kachenko *et al.*, 2011). However, with the cost of biochar presently at approximately $2000-2500/tonne (Billingham, 2012; McClintock and Powell, 2012), due to a lack of large scale production facilities in Australia, even if efficacious, its use may be uneconomic (McClintock and Powell, 2012).

Tomatoes and peppers were grown in a commercial soilless growing medium amended with 1-5% nutrient-poor, wood-derived biochar under optimal fertigation (Graber *et al.*, 2010). Tomatoes in biochar-amended media were significantly taller (on average 39% taller) and had greater leaf area compared to those in the unamended medium, but there was no effect on flower and fruit parameters. Peppers in biochar-amended media had a significantly greater number of leaf nodes, larger canopy (greater dry weight), had greater leaf area, and generally increased number of buds, flowers and fruit and fruit weight compared to those in the unamended medium. Also, there were significantly more soil-typical, culturable microbes in the biochar-amended media, particularly in the rhizosphere of biochar-amended pepper plants, including root-associated yeasts, *Trichoderma* spp. and filamentous fungi (Graber *et al.*, 2010). These gains in growth were not due to nutritional increases or to improvements in soil physical and chemical properties, but it was suggested that biochar amendment caused a shift in microbial populations towards beneficial microbes, or that low doses of biochar-derived substances stimulated plant growth (Graber *et al.*, 2010).

Two recent reviews of numerous studies collated evidence that soils amended with biochar had increased microbial biomass, and significant changes in the composition of the microbial populations and their enzyme profiles (Lehmann *et al.*, 2011; Thies and Rillig, 2009). This is probably due to the suitable growth microhabitat that is provided by the porous structure of biochar, its high internal surface area and its ability to retain moisture and adsorb soluble organic matter, gases and inorganic nutrients. Similarly to the findings of Graber *et al.* (2010), Kolton *et al.* (2011) found that the root-associated bacterial community composition of pepper grown in biochar-amended sandy soil in pots in the glasshouse was very different to that of plants grown in unamended media. The relative abundance of certain taxa increased while others decreased due to biochar amendment. Improvements in plant growth due to amendment with biochar may, in part, be due to biochar-augmented taxa (Kolton *et al.*, 2011). This may also apply in containerized growing media and further research is warranted in this area.

The indoor foliage plant *Calathea rotundifolia* Poepp. & Endl. cv. *fasciata* was grown in a peat amended with 50% or 100% biochar derived from green (tree) waste (Tian *et al.*, 2012). Plants grown in 50% biochar-amended media were significantly heavier (by 22%), having greater leaf and total biomass, compared to those grown in unamended peat. However, plants grown in 100% biochar had significantly lower leaf and total biomass, as well as lower leaf number and reduced leaf surface area, compared to those grown in unamended peat. These decreases may have been due to the bulk density, total porosity, water-filled porosity, electrical conductivity and available N and P contents being outside the ideal ranges for 100% biochar. Examining the particle size distribution of the media initially and at the end of the 6-month experiment indicated that biochar amendment reduced the rate of media decomposition and so may increase media longevity.

In some preliminary Australian work, lilly pilly (*Acmena smithii* (Poir.) Merr. & Perry syn. *Syzygium smithii* (Poir.) Nied.), viola (*Viola* v. *hybrida*) and pansy were grown in a commercial growing medium amended with 2.5%, 5% or 10% biochar (derived from Sydney blue gum (*Eucalyptus saligna* Sm.) wood) with controlled release fertilizer applied at 0, 0.5x or 1x the recommended rate (Kachenko *et al.*, 2011). Biochar had no effect on the above ground dry matter yield and did not seem to increase the nutrient concentration of the three plant species. In addition, biochar did not appear to improve the fertilizer efficiency. Interestingly, 2.5% biochar amendment combined with 1x controlled release fertilizer yielded maximum biomass for all three species, with a significant interaction between biochar rate and fertilizer rate. The authors suggested that this warranted further study using a wide variety of plant species, biomass feedstocks and production conditions to determine if there is an optimum level for this interaction (Kachenko *et al.*, 2011).

Biochar may help retain water and nutrients in containerized production. In pot trials in the glasshouse, tomato seedlings grown in sandy soil amended with wood-derived biochar had increased resistance to water stress (Mulcahy *et al.*, 2013). Amendment with 30% (v/v) biochar, concentrated in seedling root zones significantly increased the resistance of seedlings to wilting. These results should be interpreted with caution, since this study used sandy soil rather than soilless growing media.

Biochar may also affect plant resistance to pathogens by detoxifying allelopathic chemicals, nutritionally strengthening the plants ability to fight biotic stress, or may induce systemic plant defense mechanisms (Elad *et al.*, 2011). Biochar at 1-5% added to soil or a coconut fiber-tuff potting medium significantly suppressed the foliar fungal diseases grey mold (caused by the necrotrophic pathogen *B. cinerea*) and powdery mildew (caused by the biotrophic pathogen *Leveillula taurica* (Lév.) Arn.) on pepper and tomato in leaves of different ages (Elad *et al.*, 2010). Biochar induced systemic resistance to these foliar fungal diseases and to the broad mite pest (*Polyphagotarsonemus latus* Banks) on pepper. Given that the biochar was in the growing medium and these are foliar infections/infestation, indicates that biochar had no direct toxicity toward the causal agents. Also, there were no differences in the plants in terms of nutrition, water supply or osmotic stress between the treatments and the controls, so improvements due to biochar were not due to improving the nutrient supply or changing the physical properties of the media. Biochar may have induced systemic resistance by stimulating beneficial soil microbes, adding chemical elicitors such as salts and organic chemicals, or as a result of stress derived from the presence of low levels of phytotoxic compounds (Elad *et al.*, 2010).

These findings were supported in a later study where the ability of biochar from two different feedstocks to suppress disease in strawberries caused by *B. cinerea* (grey mold), *Colletotrichum acutatum* Simmonds (anthracnose) and *Podosphaera apahanis* (powdery mildew) was assessed (Meller Harel *et al.*, 2012). Biochar produced from citrus wood or biochar produced from greenhouse wastes (mainly pepper plant wastes) was mixed at 1 or 3% (w/w) with two different peat-based potting mixes. Strawberries grown in 3% biochar-amended media had reduced disease severity due to the three fungi. Biochar added at the lower rate was not consistently effective against grey mold and anthracnose, and was ineffective against powdery mildew. The three pathogens tested have different infection strategies and indicates that biochar stimulated various general defence pathways in strawberries, and in fact, induced the expression of five defence-related genes.

Warnock *et al.* (2007) reviewed the interaction between biochar and mycorrhizal fungi, albeit in soil, determining that biochar amendment can enhance mycorrhizal-plant symbiotic interactions having numerous knock-on effects, for which the authors proposed several mechanisms. In an earlier study supporting this claim, biochar (in the form of coconut charcoal and carbonized chaff, precise descriptions not given) amended to soil at 10% or 30% increased the tolerance of mycorrhizal-inoculated asparagus plants to *Fusarium* root rot caused by *F. oxysporum* f. sp. *asparagi* (Matsubara *et al.*, 2002).

Biochars produced from coir, sawdust, wheat straw and rice husks have been studied for the hydroponic production of greenhouse cucumbers (Nichols and Savidov, 2009; Nichols *et al.*, 2010). It was reported that the total yield, number of fruits and mean weight of fruits in the biochars was equivalent to or greater than these parameters in standard media (coir or sawdust) (Nichols *et al.*, 2010). However, the scientific robustness of this study is undetermined, since no statistical measures were presented (though the authors stated that the results were analysed statistically), full materials and methods were not described, and the study was published in a grower's magazine, not a peer-reviewed journal. The authors proposed that an advantage of biochar as a growing medium was that it could be sterilised between crops by passing it through a further pyrolysis process, converting any plant residues to biochar and destroying any pathogenic microorganisms (Nichols *et al.*, 2010).

Pelletized biochar could make the product easier to use. For example, biochar pellets were formed using equal proportions of biochar and wood flour (finely ground pinewood), and starch-based binders, providing a product that was easy to handle and incorporate into containers (Dumroese *et al.*, 2011). Peat moss was then amended with 25%, 50%, 75% or 100% biochar pellets and assessed for its chemical and physical properties for containerized nursery plant production. The resulting substrates were generally suitable, though ratios above 50% had high carbon:nitrogen ratios, high bulk density, and swelling associated with water absorption; whereas 25% amendment had improved water movement while maintaining the target air-filled porosity, decreased the cation exchange capacity, and offset the shrinkage of the peat component (Dumroese *et al.*, 2011). Unfortunately, no plants were grown in these substrates as an ultimate test of their utility. If biochar is valuable as an organic amendment in containerized transplant production, another bonus is that efficient, low cost, long term, below ground carbon sequestration is achieved, since carbon dioxide that originated in the atmosphere has become biochar which becomes part of the root plug that is planted out (Dumroese *et al.*, 2011; Elad *et al.*, 2011).

A related product to biochar is wood vinegar or pyroligneous acid; a fraction of liquid condensed smoke, a by-product of charcoal burning (Mungkunkamchao *et al.*, 2013). Tomato plants grown in pots were sprayed or drenched with either wood vinegar, fermented bioextract (obtained from anaerobic fermentation of ground-golden apple snail and molasses), or both. Applied as either a foliar spray or soil drench, none of the treatments had any statistically significant effect on any of the plant growth or fruit parameters, except drench application of fermented bioextract, alone or with wood vinegar, which significantly enhanced total soluble solids of the tomato fruit compared to that drenched with water only (Mungkunkamchao *et al.*, 2013). Mu *et al.* (2003) found that an appropriate dilution of bamboo vinegar (a by-product of bamboo pyrolysis) used as a seed priming agent promoted germination and radicle growth of lettuce, chrysanthemum, watercress (*Rorippa nasturtium-aquaticum* Hayek) and honewort (*Cryptotaenia japonica* Hassk.). This is similar to smoke water being used to promote the germination of some plant species, for example, some native Australian plants (Vigilante *et al.*, 1998), mediated by a group of plant growth regulators called karrikins (Chiwocha *et al.*, 2009). In a study on bedding plants, Kadota and Niimi (2004) amended a peat-based medium with 10% or 30% 1:4 wood vinegar:biochar or 3:7 barnyard manure:biochar. The wood vinegar:biochar amendment at either rate generally decreased the number of days to flowering of zinnia, melampodium (*Melampodium paludosum* Kunth F. W. H. A. von Humboldt) and scarlet sage, but not French marigold, and increased the survival of scarlet sage and zinnia. When grown in the wood vinegar:biochar-amended media, some growth parameters of scarlet sage, melampodium and zinnia were improved, but others in French marigold and scarlet sage decreased. The barnyard manure:biochar amendment at 10% increased the survival rate and height of zinnia and generally either gave equivalent growth or improved growth parameters of all species (Kadota and Niimi, 2004).

Further research is required on the efficacy of biochar in containerized plant production and the focus should be on testing a wide variety of plant species, the effect of different biomass feedstocks and varying production conditions (Kachenko *et al.*, 2011). Having said this, the high cost of biochar at approximately $2000-2500/tonne (Billingham, 2012; McClintock and Powell, 2012), due to a lack of large scale production facilities in Australia at present, will likely prohibit its use in the near future (McClintock and Powell, 2012).

2.10 Vermicomposts

Vermicomposts are produced by a non-thermogenic process under aerobic conditions, where earthworms are employed to degrade organic residues, simultaneously increasing the microbial activity and the mineralization rate, and subsequently transforming the residues to humus-like material (Arancon *et al.*, 2003; Arancon *et al.*, 2005b). The muscular gizzard of the feeding earthworm crushes large particles of the organic matter creating finer matter, enhancing the surface area, hence the activity of symbiotic microbes and gut enzymes, resulting in thorough degradation (Jayashree *et al.*, 2008).

It is as a result of the feeding and burrowing activities of earthworms, that vermicomposting is an aerobic, non-thermogenic process. There is high microbial activity and biodiversity, predominated by mesophilic bacteria and fungi, which makes it distinct from thermogenic composting which leads to the proliferation of thermophilic bacteria (Atiyeh *et al.*, 2000c; Edwards and Arancon, 2004; Jayashree *et al.*, 2008; Subler *et al.*, 1998). It is these specific microorganisms that enable the release of nitrogen as nitrate (rather than as ammonia in composting), in part, providing the desirable effects of vermicompost on plant growth (Edwards and Burrows, 1988; Edwards and Arancon, 2004; Subler *et al.*, 1998). Also, the much greater microbial activity and biodiversity in vermicompost generally led Tomati *et al.* (1993) to claim that vermicomposts are more effective and more reliable than thermogenic composts as amendments for both plant propagation and containerized production, with greater hormone-like effects and no risk of phytotoxicity, though this is not always the case (Kannangara *et al.*, 2000; Tognetti *et al.*, 2005).

Vermicomposts are stable, finely divided, peat-like substrates with a gritty, humified composition and no unpleasant smell. Importantly, they have excellent structure, desirable porosity, aeration and drainage properties, and enhanced moisture holding capacity, making them an ideal amendment for enhancing plant growth (Edwards and Arancon, 2004; Frederickson *et al.*, 1997; Szczech, 1999). Vermicomposts can contain nutrients important for plant growth, usually in adequate amounts, but importantly, in a suitable form for uptake by plants, though this varies depending on the feedstock (Edwards and Arancon, 2004; Handreck, 1986). A wide variety of plants, including vegetables, bedding plants and ornamental shrubs, have been grown in vermicompost and vermicompost-amended media in greenhouse trials, and most plants germinated faster and had comparable or superior growth than in commercial growth substrates (Edwards and Burrows, 1988; Scott, 1988).

Vermicompost production methods have been reviewed by Dominguez and Edwards (1997). Organic starting material can be sourced from plant and crop residues, municipal and industrial wastes, animal manures and sewage sludge (Arancon *et al.*, 2003; Edwards and Arancon, 2004). With respect to agricultural wastes (crop and animal wastes), Barik (2011) recently reviewed the substrate properties that are the most influential factors for vermicomposting. Feedstocks should have a C-N ratio less than 40:1, a moisture content of 40-60%, a temperature of 18-25°C, and a pH near neutral to be most conducive to the growth of earthworms. Pre-composting with bioinoculants can assist in the breakdown of recalcitrant wastes, such as those high in cellulose and lignin, which would usually lengthen the time period required for complete vermicomposting. Beneficial microorganisms and abiotic materials, such as oil cakes, rock phosphate and bone meal, can be added to improve the final product (Barik *et al.*, 2011).

When substituted into soilless container media for horticultural production of various species in the greenhouse, vermicomposts can consistently increase seed germination; improve seedling growth and development; enhance flowering, fruiting and general productivity; and suppress disease (Arancon *et al.*, 2003; Asciutto *et al.*, 2006; Atiyeh *et al.*, 2000a; Atiyeh *et al.*, 2000b; Atiyeh *et al.*, 2000c; Atiyeh *et al.*, 2001; Atiyeh *et al.*, 2002b). Such positive effects of vermicompost have been ascribed in part to improvements in the physicochemical structure of the container medium: improved porosity, increased aeration and better water retention (though high levels such as 100% vermicompost have high soluble salt concentrations and poor porosity and aeration). Also, the increased nutritional properties, due to the conversion of mineral nutrients into a balanced array of forms that are slowly released and more readily accessible by the plant, particularly the high nitrate content (Arancon *et al.*, 2003; Arancon *et al.*, 2004; Arancon *et al.*, 2005b; Arancon *et al.*, 2007b; Atiyeh *et al.*, 2001; Edwards and Arancon, 2004; Edwards *et al.*, 2006) and the humic acid content (Ali *et al.*, 2007; Edwards *et al.*, 2006). Vermicompost has higher levels of humic substances than conventional composts (Dominguez *et al.*, 1997) and these are thought to increase nutrient accumulation under both conditions of limited nutrient availability and when additional nutrients are supplied (David *et al.*, 1994).

However, other mechanisms are at work and it has been proposed that the enhanced availability of certain micronutrients; the increased microbial activity and diversity (due to the organic wastes fragmented by the earthworms having a much greater surface area and therefore abundant suitable niches for microbial growth); the presence of beneficial microbes; and the production of plant growth regulators/hormones and enzymes, all play a role (Arancon *et al.*, 2003; Arancon *et al.*, 2004; Arancon *et al.*, 2005b; Arancon *et al.*, 2007b; Atiyeh *et al.*, 2001; Edwards and Burrows, 1988; Edwards *et al.*, 2006; Frankenberger Jr and Arshad, 1995; Krishnamoorthy and Vajranabhaiah, 1986; Subler *et al.*, 1998; Tomati *et al.*, 1988). The disease suppressive ability of vermicompost has been attributed to the diverse and abundant microflora, and this has been supported in many studies, where disease suppression has disappeared after autoclaving (Asciutto *et al.*, 2006).

Vermicompost used as a media component for the production of organic greenhouse tomatoes can improve fruit yield and reduce disease incidence (Surrage *et al.*, 2010). Four growing media, with suitable pH; electrical conductivity; macro- and micronutrient concentrations; environmental implications; and cost profiles, were assessed for their ability to improve the marketable yield of tomatoes when compared with an industry standard medium (rockwool) under greenhouse conditions. Two media were based on vermicompost (feedstock not specified), while two were based on composted pig and horse manure. Tomatoes grown in vermicompost-based media, made from a proprietary blend of either coconut coir and vermicompost (GRO1) or aged pine bark, coconut coir and vermicompost (GRO2), had significantly greater marketable and commercial yields per plant, compared with plants grown in the control medium. The yields were also higher than those from plants grown in compost-based media, though only the commercial yields were of statistical significance. Also, the incidence of defective fruit was significantly reduced in plants grown in vermicompost-based media compared to those grown in the control medium. Similarly, the incidence of the disease blossom end rot was reduced in plants grown in vermicompost-based media, compared with plants grown in the control medium, with disease incidence in plants grown in GRO1 significantly lower than disease incidence in plants grown in the compost-based media. Vermicompost-based media had significantly greater container capacity than composted manure-based media (Surrage *et al.*, 2010).

The ability of vermicompost to supply plant nutrients was tested by planting seedlings of stocks (*Matthiola incana* (L.) Aiton) into a pine bark-based substrate amended with 30% vermicompost (v/v) derived from one of seven different sources including four from animal manures, one from kitchen scraps, one domestic mix and one grain-based mix (Handreck, 1986). The vermicomposts, and so the resultant substrates, varied widely in their total nutrient content, with most supplying adequate phosphorus and trace elements, but only some potassium and sulphur, and negligible amounts of soluble nitrogen to the plants. Some had toxic levels of trace elements. This highlights the importance of testing different vermicomposts for their nutrient content and effect on plant growth (Handreck, 1986). These nutrients can then translate into high nutrient levels in plant parts. For example, tomato fruit grown in 100% vermicompost or 50% vermicompost-50% soil (feedstock not specified) contained equivalent phosphorus and potassium, but significantly more calcium and vitamin C and less iron than fruit grown on hydroponic media (Premuzic *et al.*, 1998).

In most studies, vermicompost had more positive effects on plant growth when it was substituted at a low rate (10-40%) rather than at high rates (80-100%). When used alone, they can be detrimental to plant growth; for example, in the glasshouse, 100% vermicompost produced from a green waste compost feedstock inhibited the growth of lettuce (Ali *et al.*, 2007), marigolds (Atiyeh *et al.*, 2002a) and tomatoes (Atiyeh *et al.*, 2000a). Such negative effects may have been due to phytotoxicity from high salt concentrations, poor porosity or poor aeration in the media (Arancon *et al.*, 2003; Asciutto *et al.*, 2006; Atiyeh *et al.*, 2001). Such high salt concentrations can be overcome by leaching prior to planting for salt sensitive species (Mazuela and Urrestarazu, 2009) or by normal irrigation practices (Asciutto *et al.*, 2006; Atiyeh *et al.*, 2001; Chong, 2005). Conversely, Asciutto *et al.* (2006) found that impatiens grown in 75% or 100% vermicompost had increased leaf area, plant height and fresh and dry weights of aerial growth and roots, and at 75%, gave slight control of damping-off caused by *R. solani* (Asciutto *et al.*, 2006). Yet, 25% or 50% vermicompost did not suppress damping-off in impatiens.

Usually, blending the vermicompost with other substrates at a level of 10-40% can enhance plant growth (Arancon *et al.*, 2003; Arancon *et al.*, 2004; Atiyeh *et al.*, 2000a; Edwards *et al.*, 2006; Subler *et al.*, 1998). For example, mixing vermicompost derived from green waste compost feedstock, with the original green waste compost in a ratio of 20:80 (v/v), gave optimal lettuce biomass production (Ali *et al.*, 2007). Magnolia (*Magnolia virginiana* L.) plants grown in pine bark or a commercial potting medium amended with 10% vermicompost (starter feedstock unspecified) had increased shoot and root growth compared to those in unamended media (Bachman and Davis, 2000). Similarly, the substitution of 10-20% of vermicompost into container media resulted in dramatic improvements in the germination and growth of flowering plants such as petunias, marigolds, bachelor's button, and poinsettia, as well as of popular bedding plants such as bell peppers and tomatoes (Subler *et al.*, 1998).

Likewise, peppers were grown in soilless bedding plant container media containing vermicomposts produced from food waste substituted at a range of concentrations (Arancon *et al.*, 2004). Peppers grown in the 40% vermicompost-amended medium yielded 45% more fruit, heavier fruit and had 17% more mean number of fruits compared to the unamended medium. However, yields of peppers grown in the 60% or 80% vermicompost media decreased significantly, which may have been due to high soluble salt concentrations, suboptimal aeration or phytotoxic effects.

In another example, tomatoes were grown in container media containing vermicomposts produced from pig manure substituted at a range of concentrations (Atiyeh *et al.*, 2000a). Tomato seeds sown in 20%, 30% or 40% vermicompost-amended media had significantly higher germination rates compared to those in the unamended medium. Seedlings grown in the 10% or 50% vermicompost-amended media had significantly higher dry weights, whilst those grown in 100% vermicompost-amended medium were significantly shorter, had fewer leaves and lower dry weights, compared to those in the unamended medium. Tomatoes grown in the 20% vermicompost-amended medium had the largest marketable yield, and those grown in the 10%, 20% or 40% vermicompost-amended media had a lower proportion of unmarketable fruit and produced more large-size fruits, compared to those in the unamended medium (Atiyeh *et al.*, 2000a).

Finally, tomato, pepper, lettuce and marigold seeds were sown in coir-perlite or peat-perlite-based media amended with 10% or 20% vermicompost (v/v) derived from pig manure or food wastes, or in a commercial medium (Atiyeh *et al.*, 2000b). Germination of all species in the unamended coir-perlite medium was equivalent to that in the commercial medium, however, germination of tomato, pepper and lettuce was significantly reduced in the unamended peat-perlite medium. Germination of these three species generally increased when the peat-perlite medium was amended with vermicompost, to be equivalent to that in the commercial medium. Addition of food waste vermicompost to the coir-perlite medium significantly reduced the germination of pepper seeds. Plant growth, in terms of shoot and root dry weight, for all species in media amended with 10% or 20% vermicompost was generally equivalent to or in some instances greater than that in the commercial medium. This indicates that low rates of vermicompost can be amended to growing media for acceptable growth of plants, but should be tested for its effect before widespread use (Atiyeh *et al.*, 2000b).

2.10.1 Animal Manures

Vermicomposts can be prepared from a variety of animal manures. Pig manure has been investigated as a feedstock for the production of vermicompost in a number of studies (Atiyeh *et al.*, 2000a; Atiyeh *et al.*, 2000b; Atiyeh *et al.*, 2000c; Atiyeh *et al.*, 2002a; Bachman and Metzger, 2008; McGinnis *et al.*, 2009). Low rates of such vermicompost amendment had beneficial effects on plant growth (Atiyeh *et al.*, 2000a; Atiyeh *et al.*, 2000b).

Marigold seedlings grown in media amended with 40% pig manure-derived vermicompost had significantly greater shoot weights and the greatest number of flower buds compared to those in the unamended medium (Atiyeh *et al.*, 2002a). Seedlings grown in the 100% vermicompost medium weighed significantly less, were significantly shorter and had a significantly lower number of flower buds and flowers that were significantly smaller compared to those in the unamended medium (Atiyeh *et al.*, 2002a). Improvements in early plant growth and productivity of bedding plants due to the substitution of low rates of vermicompost are economically valuable (Atiyeh *et al.*, 2002a).

Atiyeh *et al.* (2000c) found differences between specific vermicomposts and composts in their nutritional make-up, the structure and activity of their microbial communities and, consequently, their subsequent influence on plant growth. Vermicomposts from pig wastes consistently led to better plant growth of tomatoes and marigolds than other vermicompost (from food waste) and composts, with the exception of composted biosolids (which gave equivalent growth of marigolds and better growth of tomatoes) (Atiyeh *et al.*, 2000c).

In another study, the growth of four bedding plant species at various stages was evaluated after substrate amendment with pig manure-derived vermicompost (Bachman and Metzger, 2008). Seed germination was not affected by vermicompost substitution. At the seedling stage, tomatoes and marigolds grown in 10% or 20% pig manure-derived vermicompost media had significantly greater shoot and root weights, leaf areas and shoot:root ratios compared to those in the unamended medium; however there was little effect on pepper or cornflower growth. When tomato, marigold and cornflower seedlings were transplanted into media amended with vermicompost, there was greater plant growth compared to those in the unamended medium; and greatest plant growth when vermicompost was used in both the germination and the transplant media.

Proposed advantages of using vermicompost in containerized production is that it will provide sufficient nutrients for satisfactory plant growth to allow the reduction or elimination of conventional fertilizer inputs, and it will improve water use efficiency (McGinnis *et al.*, 2005; McGinnis *et al.*, 2009). Hibiscus (*Hibiscus moscheutos* L.) was grown in pine bark amended with 20% pig-manure derived vermicompost, and fertilized with different controlled release fertilizer treatments (N only; N and K; N, P and K) (McGinnis *et al.*, 2009). The vermicompost amendment provided equivalent or greater P, Ca, Mg, S, Fe, Zn, and Cu but less K for uptake by the plants compared to the industry standard medium (pine bark/sand/limestone/ micronutrients plus fertilizer). Also, plants grown in vermicompost amended media were larger (40% greater plant dry weight) and had 93% more flowers than those grown in the industry standard medium. These results indicate that certain substrate additives, including lime, sulphated micronutrients and P, can be eliminated if the growing medium is amended with vermicompost (McGinnis *et al.*, 2009). However, nutrients should be released gradually from the vermicompost for maximum nutrient use efficiency by the plants (McGinnis *et al.*, 2010). This was generally the case for several nutrients, with N, Ca, Mg and S being continuously released for 16 weeks (McGinnis *et al.*, 2010). Also, hibiscus grown in pine bark substrates amended with vermicompost had improved water use efficiency, using about 25% less water compared to the control, probably due to increased container capacity of the amended substrate. Plants grown in pine bark amended with 40% or 60% vermicompost had significantly greater root dry weights and, in 10% vermicompost had increased shoot dry weight, when compared to the unamended substrate (McGinnis *et al.*, 2005).

Other manure-based vermicomposts have been tested for their efficacy at improving plant growth. Chrysanthemum was grown in a peat-based medium amended with 25%, 50%, 75% or 100% (v/v) vermicompost produced from sheep, cattle, or horse manure (Hidalgo and Harkess, 2002). Physical and chemical properties of the amended media were analysed; the bulk density, pore space, and water holding capacity increased with increasing vermicompost amendment, while air space decreased. Vermicompost (100%) derived from sheep manure had the greatest water holding capacity and bulk density. Plants grown in any of the vermicompost-peat mixtures grew as well as or better than those in 100% vermicompost, the unamended peat-based medium or other commercial medium. The best substrate for chrysanthemum production was 50% sheep vermicompost-amended media; plants in this substrate had a greater growth index at harvest, increased foliar area, more flowers per pot, greater dry weight and fewer days for flower development than plants grown in other media. This may be due to sheep (like cattle) being ruminants, that can more completely digest cellulose, and they feed on shorter more tender grasses than cattle, which would probably digest more completely. Also, plants grown in 25% cattle vermicompost- or horse vermicompost-amended media were of marketable quality, and were of greater size with more flowers and earlier flowering than plants grown in either the unamended peat-based medium or the commercial medium (Hidalgo and Harkess, 2002). In a brief report of an earlier study testing the same media at the same amendment rates, larger poinsettia plants were produced in all substrates containing vermicompost at 50%, 75% or 100% compared to those in the unamended peat-based substrate or another industry standard medium (Hidalgo and Harkess, 2000). In particular, media amended with vermicompost derived from sheep manure enabled the reduction in the amount of fertilizer required to produce a commercial quality product.

In another study, the effect of sheep manure-derived vermicompost combined in different proportions with soil (1:1, 1:2, 1:3, 1:4 or 1:5 v/v) in plastic bags on the growth parameters of tomato were assessed under shade cloth (Gutiérrez-Miceli *et al.*, 2007). Plants grown in vermicompost-amended soil were significantly taller than those in unamended soil, 85 d after transplanting. Plants grown in vermicompost-amended soil at ratios of 1:1, 1:2 or 1:3 yielded significantly more tomatoes than those in unamended soil, 100 d after transplanting. Plants grown in vermicompost-amended soil had increased soluble and insoluble solids in tomato fruits compared to those from plants in unamended soil (Gutiérrez-Miceli *et al.*, 2007). Vermicomposts prepared from sheep manure, peat moss and cardboard, amended to soil in pots significantly increased dry shoot and root weights of lettuce and orchardgrass compared to those in the unamended medium (Hammermeister *et al.*, 2006). The vermicompost treatments supported the highest lettuce biomass production compared to other organic amendments (poultry meal, feather meal and alfalfa meal) and showed no phytoxicity. The vermicompost treatments could not sustain the productivity of the long-season orchardgrass and the authors suggested they are best suited to seedlings and short maturity crops (Hammermeister *et al.*, 2006). As both these studies were conducted using sheep manure-derived vermicompost amended to soil, whether such gains are also realized in soilless growing media remains to be seen.

Cattle manure is also a useful vermicompost feedstock. Marigolds were grown in a peat- or pine bark-based medium amended with 25%, 33%, 50% or 100% (v/v) vermicompost produced from cattle manure (Hidalgo *et al.*, 2006). Vermicompost addition increased the pH, the electrical conductivity, the air space and the water holding capacity of the media. Plants grown in 100% vermicompost had a greater growth index, increased stem diameter, better root growth, higher dry weight and more flowers, compared with plants grown in peat- or pine bark-based media or other commercial medium. Plants grown in all of the vermicompost mixtures (with peat or pine bark), except pine bark amended with 25% vermicompost, had a greater growth index compared with plants grown in peat- or pine bark-based media or other commercial medium. Plants grown in peat-based medium amended with 50% vermicompost had more flowers compared with plants grown in peat- or pine bark-based media or other commercial medium (Hidalgo *et al.*, 2006).

In another study utilizing vermicompost from cattle manure, chilli peppers were grown in perlite amended with 15%, 30%, 45% or 60% (v/v) vermicompost (López-Gómez *et al.*, 2012). Only the unamended medium received fertilizer solution. Growth and fruit parameters generally increased with increasing vermicompost rate. Plants grown in vermicompost-amended media, particularly at high rates of 30-60%, were significantly taller and had more flowers and fruit than those grown in the unamended medium. Total fruit weight was greatest in plants grown in perlite amended with 60% vermicompost, which was significantly greater than all other treatments (except 45% vermicompost), and was almost 2.5 times more than that in the unamended medium (López-Gómez *et al.*, 2012).

Vermicompost derived from de-watered dairy manure compost, thermogenic compost from the same source or a commercial turkey litter compost/blood meal-based amendment were added at 20% (v/v) to a peat-based transplant medium and tested for their effect on the germination and growth of tomato, the rhizosphere microorganisms and carryover effects to mature plants in the field (and compared to other plant-based amendments) over two years (Jack *et al.*, 2011). The germination of tomato seeds in these animal manure-based vermicompost/compost-amended media was equivalent to those in the unamended control. This was despite the electrical conductivity of the vermicompost/compost-amended media being greater than that of the unamended control, particularly for the vermicompost amendment (up to 2.45 dS/m), while the pH of the amended media was similar to that of the unamended control. Tomato transplants that grew in the greenhouse were then planted in the field. At the time of transplanting, transplants grown in vermicompost-amended media were significantly heavier than those in the unamended control, and those in the thermogenic compost- and the commercial compost-amended media, and this was significantly correlated to the high nitrate content of the vermicompost-amended media. In the field, at anthesis, plants originally grown in vermicompost-amended media were significantly heavier than those in the unamended control and equivalent to (year 1) or heavier than (year 2) those in the thermogenic compost- and commercial compost-amended media. Plants originally grown in the vermicompost-amended media had equivalent (year 1) or significantly greater (year 2) early fruit yields and marketable fruit yields than those in the unamended control. These yields were equivalent to or greater than those from thermogenic compost- and commercial compost-amended media (Jack *et al.*, 2011).

At anthesis, the bacterial community from composted manure-based-amended transplant media and in the resultant rhizosphere in the field was significantly different from plant-based-amended transplant media and unamended transplant media and their resultant rhizospheres, and these populations were likely to be responsible for enhanced plant growth in the field (Jack *et al.*, 2011). This effect of transplant media on bacterial communities in the field may be due to certain taxa getting a head start in the transplant medium and then multiplying at a higher rate than indigenous soil taxa (Jack *et al.*, 2011). Similarly, plant growth promoting rhizobacteria applied to transplant media can persist in the rhizosphere after transplantation to the field (Kokalis-Burelle *et al.*, 2006). By harvest, only the vermicompost treatment and the unamended control had unique bacterial profiles, while all others were indistinguishable (Jack *et al.*, 2011). With vermicompost/compost-based amendments, there may be a trade-off between high germination percent and longer term plant growth and productivity, whereas tomatoes grown in plant-based amendments may have decreased germination but higher (sometimes significantly) biomass (Hammermeister *et al.*, 2006; Jack *et al.*, 2011).

Kannangara *et al.* (2000) also compared the effect of vermicompost and thermogenic compost from the same source. Vermicompost and compost were prepared from separated dairy solids and compared to a compost prepared from vegetable refuse using aerobic digestion, for their ability to suppress root and stem rot caused by the soil-borne fungal pathogen *F. oxysporum* f. sp. *radicis-cucumerinum* on cucumber. Cucumber plants grown in unamended media inoculated with the pathogen were stunted and had less flowers. Potting media amended with thermogenic compost suppressed these symptoms, while amendment with vermicompost or compost from aerobically digested vegetable refuse had no effect. Interestingly, all three composts had reduced the populations of the pathogen by the end of the experiment (10 weeks). High populations of fluorescent bacteria in the root zone of plants growing in potting media amended with thermogenic compost may play a role in disease suppression (Kannangara *et al.*, 2000).

Besides improving plant growth parameters, cattle manure-based vermicompost can also provide disease suppression. Tomatoes were grown in various potting media amended with cattle manure-derived vermicompost that had been inoculated with *F. oxysporum* f. sp. *lycopersici* (Szczech, 1999). Vermicompost amendments significantly inhibited the infection of tomato plants, and inhibition increased with increasing amendment rates. The total number of microorganisms and the numbers of antagonistic bacteria and fungi were significantly greater in vermicompost-amended media than in the unamended peat substrate. Vermicompost also stimulated tomato plant growth, significantly increasing the fresh weights of plants. The suppressive ability of the vermicompost can be attributed to the high microbial activity, likely due to both competition and antagonism. The higher pH and high electrical conductivity of vermicompost-amended media may have also contributed to disease suppression. In an earlier study, media amended with the same vermicompost suppressed *F. oxysporum* f. sp. *lycopersici* and *P. nicotianae* var. *nicotianae*, but not the root knot nematode *Meloidogyne hapla* on tomato, and suppressed *Plasmodiophora brassicae* Woronin, but not the nematode *Heterodera* *schachtii* Schmidt. on cabbage. Again, suppression generally increased with increasing rate of amendment (Szczech *et al.*, 1993).

Gerbera grown in media amended with 20% vermicompost derived from cattle manure had lower incidence of root and crown rot, reduced disease progress and improved growth compared to those in unamended media (Rodriguez-Navarro *et al.*, 2000). Plants grown in vermicompost-amended media were significantly taller; had significantly increased chlorophyll content; had more floral peduncles; had longer and larger floral peduncles, had more inflorescences; and had larger inflorescences compared to those in the unamended media. However, gerbera grown in media amended with 40% vermicompost did not perform well (Rodriguez-Navarro *et al.*, 2000).

The effect of rabbit-manure derived vermicompost, incorporated as a solid substrate into the potting medium, or applied as a water extract, on the germination and early development of six progeny of maritime pine was studied (Lazcano *et al.*, 2010). Germination of maritime pine seeds sown in vermicompost extract-amended potting media significantly increased, by 16%, compared to those in unamended media. Solid vermicompost addition to the medium improved germination, though not significantly compared to the control. Water soluble nutrients and organic compounds such as humic substances and plant growth regulators, in the vermicompost extract may be responsible for the improved germination. Vermicompost addition, solid or liquid, to the potting media significantly accelerated the maturation of seedlings in three of the six progenies studied. The application of solid or water extract vermicompost significantly reduced pine seedling biomass, particularly root biomass, but increased nutrient content, compared to those in unamended media,. The authors postulated that the higher germination rate and accelerated development would translate into improved plant vigour in later growth stages and post-transplant success (Lazcano *et al.*, 2010).

The effect of duck waste-derived vermicompost incorporated into peat-based media at rates ranging from 2% to 20% (v/v) on the germination and growth of tomatoes, lettuce and peppers was tested (Wilson and Carlile, 1989). The chemical parameters of vermicompost-amended media, including pH, electrical conductivity, nitrate-nitrogen and potassium levels, increased with increasing vermicompost amendment. As a result, vermicompost amendments greater than 10% had detrimentally high electrical conductivity. All species generally germinated well in vermicompost-amended media, but above 10% vermicompost, seedling development was retarded, particularly for pepper. Optimal growth in vermicompost-amended media was at the following rates: 8-10% for tomatoes and 8% for lettuce, which were better than that in the unamended medium, and 6% for pepper, which was comparable to growth in the unamended medium. However, the statistical design or analysis was not described in this study, so the results should be used as a guide only (Wilson and Carlile, 1989).

Vermicompost derived from unspecified abbatoir waste, was tested as an amendment at 50% to pine bark for the growth of three tree species, *Acacia mearnsii* De Wild., *P. patula* and *E. grandis* in forest nurseries (Donald and Visser, 1989). *E. grandis* grew and survived equally well in either vermicompost-amended pine bark or the pure pine bark. *A. mearnsii* and *P. patula* grew and survived best in pure pine bark only, as they could not tolerate the high pH and the high sodium content of the vermicompost-amended media. Leaching of the vermicompost five times removed most of the high salt content (including sodium), making it more suitable as a growing media amendment.

Certain chemical properties of vermicomposts produced from animal manures, including high pH and high soluble salt levels, require monitoring, as well as any pathogens of concern to human health. The feedstock can influence the response of plants and the benefits from vermicompost amendment may only be worthwhile for short term crops.

2.10.2 Plant Residues

Plant residues can also be used as a starter feedstock for vermicomposts. Seeds of Amashito peppers were sown in *Panicum* sp. grass:cocoa husks (1:1) vermicompost, and compared to those grown in dry cocoa husks, or cocoa husks with cow manure in germination boxes outdoors under tropical conditions (Huerta *et al.*, 2010). There was no significant difference in the rate of germination, but plants growing in vermicompost were significantly taller, heavier, had more leaves per plant and produced more fruit compared to those grown in the other two media.

Vermicompost, derived from a mixture of cotton waste and food waste, was substituted for the peat component of a commercial medium (70% peat, 20% green waste compost and 10% organic fertilizer) at 20%, 40%, 60%, 80% or 100% (v/v) and tested for its effect on the germination and growth of three tomato varieties, and carryover effects to tomato yields and fruit quality in the field (Zaller, 2007a; Zaller, 2007b). Seedling emergence was greatest in 20% vermicompost-amended media for one variety, compared to that in the unamended medium, but for the other two varieties, no vermicompost-amended media improved germination compared to that in the unamended medium (Zaller, 2007a; Zaller, 2007b). Biomass allocation differed between varieties and was significantly influenced by vermicompost amendment (Zaller, 2007a; Zaller, 2007b). In two varieties, 100% vermicompost amendment had significantly greater root:shoot ratio compared to that in all other media, indicating this level of amendment stimulated root growth in these varieties (Zaller, 2007a). Marketable yield was not influenced by vermicompost amendment, but fruit quality, in terms of parameters such as peel firmness and fructose:glucose ratio, was affected by vermicompost amendment, depending on the variety (Zaller, 2007a; Zaller, 2007b). No one amendment level improved all aspects of tomato growth, but also there were no detrimental effects due to vermicompost amendment (Zaller, 2007a; Zaller, 2007b).

There is a lack of studies on vermicomposts derived from plant residues, so there is much scope for research in this area.

2.10.3 Municipal and Industrial Waste Material

Vermicomposts can be produced from municipal and industrial waste materials. Municipal solid waste was composted, undergoing the thermophilic stage, after which it was either matured in a pile to form compost, or was inoculated with earthworms and matured to form vermicompost (Tognetti *et al.*, 2005). Another vermicompost was produced (that did not undergo a prior thermophilic stage) using carefully separated household organic refuse fed daily to earthworms. A degraded volcanic soil was then amended at 2% or 4% (w/w) of vermicompost or compost. Comparing the two municipal products, the vermicompost had significantly higher nutrient concentrations than the compost, and, when amended to soil, the vermicompost also had larger microbial populations, more microbial activity, and produced greater ryegrass yields compared to compost. However, while the non-thermophilic vermicompost had similar or higher nutrient concentrations compared to the municipal compost, it had lower soil microbial biomass and activity, and significantly lower ryegrass yields. This suggests that no generalization can be made regarding the efficacy (in terms of improved plant growth) of vermicomposts compared to composts, as the product quality depends both on the starter feedstock and the production processes (Tognetti *et al.*, 2005). It should be noted that this study was conducted using soil, rather than soilless growing media. Alves and Passoni (1997) also found that municipal solid waste could be used as a starter feedstock for the production of vermicompost and compost, both of which when amended at 33%, 66% or even 100%, improved the germination and growth of the tree species *Licania tomentosa* (Benth).

Tomati *et al.* (1993) also prepared vermicompost and compost from the same source, a 1:1 mixture of urban wastes and urban sewage sludge. They examined their effect on plant propagation and pot growth of several ornamental species, but did not present the data for the compost amendments, stating that composts were generally less effective. They did present data for vermicompost amendment, showing that, in most species tested, it significantly reduced the time to root initiation, and significantly increased root length and root biomass, compared to the unamended controls. Also, 50% vermicompost amendment enhanced rooting percentage of stem cuttings of some species, while 100% vermicompost inhibited rooting percentage of stem cuttings of some species. As a potting medium amendment, 50% vermicompost supported early growth of chrysanthemum. Upon transplantation to larger pots, 50% vermicompost-amended media required the addition of supplemental fertilizer to have equivalent growth and quality to the control, though the amount of fertilizer required was less than that of the controls (Tomati *et al.*, 1993).

Marigolds were grown in soil (in pots) amended with 10%, 20%, 30% or 40% vermicompost derived from sugar mill wastewater treatment plant sludge spiked with horse dung or vermicompost derived from cattle dung (Sangwan *et al.*, 2010). Marigolds grown in vermicompost-amended soil were taller, produced more buds and flowers, produced buds and flowers quicker, produced larger flowers, had greater fresh shoot and root weights, and had greater chlorophyll contents than those grown in unamended soil. The number of buds and flowers was generally greater in plants grown in soil amended with wastewater sludge vermicompost than those in soil amended with cattle dung vermicompost, but the vermicomposts generally had similar effects on most parameters. Overall, there was no consistent linear relationship between increasing vermicompost rate and any of the growth parameters examined (Sangwan *et al.*, 2010).

Petunia seeds were sown in a soilless growing medium amended with vermicompost produced from food wastes, paper wastes or cattle manure, at 10% increments from 10% to 100% (Arancon *et al.*, 2008). Food waste or paper waste vermicompost amendment increased germination significantly compared to the unamended control, while cattle manure vermicompost generally gave equivalent germination. Amendment with 10–100% of either food waste or paper waste vermicomposts, or 10–60% cattle manure vermicompost significantly increased shoot dry weights compared to the unamended control. Amendment with 20–40% food waste vermicompost, 40% paper waste vermicompost, or 20-40% cattle manure vermicompost significantly increased flower numbers compared to the unamended control. Greater rates of shoot and root growth due to all of the vermicomposts were much greater at lower rates of vermicompost amendment than at higher rates. The authors speculated that improved physical structure of the growing medium, enhanced populations of beneficial microorganisms, and the availability of microbial-produced substances such as hormones and humates likely contributed to the increased growth and flowering parameters (Arancon *et al.*, 2008). Faster germination, growth and flowering of petunias would translate into a shorter retention time in the greenhouse, which would be economically attractive.

Vermicomposts are also effective at suppressing mite and insect pests. Vermicomposts, produced from food waste and substituted into a soilless growing medium at 20% or 40%, were able to suppress populations of mites and insects on cucumbers, peppers, tomatoes, cabbages, bush beans and eggplants in the greenhouse (Arancon *et al.*, 2005b; Arancon *et al.*, 2007b). Vermicompost suppressed aphid and mealybug populations on peppers, decreasing significantly the losses of shoot dry weights due to the insect infestations. Similarly, vermicompost suppressed mealybugs on tomatoes and cucumbers, and cabbage white caterpillar and aphids on cabbages, decreasing significantly the losses of shoot dry weights due to the insect infestations (Arancon *et al.*, 2005b; Arancon *et al.*, 2007b). Vermicompost decreased significantly damage from spider mites on bush beans and eggplants. The arthropod populations, despite their mode of action as either sucking or chewing, were suppressed by the vermicomposts. The authors proposed mechanisms of action of the vermicomposts may have included pest preference for different forms of nitrogen available in the leaf tissues, providing some essential nutrients to affect the physiology and/or morphology of the plants, inducing the plant's resistance to the pests, or by making them less palatable to the pest via the production of phenols (Arancon *et al.*, 2005b; Arancon *et al.*, 2007b).

The effect on the preference and performance of a generalist (*Helicoverpa zea* Boddie) and specialist (*Pieris rapae* L.) lepidopterous cabbage pest when exposed to cabbage plants grown in potting mix amended with 20%, 40% or 60% food-based vermicompost was studied (Little and Cardoza, 2011). Also, the response of a generalist parasitoid (*Cotesia marginiventris* Cresson) to *H. zea* feeding on plants grown in vermicompost-amended potting mix was tested. *H. zea* larvae generally fed equally, regardless of potting mix amendment, but if offered only young leaf tissue, preferred to feed on leaf tissue from plants grown in 60% vermicompost amended media, compared to those grown in unamended media. *P. rapae* larvae preferentially ate younger leaf tissue, regardless of potting mix amendment. *P. rapae* adults oviposited significantly more on plants grown in 60% vermicompost-amended potting mix, which may be due to larger, more nutritious leaves on plants in this treatment. However, survival of *P. rapae* was significantly decreased on vermicompost-amended potting mix, while there was no effect on the survival and development of *H. zea* among treatments. There was no effect on the attraction or the development of the parasitoid *C. marginiventris* due to vermicompost amendment. Therefore, vermicompost amendments conferred resistance against *P. rapae* by reducing the performance of the larvae on cabbage (Little and Cardoza, 2011).

Like composts, there are some issues with respect to the physical and chemical properties of the amended media to be addressed, but there are many benefits to be gained from the inclusion of vermicomposts as a low rate amendment. The cost of vermicomposts is highly variable depending on the feedstock, but they are (adjusted to current prices) approximately $265-$1050/t (Quilty and Cattle, 2011).

2.10.4 Vermicompost Liquid Extracts

Worm-bed leachate (WBL) is liquid that has been passed through vermicompost and as a result, contains large amounts of plant nutrients and microorganisms (Gutiérrez-Miceli *et al.*, 2008; Gutiérrez-Miceli *et al.*, 2011). It is also known as liquid humus, since it has high levels of humic and fulvic acids, which are known to enhance plant development and stimulate nutrient uptake (Arancon *et al.*, 2005a; Atiyeh *et al.*, 2002b; Gutiérrez-Miceli *et al.*, 2011; Ortega and Fernández, 2007).

Vermicompost tea is made using the standard production method of other compost teas, but using vermicompost as the starting material. The proportion of vermicompost in the water can range from 0.5% to 33% and can be soaked in the water for as little as 12 hours or as long as 3 weeks, before draining off the liquid for use (Arancon *et al.*, 2007a; Edwards *et al.*, 2006). Vermicompost tea may be extracted under aerated or non-aerated conditions (Pant *et al.*, 2009). It has been suggested that vermicompost teas produced with aeration are more stable and more effective than those produced without aeration (Edwards *et al.*, 2006); however, this was preliminary work reported in a grower's magazine not a peer-reviewed journal, and was not supported by the work of Scheuerell and Mahaffee (2006). Aerated teas reportedly have significantly higher pH, nitrate-N, dehydrogenase activity and microbial biomass, likely due to dissolved oxygen promoting the growth of beneficial microbes (Arancon *et al.*, 2007a). However, Pant *et al.* (2011; 2009) found that there was no significant differences between aerated and non-aerated vermicompost teas in terms of pH, electrical conductivity, total nitrogen, nitrate-N or even dissolved oxygen levels. However, compared to aerated and non-aerated teas, aerated vermicompost tea augmented with supplemental nutrients had significantly higher pH (but equivalent to the water control) and electrical conductivity, higher or equivalent total nitrogen and nitrate-N, and lower dissolved oxygen levels (due to increased microbial activity), Also, these authors found that, in general, the extraction method did not affect plant growth, plant nutrient content, microbial population and activity, and that vermicompost teas, whether non-aerated, aerated, or aerated and augmented with supplemental nutrients (humic acids and kelp extract), similarly improved production of pak choi (*Brassica rapa* L.) plants. Supplemental nutrients added before extraction, such as humic extracts, kelp extract, molasses, yeast extract or various algal powders, are intended to increase microbial populations and enhance their positive activity (Arancon *et al.*, 2007a; Pant *et al.*, 2009).

Edwards *et al.* (2006) reported on trials where aerated cattle waste vermicompost tea was applied at 0.5%, 1%, 2%, 4%, 8% or 10% to tomato plants in the greenhouse at transplanting, then twice weekly for 8 weeks. All concentrations increased seed germination and plant growth over 0% tea application (Edwards *et al.*, 2006), with parameters generally increasing with increasing rate of application. When applied at 5%, 10%, 20% or 40%, the same vermicompost tea suppressed *Verticillium* wilt in tomatoes. However, given that the experimental design and analysis was not described and that these results were published in a non-peer reviewed, popular magazine, they can only be regarded as an interesting prospect.

Aerated chicken manure vermicompost tea was applied weekly for four weeks at 1%, 3%, 5% or 10% to pak choi plants (Pant *et al.*, 2012a). Plant growth (biomass, height, leaf area, root length and root surface area) was significantly increased in plants treated with vermicompost tea compared to plants treated with aerated water only, with growth increasing with increasing rate. Vermicompost tea applications also increased the plant tissue content of nitrogen, total carotenoids and total glucosinolates. The greatest plant growth response was with 5% and 10% vermicompost tea. The authors implied these parameters were affected by vermicompost:water ratios used for extraction, but more correctly, it was the application rate, as there was only one extraction ratio used, 1:10 v/v, then referred to as 10% tea, which they subsequently diluted to create 5%, 3% and 1% tea (Pant *et al.*, 2012a).

In a later study, tomatoes and cucumbers were grown in soilless growing media drenched weekly with 5%, 10% or 20% supermarket food waste vermicompost tea and exposed to green peach aphid (*Myzus persicae* Sulz.), citrus mealybug (*Planococcus citri* Risso) and two-spotted spider mite (*Tetranychus urticae* Koch.) (Edwards *et al.*, 2010). All of the vermicompost teas at all rates significantly suppressed establishment and reproduction rate of all the insect pests. Increasing the rate of vermicompost tea, increased the rate of pest suppression, in the form of reduced numbers on the plants and/or reduced damage ratings to plants and at higher rates, pest mortality. The suggested mechanism of pest suppression was a change in the pests' feeding responses to the plants absorbing and accumulating soluble phenolic materials from the vermicompost tea, making the plants much less attractive, interfering with reproduction patterns and survival (Edwards *et al.*, 2010).

Three vermicompost teas were compared to two compost teas for their effect on the growth of pak choi (Pant *et al.*, 2012b). Each of the three vermicompost teas were produced from food waste vermicompost, chicken manure-based vermicompost (aged) or chicken manure-based vermicompost (fresh); each of the two compost teas were produced from chicken manure-based thermogenic compost or green waste thermogenic compost. The teas were all aerated and applied weekly for 4 weeks. The greatest increases in growth and nutrient content of pak choi was in plants treated with aged chicken manure-based vermicompost tea, chicken manure-based thermogenic compost tea or food waste vermicompost tea, and were mostly associated with mineral nitrogen and gibberellins present in these teas. There were significantly more active microbial populations in the vermicompost teas, particularly the food waste vermicompost tea, compared to thermogenic compost teas. The electrical conductivity, pH, humic acid concentration, total N, nitrate N and other parameters of the teas were significantly affected by the compost type. In addition, the nutrient extraction efficiency was significantly affected by the type of compost, with the extraction efficiency of total N and soluble N significantly greater in vermicompost teas than thermogenic compost teas. In fact, soluble N extraction efficiencies exceeded 100% in vermicompost teas, indicating that organically bound N in the vermicompost was converted into a form accessible by the plant (Pant *et al.*, 2012b).

Vermicompost teas, like compost teas, have inherent variability being derived from a variety of feedstocks, making it difficult to predict plant response for all production systems. Similarly, it is important to tailor vermicompost tea products to specific production systems and their particular pathosystems/pests. Further work on integrating vermicompost tea applications with other inputs would be worthwhile. Vermicompost teas may find application in a production nursery environment. Quilty and Cattle (2011) reported the cost for vermicompost tea (adjusted to current prices) at $1-$21/L. However, like compost teas, the cost is comprised of the cost of the vermicompost, and depending on aeration, costs for non-aerated teas are negligible, while costs for aerated teas can range from $250-$2000 for the brewer. There may also be extras such as starter ingredients.

2.11 Humic Extracts

Naturally occurring humic substances are the most plentiful and significant constituents of soil organic matter. Traditionally, they are separated into three groups based on their solubility in alkali and acid: fulvic acids are soluble at any pH, humic acids (the major fraction which make up about 20% of the total organic matter) are soluble at pH>2, and humins are insoluble at any pH (Giannouli *et al.*, 2009). However, it has been suggested recently their separation on the basis of solubility may simply be an artefact of laboratory analysis and the existence of these fractions in soil is being questioned (Billingham, 2012; Jenkins, 2012). In nature, humic substances are very complex macromolecules, highly chemically reactive but resistant to microbial breakdown, and their formation, structure and function are not well understood. Commercial humic products (often referred to as ‘liquid humus’) are most commonly sourced from brown coals (particularly leonardite), but also from peats and organic residues such as composts, and are extracted by treatment with alkali and acid (Billingham, 2012; Ortega and Fernández, 2007). Coals and peats are legitimate sources of humic substances; however, the classification of extracts from organic residues as true humic substances is questionable. In Australia, there are about 28 different companies selling more than 200 humic products (Billingham, 2012). In the following section, the term humic extracts will be used in an attempt to avoid the argument as to whether commercial humic products actually contain humic substances.

Humic extracts can improve plant growth by stimulating germination, enhancing root initiation and growth, and increasing shoot growth by improving nutrient uptake (Chen and Aviad, 1990). For example, humic extracts (at an optimal concentration of 1280 mg/L) increased the uptake of certain nutrients and induced dry matter production of shoots and roots of tomatoes in nutrient culture (David *et al.*, 1994). Humic extracts accelerate plant uptake of nitrogen and nitrate and their metabolism; and enhance chlorophyll content and mesophyll conductance, resulting in an increase in photosynthetic activity; leading to improved yields (Haghighi *et al.*, 2012). These effects can be direct, by increasing the permeability of biological membranes, and acting as hormone-like substances (cytokinins have been identified in humic extracts (Zhang and Ervin, 2004)); or indirect, by affecting the metabolism of soil microbes, altering the availability of soil nutrients and modifying the physical structure of the soil (Cacco and Dell'Agnola, 1984; Chen and Aviad, 1990; García-Mina *et al.*, 2004; Nardi *et al.*, 2002; Trevisan *et al.*, 2010).

Increasing doses of humic extracts were applied at different time periods to sewage sludge-amended soil in pots before transplantation of lettuce seedlings (Tüfenkçi *et al.*, 2006). Increasing doses of humic extracts significantly improved various plant growth parameters including plant and neck diameter, plant height and number of leaves compared to the untreated control. Increasing doses of humic extracts also increased the nutrient content and decreased the heavy metal content of lettuces compared to the untreated control. The earlier the application of humic extracts, and the higher the rate, caused maximal increases in plant growth and nutrient contents of lettuces which have a short growing period (Tüfenkçi *et al.*, 2006). Soil was used in this study; whether these findings apply to soilless growing media is unknown.

Different levels of humic extracts (a commercial solution, source not provided), 1%, 2% or 4% (v/v) were applied once or twice to woody cuttings of lantana growing in pots containing a peat-based substrate (Costa *et al.*, 2008). Analyses indicated that the humic extracts contained 73% humic acid and 27% fulvic acid. Humic extract application significantly increased plant growth and reduced the time to flowering, compared to that of untreated controls.

Humic extracts can also be applied to plant foliage for improved plant growth. Foliar application of humic extracts to papaya seedlings increased plant height, stem diameter, shoot and root dry weight, leaf chlorophyll, root length and root volume compared to the unsprayed control (Cavalcante *et al.*, 2011). Tomato plants were treated with a foliar spray of a humic extracts-based product (which also included micronutrients and alpha-keto acids and was combined with a potassium salt of phosphorous acid); marketed as a commercial systemic resistance/plant growth promotion inducer (Vavrina *et al.*, 2004). The humic extracts-based product significantly increased stem diameter, leaf area, dry shoot weight and true leaf number (but not stem length or dry root weight) in some trials compared to the untreated control. In only two of six trials, the humic extracts-based product significantly reduced the severity of bacterial spot (caused by *X. campestris* pv. *vesicatoria*) in inoculated tomato plants. Plants growing in soil infested with root knot nematode (*M. incognita*) and treated with the humic extracts-based product had increased shoot weight and length, stem diameter but parameters of root disease were equivalent of that in the untreated plants. Timing of treatment application with respect to the physiological age and status of the plant requires better understanding to improve the consistency of this and other systemic resistance/plant growth promotion inducing products (Vavrina *et al.*, 2004).

However, there have also been reports of humic extracts being generally ineffective in increasing vegetable crop production or nutrient uptake (Hartz and Bottoms, 2010). In a greenhouse trial, lettuce was grown in four field soils of low P availability amended with one of five commercial humic extracts at typical commercial rates, with or without fertilizer. Humic extracts had no significant effect on seedling emergence, rate of emergence, phosphorus uptake, and only increased plant dry weight in one amended soil (only when combined with fertilizer) compared to the unamended control. Also, without fertilizer added, humic extracts had no effect on microbial respiration in the amended soil (Hartz and Bottoms, 2010).

Humic extracts can also have adverse effects on plant development, partly due to phytotoxic aromatic compounds, so both the source and the rate of humic extracts should be assessed carefully (de Santiago *et al.*, 2010).

2.11.1 From Composted Organic Matter

Humic extracts can also be derived from thermogenically composted organic matter, a more sustainable source than leonardite, though their legitimacy has already been queried (Billingham, 2012). Humic extracts were derived from compost stabilized green wastes and applied as an aqueous solution at different rates to soil in pots in the glasshouse. Chicory (*Cichorium intybus* L.) seeds were then sown into these pots (Valdrighi *et al.*, 1996). Humic extracts applied at ≥1000 mg/kg significantly increased the fresh and dry weights of chicory plants compared to the untreated control, with growth increasing with increasing rate. They also caused significant increases in the numbers of bacterial heterotrophs and autotrophic nitrifiers. These effects were likely due to surfactant-like properties of the humic extracts, improving the permeability of the cell membrane to nutrients, but the effects in soilless growing media was not studied.

Humic extracts from composted sewage sludge were applied at very low rates (200 or 500 mg carbon/L of commercial growing medium) and assessed for their effect on various growth parameters of peppers (Azcona *et al.*, 2011). In the vegetative stage, plant dry-matter production, plant height, leaf area, net photosynthesis and leaf stomatal conductance were significantly increased by the presence of humic extracts in the media compared to these parameters in unamended media. Plants grown in humic extracts-amended media also formed flowers and fruits significantly earlier than those in unamended media. However, although this improved growth was not maintained through to full maturity of the plant, it could still be beneficial as it may translate into enhanced establishment and survival after transplantation (Azcona *et al.*, 2011).

2.11.2 From Vermicomposted Organic Matter

Similarly to thermogenic composts, vermicomposts can be a source of humic extracts, though their definition as true humic substances is questionable (Billingham, 2012). Humic extracts from vermicompost derived from cattle manure, food- or paper-waste, incorporated at very low rates (250 or 500 mg dry humic extracts per kg of a commercial growing medium) were assessed for their effect on various growth parameters of peppers, marigolds, strawberries and tomatoes (Arancon *et al.*, 2003; Arancon *et al.*, 2006; Edwards *et al.*, 2006). Root growth of peppers, marigolds, strawberries and tomatoes was increased significantly by humic extracts derived from at least one of the different vermicomposts (Arancon *et al.*, 2003; Arancon *et al.*, 2006). Leaf area, plant height and above ground dry matter were improved, though not significantly compared to the untreated controls (Arancon *et al.*, 2003). The number of strawberry fruits also increased significantly (Arancon *et al.*, 2006). Pepper plants produced significantly more fruits and flowers when treated with humic extracts from food-waste vermicompost, than those treated with commercially-produced humic extracts (Arancon *et al.*, 2006). Other studies also found that when vermicompost-derived humic extracts were applied at the same rate as commercial humic extracts, those from vermicompost resulted in similar or better plant growth (Edwards *et al.*, 2006; Ortega and Fernández, 2007). In addition, as remarked for thermogenic compost, the production of earthworm-based humic extracts is more sustainable as it is made from a renewable resource (Ortega and Fernández, 2007).

Humic extracts sourced from vermicompost produced from pig manure or food-waste and incorporated into a soilless growing medium or vermiculite were assessed for their effect on various growth parameters of cucumber and tomato plants (Atiyeh *et al.*, 2002b). Growing media amended with either of the vermicompost-derived humic extracts increased the growth parameters of tomato and cucumber plants significantly, including plant heights, leaf areas, shoot and root dry weights compared to unamended media. Plant growth increased with increasing concentrations of humic extracts up to a certain proportion, which differed according to the plant species, the vermicompost source, and the growing medium. Plants grown in media amended with 50–500 mg/kg humic extracts generally had increased growth, but growth generally decreased significantly when the humic extracts exceeded 500–1000 mg/kg. The authors proposed that increased plant growth was likely due to hormone-like activity of the vermicompost-derived humic extracts, or due to plant growth hormones adsorbed onto the humic extracts (Atiyeh *et al.*, 2002b).

2.11.3 From Coal

Leonardite is an oxidized form of lignite coal which is mostly comprised of humic substances (O'Donnell, 1973). The auxin-like effects of leonardite and its extracts promoted root initiation and growth in geranium cuttings (O'Donnell, 1973). The addition of leonardite to growing media could allow the use of fertilizers to be reduced whilst increasing or maintaining the production quality of ornamental and other nursery-grown plants (Dudley *et al.*, 2004). Zinnia and marigold seedlings and transplants responded favourably to up to 6.25% leonardite-amended media when combined with fertilizer application. The improved growth was potentially due to an increased cation exchange capacity of the medium, the presence of water-extractable fulvic acids, or otherwise enhancing nutrient uptake (Dudley *et al.*, 2004). Similarly, tomato seedlings grown in sand amended with just ~1.5% (v/v) leonardite had greater root and shoot growth compared with plants produced with fertilizer alone (Pertuit Jr *et al.*, 2001). Increasing leonardite amendment rates from 0% to 25% increased plant growth, however, 50% leonardite amendment inhibited growth. Adding 33% leonardite and a complete fertilizer increased plant height by 40%, total leaf area by 160%, shoot fresh weight by 134%, root fresh weight by 82%, shoot dry weight by 133%, and root dry weight by 400% (Pertuit Jr *et al.*, 2001). Likewise, Reynolds *et al.* (1995) found that increasing leonardite amendment rates increased growth of grapevines (*Vitis vinifera* L.) in pots in the glasshouse, but high levels inhibited growth. Ortega and Fernández (2007) suggested that recommended rates of commercial humic extracts should be reviewed since they found that increased plant benefits resulted from application rates 15 to 26 times higher than recommended rates.

Information on the effect of humic extracts to suppress disease is lacking and further research is warranted. The interaction of humic extracts with other organic amendments would be of interest. More basic research is required to ascertain the identity of humic extracts from composted and vermicomposted organic matter. The low application rates are attractive, and the cost for humic extracts (adjusted to current prices) are \$4-\$26/L (liquid) or \$42-\$840/t (solid) (Quilty and Cattle, 2011).

2.12 Uncomposted Plant Parts

Other amendments based on uncomposted plant parts have potential as organic amendments for containerized plant production. Koller *et al.* (2004) generally advised mixing plant-based organic amendments with the growing medium at least two weeks before sowing to prevent phytotoxicity and growth inhibition. These authors tested ten plant-based products and the pre-mixing step was more important for some than others. Whether this pre-mixing is necessary should be tested in individual production systems.

2.12.1 Alfalfa Meal

Alfalfa meal has been studied as an organic amendment for plant production. While it can reduce initial growth parameters (such as germination), it generally has positive effects on plant growth. When alfalfa meal was added at 5% or 20% (v/v) to a peat-based transplant medium, the germination of tomato seeds significantly decreased compared to those in the unamended control, and this was likely due to the very high electrical conductivity of the alfalfa-amended media (4.02 dS/m and 10.50 dS/m for 5% and 20% amendments, respectively), which resulted from high potassium levels (Jack *et al.*, 2011). Tomato transplants that grew in the greenhouse were then planted in the field. At the time of transplanting, there was no significant difference in the dry weight biomass between transplants grown in 20% alfalfa meal amended media and the unamended control; however, transplants grown in 5% alfalfa meal-amended media were significantly heavier than those in the unamended control and comparable to those grown in commercial composted manure-amended media, despite the high electrical conductivity levels. This effect was then carried over to the field, as at anthesis, plants originally grown in 5% or 20% alfalfa meal-amended media were significantly heavier than those in the unamended control and equivalent to those in commercial composted manure-amended media (Jack *et al.*, 2011). There was no significant difference in the early fruit yield between plants originally grown in 20% alfalfa meal-amended media and the unamended control; however, plants originally grown in 5% alfalfa meal-amended media had significantly greater early fruit yields than those in the unamended control and equivalent to those in commercial composted manure-amended media. Plants originally grown in 5% and 20% alfalfa meal-amended media had significantly greater marketable fruit yields than those in the unamended control and equivalent to those in commercial composted manure-amended media. The bacterial community from alfalfa meal- (and other plant-based-) amended transplant media and in the resultant rhizosphere in the field was significantly different from that in composted manure-based-amended transplant media and unamended transplant media and their resultant rhizospheres, and these populations were likely to be responsible for enhanced plant growth in the field (Jack *et al.*, 2011).

In a pot experiment, alfalfa meal added to soil showed no phytotoxicity to lettuce or orchardgrass, and at high rates (equivalent to 400 and 800 kg total N/ha) significantly increased shoot and root biomass of lettuce and shoot biomass of orchardgrass compared to those in the standard medium (Hammermeister *et al.*, 2006). Its use in soilless growing media requires further evaluation.

Another alfalfa-based organic amendment, a commercial product comprised of alfalfa, meat meal, molasses and sulfate of potash, was added at 0.6%, 1.2%, 1.8% or 2.4%

to a peat-compost medium and incubated for 0, 1, 2, 3 or 4 weeks (Nair *et al.*, 2011). While germination of tomato seeds was highest in unamended media, this medium caused severe nutrient deficiencies in plants, suppressing seedling growth. Germination of tomato seeds in amended media (incubated for 1, 2 or 3 weeks) was slightly lower, but seedlings had increased stem diameter and chlorophyll content, and were taller and heavier, as long as the amended media were incubated for at least 1 week. Alfalfa-based amendment added to the medium at 0.6% or 1.2% produced transplants with commercially acceptable parameters at a reasonable estimated cost (at least in the USA). Addition of the alfalfa-based amendment increased the pH and the electrical conductivity of the media, but for the lower rates, were still acceptable. Incubation of the amendment with the growing medium 2 weeks before seeding allowed mineralization and release of nutrients and avoided seed damage and any allelopathic effects (Koller *et al.*, 2004; Nair *et al.*, 2011).

The testing of alfalfa meal as an organic amendment in containerized production is very limited and work on a wider range of species would aid in judging its potential. Issues such as high electrical conductivity, high pH and potential phytotoxicity require monitoring.

2.12.2 Coir

Coir fibre or dust (coconut mesocarp) is used as an amendment and as a medium replacement for traditional substrates for greenhouse and nursery crop production (Abad *et al.*, 2002; Handreck and Black, 2002; Islam *et al.*, 2002), including for selected Australian native plants (Offord *et al.*, 1998). Physicochemical and chemical properties of coir dust vary between and within sources, and although it has excellent physical properties, the following chemical characteristics are of concern for its use as an amendment or growing medium: high electrical conductivity, low cation exchange capacity and high carbon:nitrogen ratio (which could cause soluble nitrogen immobilization) (Abad *et al.*, 2002; Handreck and Black, 2002). The variability was likely due to differences in the raw coconut fruit, the husk processing method and the storage period of the coir dust (Abad *et al.*, 2002).

Cuttings of *Pultenaea parviflora* Sieber ex DC. grew equally well on coir mixes (coir:perlite:sand 4:7:3 or coir:perlite:sand 3:7:3) or the control mix (peat:perlite:sand 4:7:3), despite differences in the chemical and physical characteristics of the mixes (Offord *et al.*, 1998). Tubestock of *Brachyscome multifida* DC. var. *dilatata* Benth., *Correa '*Dusky Bells', *Eucalyptus melliodora* Cunn. ex Schauer and *Grevillea* x *gaudichaudii* R. Br. ex Gaudich. were potted into peat:sand 1:2, coir:sand 1:2, or coir:sand 1:3; whilst *Callicoma serratifolia* Andrews and *Lomandra longifolia* Labill. were potted into peat:sand 1:2, coir:sand 1:2 or coir:sand 1:5. There were no clear overall differences in growth characteristics over 14 months between any of the media, indicating that coir was comparable with peat (Offord *et al.*, 1998). However, Rose and Haase (2000) grew Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco) seedlings in a vermiculite-perlite medium amended with two sources of coir (25% or 50%) mixed with and without 25% peat and found that those grown in coir-based media were significantly shorter, had lower shoot and root dry weights, decreased stem diameters and lower foliar nitrogen and calcium, compared to those grown in a standard peat-vermiculite-perlite medium. The lower foliar nutrient contents indicates that the reduced growth of the plants may have been due to nutrient deficiencies (Rose and Haase, 2000).

Coir-based substrates have also been used to grow various bedding, nursery, woody and foliage plants. Growth of the indoor foliage plant *Dieffenbachia maculata* (Lodd.) G. Don in a coir-based substrate was significantly greater than in a peat-based substrate (Stamps and Evans, 1997). Coir-based substrates had greater water holding capacities than comparable peat-based substrates; as the proportion of coir increased, the air-filled pore space decreased and the bulk density, total pore space, water-filled pore space and the water holding capacity increased (Evans and Stamps, 1996). Growth of the bedding and nursery plants, geranium, marigold and petunia in coir-based substrates was equivalent to or significantly greater than that in peat-based substrates. For geranium, all parameters including number of inflorescences and days to flower, were equivalent in either coir-based or peat-based media. Only root fresh weight was significantly greater in 60-80% coir-based media than in peat-based media. For marigold and petunia, all parameters (i.e. height and shoot fresh weight and days to flower) in coir-based media were equivalent to or greater than that in peat-based media. Of particular note, marigolds grown in 20-40% coir-based media flowered quicker than those in peat-based substrates, while the number of days to flower was equivalent in all other media (for both marigolds and petunia) to that in peat-based media (Evans and Stamps, 1996). Over two seasons, the growth of the woody plants viburnum (*Viburnum dentatum* L.) and Preston lilac (*Syringa* x *prestoniae* McKelv.) in coir-based substrates was equivalent to or significantly greater than that in peat-based substrates (Evans and Iles, 1997). For viburnum, all parameters (height, width, shoot and root fresh weight) were equivalent in either coir-based or peat-based media. The exceptions were that plants were taller after the first season in 25% and 50% coir-based media, root fresh weight was greater in 50% and 100% coir-based media, and width was greater in 100% coir-based medium, compared to those in peat-based media. For lilac, all parameters (height, width, shoot and root fresh weight) were equivalent in either coir-based or peat-based media. The exceptions were that shoot fresh weight was greater in 75% coir-based medium and plant width was greater in 25% and 50% coir-based media, compared to those in peat-based media (Evans and Iles, 1997).

Growth of two subtropical ornamentals, *Pentas lanecolata* (Forssk.) Deflers and *Ixora coccinea* L. was compared in a pine bark-sand-based medium amended with 40% coir dust, sphagnum peat or sedge peat (Meerow, 1994). Growth of both species was significantly better in coir-amended media than sedge peat-amended media; particularly *Ixora*, which had a four- to six-fold increase in growth parameters. *Pentas* grew equally well in coir- and sphagnum peat-amended media, but *Ixora* had a significantly lower growth index and top dry weight in the coir-amended media than in the sphagnum peat-amended media (though root dry weights were equivalent), which may have been due to nitrogen drawdown in the coir-amended media. The authors concluded that coir dust could replace sphagnum or sedge peat as a component of soilless container media, but, depending on the plant species grown, nutritional regimes may require adjustment (Meerow, 1994).

Coir dust is already widely used in Australia, mainly as a replacement for peat due to its excellent physical properties, particularly to increase the waterholding capacity of barks and sawdusts without drastically reducing the air-filled porosity (Handreck and Black, 2002).

2.12.3 Kenaf

Though Marianthi (2006) found that *P. halepensis* seedlings grown in media containing kenaf performed poorly, Wang (1994) found that kenaf was useful as a media amendment for the growth of potted tropical foliage plants and woody nursery crops. The growth of Australian umbrella tree, hibiscus and pittosporum in 70% or 80% kenaf was similar to or greater than growth in two popular commercial mixes. The effect of kenaf on plant growth was partly dependent on the kenaf particle size and percentage in the growing medium (Webber III *et al.*, 1999). Periwinkle grown in peat-perlite media amended with 33%, 50% or 60% fine grade kenaf (average particle size 2 x 5 mm) generally had reduced yield parameters compared to those in the standard peat-perlite-vermiculite control. As the proportion of fine-grade kenaf increased, yield parameters decreased. Periwinkle plants were then grown in peat media amended with 50%, 66% or 75% coarse grade kenaf (average particle size 8 x 20 mm). Periwinkle grown in peat media amended with 50% coarse grade kenaf had equivalent or greater yield parameters compared to the standard peat-pine bark control. Kenaf addition increased the air porosity and so decreased the container capacity, and so required additional irrigations compared to unamended media (Webber III *et al.*, 1999).

On the contrary, Reichert and Baldwin (1996) found that all 23 cultivars of 17 ornamental and vegetable plant species grown in peat amended with 70% (v/v) finely ground fresh kenaf core had equivalent total numbers of flowers or numbers of open flowers to those grown in the standard peat-based medium, except one impatiens cultivar that had more open flowers. The plants grown in kenaf-amended media had greater root weights, equivalent or greater plant heights and equivalent quality scores to those grown in the standard peat-based medium.

Pill *et al.* (1995b; 1995c) also found that media amended with kenaf (and fertilizer) was satisfactory for the growth of tomatoes and impatiens. Tomatoes grown in a peat-based substrate amended with 20% to 35% kenaf had greater shoot weights than those grown in media amended with 50% kenaf, and this was in part due to increased air porosity with increased kenaf percentage (Pill *et al.*, 1995c). In contrast to the findings of Webber III *et al.* (1999), those grown in media amended with fine grade kenaf (2-4 mm diameter) had greater shoot weights than those grown in media amended with coarser grades of kenaf (4-10 mm diameter), though their grading was not directly comparable (Pill *et al.*, 1995c). Nitrogen enrichment of the kenaf by soaking it in solutions containing nitrogen prior to amendment was necessary to overcome microbial immobilization of nitrogen, decrease the carbon:nitrogen ratio and support greater shoot growth compared to that in the commercial growing medium, in the absence of weekly applications of fertilizer (Pill *et al.*, 1995b; 1995c; Pill and Bischoff, 1998). This pre-plant soaking of kenaf allowed release of the nitrogen over an extended period to support plant growth (Pill *et al.*, 1995a), but even greater shoot growth was achieved by incorporating a commercial, resin-coated, controlled release fertilizer in 65-85% kenaf-amended media with weekly fertilizer applications, equivalent to that in commercial media given the same or higher rates of controlled release fertilizer (Pill and Bischoff, 1998). Shoot growth of tomatoes grown in peat-based media amended with 10% kenaf soaked in a nitrogen solution and 20% kenaf soaked in the plant growth regulator uniconazole was similar to that in control media, but plant quality was enhanced to produce vigorous but growth-restricted tomato bedding plants (Pill *et al.*, 1995b). The growth response of impatiens to media amendments was similar to tomato and so was not detailed by the authors (Pill *et al.*, 1995b; 1995c).

Such suppression of growth in media containing kenaf can be utilized in the production of compact plants which are of value in the floriculture and, potentially, the vegetable transplant production industry (Tsakonas *et al.*, 2005). Lettuce and pepper seeds sown into sand amended with whole-stem kenaf (core and bark) at 10%, 25% or 50% led to plants with inhibited growth, in terms of height, leaf number, and fresh and dry weight. Subsequently transplanting these plants to a kenaf-free substrate, growth continued at a similar rate to that of plants in the control medium (peat and sand).

Composting kenaf could improve its utility as an amendment for containerized production (Laiche Jr and Newman, 1994). Begonia, impatiens, salvia, and vinca were grown in peat-vermiculite media amended with 10%, 20%, 30%, 40% or 50% finely ground or coarsely ground kenaf; that was fresh, composted, or composted and used as chicken litter; and charged or not charged with nitrogen (Howell *et al.*, 1993). Media containing no kenaf produced the tallest and heaviest begonia, impatiens and vinca plants. Coarse composted kenaf with the N charge produced the tallest salvia plants; however, the heaviest salvia plants were produced in media with 10-40% coarse fresh kenaf with the N charge. In general, as the rate of kenaf increased, plant height and weight decreased. Composted preparations generally resulted in plants with greater heights and weights, but not significantly better than those in the unamended media (Howell *et al.*, 1993).

Kenaf is a relatively new crop in Australia and there is a lack of large-scale commercial processing facilities, which would hinder its utility in the short term.

2.12.4 Miscellaneous Plant Tissue

Fresh tissue from macerated supermarket-bought organic Brussels sprouts, mimicking brassica waste that has been utilized in other studies for soil-borne disease control (Weerakoon *et al.*, 2012), was incorporated into soil in pots prior to transplanting tomato seedlings (Giotis *et al.*, 2009). Brussels sprouts amendment significantly reduced soil-borne disease severity caused by *P. lycopersici* and *V. albo-atrum* (measured by an increase in root fresh weight) and increased fruit yield and number per plant (Giotis *et al.*, 2009). There was also an increase in soil biological activity due to amendment indicating that increased competition from the saprophytic soil biota may be a mechanism for reducing disease and increasing fruit parameters.

Fresh, ground leaves from cannabis (*Cannabis sativa* L.) and toothache tree (*Zanthoxylum alatum* Roxb.) were mixed with soil at 2, 4, 6, 8, 10 and 20 g/kg (Kayani *et al.*, 2012). Two weeks later, cucumber seeds were sown and plants were inoculated with juvenile *Meloidogyne incognita* nematodes 10 days post-emergence. Cucumber plants grown in leaf-amended soil had significantly reduced nematode infestations/reproduction and increased growth compared to those in the unamended soil. The increased growth was due not only to nematode suppression, but may also be due to changes in the physical and chemical structure of the soil. Gall number, egg mass number, fecundity and nematode build-up were all reduced to a significantly greater extent with cannabis leaf-amended soil compared to toothache tree leaf-amended soil, with maximum reductions at the highest rate of 20 g/kg.

Ripe fruits of wild cucumber (*Cucumis myriocarpus* E. Mey. ex Naud.), leaves of fever tea (*Lippia javanica* (Burm.f.)) and fruits of castor bean (*Ricinus communis* L.) were dried, ground and applied in all permutations to soil one day after transplanting tomato seedlings inoculated with juvenile *M. incognita* nematodes (Mashela *et al.*, 2007). Tomato plants grown in media amended with the three-species combination treatment had the greatest fruit yield, tallest plants and greatest stem diameter, compared to those grown in the unamended medium. The three-species combination treatment reduced the nematode numbers by up to 98% compared to the unamended medium, the greatest decrease by any medium. The three-species combination treatment had a synergistic effect on suppression of nematode densities and improvement of fruit yield and plant biomass.

Fresh, ground leaves from oregano (*Origanum vulgare* L.), sage, rosemary, tarragon (*Artemisia dracunculus* L.), bay (*Laurus nobilis* L.), wild rocket (*Diplotaxis tenuifolia* L.), spearmint (*Mentha viridis* L.) or thyme (*Thymus vulgaris* L.) were mixed with soil at 1% w/w (Klein *et al.*, 2011). Soil-borne pathogens *F. oxysporum* f. sp. *radicis-lycopersici*, *M. phaseolina* and *R. solani* were exposed to the amended soil for two weeks under controlled laboratory conditions prior to reisolation. Oregano, thyme and bay significantly decreased the viability of *Fusarium* compared to the unamended control. Wild rocket and tarragon significantly decreased the viability of *Rhizoctonia* compared to the unamended control. No amendments affected the viability of *Macrophomina*. In a later study, fresh, ground leaves and stems from sage, tarragon, wild rocket or peppermint (*Mentha piperita* L.) were mixed with soil at 1% w/w and exposed to field conditions for one month (Klein *et al.*, 2012). This soil was transferred to pots, inoculated with the root knot nematode *M. javanica*, and planted with tomato (sage-, tarragon- or wild rocket-amended soil), basil (peppermint-amended soil) or snapdragon (wild rocket-amended soil) seedlings. There was suppression of root galling, expressed as a reduced galling index, and increased root development, foliage height and total biomass, in tomato, basil and snapdragon plants grown in the tested amended soils compared to those grown in unamended soils. The encouraging effects of these herbs on pathogen suppression would need to be tested in soilless growing media using more pathosystems.

Miscanthus sinensis L. var. *giganteus*, a bioenergy crop widely cultivated throughout Europe for the production of industrial ethanol, was degraded via a thermo-mechano-chemical process to produce steam-exploded biomass (SEB) (De Corato *et al.*, 2011). The potential disease suppressive effect of SEB of *M. sinensis* var. *giganteus* as an amendment in peat at 10%, 20% or 30% was tested in 5 pathosystems in the greenhouse: tomato/*Phytophthora nicotianae*, cucumber/*P. ultimum*, lettuce/*F. oxysporum* f. sp. *lactucae*, melon/*F. oxysporum* f. sp. *melonis* and bean/*R. solani*. SEB was as good as or significantly better than commercial compost amended at the same rate at suppressing disease for all pathosystems, except melon/*Fusarium oxysporum* f. sp. *melonis*. (However, neither SEB nor compost was significantly suppressive in the lettuce/*Fusarium oxysporum* f. sp. *lactucae* pathosystem) (De Corato *et al.*, 2011). In another study based on the same species, shredded or fibrous *Miscanthus* straw was used as a media amendment to peat at 40%, 50%, 70% or 100% for the growth of the shrubs privet and *Hypericum patulum* Thunb. (Cárthaigh *et al.*, 1997). The fresh weight of *Ligustrum* in *Miscanthus*-amended media was equivalent to that of the standard peat-composted bark medium, except in 100%

Miscanthus straw when it was significantly reduced. The fresh weight of *Hypericum* decreased with increasing *Miscanthus* amendment, with only that in 40% shredded *Miscanthus* straw and 40-50% fibrous *Miscanthus* straw being equivalent to the fresh weight in the standard peat-composted bark medium.

Included to show the range of plant tissues tested, these materials likely have little practical application.

2.12.5 Oilseed Meal

Four oilseed crop meals, cotton (*Gossypium hirsutum* L.), rapeseed (*Brassica napus* L.), sesame (*Sesamum indicum* L.) and soybean (*Glycine max* L.) were tested for their effect on disease caused by Columbia root-knot nematode (*Meloidogyne chitwoodi* Golden, O'Bannon, Santo, and Finley) on tomato in soil in the greenhouse (Hafez and Sundararaj, 1999). Even though tomato foliar fresh and dry weights were increased significantly and nematode numbers were generally reduced in all crop meal-amended media compared to these parameters in the unamended medium, rapeseed, sesame and soybean amendments caused phytotoxic symptoms on tomato.

Soil, inoculated with *F. oxysporum* and *F. solani*, was amended with one of nine plant residues, or ground crab shells, each at 1% (v/v), in closed containers in the laboratory (Zakaria and Lockwood, 1980). Oilseed meals, including linseed, cottonseed and soybean meal, caused a substantial reduction in populations of *Fusarium* chlamydospores, while crab shells caused a slight reduction, and the remaining residues were ineffective. Reduction of the viable population of *Fusarium* was correlated with a reduction in root rot of peas (Zakaria and Lockwood, 1980).

Given that oilseed meals in the first study were unacceptably phytotoxic and the second study was a laboratory experiment, these substances have little potential as organic amendments for containerized plant production.

2.12.6 Pine tree substrate

Pine tree substrates have been considered as an amendment and as an entire medium replacement for traditional substrates for greenhouse and nursery crop production (Fain *et al.*, 2008a; Fain *et al.*, 2008b; Jackson *et al.*, 2008a; Jackson *et al.*, 2008b; Jackson *et al.*, 2009; Jackson *et al.*, 2010), but they should be screened for their potential phytotoxicity (Ortega *et al.*, 1996).

Pine chips, produced by grinding loblolly pine (*Pinus taeda* L.) logs, were combined with pine bark at 0%, 75% or 100% (v/v) as container media for the growth of japanese holly, azalea and marigold (Wright and Browder, 2005). Marigolds grown in 75% pine chips had equivalent shoot dry weights to those grown in pure pine bark, but those grown in 100% pine chips had significantly lower shoot dry weights. Azaleas grown in 75% or 100% pine chips had significantly lower shoot dry weights compared to those grown in pure pine bark. However, though they had reduced shoot dry weights, the overall visual quality of both the marigold and azalea plants was acceptable. Japanese holly grown in all three substrates had equivalent shoot dry weights, but root dry weight was greater for Japanese holly grown in 75% pine chips than those grown in pure pine bark, and equivalent in 100% pine chips. Due to the different physical and chemical properties of pine chips, such as higher total porosity and lower cation exchange capacity than pine bark, irrigation and nutritional management strategies may be needed (Wright and Browder, 2005).

Chrysanthemum was grown in a similar pine chips substrate (100%) or a commercial peat-based substrate, and fertilizer at varying rates was applied (Wright *et al.*, 2008). Plants grown in pine chips required about 100 mg/L nitrogen more fertilizer compared to the peat-based substrate to obtain comparable growth. The lower nutrient levels of the pine chips substrate may be due to increased nutrient leaching as a result of pine chips being more porous and having a lower cation exchange capacity than the peat-based substrate, and greater microbial immobilization of nitrogen in pine chips compared to the peat-based substrate. This research showed that pine chips can be used as a container medium for the production of a traditional greenhouse crop, as long as fertilizer requirements are met (Wright *et al.*, 2008).

In a more extensive study, plants of a wide range of woody species were grown in either pine chips substrate (100%) or pine bark (100%) (Wright *et al.*, 2006). In the first planting of 18 species, the growth index of 15 species and the shoot dry weight of 13 species were not different between the two media; four species had greater shoot dry weights in pine bark; and one species had greater shoot dry weight in pine chips. In the second planting of 10 species, the growth index of six species and the shoot dry weight of four species were not different between the two media; six species had greater shoot dry weights in pine bark. The reduced growth of some species in pine chips compared to pine bark can be attributed to lower nutrient availability, which may be due to increased nutrient leaching from the more porous pine chips substrate that has a low cation exchange capacity, and a high carbon:nitrogen ratio leading to increased microbial nutrient immobilization, which could be corrected by supplemental fertilizer (Jackson *et al.*, 2006; Wright *et al.*, 2006). An inexpensive fertilizer source in composted turkey litter has been used to balance initial nitrogen immobilization in such substrates, with consideration of the amendment level to avoid shrinkage being the only real issue (Marble *et al.*, 2008).

Using different proportions of a mix of coarsely ground and finely ground pine tree substrates, alone or added to peat moss, aged pine bark or sand gave substrates with physical properties and resultant plant growth of species such as marigold, azalea and spirea similar to 100% peat lite or pine bark (Jackson *et al.*, 2010).

Similarly, clean chip residual (CCR), a by-product of pine tree harvesting, can also be used as a component of containerized growing media (Boyer *et al.*, 2006; Boyer *et al.*, 2008; Boyer *et al.*, 2009). CCR alone or in combination with peat did not significantly increase media settling (shrinkage) due to wood decomposition over the 105-day culture period (Boyer *et al.*, 2006). The growth of two perennial species, buddleja (*Buddleja* sp.) and verbena (*Verbena* sp.) in two screen sizes of CCR alone, or CCR blended with 20% peat (v/v), was compared with growth in standard media of pine bark and pine bark plus 20% peat. Growth parameters of the two species grown in CCR media were generally equivalent to those in the standard media. The growth of three annual species, ageratum (*Ageratum houstonianum* Mill.), salvia, and impatiens in CCR alone, or CCR blended with 10% or 20% peat (v/v), was compared with growth in standard media of pine bark, pine bark plus 10% peat, and pine bark plus 20% peat (Boyer *et al.*, 2008). Growth parameters of the three species grown in CCR media were generally equivalent to those in the standard media. Some decreases in growth parameters in 100% CCR was likely due to high air space, which lowered the water holding capacity. In a later study, the woody ornamentals lorapetalum (*Lorapetalum chinensis* var. Rubrum R. Br.), buddleja (*Buddleja davidii* Franch.), crapemyrtle (*Lagerstroemia indica* L. and *Lagerstroemia x fauriei* Wallich ex Paxt.) and azalea were grown in CCR alone and generally had comparable growth to those grown in pine bark media (Boyer *et al.*, 2009).

Japanese holly and azalea were grown in a pine tree substrate or milled pine bark with different fertilizer rates (Jackson *et al.*, 2008b). When the two species were grown in the pine tree substrate, a higher rate of fertilizer was required to achieve shoot growth comparable to that in pine bark (Jackson *et al.*, 2008b). This may be due to net nitrogen immobilization as a result of a very large carbon:nitrogen ratio, and irrigation and nutrient leaching connected with low container capacity and high porosity. Similarly, poinsettias were grown in three pine tree substrates (ground to different particle sizes) or a peat-based control at different fertilizer rates (Jackson *et al.*, 2008a). Pine tree substrates, either small particles (2.38-mm screen), or large particles (4.76-mm screen) amended with 25% peat, were useful media for the growth of poinsettia, producing plants with similar shoot dry weights, growth and quality indices, and similar or better bract lengths, as those grown in the peat-based control. Such amendments resulted in physical properties such as container capacity and air space similar to those of the peat-based control (Jackson *et al.*, 2008a). Pine tree substrates have an inherently higher pH than the standard peat-perlite medium, and whilst marigold grew well in 100% pine tree substrate, for optimum growth of geranium, amendment of the pine tree substrate with peat and limestone was required (Jackson *et al.*, 2009).

Whole pine trees of three species of pine were processed for use as containerized substrates for the production of annual vinca (Fain *et al.*, 2008a). While plants grown in 100% pine bark substrate (standard medium) had shoot dry weights 15% greater than those grown in the three 100% whole pine tree substrates, there were no differences in root growth or growth indices for any substrate. The differences in growth were probably due to differences in certain physical properties of the media, with the whole pine tree substrates having higher air space and lower container capacity which resulted in less available water. This issue can be addressed by altering irrigation practices or adjusting manufacturing processes to produce whole pine tree substrates with more desirable physical properties (Fain *et al.*, 2008a).

Petunia and marigold were grown in whole pine tree substrate from loblolly pine either alone (100%) or combined at 50% or 80% (v/v) with peat, or in an industry standard peat-lite mix (80% peat, 10% vermiculite, 10% perlite (v/v), and were amended with different rates of starter fertilizer (Fain *et al.*, 2008b). Generally, petunia shoot dry weight was highest for any peat-containing substrate with a medium to high starter fertilizer rate, except petunia grown in whole pine tree substrate at high starter fertilizer rate had similar dry weight as all other treatments. Shoot dry weight of marigold was similar for all substrates when a medium to high starter fertilizer rate was used. Again, issues with air space and container capacity played a role in plant growth differences (Fain *et al.*, 2008b). In a separate study, impatiens and marigold were grown in the same media as above at the same rates, and there were no differences in the numbers of flowers between media for either species (Fain *et al.*, 2006). From these two studies, it was concluded that whole pine tree was a suitable substrate component to replace the majority of peat in the production of petunia, marigold and impatiens, as long as an adequate starter nutrient charge was provided (Fain *et al.*, 2006; Fain *et al.*, 2008b).

The benefits of using pine tree substrates include: the substrates can be used immediately after milling (as opposed to others that need to mature); the potential to grow pine nearby to nursery production, minimizing transportation costs; and the requirements of specific plants and container sizes for certain physical properties can be met by adjusting the grinding during the manufacturing process (Jackson *et al.*, 2010).

Whole trees of eastern red-cedar (*Juniperus virginiana* L.) were processed for use as an amendment to containerized substrates for the production of Chinese pistache (*Pistacia chinensis* Bunge) and Indian-cherry (*Frangula caroliniana* (Walt.) Gray) (Griffin, 2009). Seedlings were transplanted into a pine bark-based medium amended with 5%, 10%, 20%, 40%, or 80% eastern red-cedar chips. In general, both species grew as well as or better in amended media, in terms of height and shoot weight compared to plants growing in unamended media, except at 10% and 80% amendment, when plants were shorter and had lower shoot weights. However, this was only reported as a conference abstract, with no statistical details or data presented and only brief methodology, so the scientific rigour of the study is undetermined.

With extensive pine plantations in Australia, whole pine tree, clean chip residual and pine chips are potential media components. The potential phytotoxicity of such substrates to different plant species, nitrogen immobilization, shrinkage, the need to vary irrigation and nutritional management strategies are issues to consider.

2.12.7 Plant Extracts

Extracts and essential oils of higher plants such as neem, pyrethrum, willow and various herbs have been used to control plant diseases. For example, neem oil, a seed extract from the neem tree, was applied as a foliar spray to reduce the incidence of bacterial spot of tomatoes and peppers (Abbasi *et al.*, 2003), and whilst it was phytotoxic in the greenhouse, causing stunting, chlorosis, epinasty and a narrowing of the leaf blades, no negative effects were reported in the field. In another example, neem and willow leaf extracts reduced the incidence and severity of wilt of tomatoes caused by *F. oxysporum* f. sp. *lycopersici* in a glasshouse trial, likely by increasing the activities of antioxidant defensive enzymes and decreasing the level of lipid peroxidation (Farag Hanaa *et al.*, 2011). The use of plant extracts to improve plant growth has been reviewed recently (Deepak, 2011) and is beyond the scope of this review.

2.12.8 River Waste

River waste is the accumulation of plant debris in an anaerobic environment which is dredged from river banks (Di Benedetto *et al.*, 2004) and it has been considered as an organic amendment. Nineteen ornamental perennials were grown in peat amended with 50% river waste, 100% river waste or peat-based soilless media (control). Nine species grown in 50% river waste-amended media had the same or higher total plant dry weights compared to those grown in peat-based soilless media (Di Benedetto *et al.*, 2004). (Plants grown in 100% river waste had lower dry weights).

While initial physical properties of 100% river waste were suitable, they were unstable and deteriorated over the 10 week cropping period; however 50% river waste was more stable and suitable. A later study supported these results, showing that high quality petunia and impatiens plants could be grown in river waste-amended media, despite high pH, low organic matter and low contents of some nutrients (Chavez *et al.*, 2008). Though not discussed in these studies, river waste is likely to contain plant pathogens and so would not be a viable option as an organic amendment for plant production.

2.12.9 Sesame Meal

Sesame meal added at 1%, 2.5% or 20% (v/v) to a peat-based transplant medium was tested for its effect on the germination and growth of tomato, the rhizosphere microorganisms and carryover effects to mature plants in the field (Jack *et al.*, 2011). The chemical properties of sesame-amended media were similar to those of unamended media. The germination of tomato seeds was significantly decreased in 20% sesame meal-amended media compared to those in the unamended control, and this was likely due to the formation of allelopathic compounds as the meal decomposed. Tomato transplants that grew in the greenhouse were then planted in the field. At the time of transplanting, there was no significant difference in the dry weight biomass between transplants grown in 20% sesame meal-amended media and the unamended control; however, transplants grown in 1% or 2.5% sesame meal-amended media were significantly heavier than those in the unamended control and the commercial composted manure-amended media. At anthesis, plants originally grown in any of the sesame meal-amended media were significantly heavier than those in the unamended control and the commercial composted manure-amended media (Jack *et al.*, 2011). Plants originally grown in any of the sesame meal-amended media had significantly greater early fruit yields and marketable fruit yield than those in the unamended control, and equivalent to those in the commercial composted manure-amended media. The bacterial community from sesame meal- (and other plant-based-) amended transplant media and in the resultant rhizosphere in the field was significantly different from those in composted manure-based-amended transplant media and unamended transplant media and their resultant rhizospheres, and these populations were likely to be responsible for enhanced plant growth in the field (Jack *et al.*, 2011).

Whilst the results of this work on tomato were positive, no other studies assessing sesame meal were found. If it was to be considered as an organic amendment, more research on the efficacy on other plant species and rates would be required, but given Australia's small sesame seed industry, this is probably inconsequential.

2.13 Amino Acids and Organic Acids

While there are many products that are based on amino acids and organic acids sold as liquid fertilizers, there are relatively few scientific reports on their effect on plant growth, and they are mostly on field-grown plants (Aml *et al.*, 2011; Shehata *et al.*, 2011; Thomas *et al.*, 2009) rather than containerized plant production. One report of a containerized trial involved foliar application of 0.05%, 0.1% or 0.15% v/v amino acids to *Aloe vera* L. plants (growing medium unspecified). Foliar application of 0.1% and 0.15% v/v amino acids increased the total soluble sugar content, induced the production of secondary metabolites such as phenols and alkaloids, and stimulated the activity of antioxidant enzymes in the plants (Ardebili *et al.*, 2012). In another study, foliar application of mixed amino acids to leafy radish grown in pots (in commercialized artificial soil) affected the activities of nitrogen assimilation enzymes, increased nitrogen uptake and increased the fresh weight, dry weight, and nitrogen yield of the plants (Liu *et al.*, 2008).

The studies on field-grown plants indicate that such formulations can improve plant growth, but Edmeades (2002) review of trials involving liquid fertilizer products included three amino acids-based products (one of these also contained seaweed extracts) and did not find any evidence of an effect on plant growth (under field conditions). The release of phosphorus from insoluble phosphates has been reported for several soil microorganisms (phosphate solubilizing bacteria) and has been attributed mainly to the production of organic acids and their chelation capacity (Chen *et al.*, 2006; Kim *et al.*, 1998; Vyas and Gulati, 2009). Therefore, theoretically, the application of organic acid broths may release phosphorus from bound sources, potentially improving plant growth if it was deficient in phosphorus.

Considering the number of liquid fertilizer products on the market that are based on amino acids and organic acids, research into their efficacy at their recommended rates should be conducted on various plant species.

3. Benefits of Organic Amendment Application – Main Claims and Supporting Evidence

Manufacturers of organic amendments claim there are many benefits to plant growth from their application. Benefits in agricultural field situations, many of which are similar in containerized production, have been detailed in Quilty and Cattle (2011). Much of the supporting evidence for the main claims has already been described for each organic amendment within section 2 'Types of Organic Amendments'. The following section summarizes this evidence.

3.1 Nutrient Source to Plants

One of the main claims regarding organic amendments is that they are a significant source of plant nutrients (Quilty and Cattle, 2011). Composts can contain substantial amounts of particular plant macro- and micro-nutrients, but as expected, composition varies with the feedstock (Fitzpatrick *et al.*, 1998; Quilty and Cattle, 2011). Fitzpatrick *et al.* (1998) claimed the nutrients in compost were not in adequate concentrations or the comprehensive suite to completely satisfy the needs of ornamental plants, so they may only be able to reduce fertilizer requirements rather than replace them (Marble *et al.*, 2011). Their composition should always be analysed and reviewed in terms of the needs of individual crops. Vermicomposts are reported to have their nitrogen in the form of nitrate, rather than as ammonia in composts, which is a more accessible form of nitrogen to the plant, thus having a more beneficial effect on plant growth (Edwards and Burrows, 1988; Edwards and Arancon, 2004; Subler *et al.*, 1998). Quilty and Cattle (2011) in their review of organic amendments used in Australian agriculture, presented the macro- and micro-nutrient contents of a range of commonly used organic amendments. In general, composts; vermicomposts; meat, blood and bone meals; fish emulsions; and uncomposted organic waste materials; all have useful levels of nutrients which can contribute to plant growth; their use should enable the reduction of fertilizer inputs. Humic products and biochars have only moderate amounts of nutrients; while compost teas/extracts and seaweed extracts have very low levels whose contribution would be trivial, and so it is unlikely that their use would allow a decrease in the rates of synthetic fertilizer applied (Edmeades, 2002; Quilty and Cattle, 2011). However, the application of seaweed and humic extracts can increase the efficacy of fertilizer use (Crouch *et al.*, 1990; David *et al.*, 1994; Haghighi *et al.*, 2012; Papenfus *et al.*, 2013; Turan and Köse, 2004).

3.2 Stimulation of Plant Growth and Enhancement of Plant Quality

A multitude of studies have shown that organic amendments can stimulate the growth of plants in containerized production; however the suite of species has been limited and the production period generally short. Composts derived from a variety of materials are beneficial. Composts created from the following plant residues have enhanced the growth of vegetable and ornamental species: coffee waste (Berecha *et al.*, 2011), cotton waste (Khah *et al.*, 2012; Owings, 1993), grape marc (Chen *et al.*, 1988; Inbar *et al.*, 1986), green waste (Ceglie *et al.*, 2011; Hummel *et al.*, 2001; Manning *et al.*, 1995; Mugnai *et al.*, 2007), olive waste (Ceglie *et al.*, 2011) and spent mushroom (Chong *et al.*, 1991). Composts using the following animal manures have increased the growth of various ornamentals, bedding plants, nursery species and vegetable transplants: cattle dung (Chen *et al.*, 1988; Inbar *et al.*, 1986; Raviv *et al.*, 1998a; Raviv, 2005), poultry manure (Hammermeister *et al.*, 2006; Hu and Barker, 2004; Kraus and Warren, 2000; Marble *et al.*, 2011) and blends of the two (De Brito Alvarez *et al.*, 1995). Composts obtained from municipal and industrial waste materials were also useful, such as MSW (Cendón *et al.*, 2008; Lievens *et al.*, 2001; Lu *et al.*, 2005; Radin and Warman, 2011; Ribeiro *et al.*, 2000), sewage sludge (Bugbee and Frink, 1989; Danielson *et al.*, 2004; Fitzpatrick, 1986; Grigatti *et al.*, 2007; Jayasinghe *et al.*, 2010; Klock-Moore, 1999a; Klock-Moore, 1999b; Klock-Moore, 2000; Klock, 1997a; Klock, 1997b; Klock and Fitzpatrick, 1997; Ostos *et al.*, 2008; Ozores-Hampton *et al.*, 1999; Pinamonti *et al.*, 1997; Sloan *et al.*, 2010; Vabrit *et al.*, 2008; Wilson *et al.*, 2004; Wilson and Stoffella, 2006; Wootton *et al.*, 1981), paper mill waste (Fitzpatrick, 1989; Tripepi *et al.*, 1996), brewing waste and olive mill waste (Garcia-Gomez *et al.*, 2002). Only compost tea derived from empty fruit bunch (presumably from palm oil) and chicken manure stimulated growth of an ethnomedicinal herb (Siddiqui *et al.*, 2011).

Amendment of media with blood meal, meat meal and fish products led to better plant growth of ornamentals (Hummel *et al.*, 2000), vegetables (Abbasi *et al.*, 2002; Abbasi *et al.*, 2004; Abbasi *et al.*, 2006; Cheng, 1987; Gagnon and Berrouard, 1994) and herbs (Succop and Newman, 2004). Seaweed extracts also stimulated growth of vegetables (Aldworth and Van Staden, 1987; Cassan *et al.*, 1992; Crouch and van Staden, 1991; Crouch *et al.*, 1992; Crouch and Van Staden, 1992; Featonby-Smith and Van Staden, 1983; Kim *et al.*, 2012; Kowalski *et al.*, 1999; Sharma *et al.*, 2012; Vinoth *et al.*, 2012), ornamentals (Aldworth and Van Staden, 1987; Lindsey *et al.*, 1998; Morales-Payan, 2006; Russo *et al.*, 1994; Urbanek Krajnc *et al.*, 2012), tree species (Atzmon and Van Staden, 1994; Van Staden *et al.*, 1995) and other species (Rayorath *et al.*, 2008; Steveni *et al.*, 1992). Uncomposted organic wastes were also beneficial to plant growth of *Pinus* (Maňas *et al.*, 2009), ornamentals (Chong and Cline, 1993; Chong *et al.*, 2008; Gori *et al.*, 2000; Jayasinghe *et al.*, 2009) and vegetables (Abbasi *et al.*, 2007; Gagnon and Berrouard, 1994).

There is evidence to support the claim that bio-inoculants can enhance growth. Mycorrhiza were beneficial for ornamental (Aboul-Nasr, 1996; Carpio *et al.*, 2005; Gaur *et al.*, 2000; Linderman and Davis, 2003; Maya and Matsubara, 2013; Nowak, 2004; Sohn *et al.*, 2003) and vegetable species (Linderman and Davis, 2001). Plant growth-promoting rhizobacteria improved the growth of ornamental (Muthukumar and Udaiyan, 2010), vegetable (Gravel *et al.*, 2007; Raviv *et al.*, 1998b; Russo, 2006; Yildrim *et al.*, 2008) and other species (Aseri *et al.*, 2008; Aseri *et al.*, 2009; Mohan and Radhakrishnan, 2012). A few studies indicated that media amendment with biochar may have positive growth effects (Graber *et al.*, 2010; Kadota and Niimi, 2004; Tian *et al.*, 2012).

Some plants grown in media amended with vermicomposts showed improved growth parameters. This included various ornamental plants (Alves and Passoni, 1997; Arancon *et al.*, 2008; Atiyeh *et al.*, 2002a; Bachman and Metzger, 2008; Hidalgo and Harkess, 2000; Hidalgo and Harkess, 2002; Hidalgo *et al.*, 2006; McGinnis *et al.*, 2009; Rodriguez-Navarro *et al.*, 2000; Sangwan *et al.*, 2010; Subler *et al.*, 1998), as well as vegetable species (Atiyeh *et al.*, 2000a; Atiyeh *et al.*, 2000c; Bachman and Metzger, 2008; Gutiérrez-Miceli *et al.*, 2007; Hammermeister *et al.*, 2006; Huerta *et al.*, 2010; Jack *et al.*, 2011; López-Gómez *et al.*, 2012). The application of vermicompost tea was also useful for enhancing the growth of tomatoes (Edwards *et al.*, 2006) and pak choi (Pant *et al.*, 2012a; Pant *et al.*, 2012b).

Humic extracts improved the growth of lantana (Costa *et al.*, 2008) and various fruit and vegetable species (Atiyeh *et al.*, 2002b; Azcona *et al.*, 2011; Cavalcante *et al.*, 2011; Ortega and Fernández, 2007; Pertuit Jr *et al.*, 2001; Tüfenkçi *et al.*, 2006; Valdrighi *et al.*, 1996). Uncomposted plant parts were also useful amendments for enhancing the growth of ornamental (Evans and Stamps, 1996; Evans and Iles, 1997; Klein *et al.*, 2012; Meerow, 1994; Pill *et al.*, 1995c; Pill and Bischoff, 1998; Stamps and Evans, 1997; Wang, 1994) and vegetable species (Giotis *et al.*, 2009; Hammermeister *et al.*, 2006; Jack *et al.*, 2011; Kayani *et al.*, 2012; Klein *et al.*, 2012; Mashela *et al.*, 2007; Nair *et al.*, 2011; Pill *et al.*, 1995c; Pill and Bischoff, 1998).

Reducing growth in particular parameters can sometimes be a desirable effect, for example to produce compact plants enabling a reduction in the use of growth retardants. A few studies have indicated that cotton waste compost (Papafotiou *et al.*, 2001b; Papafotiou and Vagena, 2012) and olive mill waste compost (Papafotiou *et al.*, 2004; Papafotiou *et al.*, 2005) may have potential in this area, but more studies are required.

3.2.1 Plant Hormones

Seaweed extracts contain various plant hormones. The level of response in plant growth parameters in various studies cannot be explained by the amount of mineral nutrients in commercial preparations (Crouch and Van Staden, 1993). The effects are, in part, due to plant growth regulators, such as cytokinins, auxins, abscisic acid and similar compounds, other low molecular weight organic compounds such as betaines (that help alleviate osmotic stress), and larger polymers (Craigie, 2011; Crouch and Van Staden, 1993; Crouch and Van Staden, 1994; Khan *et al.*, 2009; Stirk and Van Staden, 1997). For example, the seaweed extract Kelpak has been shown to promote root growth via the presence of auxins (Crouch and van Staden, 1991; Crouch *et al.*, 1992). Plant hormones, such as IAA and cytokinins, have been identified in Maxicrop and similar *Ascophyllum*-based products (Sanderson and Jameson, 1986; Sanderson *et al.*, 1987; Zhang and Ervin, 2004), and Seasol (made from Tasmanian giant bull kelp, *Durvillea potatorum*) (Tay *et al.*, 1985; Tay *et al.*, 1987) and so, may play a role in improving plant growth. For example, Seamac 600, a cytokinin-rich extract of *Ascophyllum*, sprayed onto greenhouse roses produced 14-47% more "bottom breaks" - sprouting of renewal canes from the base of the plant - in the roses, compared to the controls (Raviv, 1986).

Microbes can also produce hormones, so any amendment that increases microbial numbers and diversity, may well lead to an increase in production of hormones, having positive growth effects on plants. This has been speculated as part of the mechanism for improvements in plant growth and flowering parameters due to vermicomposts (Arancon *et al.*, 2008) and vermicompost-derived humic extracts (Atiyeh *et al.*, 2002b).

3.2.2 Seed Priming

It is claimed that some organic amendments can play a role in seed priming, providing physiological improvement to seeds. The seaweed product Maxicrop had no positive effect on pepper seeds compared to priming in water; in fact total germination rate decreased and mean germination time increased with increasing seaweed concentration (Sivritepe and Sivritepe, 2008). However, bamboo vinegar (a by-product of bamboo pyrolysis) promoted germination and radicle growth of four species including lettuce and chrysanthemum (Mu *et al.*, 2003), analogous to smoke water promoting germination in many species. There is much scope for future research in this area.

3.3 Pest and Disease Control

One potential method for the management of soil-borne plant diseases is the addition of organic amendments, however, inconsistent results have hampered their widespread recommended use (Bonanomi *et al.*, 2010; Pane *et al.*, 2011). Bonanomi *et al.* (2007) reviewed 2423 studies (including field use) from 250 papers and found that organic matter was suppressive to disease incidence or pathogen populations in 45% of studies, had no significant effect in 35% of studies and increased disease incidence or pathogen populations in 20% of studies. Furthermore, organic matter amendments were highly suppressive (defined as >80% disease reduction) in only 12% of studies. When the different types of organic matter were broadly grouped, both compost and organic wastes were the most suppressive, each giving effective disease control in more than 50% of studies.

Bonanomi *et al.* (2010), using the same dataset, found that the suppressive ability of organic matter was pathogen-specific (Bonanomi *et al.*, 2007), i.e. an organic material that was suppressive to one pathogen, was ineffective or conducive to another pathogen. In 73% of studies, the process of organic matter decomposition affected suppression but the relationship was very variable and no specific predictors of disease suppression could be characterised. Enzymatic and microbiological parameters (such as fluorescein diacetate (FDA) hydrolysis, an indicator of biological activity, and total culturable bacteria) were more informative for predicting suppression than chemical parameters (such as C-N ratio). However, no single parameter could be used as a reliable and consistent indicator of the suppressive ability of different organic matter amendments against different pathogens, probably due to different mechanisms of disease suppression at play (Bonanomi *et al.*, 2010; Hadar, 2011; Pane *et al.*, 2011). Therefore, quality control of organic amendments relies on pathogen- or disease-specific bioassays (Hadar, 2011).

Noble and Coventry (2005) reviewed the suppression of soil-borne plant diseases with composts and found that numerous container-based studies consistently showed a suppressive effect of composts on damping-off, root rots and wilts. This effect generally increased with application rate, with a minimum of 20% usually required, but levels of suppression were variable. Factors such as the base substrate (e.g. peat), the feedstock, and the degree of decomposition of the compost (maturity) may influence suppression, and these authors recommended that biocontrol agent-fortified compost offer the best commercial opportunity (at about half the cost of a single fungicide drench) (De Ceuster and Hoitink, 1999). The mechanisms responsible for the suppression have not been fully elucidated, but are thought to be predominantly biological, with chemical and physical factors playing a lesser role (Noble and Coventry, 2005). Proposed biological mechanisms include competition (for nutrients, oxygen and infection sites), parasitism, antibiosis, induced systemic resistance and enhanced disease resistance due to improved plant nutrition and vigour (Hoitink and Boehm, 1999; Litterick and Wood, 2009; Noble and Coventry, 2005).

There are some reports of compost amendment increasing disease severity, for example, the incidence of *Fusarium* wilt in cyclamen and black root rot in poinsettias was increased by the addition of 50% spruce bark compost, compared to the peat control (Krebs, 1990 cited in Noble and Coventry, 2005), yet the same amendment caused a decrease in *Phytophthora* root rot in African violets (*Saintpaulia* spp.). Noble (2011) recently reviewed 79 experiments where soil was amended with ≥20% v/v compost in container bioassays and found that compost suppressed disease in 59 experiments, whilst compost promoted disease in only 6 experiments. Two points should be noted: 1) these were bioassays simulating the effect of adding compost to field soil, not to potting media such as peat; and 2) there may be inherent bias, as studies showing positive (i.e. suppressive) effects are more likely to be published than those showing negative or no significant effects, skewing the data so that the number of experiments promoting disease may be an underestimate (Noble, 2011), as per Edmeades (2002). Various techniques measuring microbial activity, such as fluorescein diacetate hydrolysis, dehydrogenase activity, or basal respiration, have been inconsistent in accurately predicting the disease suppressive ability of composts, whereas methods to identify shifts in microbial populations, such as T-RFLP and DGGE analyses, have been better indicators (Noble, 2011). For example, there were no determining biotic or abiotic characteristics of suppression against the soil-borne and foliar pathogens among nine composts tested, highlighting the complexity of the phenomenon and the importance of individual evaluation of compost products for specific uses (Ntougias *et al.*, 2008).

The following are some of the recent examples of the numerous studies that have shown that organic amendments can suppress disease including composts (Bruns and Schüler, 2000; Kuter *et al.*, 1988; Mandelbaum *et al.*, 1988; Pane *et al.*, 2011; Postma *et al.*, 2003; Romaine and Holcomb, 2001; Scheuerell *et al.*, 2005; Termorshuizen *et al.*, 2004; van der Gaag *et al.*, 2007; Veeken *et al.*, 2005), compost teas (Al-Dahmani *et al.*, 2003; Haggag and Saber, 2007; Koné *et al.*, 2010), fish emulsions (Abbasi *et al.*, 2002; Abbasi *et al.*, 2004; El-Tarabily *et al.*, 2003), seaweed extracts (Sultana *et al.*, 2011), industrial waste materials (Abbasi *et al.*, 2007), bioinoculants (Abdul-Khaliq *et al.*, 2011; Gravel *et al.*, 2009; Hu *et al.*, 2010; Tong-Jian *et al.*, 2013), biochar (Elad *et al.*, 2010; Elad *et al.*, 2011; Meller Harel *et al.*, 2012), vermicomposts (Edwards *et al.*, 2010) and fresh plant tissue (De Corato *et al.*, 2011; Giotis *et al.*, 2009; Kayani *et al.*, 2012; Klein *et al.*, 2011; Klein *et al.*, 2012; Mashela *et al.*, 2007).

Some vermicomposts suppressed populations of mites and insects on cucumbers, peppers, tomatoes, cabbages, bush beans and eggplants in the greenhouse (Arancon *et al.*, 2005b; Arancon *et al.*, 2007b).

Organic amendments have also been evaluated for their ability to suppress the growth of weeds in container grown-ornamentals. Dried distiller grains with solubles (DDGS) incorporated at various rates into a commercial pine bark potting mix reduced emergence and growth of common chickweed (*Stellaria media*) at ≥5% (w/w) and annual bluegrass (*Poa annua*) at ≥10% (w/w) (Boydston *et al.*, 2008). However, potting soil amended with ≥10% (w/w) DDGS caused severe stunting, reduced flowering and, at 20%, death of rose (*Rosa* hybrid), phlox (*Phlox paniculata*) and coreopsis (*Coreopsis auriculata*). Due to this unacceptable phytotoxicity, DDGS was then surface-applied but impractical rates of 800 or 1600 g m^{-2} were required to reduce the number of annual bluegrass plants by 40% and 57%, and common chickweed by 33% and 58%, respectively (Boydston *et al.*, 2008).

3.3.1 Increased Diversity/Activity of Beneficial Microbes

Several authors agree that it is the diversity of the microbial populations (specific sub-populations) rather than the abundance (total population numbers) that is important for disease suppression by organic amendments such as compost and compost tea (Kannangara *et al.*, 2000; Palmer *et al.*, 2010b; Scheuerell and Mahaffee, 2002; Scheuerell and Mahaffee, 2004; Scheuerell and Mahaffee, 2006; Weltzien, 1991). Perhaps both increased competition from the saprophytic soil biota (Giotis *et al.*, 2009) and increased populations of antagonistic microbes (Gorodecki and Hadar, 1990) play a role in reducing plant disease. There are positive correlations between microbial activity in substrates with certain organic amendments and suppression of plant disease (Labrie *et al.*, 2001). For example in one study, compost amendments did not increase the number of microorganisms in the rhizosphere compared to the control, but altered the species composition, increasing the incidence of plant growth-promoting bacteria antagonistic to some pathogens (De Brito Alvarez *et al.*, 1995). Likewise, in other studies, suppressive media (containing amendments) had more diverse microbial populations, and were comprised of more fluorescent pseudomonads, heterotrophic fungi, actinomycetes, endospore-forming bacteria and oligotrophic bacteria than less suppressive media (Aryantha *et al.*, 2000; Diab *et al.*, 2003; Gorodecki and Hadar, 1990). In another example, biphasic composting altered the resident microbial populations in the compost, promoting the proliferation of Gram-positive bacteria antagonistic to oomycete plant pathogens such as *Pythium ultimum* (Labrie *et al.*, 2001).

There is potential for specific disease-suppressive microbes to be isolated, mass produced and added back into media to enhance disease control (Hardy and Sivasithamparam, 1995). Amendments, in this case fish emulsion, can not only act as a nutrient base for the growth and increased activity of specific microbes such as plant growth-promoting rhizobacteria, but also provide precursors for the production of plant growth regulators such as auxins, gibberellins and cytokinins (Abbasi *et al.*, 2004; El-Tarabily *et al.*, 2003).

3.3.2 Antagonistic Microbial Species

Composts can act as a natural reservoir of biocontrol agents or can be a food base for specific introduced biocontrol agents, allowing them to establish as part of an active microbial community, resulting in sustained biological control (Hoitink and Boehm, 1999). It is important to determine optimal compost conditions for maximal colonization of the compost by antagonists and inoculate accordingly (Chung and Hoitink, 1990). The recolonization of composts by biocontrol agents is affected by factors such as the starter feedstock, compost maturity and stability, moisture content, pH, irrigation practices, and rate of compost application (Zinati, 2005). Measuring the level of decomposition of organic matter and the microbial activity can give an indication of disease suppressive ability of a compost (Zinati, 2005).

For example, a naturally disease suppressive compost amended with a non-pathogenic isolate of *Fusarium oxysporum* was highly suppressive to *Fusarium* wilt of tomato, giving significantly greater suppression than that caused by the compost alone (Cotxarrera *et al.*, 2002). The conditions in this substrate were presumably conducive to the growth and effective colonization by the microbe, forming large populations.

3.3.3 Enhanced Resistance

It has been proposed that composts can suppress plant diseases by inducing systemic acquired resistance (SAR) (Zhang *et al.*, 1998). Compost, containing biological control agents and suppressive to several soil-borne diseases, induced SAR in cucumber against anthracnose caused by *Colletotrichum orbiculare* and in *Arabidopsis* against bacterial speck caused by *Pseudomonas syringae* pv. *maculicola*. Compost-amended mixes support high populations of microorganisms that are the likely mechanism for induction of SAR (Zhang *et al.*, 1998). Lievens *et al.* (2001) postulated that compost derived from domestic garden waste induced systemic resistance against *Pythium* root rot of cucumber caused by *Pythium ultimum*. Three of nine composts induced systemic resistance against the foliar pathogen *Septoria lycopersici* in tomatoes (Ntougias *et al.*, 2008).

Biochar may induce systemic resistance to pathogens of strawberries, tomato and pepper (and a pest of pepper) by stimulating beneficial soil microbes, adding chemical elicitors such as salts and organic chemicals, or as a result of stress derived from the presence of low levels of phytotoxic compounds (Elad *et al.*, 2010; Elad *et al.*, 2011; Meller Harel *et al.*, 2012).

3.3.4 Production of Inhibitory and Antimicrobial Compounds

Some organic amendments can suppress nematodes by releasing pre-existing nematicidal chemicals, generating nematicidal compounds during decomposition, but also by enhancing populations of antagonistic organisms, increasing plant tolerance or resistance, or causing physical changes to the substrate (Oka, 2010). Vermicompost tea was able to suppress the establishment and reproduction rate of green peach aphid, citrus mealybug and two-spotted spider mite on tomatoes and cucumbers (Edwards *et al.*, 2010). The suggested mechanism of pest suppression was a change in the pests' feeding responses to the plants absorbing and accumulating soluble phenolic materials from the vermicompost tea, making the plants much less attractive, interfering with reproduction patterns and survival (Edwards *et al.*, 2010).

3.4 Increased Beneficial Microbial Biomass

The addition of organic amendments to substrates can increase the populations of known beneficial microorganisms such as AM fungi (Aleklett and Wallander, 2012; St. John *et al.*, 1983). The application of beneficial microorganisms can promote the growth of other beneficial microorganisms. For instance, the ectomycorrhizal fungus *Pisolithus* sp. inoculated onto Allepo pine (*Pinus halepensis* Mill.) seedlings grown in soil in pots significantly altered the functions of soil microbial populations, favouring microorganisms potentially beneficial to plant growth, such as phosphate solubilizing bacteria (Ouahmane *et al.*, 2009). Tea compost or flower compost (unspecified), as well as two other treatments of sugarcane bagasse and molasses, increased significantly the numbers of desirable free-living nematodes when applied to naturally infested flower beds before planting carnation, compared to unamended beds (Langat *et al.*, 2008). Free-living nematodes play an important role in nutrient cycling (but any effect on plant parasitic nematodes was not discussed).

Various organic amendments increase microbial biomass. Seaweed extracts can promote the growth of beneficial microorganisms (Khan *et al.*, 2009). Large and diverse microbial populations in vermicomposts may contribute to their positive effects on plant growth (Arancon *et al.*, 2008; Atiyeh *et al.*, 2000c; Pant *et al.*, 2012b; Szczech *et al.*, 1993; Tognetti *et al.*, 2005). It has been suggested that biochar amendment caused a shift in microbial populations towards beneficial microbes (Graber *et al.*, 2010; Kolton *et al.*, 2011; Lehmann *et al.*, 2011; Thies and Rillig, 2009). In the growth room, tomato seeds were sown in field soil amended with 2%, 4% or 8% spearmint (*Mentha spicata* L.) or sage (*Salvia fruticosa* Mill.) compost (Chalkos *et al.*, 2010). In general, the abundance of bacterial and fungal soil microbes increased, the population of nitrifying bacteria were maintained and tomato growth was stimulated, with increasing rate of both composts compared to those in the standard medium. The highest bacterial density, the highest fungal density, the tallest tomato plants (3 x taller), the greatest plant biomass and the best weed suppression was associated with the 8% spearmint compost. So whilst known beneficial species may not have been positively identified, the presence of large and diverse microbial populations may have some favourable effects on plant growth.

3.5 Increased Tolerance to Water Stress

Organic amendments may help retain water and nutrients in containerized production, but there is negligible data to support this claim. In pot trials in the glasshouse, tomato seedlings grown in sandy soil amended with wood-derived biochar had increased resistance to water stress (Mulcahy *et al.*, 2013). Amendment with 30% (v/v) biochar, concentrated in seedling root zones significantly increased the resistance of seedlings to wilting. However, amendment of peat-based substrates with high rates (75% or 100%) of composted green waste increased the susceptibility of *Viburnum* and *Photinia* to water stress (Mugnai *et al.*, 2007).

3.6 Increased Flower and/or Fruit Set

Many studies have shown that a variety of organic amendments can increase flower set and/or fruit set of plants in containerized production. Ornamental plants grown in media amended with composts derived from the following feedstocks showed improved flower and/or fruit set: cotton waste (Papafotiou *et al.*, 2001b), spent mushroom (Dallon Jr, 1987), MSW (Ribeiro *et al.*, 2000) and sewage sludge (Klock-Moore, 2000; Wilson *et al.*, 2004; Wilson and Stoffella, 2006). Flower and/or fruit set was improved in tomatoes, poinsettias and marigolds treated with a seaweed extract (Aitken and Senn, 1965; Aldworth and Van Staden, 1987; Crouch and Van Staden, 1992; Russo *et al.*, 1994; Van Staden *et al.*, 1994), or marigolds grown in media amended with oil palm waste (Jayasinghe *et al.*, 2009). Ornamental plants inoculated with AM fungi had enhanced flower and/or fruit set (Aboul-Nasr, 1996; Gaur *et al.*, 2000; Perner *et al.*, 2007). Vermicomposts increased flower set and/or fruit set of vegetables (Arancon *et al.*, 2004; López-Gómez *et al.*, 2012) and ornamentals (Arancon *et al.*, 2008; Atiyeh *et al.*, 2002a; Hidalgo and Harkess, 2002; Hidalgo *et al.*, 2006; Rodriguez-Navarro *et al.*, 2000; Sangwan *et al.*, 2010). Finally, humic extracts showed some ability to improve flower and/or fruit set (Arancon *et al.*, 2006).

3.7 Increased Root Formation in Cuttings

There is limited evidence to support the claim that organic amendments can increase root formation in cuttings. Cuttings of ornamental species, including some shrubs, had increased rooting after the application of MSW compost (Chong, 2000; Pacholczak *et al.*, 2012), a seaweed extract (Crouch and van Staden, 1991) or vermicompost (Tomati *et al.*, 1993). The seaweed extract also improved rhizogenesis in cuttings of a *Pinus* species (Jones and Van Staden, 1997).

3.8 Increased Yield

Organic amendments are claimed to increase yields. There is evidence to support this from studies investigating different vegetable and herb crops. Compost derived from cattle dung (Raviv *et al.*, 1998a; Raviv *et al.*, 2005) or MSW (in combination with MSW compost tea)(Radin and Warman, 2011) improved the yield of tomatoes. Similarly, uncomposted MSW increased the yield of herbs (Zheljazkov, 2005). The yield of various vegetables was enhanced by seaweed extracts (Arthur *et al.*, 2003;

Beckett *et al.*, 1994; Crouch *et al.*, 1990; Crouch and Van Staden, 1992). Plant growth-promoting bacteria did as their name suggests, causing yields of vegetables to increase significantly (Gravel *et al.*, 2007; Gül *et al.*, 2013; Mena-Violante *et al.*, 2005; Mena-Violante and Olalde-Portugal, 2007). Capsicum (Arancon *et al.*, 2004) and tomato (Atiyeh *et al.*, 2000a; Gutiérrez-Miceli *et al.*, 2007; Jack *et al.*, 2011) yields were improved due to media amendment with vermicomposts. Tomato yields also benefitted from the amendment of growing media with uncomposted plants (Jack *et al.*, 2011; Mashela *et al.*, 2007).

3.9 Reduced Transport Shock

Transplant shock, the period between transplanting and the resumption of vigorous growth, is due to internal water deficits (Sammons and Struve, 2004). Reducing these, via increased water uptake, rapid root regeneration, or reduced transpirational water loss would reduce internal water stress and increase transplant success. Some organic amendments claim to reduce transport shock.

Of the following studies, none measured transpiration rate or water uptake, and only Kowalski *et al.* (1999) recorded the rate of root regeneration. Applications of seaweed concentrates to seedlings of marigold, cabbage (Aldworth and Van Staden, 1987) and tomato (Crouch and Van Staden, 1992) increased root size and vigour and consequently, reduced transplant shock. When applied to the cut stem-base of cuttings of pelargonium, it reduced the stress of inserting the cuttings into the soil (Urbanek Krajnc *et al.*, 2012). The addition of seaweed extracts to the *in vitro* culture medium for potato and tomato propagation enhanced plantlet quality, increased survival and translated to better establishment in the greenhouse (Kowalski *et al.*, 1999; Vinoth *et al.*, 2012). Application as a soil drench following transplantation of *in vitro* grown plantlets of two species aided in acclimatization (Lindsey *et al.*, 1998).

There is evidence that mycorrhizal association can also aid in overcoming transplant shock, as demonstrated for micropropagated plantlets of the non-ornamental *Sesbania sesban* (Subhan *et al.*, 1998).

3.10 Improved Media Structure

The physical and chemical structure of the growing medium can be affected by different organic amendments. When producing compost from plant residues for use as a horticultural growing medium, the choice of the starting feedstock is crucial in terms of not only nutritional quality, but also structural quality (Dresbøll and Thorup-Kristensen, 2005; Dresbøll and Magid, 2006). Root development and proliferation is influenced by the physical structure and stability of the medium (Dresbøll and Thorup-Kristensen, 2005). Feedstocks with different lignin and cellulose contents, and different morphological properties, such as tissue arrangement, affect the features of the final compost product. The geometry and surface characteristics of particles and the resultant pores created determine the water retention properties and the air and water availability to roots (Dresbøll and Thorup-Kristensen, 2005).

Amendment of growth media with various composts, for example, those derived from grape marc, rice hulls, spent mushroom substrate or cattle manure, could improve some of the physical and chemical properties such as bulk density, total porosity and air-filled porosity, water holding capacity, cation exchange capacity, nutrient contents, carbon:nitrogen ratio and neutralize the pH.

Other organic amendments such as seaweed extracts, humic extracts and biochar, can also influence the physical and chemical properties of growing media, which in turn affect plant growth (Dudley *et al.*, 2004; Khan *et al.*, 2009; Thies and Rillig, 2009; Van Zwieten *et al.*, 2012). For instance, seaweeds can improve the water holding capacity of media, improving plant growth (Khan *et al.*, 2009). The improved growth of zinnia and marigold was potentially due, in part, to an increased cation exchange capacity of the medium due to the addition of leonardite (Dudley *et al.*, 2004). Finally, biochar may improve the physical structure of amended growing media and neutralizes acidic media (Thies and Rillig, 2009; Van Zwieten *et al.*, 2012).

4. Issues and Risks of Organic Amendment Application

4.1 Biological Contaminants in Organic Amendments

4.1.1 Human Hazards

Some organic amendments can pose a hazard to human health and safety. This topic was recently reviewed by Goss *et al.* (2013), but this paper discussed only field application of organic amendments, not their use in containerized production and focussed on the risks from animal manures and sewage biosolids only. For instance, MSW compost poses potential health hazards to the consumer and general public, as well as occupational health and safety of compost production workers (Gillett, 1992). This stems from the risk of contaminants such as heavy metals and organic pollutants and physical risks from sharps (glass, metal, plastic) (Farrell and Jones, 2009). The human (and environmental) health hazards of such urban waste composts have been reviewed by Déportes *et al.* (1995).

Similarly, compost and vermicompost and their teas can pose a risk, mostly in the form of potential pathogen contamination, to nursery staff when these are applied in production nurseries. Furthermore, if compost and vermicompost and their teas are to be used on food crops, such risks to both human and animal health need to be considered (Avery *et al.*, 2012; Edwards *et al.*, 2006). The Compost Tea Taskforce Report to the USA National Organic Standards Board recommended such application is to be avoided at all costs (Anonymous, 2004). This would be particularly so for compost and vermicompost teas employing animal wastes as the starter feedstock (Arancon *et al.*, 2007a), as regrowth of human pathogenic bacteria such as *Salmonella* is dependent on the type starter feedstock (Duffy *et al.*, 2004). Despite these concerns, no cases of food-borne illness from the use of compost tea have been reported (Anonymous, 2004).

Also, during compost tea production, supplements are often added with the aim of increasing the populations of beneficial microbes (which presumably translates into significant benefits to plant production, such as increased disease control)(Scheuerell and Mahaffee, 2004) but these may also support the growth of human pathogens (Anonymous, 2004; Duffy *et al.*, 2004; Ingram and Millner, 2007). Duffy *et al.* (2004) found that augmentation with molasses stimulated regrowth of human pathogenic bacteria, such as *E. coli* and *Salmonella enterica* (ex Kauffman & Edwards) Le Minor & Popoff, posing a serious human health hazard, particularly on produce destined for fresh consumption. The higher the molasses concentration, the higher the populations of *Salmonella* and *E. coli*; but these organisms did not grow when molasses was eliminated or kept at 0.2% (Duffy *et al.*, 2004).

Brinton *et al.* (2004) found that two commercial compost tea production systems (based on differing forms of mechanical aeration), and their individual commercial ingredients (supplied compost and nutrient source), when inoculated artificially, could support the growth of *E. coli*. Uninoculated production systems/ingredients did not produce *E. coli*-contaminated tea. This study also found that if a small amount of *E. coli* was introduced into compost tea (no additives), its population will decline to non-detectable levels in 72-120 hours; only when a large amount of *E.coli* was introduced into compost tea, did the levels remain elevated (regardless of aeration). The authors recommended that contamination of compost teas with *E. coli* should be avoided by employing clean handling techniques at every step and starting with composts with no detectable *E. coli* populations, i.e. composts that are very mature, no fresh manures, and no exposure to faecal matter during storage (Brinton *et al.*, 2004).

In a later study, Ingram and Millner (2007) tested commercial supplements added individually or in combination for their effect on the very low starter populations of *E. coli*, *Salmonella*, *Enterococcus* and faecal coliforms in aerated and non-aerated compost tea (compost starter feedstock was animal manure and domestic garden trimmings). These supplements included a bacterial nutrient solution that is a proprietary blend of molasses, bat guano, sea bird guano, soluble kelp, citric acid, Epsom salts, ancient seabed minerals and calcium carbonate; a blend of powdered soluble kelp, liquid humic acids and glacial rock dust; and, individually the following unspecified ingredients: fish hydrolysate 1; 'soil soup'; seaweed; fish hydrolysate + seaweed; humic acid; kelp; and fish hydrolysate 2. The authors found that the addition of such supplements alone or combined increased populations of *E. coli*, *Salmonella* and faecal coliforms in both aerated and non-aerated compost tea, in some cases up to 1000-fold (Ingram and Millner, 2007). Aerated compost tea augmented with supplements supported higher levels of *E. coli*, *Salmonella* and faecal coliforms than did augmented non-aerated compost tea. The opposite was reported by Kannangara *et al.* (2006) who found aerated compost tea supplemented with molasses and kelp had significantly lower concentrations of *E. coli* than supplemented non-aerated compost tea. This may have been influenced by their much higher starter inoculum concentration of 10^6 to 10^7 CFU/mL (Kannangara *et al.*, 2006). Moreover, *E. coli* density increased with increasing concentration of molasses and kelp, and molasses lead to higher concentrations than kelp. Having said this, *E. coli* was not detected in uninoculated compost teas, and so the addition of supplements may not be detrimental if the compost used is relatively free of pathogens (Kannangara *et al.*, 2006). Yet, to be sure, supplements should not be employed when compost tea is to be used on fresh produce crops.

Also, *E. coli* density in compost teas differed with the starter feedstock (Kannangara *et al.*, 2006). In a study assessing a range of starter feedstocks, the order of increasing *E. coli* density was separated dairy solids vermicompost tea, horse manure compost tea, dairy manure compost tea and swine manure compost tea. Concerns about the potential contamination by *E. coli* may possibly be allayed by adding carrot juice to the tea production process, since the addition of carrot juice to swine manure compost tea (the only one tested) significantly reduced the growth of *E. coli* under aerated and non-aerated conditions, but further studies are required (Kannangara *et al.*, 2006). Earlier work by Dominguez and Edwards (1997) and Eastman *et al.* (2001) that indicated that populations of human pathogens were substantially reduced by vermicomposting. Dominguez and Edwards (1997) found that after 60 days of vermicomposting, faecal coliform bacteria in biosolids dropped from 39,000 MPN/g to 0 MPN/g, and *Salmonella* sp. dropped from <3 MPN/g to <1 MPN/g (MPN=most probable number; a standard method for enumerating such bacteria). Eastman *et al.* (2001) found that in windrows of biosolids inoculated with earthworms, the populations of human pathogen indicator species decreased significantly compared to control windrows of biosolids within 144 hours. This included a 6.4-log reduction in faecal coliforms, an 8.6-log reduction in *Salmonella* spp., a 4.6-log reduction in enteric viruses, and a 1.9-log reduction in helminth ova; in the vermicompost compared to the windrows not seeded with earthworms.

Supplements added during compost tea production can cause other sanitary issues. For example, supplements such as the bacterial nutrient solution and the kelp-humic acids-rock dust blend described earlier caused a substantial microbial biofilm to develop on the brewing equipment. Biofilms protect microbes from disinfectants, mechanical washing and antibiotics, so the equipment would need to be thoroughly sanitized before brewing the next batch of compost tea to avoid a build-up of human pathogenic bacteria (Ingram and Millner, 2007).

This same study by Ingram and Millner (2007) compared the effect of aerated and non-aerated compost tea production methods, without any supplements, on the growth and survival of the same microorganisms. Inoculated *Salmonella*, *Enterococcus* and faecal coliforms grew in aerated compost tea, but *E.coli* did not, whilst non-aerated compost tea contained no detectable levels of any of these inoculated microorganisms. Kannangara *et al.* (2006) and Palmer *et al.* (2010a) also found no growth of *E. coli* in compost tea without supplements. However, aerated compost tea supplemented with 0.8% fish hydrolysate or 1% molasses caused a significant increase in the growth of inoculated *E. coli*. However, the addition of 0.5-2% liquid kelp or a mixture of 1.7% liquid kelp/0.8% fish hydrolysate led to a decrease in *E. coli* numbers (Palmer *et al.*, 2010a). Non-aerated tea was not tested. The aerated compost tea was also tested for any naturally occurring human pathogens, such as *E. coli, L. monocytogenes* and *Bacillus cereus*, and none of these was detected (Palmer *et al.*, 2010a). Brinton *et al.* (2004) advised that the presence or absence of aeration was of less significance than compost quality and hygienic production methods, and that growers and composters should focus attention on these issues.

Bess *et al.* (2002) used a manure-based compost that had low endemic levels of *E. coli* to test the effects of additional nutrient sources on the regrowth of *E. coli* in aerated compost teas. The nutrient sources tested were molasses, yeast extract, barley malt, seaweed extract, fish emulsion, and a combination product of fish and manure. The addition of nutrients containing simple sugars, such as molasses, yeast extract, and barley malt, resulted in pathogen regrowth to significantly high levels, compared to the unamended tea. More complex nutrient sources, such as seaweed extract, fish emulsion and the combination product of fish and manure, did not result in increased *E. coli* populations.

Given that regrowth of human pathogens does not seem to occur in compost teas that have not been supplemented with nutrients (Mahaffee and Scheuerell, 2006), it may be prudent to only use these products on containerized crops destined for human consumption.

During the composting process, pathogen populations are generally reduced to below disease-causing thresholds mainly by thermal destruction, but it is thought that other mechanisms including competition between microorganisms, the exhaustion of nutrients and by-product toxicity play a role (Avery *et al.*, 2012). However, this competition hypothesis was not supported in these studies where the natural microbial community did not prevent regrowth of pathogenic microbes (at least in teas with supplements) (Bess *et al.*, 2002; Duffy *et al.*, 2004; Ingram and Millner, 2007). According to the Australian Standard AS4454-2012, human pathogens are eliminated by pasteurization by preparing thermogenic composts with three turns of the material, with internal minimum temperatures above 55°C for more than 72 hours before each turn, or by other methods that can guarantee the same level of pathogen reduction (e.g. 2-3 weeks in well-managed turned windrows). Arancon *et al.* (2007a) suggested vermicomposting for more than 50 days would meet this criterion. To reiterate, the temperature and time profiles must apply throughout the compost for the elimination of high risk microorganisms (Noble and Roberts, 2004; Noble *et al.*, 2009).

4.1.2 Plant Hazards

Lethal temperatures and adequate exposure times are crucial in eliminating plant pathogens and pests in organic amendments through processes such as composting, and this has been recently reviewed by Noble *et al.* (2009) and Noble and Roberts (2004). Pathogen and pest eradication is influenced to a lesser extent by other factors of the compost, such as moisture; feedstock type, particle size and mixing process; the presence of toxic compounds and volatiles; and microbial antagonism (Noble and Roberts, 2004; Noble and Coventry, 2005; Noble *et al.*, 2009). It is essential that detection methods used for particular organisms not only assess the presence of the pathogen, but also its viability (Noble *et al.*, 2009). Particular attention needs to be paid to the consistency of the lethal temperature throughout the entire compost mass, since pathogens could potentially survive in cooler areas of the compost, especially in systems where the compost is not turned (Noble and Roberts, 2004).

Similarly, lethal temperatures and adequate exposure times are essential in eradicating viable weed seeds, which are most likely to be found in composts derived from animal manure (Larney and Blackshaw, 2003; Quilty and Cattle, 2011). Such lethal temperatures to eliminate viability are species-dependent, but the majority will be destroyed under usual composting conditions.

4.2 Non-Biological Contaminants in Organic Amendments

The main risk of non-biological contaminants is glass, metal and plastic fragments in MSW compost (Castillo *et al.*, 2004; Chong, 2005; Diener *et al.*, 1993). The source material must be effectively separated and screened to ensure the safety of the amendment. The possibility of heavy metals being present in composts made from MSW, sewage sludge and paper mill sludge must also be considered and batches analysed to ensure safety (Bellamy *et al.*, 1995; Castillo *et al.*, 2004; Chong, 2005; Diener *et al.*, 1993; Goicoechea, 2009; Tripepi *et al.*, 1996). Organic contaminants like dioxins and polychlorinated biphenyls (PCBs) may also be an issue in paper mill sludge compost (Bellamy *et al.*, 1995; Chong, 2005; Tripepi *et al.*, 1996).

4.3 Inconsistent Composition

Shifts in time and source can lead to inconsistency in the constitution of a specific organic amendments (Hicklenton *et al.*, 2001), such as the starter feedstock used for composts and vermicomposts. Variation in physical, chemical and biological parameters across and within compost types, sources and batches has hindered its widespread use as an organic amendment (St. Martin and Brathwaite, 2012). Factors such as starter feedstock type; production methods including pre- and post-processing methods; level of compost maturity and stability; and the resulting chemical, physical and biological attributes of the compost impact the efficacy of compost to improve plant growth and/or suppress disease (Fitzpatrick *et al.*, 1998; Litterick and Wood, 2009; Nkongolo *et al.*, 2000).

4.4 Variable Efficacy

Organic amendments are thought to have great potential to improve plant growth and control soil-borne disease but their effects have been generally inconsistent (Bonanomi *et al.*, 2007). Such inconsistent results have hampered their widespread recommended use (Bonanomi *et al.*, 2010; Pane *et al.*, 2011). Bonanomi *et al.* (2007) reviewed 2423 studies (including field use) from 250 papers and found that organic matter was suppressive to disease incidence or pathogen populations in 45% of studies, had no significant effect in 35% of studies and increased disease incidence or pathogen populations in 20% of studies. Also, shifts in time and source can lead to inconsistency in the constitution of a specific organic amendment and variation in characteristics of the resultant growing media (Hicklenton *et al.*, 2001). For instance, an organic amendment that improves plant production at one locale, may not do so in other regions with a different climate, plant materials and cultural conditions (Chong, 2005).

Compost and vermicompost production methods and application rates, and those of their teas, need to be standardized to ensure that a safe and effective product can be consistently manufactured and delivered (Edwards *et al.*, 2006). Furthermore, with respect to seaweed extracts, it has been proposed that rapid bioassays could be used for quality control purposes to ensure levels of bioactive compounds were consistent and effective, despite variation in factors such as geographic area of collection, season and growth stage (Rayorath *et al.*, 2008). Also, the effect of organic amendments on plants can be species-specific and cultivar-specific (Chong, 2005), and likewise for their effect on plant pathogens (Bonanomi *et al.*, 2007).

4.5 Phytoxicity and Changes to the Physical and Chemical Properties of Media

The application of some organic amendments, especially at high rates, can cause phytotoxicity to the desirable crop (Carballo *et al.*, 2009; Ceglie *et al.*, 2011; Chong, 1999; Chong, 2005; Goicoechea, 2009; Hammermeister *et al.*, 2006). Phytotoxicity varies with different organic amendments *per se*, and with different rates within those amendments; for example, the minimum application rate at which phytotoxicity occurred was very low for crop residues (undecomposed matter) at ~2% (v/v), but quite high for composts at 50% (v/v) (Bonanomi *et al.*, 2007).

Organic amendments can cause undesirable changes to the physical and chemical properties of soilless growing media. For example, organic amendments can cause a reduction in the total porosity (Papafotiou *et al.*, 2005; Papafotiou and Vagena, 2012), the water availability/water holding capacity (Burger *et al.*, 1997; Carmona *et al.*, 2012; Lopez-Real *et al.*, 1989; Medina *et al.*, 2009; Papafotiou *et al.*, 2005; Papafotiou and Vagena, 2012; Tosi *et al.*, 1989), and the cation exchange capacity (Jackson *et al.*, 2006; Lopez-Real *et al.*, 1989; Tripepi *et al.*, 1996; Wright and Browder, 2005; Wright *et al.*, 2006). They can also cause an increase the bulk density (Dumroese *et al.*, 2011; Lopez-Real *et al.*, 1989; Papafotiou *et al.*, 2005), the carbon:nitrogen ratio (Benito *et al.*, 2005; Benito *et al.*, 2006; Dumroese *et al.*, 2011; Jackson *et al.*, 2006; Wright *et al.*, 2006), the souble salt levels (Bellamy *et al.*, 1995; Chong and Rinker, 1994; Chong, 1999; Chong, 2005; Fidanza *et al.*, 2010; Garcia-Gomez *et al.*, 2002; Gils *et al.*, 2005; Gouin, 1993; Jack *et al.*, 2011; Papafotiou *et al.*, 2005; Radin and Warman, 2011; Shiralipour *et al.*, 1992; Spiers and Fietje, 2000), the nitrogen drawdown (Handreck and Black, 2002), the pH (Chong and Rinker, 1994; Chong, 1999; Chong, 2005; Fidanza *et al.*, 2010; Handreck and Black, 2002; Herrera *et al.*, 2008; Koller *et al.*, 2004; Nair *et al.*, 2011), the ammonium concentration (Chong, 2005; Handreck and Black, 2002), the slumpage (Bellamy *et al.*, 1995; Chong, 1992; Chong and Rinker, 1994; Chong, 1999; Handreck and Black, 2002), the air-filled porosity (Burger *et al.*, 1997), and the nitrogen immbolization (Bellamy *et al.*, 1995; Chong *et al.*, 1998; Chong, 1999; Chong, 2005; Handreck and Black, 2002; Hue and Sobieszczyk, 1999). High rates can also cause an increased susceptibility to water stress (Mugnai *et al.*, 2007). These can all reduce plant growth.

The widespread use of organic amendments, such as compost, is restricted by a lack of homogeneous characteristics, potentially high levels of soluble salts and the risk of other phytotoxic compounds (Ceglie *et al.*, 2011). In particular, poultry/turkey litter composts (Chong, 2005), spent mushroom compost (Maher, 1991; Maher, 1994) and some vermicomposts (Arancon *et al.*, 2003; Asciutto *et al.*, 2006; Atiyeh *et al.*, 2001) have high salt levels that are phytotoxic and must be tested thoroughly, and used at low rates and/or further processed to avoid deleterious effects on plants.

4.6 Ideal Application Rates

It is difficult to identify ideal application rates of the different organic amendments from the literature. This is in part due to differential plant responses; what is optimal for one species may be different for another. For example, the effect of composted green waste on the growth of ornamentals was species-specific; it increased *Viburnum* growth, but decreased *Photinia* growth (Mugnai *et al.*, 2007). The numerous variables that can be manipulated also add to the challenge of determining ideal application rates, such as feedstock type, maturity, and the myriad of production parameters. Also, the inconsistent efficacy of some organic amendments (Bonanomi *et al.*, 2007; Bonanomi *et al.*, 2010) makes it hard to ascertain the effective rate. In addition, different techniques have been used in different studies, for example with the application of mycorrhizal fungi, many researchers used their own inocula generated from growing the fungi on host plants (Gaur and Adholeya, 2005; Russo, 2006; Sohn *et al.*, 2003) while others used commercial inocula (Nowak, 2004). Rates also depend on other components of the medium.

4.7 Public Perception

Composts derived from waste materials or by-products from other industries may be useful as an ingredient in container media in ornamental, nursery crop and vegetable transplant production systems (Epstein, 1997; Fitzpatrick, 2001; Sterrett, 2001). Whilst there may be reluctance to use some of these composts for food crop production, due in part to a negative perception by society of the source feedstock (for example, sewage sludge biosolids and municipal solid waste), these composts may find more acceptance for the production of non-edible crops such as ornamentals, forest and garden trees and shrubs (Alexander, 2001; Farrell and Jones, 2009; Raviv, 2005; Raviv, 2008). The response of plant species to media amendment with waste-derived compost has been variable, ranging from detrimental to no effect to beneficial. If the addition of waste-derived composts has no effect on plant growth and no undesirable effects on media properties, they should not be discounted as they may still have merit as a cost-effective and sustainable component of the production system.

4.8 Environmental Footprint and Sustainability

The sustainability of manufacturing fish-based liquid fertilizers has been questioned, since they may be contributing to supporting unsustainable fishing practices (Giotis *et al.*, 2009). This can be avoided by manufacturing the product from the processing of feral fish species, which not only preserves natural fish populations, but targets pest species that have numerous ecological effects.

Similarly, the sustainability of harvesting seaweed from the ocean has been examined (Ugarte and Sharp, 2001). This review, focussing on *Ascophyllum nodosum*, acknowledged that seaweeds play an important role as a habitat for invertebrates and vertebrates, and discussed a pilot program of management measures implemented in eastern Canada, such as a maximum exploitation rate, recommended cutting heights, imposed gear restrictions, and created protected areas. The sustainability of harvesting drifting and beach-cast seaweeds in Australia requires more research (Kirkman and Kendrick, 1997). Aquaculture of seaweeds, which is widespread in some parts of the world, can be integrated with fish and shrimp aquaculture to improve the sustainability of these processes (Chopin *et al.*, 2001).

5. Summary of Organic Amendments, Features, Costs, Application Rates, Potential Drawbacks and Practical Relevance

A summary of organic amendments, their features (verified by scientific publications), approximate current costs, suggested application rates, potential drawbacks and practical relevance of the technology are presented in Table 1.

Table 1. Organic amendments used in containerized production, their features (verified by scientific publications), estimated costs (adapted from Quilty and Cattle, 2011), application rate, potential drawbacks and practical relevance.

Organic Amendment	Feature (verified by scientific publications)[a]	Approximate Costs 2013	Application Rate	Potential Drawbacks	Practical Relevance[b]
Composts	Good nutrient source to plants Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases flower and/or fruit set Increases root formation in cuttings Increases yield Improves media structure	Pelletised products: $105-$525/t Non-pelletised products: $7-$840/t	20-50% v/v but varies for different composts and plant species	• Can have detrimental effects on physical and chemical properties of media e.g. animal manures, green waste, MSW, spent mushroom, sewage sludge • Can have variability in properties between batches e.g. green waste, MSW, sewage sludge • Potential human health issues from pathogens and/or sharps e.g. animal manures, MSW • Potential plant health issues e.g. MSW • Unpleasant odours e.g. MSW • Heavy metals/Organic contaminants e.g. MSW, sewage sludge, paper mill sludge • Inconsistent efficacy • Effect can be species-specific	Ease: Variable, generally easy-moderate Costs: Minimal
Compost Teas	Stimulates plant growth Suppresses disease	Cost of compost: $7-$840/t; Then depends on aeration: Non-aerated: negligible Aerated: $250-$2000	A 1:1 to a 1:9 dilution, apply equivalent to 50 L/ha every 14 days; but requires optimization	• Potential human health issues from pathogens e.g. particularly nutrient-amended • Inconsistent efficacy • Need to be made fresh • Effect can be species-specific	Ease: Variable, generally easy-moderate Costs: Minimal-moderate
Meat, Blood and Bone Meal	Good nutrient source to plants Stimulates plant growth	Liquids: $11-$32/L Solids: $840-$1260/t	Liquids: unknown Solids: 1-5% v/v	• Unpleasant odours • Potential human health issues from pathogens? (BSE overseas)	Ease: Easy Costs: Minimal
Fish Emulsions	Good nutrient source to plants Stimulates plant growth Suppresses disease	$16-$26/L	0.5-2% v/v	• Unpleasant odours	Ease: Easy Costs: Minimal
Seaweed Extracts	Stimulates plant growth (hormones) Suppresses disease Increases beneficial microbial biomass Increases flower and/or fruit set Increases root formation in cuttings	$11-$32/L	0.4-2% v/v (20% v/v for some species)	• Potential human health issues from pathogens e.g. composted seaweed • Inconsistent efficacy	Ease: Easy Costs: Minimal

	Increases yield Reduces transplant shock Improves media structure				
Organic Waste Materials, Uncomposted	Good nutrient source to plants Stimulates plant growth Suppresses disease Suppresses weeds Increases flower and/or fruit set Increases yield	Variable, undetermined	2.5-25% v/v	• Potential human health issues from pathogens e.g. activated sewage sludge • Unpleasant odours e.g. activated sewage sludge • Heavy metals/Organic contaminants e.g. raw paper mill sludge • Inconsistent efficacy	Ease: Variable, moderate Costs: Minimal
Bioinoculants	Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases flower and/or fruit set Increases yield Reduces transplant shock	$11-$80/L	Varies; Liquid: 30-60 mL/ 7.6 L container Solid (experimental) - colonized host plant roots, spores, mycelia, substrate): e.g. 2 g/hole of 50 spore/g inocula)	• Effect may be neutral or negative • Effect can be species-specific	Ease: Easy-moderate Costs: Minimal
Biochar	Moderate nutrient source to plants Stimulates plant growth Suppresses disease Increases beneficial microbial biomass Increases tolerance to water stress Improves media structure	$2500/t[c]	1-10% v/v	• May decrease the efficacy of some pesticides • May negatively affect the availability of nutrients • May release bound toxicants such as heavy metals • If allowed to dry out, can become water repellent • Expensive due to lack of large scale production facilities	Ease: Difficult Costs: Minimal
Vermicomposts	Good nutrient source to plants Stimulates plant growth Suppresses disease Suppresses pests Increases beneficial microbial biomass Increases flower and/or fruit set Increases root formation in cuttings Increases yield Improves media structure	Liquids: $1-$21/L Solids: $265-$1050/t	Liquids: A 1-10% solution, applied as drench or spray equivalent to 150-200 mL/25 cm pot every 7 days; but requires optimization Solids: 10-40% v/v but varies for different vermicomposts and plant species	• Can have detrimental effects on physical and chemical properties of media e.g. animal manures	Ease: Variable, generally easy-moderate Costs: Minimal-moderate

Humic Extracts	Moderate nutrient source to plants Stimulates plant growth Increases flower and/or fruit set Improves media structure	Liquids: $4-$26/L Solids: $42-$840/t	250-1000 mg humic extracts/kg medium (solid)	• Potential phytotoxic aromatic compounds	Ease: Minimal Costs: Minimal
Uncomposted Plant Parts	Stimulates plant growth Suppresses disease Increases yield	Variable, undetermined	Variable, depending on plant parts	• Can have detrimental effects on physical and chemical properties of media e.g. alfalfa meal, coir, pine tree substrate • Potential phytotoxic compounds e.g. alfalfa meal, oilseed meal, pine tree substrate, plant extracts	Ease: Variable, generally easy-moderate Costs: Minimal

[a]See section 3 of this report
[b]Practical relevance concerns issues such as Ease (Ease of sourcing product/materials/equipment) and Costs (Costs to retrofit and/or apply the product)
[c](Billingham, 2012)

6. Current Knowledge Gaps in the Efficacy of Organic Amendments used in Plant Production

6.1 Recommendations for Future Research Investment

The following recommendations were developed based on the review of the literature:

Recommendation 1: Evaluate the efficacy and optimal application rate of emerging organic amendments for containerized production.
There is very limited scientific assessment of some of the emerging organic amendments such as biochar, amino acid products, organic acid broths and microbial products. Robust scientific assessment of these products is required in a wide range of crops, including annuals, perennials, shrubs and trees, to thoroughly evaluate their efficacy and reliability, and to inform nursery operators of their applicability to their production system. Application rates need to be optimized in individual production systems.

Recommendation 2: Evaluate the shelf life of organic amendments.
There are few studies on the shelf life of organic amendments. Data is required on the time period for which these products retain their efficacy under normal storage conditions.

Recommendation 3: Determine the optimal base level nutritional benchmarks for all nursery crops.
To achieve the highest quality product from nursery crops, careful management of the nutrient levels within the plants is required. It is essential that nutrients are taken up effectively and efficiently to ensure healthy, vigorous growth. While optimal base level nutritional benchmarks at the end of the nursery growing cycle are established for many nursery crops, there are still some data gaps. This knowledge is required so that it can be determined which organic amendments can be used to supply or partly supply these nutrients.

Recommendation 4: Match nutrient charting and responsive fertilizer applications to nutrient release from organic amendments.
Whilst optimal base level nutritional benchmarks are established for many nursery crops at the end of the nursery growing cycle, it is more desirable to calculate the nutritional needs for these crops over their growing cycle (for example, weekly nitrogen uptake). Nutrient charting monitors the nutrient status of the plant, so that nutrients can be supplied in the precise quantity required, at the correct time, to achieve a desired product quality. Nutrient charting and responsive fertilizer applications should be matched to nutrient release from organic amendments, to determine the precise application timing of organic amendment products for optimal efficacy.

Recommendation 5: Investigate using blends and sequential application of organic amendments matched to crop requirements.
Nutrient charting, responsive fertilizer applications and organic amendment nutrient release data can then be used to determine the optimal composition of blends and/or

the order of sequential application of individual organic amendments for specific crops for optimal plant production.

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8. References

ABAD, M., NOGUERA, P. & BURÉS, S. 2001. National inventory of organic wastes for use as growing media for ornamental potted plant production: case study in Spain. *Bioresource Technology,* 77: 197-200.

ABAD, M., NOGUERA, P., PUCHADES, R., MAQUIEIRA, A. & NOGUERA, V. 2002. Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. *Bioresource Technology,* 82: 241-245.

ABBASI, P. A., CONN, K. L. & LAZAROVITS, G. 2002. Suppression of seedling damping-off diseases and promotion of plant growth with fish-emulsion amended planting mix. *Canadian Journal of Plant Pathology,* 24: 380 (Abstr.).

ABBASI, P. A., CUPPELS, D. A. & LAZAROVITS, G. 2003. Effect of foliar applications of neem oil and fish emulsion on bacterial spot and yield of tomatoes and peppers. *Canadian Journal of Plant Pathology,* 25: 41-48.

ABBASI, P. A., CONN, K. L. & LAZAROVITS, G. 2004. Suppression of Rhizoctonia and Pythium damping-off of radish and cucumber seedlings by addition of fish emulsion to peat mix or soil. *Canadian Journal of Plant Pathology,* 26: 177-187.

ABBASI, P. A., CONN, K. L. & LAZAROVITS, G. 2006. Effect of fish emulsion used as a preplanting soil amendment on verticillium wilt, scab, and tuber yield of potato. *Canadian Journal of Plant Pathology,* 28: 509-518.

ABBASI, P. A., CONN, K. L. & LAZAROVITS, G. 2007. Managing soilborne diseases of vegetable crops with a pre-plant soil or substrate amendment of a corn distillation product. *Biocontrol Science and Technology,* 17, 4: 331-344.

ABDUL-KHALIQ, M. A., SATTAR, A. & SINGH, H. N. 2011. Influence of bio-inoculants on the control of root rot and wilt disease of pyrethrum caused by *Rhizoctonia solani*. *Archives of Phytopathology and Plant Protection,* 44, 15: 1490-1500.

ABETZ, P. 1980. Seaweed extracts: have they a place in Australian agriculture or horticulture? *The Journal of the Australian Institute of Agricultural Science,* 46: 23-29.

ABOUL-NASR, A. 1996. Effects of vesicular-arbuscular mycorrhiza on *Tagetes erecta* and *Zinnia elegans*. *Mycorrhiza,* 6: 61-64.

ACCATI, E., RAVIV, M., DEVECCHI, M. & ASSONE, S. 1996. Use of alternative media for bedding plant production. *Agricoltura Mediterranea,* 126: 105-112.

AITKEN, J. B. & SENN, T. L. 1965. Seaweed products as a fertilizer and soil conditioner for horticultural crops. *Botanica Marina,* 8: 144-148.

AKHTAR, M. & MAHMOOD, I. 1995. Suppression of nematode populations with animal by-products. *Bioresource Technology,* 51: 269-271.

AL-DAHMANI, J. H., ABBASI, P. A., MILLER, S. A. & HOITINK, H. A. J. 2003. Suppression of bacterial spot of tomato with foliar sprays of compost extracts under greenhouse and field conditions. *Plant Disease,* 87, 8: 913-919.

ALDAHMANI, J. H., ABBASI, P. A., SAHIN, F., HOITINK, H. A. J. & MILLER, S. A. 2005. Reduction of bacterial leaf spot severity on radish, lettuce, and tomato plants grown in compost amended potting mixes. *Canadian Journal of Plant Pathology,* 27: 186-193.

ALDWORTH, S. J. & VAN STADEN, J. 1987. The effect of seaweed concentrate on seedling transplants. *South African Journal of Botany,* 53, 3: 187-189.

ALEKLETT, K. & WALLANDER, H. 2012. Effects of organic amendments with various nitrogen levels on arbuscular mycorrhizal fungal growth. *Applied Soil Ecology,* 60: 71-76.

ALEXANDER, R. 2001. Compost utilization in landscapes. *In:* STOFFELLA, P. J. & KAHN, B. A. (eds.) *Compost utilization in horticultural cropping systems.* Boca Raton, FL, USA: Lewis Publishers, CRC Press LLC. Ch. 7: pp. 151-175.

ALI, M., GRIFFITHS, A. J., WILLIAMS, K. P. & JONES, D. L. 2007. Evaluating the growth characteristics of lettuce in vermicompost and green waste compost. *European Journal of Soil Biology,* 43: S316-S319.

ALVES, W. L. & PASSONI, A. A. 1997. Compost and vermicompost of urban solid waste in *Licania tomentosa* (Benth) seedlings production to arborization (In Spanish). *Pesquisa Agropecuária Brasileira,* 32, 10: 1053-1058.

AML, R. M. Y., MOSTAFA, E. A. M. & SALEH, M. M. S. 2011. Response of olive seedlings to foliar sprays with amino acids and some micro elements. *Agriculture and Biology Journal of North America,* 2, 7: 1108-1112.

ANDARWULAN, N. & SHETTY, K. 1999. Improvement of pea (*Pisum sativum*) seed vigour response by fish protein hydrolysates in combination with acetyl salicylic acid. *Process Biochemistry,* 35: 159–165.

ANONYMOUS 2003. More firms develop ways to control plant disease without pesticides. *In Business,* 25, 1: 13-15.

ANONYMOUS. 2004. *National Organic Standards Board Compost Tea Task Force Report* [Online]. Agricultural Marketing Service, United States Department of Agriculture. Available: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5058470 [Accessed 11 July 2013].

ANONYMOUS. 2006. *Municipal solid waste: compost market development project; project # GRW /01/03* [Online]. Organic Farming Systems; Southern Metropolitan Regional Council; Government of Western Australia. Available: http://www.organicfarming.com.au/Uploads/Downloads/finalreport.pdf [Accessed 18 August 2013].

ANONYMOUS. 2013. *Charlie Carp* [Online]. Available: http://www.charliecarp.com/ [Accessed 13 July 2013].

APVMA. 2013. *Australian Pesticides and Veterinary Medicines Authority - Agricultural manual of requirements and guidelines - legal background* [Online]. Available: http://www.apvma.gov.au/morag_ag/vol_1/legal_background.php#gen8 [Accessed 9 August 2013].

ARANCON, N. Q., LEE, S., EDWARDS, C. A. & ATIYEH, R. 2003. Effects of humic acids derived from cattle, food and paper-waste vermicomposts on growth of greenhouse plants. *Pedobiologia,* 47: 741-744.

ARANCON, N. Q., EDWARDS, C. A., ATIYEH, R. & METZGER, J. D. 2004. Effects of vermicomposts produced from food waste on the growth and yields of greenhouse peppers. *Bioresource Technology,* 93: 139-144.

ARANCON, N. Q., EDWARDS, C. A., BIERMAN, P., METZGER, J. D. & LUCHT, C. 2005a. Effects of vermicomposts produced from cattle manure, food waste and paper waste on the growth and yield of peppers in the field. *Pedobiologia,* 49: 297-306.

ARANCON, N. Q., GALVIS, P. A. & EDWARDS, C. A. 2005b. Suppression of insect pest populations and damage to plants by vermicomposts. *Bioresource Technology,* 96: 1137-1142.

ARANCON, N. Q., EDWARDS, C. A., LEE, S. & BYRNE, R. 2006. Effects of humic acids from vermicomposts on plant growth. *European Journal of Soil Biology,* 42: S65-S69.

ARANCON, N. Q., EDWARDS, C. A., DICK, R. & DICK, L. 2007a. Vermicompost tea production and plant growth impacts. *BioCycle,* 48, 11: 51-52.

ARANCON, N. Q., EDWARDS, C. A., YARDIM, E. N., OLIVER, T. J., BYRNE, R. J. & KEENEY, G. 2007b. Suppression of two-spotted spider mite (*Tetranychus urticae*), mealy bug (*Pseudococcus* sp.) and aphid (*Myzus persicae*) populations and damage by vermicomposts. *Crop Protection,* 26: 29-39.

ARANCON, N. Q., EDWARDS, C. A., BABENKO, A., CANNON, J., GALVIS, P. & METZGER, J. D. 2008. Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Applied Soil Ecology,* 39: 91-99.

ARDEBILI, Z. O., MOGHADAM, A. R. L., ARDEBILI, N. O. & PASHAIE, A. R. 2012. The induced physiological changes by foliar application of amino acids in *Aloe vera* L. plants. *Plant Omics Journal,* 5, 3: 279-284.

ARTHUR, G. D., STIRK, W. A. & VAN STADEN, J. 2003. Effect of a seaweed concentrate on the growth and yield of three varieties of *Capsicum annuum*. *South African Journal of Botany,* 69, 2: 207-211.

ARYANTHA, I. P., CROSS, R. & GUEST, D. I. 2000. Suppression of *Phytophthora cinnamomi* in potting mixes amended with uncomposted and composted animal manures. *Phytopathology,* 90, 7: 775-782.

ASCIUTTO, K., RIVERA, M. C., WRIGHT, E. R., MORISIGUE, D. & LOPEZ, M. V. 2006. Effect of vermicompost on the growth and health of *Impatiens wallerana*. *Phyton,* 75: 115-123.

ASERI, G. K., JAIN, N., PANWAR, J., RAO, A. V. & MEGHWAL, P. R. 2008. Biofertilizers improve plant growth, fruit yield, nutrition, metabolism and rhizosphere enzyme activities of Pomegranate (*Punica granatum* L.) in Indian Thar Desert. *Scientia Horticulturae,* 117: 130-135.

ASERI, G. K., JAIN, N. & MEGHWAL, P. R. 2009. Influence of bio-fertilizers on *aonla* establishment and production in Indian Thar desert. *Indian Journal of Horticulture,* 66, 4: 449-455.

ATIYEH, R. M., ARANCON, N., EDWARDS, C. A. & METZGER, J. D. 2000a. Influence of earth-worm-processed pig manure on the growth and yield of greenhouse tomatoes. *Bioresource Technology,* 75: 175-180.

ATIYEH, R. M., EDWARDS, C. A., SUBLER, S. & METZGER, J. D. 2000b. Earthworm-processed organic wastes as components of horticultural potting media for growing marigold and vegetable seedlings. *Compost Science and Utilization,* 8, 3: 215-223.

ATIYEH, R. M., SUBLER, S., EDWARDS, C. A., BACHMAN, G., METZGER, J. D. & SHUSTER, W. 2000c. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. *Pedobiologia,* 44: 579-590.

ATIYEH, R. M., EDWARDS, C. A., SUBLER, S. & METZGER, J. D. 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. *Bioresource Technology,* 78: 11-20.

ATIYEH, R. M., ARANCON, N. Q., EDWARDS, C. A. & METZGER, J. D. 2002a. The influence of earthworm-processed pig manure on the growth and productivity of marigolds. *Bioresource Technology,* 81: 103-108.

ATIYEH, R. M., LEE, S., EDWARDS, C. A., ARANCON, N. Q. & METZGER, J. D. 2002b. The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresource Technology,* 84: 7-14.

ATZMON, N. & VAN STADEN, J. 1994. The effect of seaweed concentrate on the growth of *Pinus pinea* seedlings. *New Forests,* 8: 279-288.

AUNG, L. H. & FLICK JR, G. J. 1980. The influence of fish solubles on growth and fruiting of tomato. *HortScience,* 15, 1: 32-33.

AVERY, L. M., BOOTH, P., CAMPBELL, C., TOMPKINS, D. & HOUGH, R. L. 2012. Prevalence and survival of potenial pathogens in source-segregated green waste compost. *Science of the Total Environment,* 431: 128-138.

AZCONA, I., PASCUAL, I., AGUIRREOLEA, J., FUENTES, M., GARCIA-MINA, J. M. & SANCHEZ-DIAZ, M. 2011. Growth and development of pepper are affected by humic substances derived from composted sludge. *Journal of Plant Nutrition and Soil Science,* 174: 916-924.

BACHMAN, G. R. & DAVIS, W. E. 2000. Growth of *Magnolia virginiana* liners in vermicompost-amended media. *Proceedings of the Southern Nurseryman's Association Research Conference,* 45: 65-67.

BACHMAN, G. R. & METZGER, J. D. 2008. Growth of bedding plants in commercial potting substrate amended with vermicompost. *Bioresource Technology,* 99: 3155-3161.

BARAN, A., ÇAYCI, G., KÜTÜK, C. & HARTMANN, R. 2001. Composted grape marc as growing medium for hypostases (*Hypostases phyllostagya*). *Bioresource Technology,* 78: 103-106.

BARIK, T., GULATI, J. M. L., GARNAYAK, L. M. & BASTIA, D. K. 2011. Production of vermicompost from agricultural wastes - a review. *Agricultural Reviews,* 31, 3: 172-183.

BECKETT, R. P. & VAN STADEN, J. 1990. The effect of seaweed concentrate on the uptake of foliar-applied Cu, Mn and Zn by tomato seedlings. *South African Journal of Botany,* 56, 3: 389-392.

BECKETT, R. P., MATHEGKA, A. D. M. & VAN STADEN, J. 1994. Effect of seaweed concentrate on yield of nutrient-stressed tepary bean (*Phaseolus acutifolius* Gray). *Journal of Applied Phycology,* 6: 429-430.

BEESON JR, R. C. 1996. Composted yard waste as a component of container substrates. *Journal of Environmental Horticulture,* 14, 3: 115-121.

BELLAMY, K. L., CHONG, C. & CLINE, R. A. 1995. Paper sludge utilization in agriculture and container nursery culture. *Journal of Environmental Quality,* 24: 1074-1082.

BENITO, M., MASAGUER, A., DE ANTONIO, R. & MOLINER, A. 2005. Use of pruning waste compost as a component in soilless growing media. *Bioresource Technology,* 96: 597-603.

BENITO, M., MASAGUER, A., MOLINER, A. & DE ANTONIO, R. 2006. Chemical and physical properties of pruning waste compost and their seasonal variabilty. *Bioresource Technology,* 97: 2071-2076.

BERECHA, G., LEMESSA, F. & WAKJIRA, M. 2011. Exploring the suitability of coffee pulp compost as growth media substitute in greenhouse production. *International Journal of Agricultural Research,* 6, 3: 255-267.

BESS, V. H. 2000. Understanding compost tea. *BioCycle,* 41, 10: 71-73.

BESS, V. H., MANES, M., RICHTER, B. S. & SNODGRASS, J. L. 2002. *E. coli* survival in compost tea using different nutrient substrates. *In:* MICHEL JR, F. C., RYNK, R. F. & HOITINK, H. A. J. (eds.) *International Symposium on Composting and Compost Utilization, Proceedings.* Columbus, Ohio, USA.

BEZDICEK, D., FAUCI, M., CALDWELL, D., FINCH, R. & LANG, J. 2001. Persistent herbicides in compost. *BioCycle,* 42, 7: 25-30.

BILLINGHAM, K. 2012. *Humic products: potential or presumption for agriculture,* Taree, NSW, Australia, NSW Department of Primary Industries.

BLATT, C. R. & MCRAE, K. B. 1998. Comparison of four organic amendments with a chemical fertilizer applied to three vegetables in rotation. *Canadian Journal of Plant Science,* 78: 641-646.

BONANOMI, G., ANTIGNANI, V., PANE, C. & SCALA, F. 2007. Suppression of soilborne fungal diseases with organic amendments. *Journal of Plant Pathology,* 89, 3: 311-324.

BONANOMI, G., ANTIGNANI, V., CAPODILUPO, M. & SCALA, F. 2010. Identifying the characteristics of organic soil amendments that suppress soilborne plant diseases. *Soil Biology and Biochemistry,* 42: 136-144.

BORRERO, C., TRILLAS, M. I., ORDOVÁS, J., TELLO, J. C. & AVILÉS, M. 2004. Predictive factors for the suppression of Fusarium wilt of tomato in plant growth media. *Phytopathology,* 94, 10: 1094-1101.

BORRERO, C., ORDOVÁS, J., TRILLAS, M. I. & AVILÉS, M. 2006. Tomato Fusarium wilt suppressiveness. The relationship between the organic plant growth media and their microbial communities as characterised by Biolog®. *Soil Biology and Biochemistry,* 38: 1631-1637.

BOYDSTON, R. A., COLLINS, H. P. & VAUGHN, S. F. 2008. Response of weeds and ornamental plants to potting soil amended with dried distillers grains. *HortScience,* 43, 1: 191-195.

BOYER, C. R., GILLIAM, C. H., SIBLEY, J. L., FAIN, G. B., GALLAGHER, T. V. & TORBERT, H. A. 2006. A new substrate for container-grown plants: clean chip residual. *Combined Proceedings of the International Plant Propagators' Society,* 56: 553-559.

BOYER, C. R., FAIN, G. B., GILLIAM, C. H., GALLAGHER, T. V., TORBERT, H. A. & SIBLEY, J. L. 2008. Clean chip residual: a substrate component for growing annuals. *HortTechnology,* 18, 3: 423-432.

BOYER, C. R., GILLIAM, C. H., FAIN, G. B., GALLAGHER, T. V., TORBERT, H. A. & SIBLEY, J. L. 2009. Production of woody nursery crops in clean chip residual substrate. *Journal of Environmental Horticulture,* 27, 1: 56-62.

BRINTON, D. F., TRÄNKNER, A. & DROFFNER, M. 1996. Investigations into liquid compost extracts. *BioCycle,* 37, 11: 68-70.

BRINTON, W., STORMS, P., EVANS, E. & HILL, J. 2004. Compost teas: microbial hygiene and quality in relation to method of preparation. *Biodynamics Journal,* 249, Summer: 36-45.

BROSCHAT, T. K. 1991. Manganese binding by municipal waste composts used as potting media. *Journal of Environmental Horticulture,* 9, 2: 97-100.

BRUNS, C. & SCHÜLER, C. 2000. Suppressive effects of yard waste compost amended growing media on soilborne plant pathogens in organic horticulture. *In:* ALFÖLDI, T., LOCKERETZ, W. & NIGGLI, U. (eds.) *IFOAM, The World Grows Organic; 13th International Scientific Conference.* Basle: Research Institute of Organic Agriculture

BUGBEE, G. J. & FRINK, C. R. 1989. Composted waste as a peat substitute in peat-lite media. *HortScience,* 24, 4: 625-627.

BURGER, D. W., HARTZ, T. K. & FORISTER, G. W. 1997. Composted green waste as a container medium amendment for the production of ornamental plants. *HortScience,* 32, 1: 57-60.

BUSTAMANTE, M. A., PAREDES, C., MORAL, R., AGULLÓ, E., PÉREZ-MURCIA, M. D. & ABAD, M. 2008. Composts from distillery wastes as peat substitutes for transplant production. *Resources, Conservation and Recycling,* 52: 792-799.

CABALLERO, R., PAJUELO, P., ORDOVÁS, J., CARMONA, E. & DELGADO, A. 2009. Evaluation and correction of nutrient availability to *Gerbera jamesonii* H. bolus in various compost-based growing media. *Scientia Horticulturae,* 122: 244-250.

CACCO, G. & DELL'AGNOLA, G. 1984. Plant growth regulator activity of soluble humic complexes. *Canadian Journal of Soil Science,* 64: 225-228.

CALVET, C., PERA, J. & BAREA, J. M. 1993. Growth response of marigold (*Tagetes erecta* L.) to inoculation with *Glomus mosseae*, *Trichoderma aureoviride* and *Pythium ultimum* in a peat-perlite mixture. *Plant and Soil,* 148: 1-6.

CARBALLO, T., GIL, M. V., CALVO, L. F. & MORÁN, A. 2009. The influence of aeration system, temperature and compost origin on the phytotoxicity of compost tea *Compost Science and Utilization,* 17, 2: 127-139.
CARLILE, W. R. 2008. The use of composted materials in growing media. *Acta Horticulturae,* 779: 321-327.
CARMONA, E., MORENO, M. T., AVILÉS, M. & ORDOVÁS, J. 2012. Use of grape marc compost as a substrate for vegetable seedlings. *Scientia Horticulturae,* 137: 69-74.
CARPIO, L. A., DAVIES JR, F. T. & ARNOLD, M. A. 2005. Arbuscular mycorrhizal fungi, organic and inorganic controlled-release fertilizers: effect of growth and leachate of container-grown bush morning glory (*Ipomoea carnea* ssp. *fistulosa*) under high production temperatures. *Journal of the American Society for Horticultural Science,* 130, 1: 131-139.
CÁRTHAIGH, D. M., STURM, A. & SCHMUGLER, A. 1997. The use of *Miscanthus* as a growing medium additive. *Acta Horticulturae,* 450: 57-61.
CASSAN, L., JEANNIN, I., LAMAZE, T. & MOROT-GAUDRY, J.-F. 1992. The effect of the *Ascophyllum nodosum* extract Goëmar GA 14 on the growth of spinach. *Botanica Marina,* 35: 437-439.
CASTALDI, P. & MELIS, P. 2004. Growth and yield characteristics and heavy metal content on tomatoes grown in different growing media. *Communications in Soil Science and Plant Analysis,* 35, 1 & 2: 85-98.
CASTILLO, J. E., HERRERA, F., LÓPEZ-BELLIDO, R. J., LÓPEZ-BELLIDO, F. J., LÓPEZ-BELLIDO, L. & FERNÁNDEZ, E. J. 2004. Municipal solid waste (MSW) compost as a tomato transplant medium. *Compost Science and Utilization,* 12, 1: 86-92.
CAVALCANTE, I. H. L., DA SILVA, R. R. S., ALBANO, F. G., DE LIMA, F. N. & MARQUES, A. D. S. 2011. Foliar spray of humic substances on seedling production of papaya (pawpaw). *Journal of Agronomy,* 10, 4: 118-122.
CEGLIE, F. G., ELSHAFIE, H., VERRASTRO, V. & TITTARELLI, F. 2011. Evaluation of olive pomace and green waste composts as peat substitutes for organic tomato seedling production. *Compost Science and Utilization,* 19, 4: 293-300.
CENDÓN, Y., MOLDES, A. & BARRAL, M. T. 2008. Evaluation of municipal solid waste compost as a growing media component for potted plant production. *Acta Horticulturae,* 779: 591-597.
CHALKOS, D., KADOGLIDOU, K., KARAMANOLI, K., FOTIOU, C., PAVLATOU-VE, A. S., ELEFTHEROHORINOS, I. G., CONSTANTINIDOU, H.-I. A. & VOKOU, D. 2010. *Mentha spicata* and *Salvia fruticosa* composts as soil amendments in tomato cultivation. *Plant and Soil,* 332: 495-509.
CHAN, K. Y., VAN ZWIETEN, L., MESZAROS, I., DOWNIE, A. & JOSEPH, S. 2007a. Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research,* 45: 629-634.
CHAN, K. Y., VAN ZWIETEN, L., MESZAROS, I., DOWNIE, A. & JOSEPH, S. 2008. Using poultry litter biochars as soil amendments. *Australian Journal of Soil Research,* 46: 437-444.
CHAN, W. I., LO, K. V. & LIAO, P. H. 2007b. Solubilization of blood meal to be used as a liquid fertilizer. *Journal of Environmental Science and Health Part B,* 42: 417-422.
CHANEY, R. L., MUNNS, J. B. & CATHEY, H. M. 1980. Effectiveness of digested sewage sludge compost in supplying nutrients for soilless potting media.

Journal of the American Society for Horticultural Science, 105, 4: 485-492.

CHANG, D. C. N. 1994. What is the potential for management of vesicular-arbuscular mycorrhizae in horticulture? *In:* ROBSON, A. D., ABBOTT, L. K. & MALAJCZUK, N. (eds.) *Management of mycorrhizas in agriculture, horticulture and forestry.* Dordrecht, The Netherlands: Kluwer Academic Publishers. pp. 187-190.

CHANG, K. H., WU, R. Y., CHUANG, K. C., HSIEH, T. F. & CHUNG, R. S. 2010. Effects of chemical and organic fertilizers on the growth, flower quality and nutrient uptake of *Anthurium andreanum*, cultivated for flower production. *Scientia Horticulturae,* 125: 434-441.

CHAVEZ, W., DI BENEDETTO, A., CIVEIRA, G. & LAVADO, R. 2008. Alternative soilless media for growing *Petunia* x *hybrida* and *Impatiens wallerana*: physical behavior, effect of fertilization and nitrate losses. *Bioresource Technology,* 99: 8082-8087.

CHEF, D. G., HOITINK, H. A. J. & MADDEN, L. V. 1983. Effects of organic components in container media on suppression of Fusarium wilt of chrysanthemum and flax. *Phytopathology,* 73, 2: 279-281.

CHEN, Y., INBAR, Y. & HADAR, Y. 1988. Composted agricultural wastes as potting media for ornamental plants. *Soil Science,* 145, 4: 298-303.

CHEN, Y. & AVIAD, T. 1990. Effects of humic substances on plant growth. *In:* MACCARTHY, P., CLAPP, C. E., MALCOLM, R. L. & BLOOM, P. R. (eds.) *Humic substances in soil and crop sciences: selected readings.* Madison, WI, USA: American Society of Agronomy, Inc.; Soil Science Society of America, Inc. Ch. 7: pp. 161-186.

CHEN, Y. P., REKHA, P. D., ARUN, A. B., SHEN, F. T., LAI, W.-A. & YOUNG, C. C. 2006. Phosphate solubilizing bacteria from subtropical soil and their tricalcium phosphate solubilizing abilities. *Applied Soil Ecology,* 34: 33-41.

CHENG, B. T. 1987. Sawdust as a greenhouse growing medium. *Journal of Plant Nutrition,* 10, 9-16: 1437-1446.

CHIWOCHA, S. D. S., DIXON, K. W., FLEMATTI, G. R., GHISALBERTI, E. L., MERRITT, D. J., NELSON, D. C., RISEBOROUGH, J. M., SMITH, S. M. & STEVENS, J. C. 2009. Karrikins: a new family of plant growth regulators in smoke. *Plant Science,* 177, 4: 252-256.

CHONG, C., CLINE, R. A., RINKER, D. L. & ALLEN, O. B. 1991. Growth and mineral nutrient status of containerized woody species in media amended with spent mushroom compost. *Journal of the American Society for Horticultural Science,* 116, 2: 242-247.

CHONG, C. 1992. Apple pomace as an amendment in cotainer growing media. *HortScience,* 27, 10: 1138.

CHONG, C. & CLINE, R. A. 1993. Response of four ornamental shrubs to container substrate amended with two sources of raw paper mill sludge. *HortScience,* 28, 8: 807–809.

CHONG, C., CLINE, R. A. & RINKER, D. L. 1994. Bark- and peat-amended spent mushroom compost for containerized culture of shrubs. *HortScience,* 29, 7: 781-784.

CHONG, C. & RINKER, D. L. 1994. Use of spent mushroom substrate for growing containerized woody ornamentals: an overview. *Compost Science and Utilization,* 2, 3: 45-53.

CHONG, C., HAMERSMA, B. & BELLAMY, K. L. 1998. Comparative rooting of deciduous landscape shrub cuttings in media amended with paper mill biosolids from four different sources. *Canadian Journal of Plant Science,* 78: 519-526.

CHONG, C. 1999. Experiences with the utilization of wastes in nursery potting mixes and as field soil amendments. *Canadian Journal of Plant Science,* 79: 139-148.

CHONG, C. 2000. Relationship of soluble salts content in MSW compost media and rooting of evergreen cuttings. *Compost Science and Utilization,* 8, 1: 29-35.

CHONG, C. 2004. Three waste-derived composts compared in container substrates. *Combined Proceedings of the International Plant Propagators' Society,* 54: 541-544.

CHONG, C. 2005. Experiences with wastes and composts in nursery susbstrates. *HortTechnology,* 15, 4: 739-747.

CHONG, C. & PURVIS, P. 2005. Use of paper-mill sludges and municipal compost in nursery substrates. *Combined Proceedings of the International Plant Propagators' Society,* 55: 428-432.

CHONG, C., YANG, J., HOLBEIN, B., LIU, H.-W., VORONEY, R. P. & ZHOU, H. 2005. Rooting cuttings hydroponically in compost tea and wastewater. *Combined Proceedings of the International Plant Propagators' Society,* 55: 333-337.

CHONG, C., PURVIS, P., LUMIS, G., HOLBEIN, B. E., VORONEY, R. P., ZHOU, H., LIU, H.-W. & ALAM, M. Z. 2008. Using mushroom farm and anaerobic digestion wastewaters as supplemental fertilizer sources for growing container nursery stock in a closed system. *Bioresource Technology,* 99: 2050-2060.

CHOPIN, T., BUSCHMANN, A. H., HALLING, C., TROELL, M., KAUTSKY, N., NEORI, A., KRAEMER, G. P., ZURTUCHE-GONZÁLEZ, J. A., YARISH, C. & NEEFUS, C. 2001. Integrating seaweeds into marine aquaculture systems: a key toward sustainability. *Journal of Phycology,* 37: 975-986.

CHUNG, Y. R. & HOITINK, H. A. J. 1990. Interactions between thermophilic fungi and *Trichoderma hamatum* in suppression of Rhizoctonia damping-off in a bark compost-amended container medium. *Phytopathology,* 80, 1: 73-77.

CLARK, S. & CAVIGELLI, M. 2005. Suitability of composts as potting media for production of organic vegetable transplants. *Compost Science and Utilization,* 13: 150-156.

CONNIFF, R. 2012. The Oiliest Catch. *Conservation Magazine* [Online]. Available: http://www.conservationmagazine.org/2012/12/the-oiliest-catch/ [Accessed 11 July 2013].

CORKIDI, L., EVANS, M. & BOHN, J. 2008. Infectivity and effectiveness of arbuscular mycorrhizal fungi in horticultural practices. *Combined Proceedings of the International Plant Propagators' Society,* 58: 241-244.

COSTA, G., LABROUSSE, P., BODIN, C., LHERNOULD, S., CARLUÉ, M. & KRAUSZ, P. 2008. Effects of humic substances on the rooting and development of woody plant cuttings. *Acta Horticulturae,* 779: 255-261.

COTXARRERA, L., TRILLAS-GAY, M. I., STEINBERG, C. & ALABOUVETTE, C. 2002. Use of sewage sludge compost and *Trichoderma asperellum* isolates to suppress Fusarium wilt of tomato. *Soil Biology and Biochemistry,* 34: 467-476.

COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. 2012. *Prospects for the use of biochar in Australian horticulture*, NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006.

COX, J. & VAN ZWIETEN, L. 2012. Use of biochar in crop production systems. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 5: pp. 37-48.

CRAIGIE, J. S. 2011. Seaweed extract stimuli in plant science and agriculture. *Journal of Applied Phycology,* 23: 371-393.

CROUCH, I. J., BECKETT, R. P. & VAN STADEN, J. 1990. Effect of seaweed concentrate on the growth and mineral nutrition of nutrient-stressed lettuce. *Journal of Applied Phycology,* 2: 269-272.

CROUCH, I. J. & VAN STADEN, J. 1991. Evidence for rooting factors in a seaweed concentrate prepared from *Ecklonia maxima*. *Journal of Plant Physiology,* 137: 319-322.

CROUCH, I. J., SMITH, M. T., VAN STADEN, J., LEWIS, M. J. & HOAD, G. V. 1992. Identification of auxins in a commercial seaweed concentrate. *Journal of Plant Physiology,* 139: 590-594.

CROUCH, I. J. & VAN STADEN, J. 1992. Effect of seaweed concentrate on the establishment and yield of greenhouse tomato plants. *Journal of Applied Phycology,* 4: 291-296.

CROUCH, I. J. & VAN STADEN, J. 1993. Evidence for the presence of plant growth regulators in commercial seaweed products. *Plant Growth Regulation,* 13: 21-29.

CROUCH, I. J. & VAN STADEN, J. 1994. Commercial seaweed products as biostimulants in horticulture. *Journal of Home and Consumer Horticulture,* 1: 19-76.

DAFT, G. C., POOLE, H. A. & HOITINK, H. A. J. 1979. Composted hardwood bark: a substitute for steam sterilization and fungicide drenches for control of poinsettia crown and root rot. *HortScience,* 14, 2: 185-187.

DALLON JR, J. 1987. Effects of spent mushroom compost on the production of greenhouse-grown crops. *Combined Proceedings of the International Plant Propagators' Society,* 37: 323-329.

DANIELSON, H. E., WILSON, S. B., SCHOELLHORN, R. K. & STOFFELLA, P. J. 2004. Container and field evaluation of *Gaillardia pulchella* production in compost-based media. *Combined Proceedings of the International Plant Propagators' Society,* 54: 637-642.

DARVODELSKY, P. 2012. *Biosolids snapshot* [Online]. Department of Sustainability, Environment, Water, Population and Communities. Available: http://www.environment.gov.au/wastepolicy/publications/pubs/biosolids-snapshot.pdf [Accessed 19 August 2013].

DAVID, P. P., NELSON, P. V. & SANDERS, D. C. 1994. A humic acid improves growth of tomato seedling in solution culture. *Journal of Plant Nutrition,* 17, 1: 173-184.

DAVIES JR, F. T. 2008. Opportunities from down under: how mycorrhizal fungi can benefit nursery propagation and production systems. *Combined Proceedings of the International Plant Propagators' Society,* 58: 539-548.

DE BRITO ALVAREZ, M. A., GAGNÉ, S. & ANTOUN, H. 1995. Effect of compost on rhizosphere microflora of the tomato and on the incidence of plant growth-promoting rhizobacteria. *Applied and Environmental Microbiology,* 61, 1: 194-199.

DE CEUSTER, T. J. J. & HOITINK, H. A. J. 1999. Prospects for composts and biocontrol agents as substitutes for methyl bromide in biological control of plant diseases. *Compost Science and Utilization,* 7, 3: 6-15.

DE CORATO, U., SHARMA, N., MACCIONI, O. & ZIMBARDI, F. 2011. Suppressiveness of steam-exploded biomass of *Miscanthus sinensis* var. *giganteus* against soil-borne plant pathogens. *Crop Protection,* 30: 246-252.

DE SANTIAGO, A., EXPÓSITO, A., QUINTERO, J. M. & CARMONA, E. 2010. Adverse effects of humic substances from different origin on lupin as related to iron sources. *Journal of Plant Nutrition,* 33: 143-156.

DEBACCO, M. 2011. *Compost tea and milk to suppress powdery mildew (Podosphaera xanthii) on pumpkins and evaluation of horticultural pots made from recyclable fibers under field conditions.* Master of Science, University of Connecticut.

DEEPAK 2011. Soil amendments, plant extracts and plant products for integrated disease management in agricultural crops: a review. *African Journal of Agricultural Research,* 6, 33: 6790-6797.

DÉPORTES, I., BENOIT-GUYOD, J.-L. & ZMIROU, D. 1995. Hazard to man and the environment posed by the use of urban waste compost: a review. *The Science of the Total Environment,* 172: 197-222.

DI BENEDETTO, A. H., KLASMAN, R. & BOSCHI, C. 2004. Use of river waste in growing media for ornamental herbaceous perennials. *Journal of Horticultural Science and Biotechnology,* 79, 1: 119-124.

DIAB, H. G., HU, S. & BENSON, D. M. 2003. Suppression of *Rhizoctonia solani* on impatiens by enhanced microbial activity in composted swine waste-amended potting mixes. *Phytopathology,* 93, 9: 1115-1123.

DIÁNEZ, F., SANTOS, M., BOIX, A., DE CARA, M., TRILLAS, I., AVILÉS, M. & TELLO, J. C. 2006a. Grape marc compost tea suppressiveness to plant pathogenic fungi: role of siderophores. *Compost Science and Utilization,* 14, 1: 48-53.

DIÁNEZ, F., SANTOS, M., DE CARA, M. & TELLO, J. C. 2006b. Presence of siderophores on grape marc aerated compost tea. *Geomicrobiology Journal,* 23: 323–331.

DIENER, R. G., COLLINS, A. R., MARTIN, J. H. & BRYAN, W. B. 1993. Composting of source-separated municipal solid waste for agricultural utilization - a conceptual approach for closing the loop. *Applied Engineering in Agriculture,* 9, 5: 427-436.

DIVER, S. 1999. Biodynamic farming and compost preparation: alternative farming systems guide. Appropriate Technology Transfer for Rural Areas, USDA Rural Business Co-operative Service.

DOMINGUEZ, J. & EDWARDS, C. A. 1997. A comparison of vermicomposting and composting. *BioCycle,* 38, 4: 57-59.

DOMINGUEZ, J., EDWARDS, C. A. & SUBLER, S. 1997. A comparison of vermicomposting and composting. *BioCycle,* 38, 4: 57-59.

DONALD, D. G. M. & VISSER, L. B. 1989. Vermicompost as a possible growth medium for the production of commercial forest nursery stock. *Applied Plant Science,* 3, 2: 110-113.

DOWNIE, A. 2012. Risk. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 3: pp. 19-26.

DRESBØLL, D. B. & THORUP-KRISTENSEN, K. 2005. Structural differences in wheat (*Triticum aestivum*), hemp (*Cannabis sativa*) and Miscanthus (*Miscanthus ogiformis*) affect the quality and stability of plant based compost. *Scientia Horticulturae,* 107: 81-89.

DRESBØLL, D. B. & MAGID, J. 2006. Structural changes of plant residues during decomposition in a compost environment. *Bioresource Technology,* 97: 973-981.

DRUEGE, U., XYLAENDER, M., ZERCHE, S. & VON ALTEN, H. 2006. Rooting and vitality of poinsettia cuttings was increased by arbuscular mycorrhiza in the donor plants. *Mycorrhiza,* 17: 67-72.

DUDLEY, J. B., PERTUIT JR, A. J. & TOLER, J. E. 2004. Leonardite influences zinnia and marigold growth. *HortScience,* 39, 2: 251-255.

DUEITT, S., HOWELL, J. & NEWMAN, S. E. 1993. Rice hulls as a vermiculite substitute in peat-based media for growing greenhouse bedding plants. *Proceedings of the Southern Nurseryman's Association Research Conference,* 38: 62-64.

DUFFY, B., SARREAL, C., RAVVA, S. & STANKER, L. 2004. Effect of molasses on regrowth of *E. coli* O157:H7 and *Salmonella* in compost teas. *Compost Science and Utilization,* 12, 1: 93-96.

DUMROESE, R. K., HEISKANEN, J., ENGLUND, K. & TERVAHAUTA, A. 2011. Pelleted biochar: chemical and physical properties show potential use as a substrate in container nurseries. *Biomass and Bioenergy,* 35: 2018-2027.

EASTMAN, B. R., KANE, P. N., EDWARDS, C. A., TRYTEK, L., GUNADI, B., STERMER, A. & MOBLEY, J. R. 2001. The effectiveness of vermiculture in human pathogen reduction for USEPA biosolids stabilization. *Compost Science and Utilization,* 9, 1: 38-49.

EBID, A., UENO, H., GHONEIM, A. & ASAGI, N. 2008. Nitrogen uptake by radish, spinach and "Chingensai" from composted tea leaves, coffee waste and kitchen garbage. *Compost Science and Utilization,* 16, 3: 152-158.

EDMEADES, D. C. 2000. *Science friction: the Maxicrop case and the aftermath,* Hamilton, New Zealand, Fertiliser Information Services Ltd.

EDMEADES, D. C. 2001. Defamation battle went to the top. *Manawatu Standard. Features - Letters. June 16. pg 7.*

EDMEADES, D. C. 2002. The effects of liquid fertilizers derived from natural products on crop, pasture, and animal production: a review *Australian Journal of Agricultural Research,* 53: 965-976.

EDWARDS, C. A. & BURROWS, I. 1988. The potential of earthworm composts as plant growth media. *In:* EDWARDS, C. A. & NEUHAUSER, E. F. (eds.)

Earthworms in waste and environmental management. The Hague, The Netherlands: SPB Academic Publishing. pp. 211-219.

EDWARDS, C. A. & ARANCON, N. Q. 2004. The use of earthworms in the breakdown of organic wastes to produce vermicomposts and animal feed protein. *In:* EDWARDS, C. A. (ed.) *Earthworm ecology; second edition.* Boca Raton, FL, USA: CRC Press. Ch. 18: pp. 345-379.

EDWARDS, C. A., ARANCON, N. Q. & GREYTAK, S. 2006. Effects of vermicompost teas on plant growth and disease. *BioCycle,* 47, 5: 28-31.

EDWARDS, C. A., ARANCON, N. Q., VASKO-BENNETT, M., ASKAR, A., KEENEY, G. & LITTLE, B. 2010. Suppression of green peach aphid (*Myzus persicae*) (Sulz.), citrus mealybus (*Planococcus citri*) (Risso) and two-spotted spider mite (*Tetranychus urticae*) (Koch.) attacks on tomatoes and cucumbers by aqueous extracts from vermicomposts. *Crop Protection,* 29: 80-93.

EINERT, A. E. & BAKER, E. C. 1973. Rice hulls as a growing medium component for cut tulips. *Journal of the American Society for Horticultural Science,* 98, 6: 556-558.

EKLIND, Y., RÄMERT, B. & WIVSTAD, M. 2002. Evaluation of growing media containing farmyard manure compost, household waste compost or chicken manure for the propagation of lettuce (*Lactuca sativa* L.). *Biological Agriculture and Horticulture,* 19, 2: 157-181.

EL-TARABILY, K. A., NASSAR, A. H., HARDY, G. E. S. J. & SIVASITHAMPARAM, K. 2003. Fish emulsion as a food base for rhizobacteria promoting growth of radish (*Raphanus sativus* L. var. *sativus*) in a sandy soil. *Plant and Soil,* 252: 397–411.

ELAD, Y., DAVID, D. R., MELLER HAREL, Y., BORENSHTEIN, M., KALIFA, H. B., SILBER, A. & GRABER, E. R. 2010. Induction of systemic resistance in plants by biochar, a soil-applied carbon sequestering agent. *Phytopathology,* 100: 913-921.

ELAD, Y., CYTRYN, E., MELLER HAREL, Y., LEW, B. & GRABER, E. R. 2011. The biochar effect: plant resistance to biotic stresses. *Phytopathologia Mediterranea,* 50: 335-349.

EMINO, E. R. 1981. Effectiveness of fish soluble nutrients as fertilizers on container-grown plants. *HortScience,* 16, 3: 338.

EPSTEIN, E. 1997. *The science of composting,* Basel, Switzerland, Technomic Publishing Company, Inc.

EVANS, M. R. & STAMPS, R. H. 1996. Growth of bedding plants in sphagnum peat and coir dust-based substrates *Journal of Environmental Horticulture,* 14, 4: 187-190.

EVANS, M. R. & ILES, J. K. 1997. Growth of *Viburnum dentatum* and *Syringa* x *prestoniae* 'Donald Wyman' in *Sphagnum* peat and coir dust-based substrates. *Journal of Environmental Horticulture,* 15, 3: 156-159.

FAIN, G. B., GILLIAM, C. H., SIBLEY, J. L. & BOYER, C. R. 2006. Suitability of processed whole pine tree as a substrate component for production of greenhouse crops. *Combined Proceedings of the International Plant Propagators' Society,* 56: 180-187.

FAIN, G. B., GILLIAM, C. H., SIBLEY, J. L. & BOYER, C. R. 2008a. *WholeTree* substrates derived from three species of pine in production of annual vinca. *HortTechnology,* 18, 1: 13-17.

FAIN, G. B., GILLIAM, C. H., SIBLEY, J. L., BOYER, C. R. & WITCHER, A. L. 2008b. *WholeTree* substrate and fertilizer rate in production of greenhouse-grown petunia (*Petunia* x *hybrida* Vilm.) and marigold (*Tagetes patula* L.). *HortScience,* 43, 3: 700-705.

FARAG HANAA, R. M., ABDOU, Z. A., SALAMA, D. A., IBRAHIM, M. A. R. & SROR, H. A. M. 2011. Effect of neem and willow aqueous extracts on fusarium wilt disease in tomato seedlings: induction of antioxidant defensive enzymes. *Annals of Agricultural Science,* 56: 1-7.

FARRELL, M. & JONES, D. L. 2009. Critical evaluation of municipal solid waste composting and potential compost markets. *Bioresource Technology,* 100: 4301-4310.

FEATONBY-SMITH, B. C. & VAN STADEN, J. 1983. The effect of seaweed concentrate on the growth of tomato plants in nematode-infested soil. *Scientia Horticulturae,* 20: 137-146.

FICHTNER, E. J., BENSON, D. M., DIAB, H. G. & SHEW, H. D. 2004. Abiotic and biological suppression of *Phytophthora parasitica* in a horticultural medium containing composted swine waste. *Phytopathology,* 94: 780-788.

FIDANZA, M. A., SANFORD, D. L., BEYER, D. M. & AURENTZ, D. J. 2010. Analysis of fresh mushroom compost. *HortTechnology,* 20, 2: 449-453.

FITZPATRICK, G. E. 1986. Sludge processing effect on compost quality. *BioCycle,* 27: 32-35.

FITZPATRICK, G. E., DONSELMAN, H. & CARTER, N. S. 1986. Interactive effects of sewage effluent irrigation and supplemental fertilization on container-grown trees. *HortScience,* 18: 187-189.

FITZPATRICK, G. E. 1989. Solid waste composts as growing media. *BioCycle,* 30, 9: 62-64.

FITZPATRICK, G. E., DUKE, E. R. & KLOCK-MOORE, K. A. 1998. Use of compost products for ornamental crop production: research and grower experiences *HortScience,* 33, 6: 941-944.

FITZPATRICK, G. E. 2001. Compost utilization in ornamental and nursery crop production systems. *In:* STOFFELLA, P. J. & KAHN, B. A. (eds.) *Compost utilization in horticultural cropping systems.* Boca Raton, FL, USA: Lewis Publishers, CRC Press LLC. Ch. 6: pp. 135-150.

FRANKENBERGER JR, W. T. & ARSHAD, M. 1995. *Phytohormones in soils: microbial production and function,* New York, NY, USA, Marcel Dekker, Inc.

FRAVEL, D. R., MAROIS, J. J., LUMSDEN, R. D. & CONNICK JR, W. J. 1985. Encapsulation of potential biocontrol agents in an alginate clay mixture. *Phytopathology,* 75: 774–777.

FREDERICKSON, J., BUTT, K. R., MORRIS, R. M. & DANIEL, C. 1997. Combining vermiculture with traditional green waste composting systems. *Soil Biology and Biochemistry,* 29, 3/4: 725-730.

GAGNON, B. & BERROUARD, S. 1994. Effects of several organic fertilizers on growth of greenhouse tomato transplants. *Canadian Journal of Plant Science,* 74: 167-168.

GAMLIEL, A., AUSTERWEIL, M. & KRITZMAN, G. 2000. Non-chemical approach to soilborne pest management - organic amendments. *Crop Protection,* 19: 847-853.

GARCIA-GOMEZ, A., BERNAL, M. P. & ROIG, A. 2002. Growth of ornamental plants in two composts prepared from agroindustrial wastes. *Bioresource Technology,* 83: 81-87.

GARCÍA-MINA, J. M., ANTOLÍN, M. C. & SANCHEZ-DIAZ, M. 2004. Metal-humic complexes and plant micronutrient uptake: a study based on different plant species cultivated in diverse soil types. *Plant and Soil,* 258: 57-68.

GAUR, A., GAUR, A. & ADHOLEYA, A. 2000. Growth and flowering in *Petunia hybrida*, *Callistephus chinensis* and *Impatiens balsamina* inoculated with mixed AM inocula or chemical fertilizers in a soil of low P fertility. *Scientia Horticulturae,* 84: 151-162.

GAUR, A. & ADHOLEYA, A. 2005. Diverse response of five ornamental plant species to mixed indigenous and single isolate arbuscular-mycorrhizal inocula in marginal soil amended with organic matter. *Journal of Plant Nutrition,* 28: 707-723.

GIANNOULI, A., KALAITZIDIS, S., SIAVALAS, G., CHATZIAPOSTOLOU, A., CHRISTANIS, K., PAPAZISIMOU, S., PAPANICOLAOU, C. & FOSCOLOS, A. 2009. Evaluation of Greek low-rank coals as potential raw material for the production of soil amendments and organic fertilizers. *International Journal of Coal Geology,* 77: 383-393.

GILLETT, J. W. 1992. Issues in risk assessment of compost from municipal solid waste: occupational health and safety, public health, and environmental concerns. *Biomass and Bioenergy,* 3, 3-4: 145-162.

GILS, J., CHONG, C. & LUMIS, G. 2005. Response of container-grown ninebark to crude and nutrient-enriched recirculating compost leachates. *HortScience,* 40, 5: 1507-1512.

GIOTIS, C., MARKELOU, E., THEODOROPOULOU, A., TOUFEXI, E., HODSON, R., SHOTTON, P., SHIEL, R., COOPER, J. & LEIFERT, C. 2009. Effect of soil amendments and biological control agents (BCAs) on soil-borne root diseases caused by *Pyrenochaeta lycopersici* and *Verticillium albo-atrum* in organic greenhouse tomato production systems. *European Journal of Plant Pathology,* 123: 387-400.

GOICOECHEA, N. 2009. To what extent are soil amendments useful to control Verticillium wilt? *Pest Management Science,* 65: 831-839.

GORI, R., FERRINI, F., NICESE, F. P. & LUBELLO, C. 2000. Effect of reclaimed wastewater on the growth and nutrient content of three landscape shrubs. *Journal of Environmental Horticulture,* 18, 2: 108-114.

GORODECKI, B. & HADAR, Y. 1990. Suppression of *Rhizoctonia solani* and *Sclerotium rolfsii* diseases in container media containing composted separated cattle manure and composted grape marc. *Crop Protection,* 9: 271-274.

GOSS, M. J., TUBEILEH, A. & GOORAHOO, D. 2013. A review of the use of organic amendments and the risk to human health. *Advances in Agronomy. . Volume 120.* Amsterdam, The Netherlands: Elsevier. Ch. 5: pp. 275-379.

GOUIN, F. R. 1985. Growth of hardy chrysanthemums in containers of media amended with composted municipal sewage sludge. *Journal of Environmental Horticulture,* 3, 2: 53-55.

GOUIN, F. R. 1993. Utilization of sewage sludge compost in horticulture. *HortTechnology,* 3, 2: 161-163.

GRABER, E. R., MELLER HAREL, Y., KOLTON, M., CYTRYN, E., SILBER, A., DAVID, D. R., TSECHANSKY, L., BORENSHTEIN, M. & ELAD, Y. 2010. Biochar impact on development and productivity of pepper and tomato grown in fertigated soilless media. *Plant and Soil,* 337: 481-496.

GRAVEL, V., ANTOUN, H. & TWEDDELL, R. J. 2007. Growth stimulation and fruit yield improvement of greenhouse tomato plants by inoculation with *Pseudomonas putida* or *Trichoderma atroviride*: possible role of indole acetic acid (IAA). *Soil Biology and Biochemistry,* 39: 1968–1977.

GRAVEL, V., MÉNARD, C. & DORAIS, M. 2009. Pythium root rot and growth responses of organically grown geranium plants to beneficial microorganisms. *HortScience,* 44, 6: 1622-1627.

GREWAL, S., SREEVATSAN, S. & MICHEL JR, F. C. 2007. Persistence of *Listeria* and *Salmonella* during swine manure treatment. *Compost Science and Utilization,* 15, 1: 53-62.

GREWAL, S. K., RAJEEV, S., SREEVATSAN, S. & MICHEL JR, F. C. 2006. Persistence of *Mycobacterium avium* subsp. *paratuberculosis* and other zoonotic pathogens during simulated composting, manure packing, and liquid storage of dairy manure. *Applied and Environmental Microbiology,* 72, 1: 565-574.

GRIFFIN, J. 2009. Eastern red-cedar (*Juniperus virginiana*) as a substrate component for container production of woody plants. *HortScience,* 44, 4: 1131 (Abstr.).

GRIGATTI, M., GIORGIONI, M. E. & CIAVATTA, C. 2007. Compost-based growing media: influence on growth and nutrient use of bedding plants. *Bioresource Technology,* 98: 3526–3534.

GRUDA, N., MAHER, M. J. & PRASAD, M. 2008. The effect of microbial additives in organic substrates on plant growth and some quality parameters. *Acta Horticulturae,* 779: 79-84.

GUÉRIN, V., LEMAIRE, F., MARFÀ, O., CACERES, R. & GIUFFRIDA, F. 2001. Growth of *Viburnum tinus* in peat-based and peat-substitute growing media. *Scientia Horticulturae,* 89: 129-142.

GUERRERO, F., GASCÓ , J. M. & HERNÁNDEZ-APAOLAZA, L. 2002. Use of pine bark and sewage sludge compost as components of substrates for *Pinus pinea* and *Cupressus arizonica* production. *Journal of Plant Nutrition,* 25, 1: 129-141.

GÜL, A., ÖZAKTAN, H., KIDOĞLU, F. & TÜZEL, Y. 2013. Rhizobacteria promoted yield of cucumber plants grown in perlite under Fusarium wilt stress. *Scientia Horticulturae,* 153: 22-25.

GUTIÉRREZ-MICELI, F. A., SANTIAGO-BORRAZ, J., MONTES MOLINA, J. A., NAFATE, C. C., ABUD-ARCHILA, M., OLIVA LLAVEN, M. A., RINCÓN-ROSALES, R. & DENDOOVEN, L. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum* (sic) *esculentum*). *Bioresource Technology,* 98: 2781-2786.

GUTIÉRREZ-MICELI, F. A., GARCÍA-GÓMEZ, R. C., RINCÓN ROSALES, R., ABUD-ARCHILA, M., OLIVA LLAVEN, M. A., GUILLÉN CRUZ, M. J. & DENDOOVEN, L. 2008. Formulation of a liquid fertilizer for sorghum (*Sorghum biocolor* (L.) Moench) using vermicompost leachate. *Bioresource Technology,* 99: 6174-6180.

GUTIÉRREZ-MICELI, F. A., OLIVA LLAVEN, M. A., MENDOZA NAZAR, P., RUÍZ SESMA, B., ÁLVAREZ-SOLÍS, J. D. & DENDOOVEN, L. 2011. Optimization of vermicompost and worm-bed leachate for the organic cultivation of radish *Journal of Plant Nutrition,* 34: 1642-1653.

HADAR, Y. & MANDELBAUM, R. 1986. Suppression of *Pythium aphanidermatum* damping-off in container media containing composted liquorice roots. *Crop Protection,* 5, 2: 88-92.

HADAR, Y. 2011. Suppressive compost: when plant pathology met microbial ecology. *Phytoparasitica,* 39: 311-314.

HAFEZ, S. L. & SUNDARARAJ, P. 1999. Efficacy of seed crop meals for the management of Columbia root-knot nematode (*Meloidogyne chitwoodi*) on tomato under greenhouse conditions. *Nematropica,* 29, 2: 171-177.

HAGGAG, W. M. & SABER, M. S. M. 2007. Suppression of early blight on tomato and purple blight on onion by foliar sprays of aerated and non-aerated compost teas. *Journal of Food, Agriculture and Environment,* 5, 2: 302-309.

HAGHIGHI, M., KAFI, M. & FANG, P. 2012. Photosynthetic activity and N metabolism of lettuce as affected by humic acid. *International Journal of Vegetable Science,* 18: 182-189.

HAMMERMEISTER, A. M., ASTATKIE, T., JELIAZKOVA, E. A., WARMAN, P. R. & MARTIN, R. C. 2006. Nutrient supply from organic amendments applied to unvegetated soil, lettuce and orchardgrass. *Canadian Journal of Soil Science,* 86: 21-33.

HANDRECK, K. & BLACK, N. 2002. *Growing media for ornamental plants and turf,* Sydney, NSW, Australia, University of New South Wales Press Ltd.

HANDRECK, K. A. 1986. Vermicomposts as components of potting media. *BioCycle,* 27, 9: 58-62.

HANKINS, S. D. & HOCKEY, H. P. 1990. The effect of a liquid seaweed extract from *Ascophyllum nodosum* (Fucales, Phaeophyta) on the two-spotted red spider mite *Tetranychus urticae*. *Hydrobiologia,* 204/205: 555-559.

HARDY, G. E. S. J. & SIVASITHAMPARAM, K. 1991. Suppression of *Phytophthora* root rot by a composted *Eucalyptus* bark mix. *Australian Journal of Botany,* 39: 153-159.

HARDY, G. E. S. J. & SIVASITHAMPARAM, K. 1995. Antagonism of fungi and actinomycetes isolated from composted eucalyptus bark to *Phytophthora drechsleri* in a steamed and non-steamed composted eucalyptus bark-amended container medium. *Soil Biology and Biochemistry,* 27, 2: 243-246.

HARRISON, E. Z. & RICHARD, T. L. 1992. Municipal solid waste composting: policy and regulation. *Biomass and Bioenergy,* 3, 3-4: 127-143.

HARTZ, T. K., COSTA, F. J. & SCHRADER, W. L. 1996. Suitability of composted green waste for horticultural uses. *HortScience,* 31, 6: 961-964.

HARTZ, T. K. & BOTTOMS, T. G. 2010. Humic substances generally ineffective in improving vegetable crop nutrient uptake or productivity *HortScience,* 45, 6: 906-910.

HEISKANEN, J. 2013. Effects of compost additive in sphagnum peat growing medium on Norway spruce container seedlings. *New Forests,* 44: 101-118.

HERRERA, F., CASTILLO, J. E., CHICA, A. F. & LÓPEZ BELLIDO, L. 2008. Use of municipal solid waste compost (MSWC) as a growing medium in the nursery production of tomato plants. *Bioresource Technology,* 99: 287-296.

HICKLENTON, P. R., RODD, V. & WARMAN, P. R. 2001. The effectiveness and consistency of source-separated municipal solid waste and bark composts as components of container growing media. *Scientia Horticulturae,* 91: 365-378.

HIDALGO, P. R. & HARKESS, R. L. 2000. Fertilizer rate effect on poinsettia production in vermicompost substrates. *Proceedings of the Southern Nurseryman's Association Research Conference,* 45: 30-33.

HIDALGO, P. R. & HARKESS, R. L. 2002. Earthworm castings as a substrate amendment for chrysanthemum production. *HortScience,* 37, 7: 1035-1039.

HIDALGO, P. R., MATTA, F. B. & HARKESS, R. L. 2006. Physical and chemical properties of substrates containing earthworm castings and effects on marigold growth. *HortScience,* 41, 6: 1474-1476.

HOITINK, H. A. J., VANDOREN JR, D. M. & SCHMITTHENNER, A. F. 1977. Suppression of *Phytophthora cinnamomi* in a composted hardwood bark potting medium. *Phytopathology,* 67: 561-565.

HOITINK, H. A. J. 1980. Composted bark, a light weight growth medium with fungicidal properties. *Plant Disease,* 64, 2: 142-147.

HOITINK, H. A. J. & FAHY, P. C. 1986. Basis for the control of soilborne plant pathogens with compost. *Annual Review of Phytopathology,* 24: 93-114.

HOITINK, H. A. J., INBAR, Y. & BOEHM, M. J. 1991. Status of compost-amended potting mixes naturally suppressive to soilborne diseases of floricultural crops. *Plant Disease,* 75: 869-873.

HOITINK, H. A. J., STONE, A. G. & HAN, D. Y. 1997. Suppression of plant diseases by composts. *HortScience,* 32, 2: 184-187.

HOITINK, H. A. J. & BOEHM, M. J. 1999. Biocontrol within the context of soil microbial communities: a substrate-dependent phenomenon. *Annual Review of Phytopathology,* 37: 427-446.

HOWELL, J., DUEITT, S. & NEWMAN, S. E. 1993. Kenaf fiber core as a vermiculite substitute in peat-based media for growing greenhouse bedding plants. *Proceedings of the Southern Nurseryman's Association Research Conference,* 38: 59-62.

HU, J.-L., LIN, X.-G., WANG, J.-H., SHEN, W.-S., WU, S., PENG, S.-P. & MAO, T.-T. 2010. Arbuscular mycorrhizal fungal inoculation enhances suppression of cucumber fusarium wilt in greenhouse soils. *Pedosphere,* 20, 5: 586-593.

HU, Y. & BARKER, A. V. 2004. Effects of composts and their combinations with other materials on nutrient accumulation in tomato leaves. *Communications in Soil Science and Plant Analysis,* 35, 19 & 20: 2809-2823.

HUANG, J.-W. & HUANG, H. C. 2000. A formulated container medium suppressive to Rhizoctonia damping-off of cabbage. *Botanical Bulletin of Academia Sinica,* 41: 49-56.

HUBER, G. W., IBORRA, S. & CORMA, A. 2006. Synthesis of transportation fuels from biomass: chemistry, catalysts, and engineering. *Chemical Reviews,* 106, 9: 4044-4098.

HUE, N. V. & SOBIESZCZYK, B. A. 1999. Nutritional values of some biowastes as soil amendments. *Compost Science and Utilization,* 7, 1: 34-41.

HUERTA, E., VIDAL, O., JARQUIN, A., GEISSEN, V. & GOMEZ, R. 2010. Effect of vermicompost on the growth and production of Amashito pepper, interactions with earthwroms and rhizobacteria. *Compost Science and Utilization,* 18, 4: 282-288.

HUMMEL, R. L., KUO, S., PRIVETT, D. W. & JELLUM, E. J. 1993. Effect of nitrogen on blueberry and juniper grown in a fish waste compost:fir bark medium. *Combined Proceedings of the International Plant Propagators' Society,* 43: 201-204.

HUMMEL, R. L., KUO, S., WINTERS, D. & JELLUM, E. J. 2000. Fishwaste compost medium improves growth and quality of container-grown marigolds and gernaniums without leaching. *Journal of Environmental Horticulture,* 18, 2: 93-98.

HUMMEL, R. L., JOHNSON, C. R., RILEY, R. & SMITH, S. 2001. Yard trimmings compost as a growth medium component and nutrient source for chrysanthemum and fuchsia production *Combined Proceedings of the International Plant Propagators' Society,* 51: 295-299.

HUTCHINSON, D. 2008. An advisor's experience of the use of compost teas in nursery stock production. *Combined Proceedings of the International Plant Propagators' Society,* 58: 440-442.

INBAR, Y., CHEN, Y. & HADAR, Y. 1986. The use of composted separated cattle manure and grape marc as peat substitute in horticulture. *Acta Horticulturae,* 178: 147-154.

INBAR, Y., CHEN, Y. & HOITINK, H. A. J. 1993. Properties for establishing standards for utilization of composts in container media. *In:* HOITINK, H. A. J. & KEENER, H. M. (eds.) *Science and engineering of composting: design, environmental, microbiological and utilization aspects.* Worthington, OH, USA: Renaissance Publications. 668-694.

INGELMO, F., CANET, R., IBAŇEZ, M. A., POMARES, F. & GARCÍA, J. 1998. Use of MSW compost, dried sewage sludge and other wastes as partial substitutes for peat and soil. *Bioresource Technology,* 63: 123-129.

INGHAM, E. 1999a. What is compost tea? Part 1. *BioCycle,* 40, 3: 74-75.

INGHAM, E. 1999b. Making a high quality compost tea. Part 2. *BioCycle,* 40, 4: 94.

INGRAM, D. T. & MILLNER, P. D. 2007. Factors affecting compost tea as a potential source of *Escherichia coli* and *Salmonella* on fresh produce. *Journal of Food Protection,* 70, 4: 828-834.

ISLAM, M. S., KHAN, S., ITO, T., MARUO, T. & SHINOHARA, Y. 2002. Characterization of the physico-chemical properties of environmentally friendly organic substrates in relation to rockwool. *Journal of Horticultural Science and Biotechnology,* 77, 2: 143-148.

JACK, A. L. H., RANGARAJAN, A., CULMAN, S. W. & SOOKSA-NGUAN, T. 2011. Choice of organic amendments in tomato transplants has lasting effects on bacterial rhizosphere communities and crop performance in the field. *Applied Soil Ecology,* 48: 94-101.

JACKSON, B. E., WRIGHT, A. N. & SIBLEY, J. L. 2005. Effect of cotton gin compost and pine bark substrate blends on root growth of two horticulture crops. *Proceedings of the Southern Nurseryman's Association Research Conference,* 50: 54-58.

JACKSON, B. E., BROWDER, J. F. & WRIGHT, R. D. 2006. A comparison of nutrient requirements between pine chip and pine bark substrates.

Combined Proceedings of the International Plant Propagators' Society, 56: 623-626.

JACKSON, B. E., WRIGHT, E. R. & BARNES, M. C. 2008a. Pine tree substrate, nitrogen rate, particle size, and peat amendment affect poinsettia growth and substrate physical properties. *HortScience,* 43, 7: 2155-2161.

JACKSON, B. E., WRIGHT, R. D., BROWDER, J. F., HARRIS, J. R. & NIEMIERA, A. X. 2008b. Effect of fertilizer rate on growth of azalea and holly in pine bark and pine tree substrates. *HortScience,* 43, 5: 1561-1568.

JACKSON, B. E., WRIGHT, E. R. & GRUDA, N. 2009. Container medium pH in a pine tree substrate amended with peatmoss and dolomitic limestone affects plant growth. *HortScience,* 44, 7: 1983-1987.

JACKSON, B. E., WRIGHT, R. D. & BARNES, M. C. 2010. Methods of constructing a pine tree substrate from various wood particle sizes, organic amendments, and sand for desired physical properties and plant growth. *HortScience,* 45, 1: 103-112.

JACKSON, M. J. 1998. *Chemical characterisation and compost-recycling of a pulp and paper mill sludge.* Doctor of Philosophy, The University of Tasmania.

JAYASHREE, S., RATHINAMALA, J. & LAKSHMANAPERUMALSAMY, P. 2008. Bio composting of leaf litters by *Eudrilus eugeniae* and its application on the growth of green gram (*Vigna radiata* (L) CO. 6). *Journal of Solid Waste Technology and Management,* 34, 2: 102-112.

JAYASINGHE, G. Y., TOKASHIKI, Y., KITOU, M. & KINJO, K. 2009. Coal fly ash-based synthetic aggregates as potential alternative container substrates for ornamentals. *Journal of Plant Nutrition and Soil Science,* 172: 720-728.

JAYASINGHE, G. Y., TOKASHIKI, Y., ARACHCHI, I. D. L. & ARAKAKI, M. 2010. Sewage sludge sugarcane trash based compost and synthetic aggregates as peat substitutes in containerized media for drop production. *Journal of Hazardous Materials,* 174: 700-706.

JENKINS, A. 2012. The role of carbon in the soil. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 1: pp. 1-10.

JENKINS, A. & VAN ZWIETEN, L. 2012. Biochar production. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 2: pp. 11-18.

JI, P., CAMPBELL, H. L., KLOEPPER, J. W., JONES, J. B., SUSLOW, T. V. & WILSON, M. 2006. Integrated biological control of bacterial speck and spot of tomato under field conditions using foliar biological control agents and plant growth-promoting rhizobacteria. *Biological Control,* 36: 358-367.

JONES, N. B. & VAN STADEN, J. 1997. The effect of a seaweed application on the rooting of pine cuttings. *South African Journal of Botany,* 63, 3: 141-145.

KACHENKO, A., HOUSLEY, C. & SINGH, B. 2011. The effect of biochar amended growing media on plant nutrition and growth. *Nursery Papers,* November, 9: 1-4.
KADOTA, M. & NIIMI, Y. 2004. Effects of charcoal with pyroligneous acid and barnyard manure on bedding plants. *Scientia Horticulturae,* 101: 327-332.
KAHN, B. A., HYDE, J. K., COLE, J. C., STOFFELLA, P. J. & GRAETZ, D. A. 2005. Replacement of a peat-lite medium with compost for cauliflower transplant production. *Compost Science and Utilization,* 13, 3: 175-179.
KANNANGARA, T., UTKHEDE, R. S., PAUL, J. W. & PUNJA, Z. K. 2000. Effects of mesophilic and thermophilic composts on suppression of Fusarium root and stem rot of greenhouse cucumber. *Canadian Journal of Microbiology,* 46: 1021-1028.
KANNANGARA, T., FORGE, T. & DANG, B. 2006. Effects of aeration, molasses, kelp, compost type and carrot juice on the growth of *Escherichia coli* in compost teas. *Compost Science and Utilization,* 14, 1: 40-47.
KAYANI, M. Z., MUKHTAR, T. & HUSSAIN, M. A. 2012. Evaluation of nematicidal effects of *Cannabis sativa* L. and *Zanthoxylum alatum* Roxb. against root-knot nematodes, *Meloidogyne incognita*. *Crop Protection,* 39: 52-56.
KEILUWEIT, M., NICO, P. S., JOHNSON, M. G. & KLEBER, M. 2010. Dynamic molecular structure of plant biomass-derived black carbon (biochar). *Environmental Science and Technology,* 44: 1247-1253.
KHAH, E. M., PETROPOULOS, S. A., KARAPANOS, I. C. & PASSAM, H. C. 2012. Evaluation of growth media incorporating cotton ginning by-products for vegetable production. *Compost Science and Utilization,* 20, 1: 24-28.
KHAN, M. R. & ANWER, M. A. 2011. Fungal bioinoculants for plant disease management. *In:* AHMAD, I., AHMAD, F. & PICHTEL, J. (eds.) *Microbes and microbial technology: agricultural and environmental applications.* New York, NY, USA: Springer. Ch. 17: pp. 447-488.
KHAN, W., RAYIRATH, U. P., SUBRAMANIAN, S., JITHESH, M. N., RAYORATH, P., HODGES, D. M., CRITCHLEY, A. T., CRAIGIE, J. S., NORRIE, J. & PRITHIVIRAJ, B. 2009. Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation,* 28: 386-399.
KIM, G.-S., LEE, S.-E., NOH, H.-J., KWON, H., LEE, S.-W., KIM, S.-Y. & KIM, Y.-B. 2012. Effects of natural bioactive products on the growth and ginsenoside contents of *Panax ginseng* cultured in an aeroponic system. *Journal of Ginseng Research,* 36, 4: 430-441.
KIM, K. Y., JORDAN, D. & MCDONALD, G. A. 1998. Enterobacter agglomerans, phosphate solubilizing bacteria, and microbial activity in soil: effect of carbon sources. *Soil Biology and Biochemistry,* 30, 8/9: 995-1003.
KIRKMAN, H. & KENDRICK, G. A. 1997. Ecological significance and commercial harvesting of drifting and beachcast macroalgae and seagrasses in Australia: a review. *Journal of Applied Phycology,* 9: 311-326.
KLEIN, E., KATAN, J. & GAMLIEL, A. 2011. Combining residues of herb crops with soil heating for control of soilborne pathogens in a controlled laboratory system. *Crop Protection,* 30: 368-374.
KLEIN, E., KATAN, J. & GAMLIEL, A. 2012. Soil suppressiveness to *Meloidogyne javanica* as induced by organic amendments and solarization in greenhouse crops. *Crop Protection,* 39: 26-32.
KLOCK-MOORE, K. 1999a. Growth of impatiens 'Accent Orange' in two compost products. *Compost Science and Utilization,* 7, 1: 58-62.

KLOCK-MOORE, K. A. 1999b. Bedding plant growth in greenhouse waste and biosolid compost. *HortTechnology,* 9, 2: 210-213.

KLOCK-MOORE, K. A. 2000. Comparison of salvia growth in seaweed compost and biosolids compost. *Compost Science and Utilization,* 8, 1: 24-28.

KLOCK-MOORE, K. A. & FITZPATRICK, G. E. 2000. Management of urban waste compost amendments in ornamental production systems in Florida. *Soil and Crop Science Society of Florida Proceedings,* 59: 14-16.

KLOCK, K. A. 1997a. Growth of salt sensitive bedding plants in media amended with composted urban waste. *Compost Science and Utilization,* 5, 3: 55-59.

KLOCK, K. A. 1997b. Growth of dianthus and petunia in media amended with composted urban waste. *Journal of Environmental Horticulture,* 15, 3: 135-137.

KLOCK, K. A. & FITZPATRICK, G. E. 1997. Growth of impatiens 'Accent Red' in three compost products. *Compost Science and Utilization,* 5, 4: 26-30.

KOKALIS-BURELLE, N., KLOEPPER, J. W. & REDDY, M. S. 2006. Plant growth-promoting rhizobacteria as transplant amendments and their effects on indigenous rhizosphere microorganisms. *Applied Soil Ecology,* 31: 91-100.

KOLLER, M., ALFÖLDI, T., SIEGRIST, M. & WEIBEL, F. 2004. A comparison of plant and animal based fertilizer for the production of organic vegetable transplants. *Acta Horticulturae,* 631: 209-215.

KOLTON, M., MELLER HAREL, Y., PASTERNAK, Z., GRABER, E. R., ELAD, Y. & CYTRYN, E. 2011. Impact of biochar application to soil on the root-associated bacterial community structure of fully developed greenhouse pepper plants. *Applied and Environmental Microbiology,* 77, 14: 4924-4930.

KONÉ, S. B., DIONNE, A., TWEDDELL, R. J., ANTOUN, H. & AVIS, T. J. 2010. Suppressive effect of non-aerated compost teas on foliar fungal pathogens of tomato. *Biological Control,* 52: 167-173.

KOOKANA, R. S., SARMAH, A. K., VAN ZWIETEN, L., KRULL, E. & SINGH, B. 2011. Biochar application to soil: agronomic and environmental benefits and unintended consequences. *In:* DONALD, L. S. (ed.) *Advances in Agronomy. Volume 112.* San Diego, CA, USA: Academic Press. Ch. 3: pp. 103-143.

KOWALSKI, B., JÄGER, A. K. & VAN STADEN, J. 1999. The effect of a seaweed concentrate on the *in vitro* growth and acclimatization of potato plantlets. *Potato Research,* 42: 131-139.

KRAUS, H. T. & WARREN, S. L. 2000. Performance of turkey litter compost as a slow-release fertilizer in containerized plant production. *HortScience,* 35, 1: 19-21.

KRESTEN JENSEN, H. E., LETH, M. & LØNSMANN IVERSEN, J. J. 2001. Growth of *Hedera helix* and *Fatsia japonica* pot plants in compost substrates based on *Miscanthus* straw and various N-sources. *Acta Horticulturae,* 549: 137-145.

KRISHNAMOORTHY, R. V. & VAJRANABHAIAH, S. N. 1986. Biological activity of earthworm casts: an assessment of plant growth promotor levels in the casts. *Proceedings of the Indian Academy of Science (Animal Science),* 95, 3: 341-351.

KRISHNAMURTHY, V. 2011. Compost tea basics - and beyond. *Organic Farming,* Summer, 107: 40-41.

KRUMFOLZ, L. A., WILSON, S. B. & STOFFELLA, P. J. 2000. Use of compost as a media amendment for containerized production of the perennial, cat whiskers. *Proceedings of the Southern Nurseryman's Association Research Conference,* 45: 68-72.

KU, C. S. M., BOUWCAMP, J. C. & GOUIN, F. R. 1998. Effects of compost source and timing of fertigation initiation on growth of potted poinsettia. *Compost Science and Utilization,* 6, 4: 57-66.

KUO, S., HUMMEL, R. L., JELLUM, E. J. & PRIVETT, D. 1997. Fishwaste compost effects on rhododendron growth and nitrogen leaching and transformation. *Journal of Environmental Quality,* 26, 3: 733-739.

KUO, S., ORTIZ-ESCOBAR, M. E., HUE, N. V. & HUMMEL, R. L. 2004. Composting and compost utilization for agronomic and container crops. *Recent Research Developments in Environmental Biology,* 1: 451-513.

KUTER, G. A., NELSON, E. B., HOITINK, H. A. J. & MADDEN, L. V. 1983. Fungal populations in container media amended with composted hardwood bark suppressive and conducive to Rhizoctonia damping-off. *Phytopathology,* 73, 10: 1450-1456.

KUTER, G. A., HOITINK, H. A. J. & CHEN, W. 1988. Effects of municipal sludge compost curing time on suppression of Pythium and Rhizoctonia diseases of ornamental plants. *Plant Disease,* 72, 9: 751-756.

LABRIE, C., LECLERC, P., CÔTÉ, N., ROY, R., BRZEZINSKI, R., HOGUE, R. & BEAULIEU, C. 2001. Effect of chitin waste-based composts produced by two-phase composting on two oomycete plant pathogens. *Plant and Soil,* 235: 27-34.

LAICHE JR, A. J. & NASH, V. E. 1990. Evaluation of composted rice hulls and a lightweight clay aggregate as components of container-plant growth media. *Journal of Environmental Horticulture,* 8, 1: 14-18.

LAICHE JR, A. J. & NEWMAN, S. E. 1994. Kenaf core as a container media component for woody landscape plants and greenhouse bedding plants. *In:* GOFORTH, C. E. & FULLER, M. J. (eds.) *A summary of kenaf production and product development research 1989-1993. Mississippi State University Bulletin 1011.* Mississippi, USA: Mississippi State University. p. 30.

LANGAT, J. K., KIMENJU, J. W., MUTUA, G. K., MUIRU, W. M. & OTIENO, W. 2008. Response of free-living nematodes to treatments targeting plant parasitic nematodes in carnation. *Asian Journal of Plant Sciences,* 7, 5: 467-472.

LARNEY, F. J. & BLACKSHAW, R. E. 2003. Weed seed viability in composted beef cattle feedlot manure. *Journal of Environmental Quality,* 32, 3: 1105-1113.

LAZCANO, C., SAMPEDRO, L., ZAS, R. & DOMÍNGUEZ, J. 2010. Vermicompost enhances germination of the maritime pine (*Pinus pinaster* Ait.). *New Forests,* 39: 387-400.

LEHMANN, J., RILLIG, M. C., THIES, J., MASIELLO, C. A., HOCKADAY, W. C. & CROWLEY, D. 2011. Biochar effects on soil biota - a review. *Soil Biology and Biochemistry,* 43: 1812-1836.

LI, H., WHITE, D., LAMZA, K. A., BERGER, F. & LEIFERT, C. 1998. Biological control of *Botrytis*, *Phytophthora* and *Pythium* by *Bacillus subtilis* Cot1

and CL27 of micropropagated plants in high-humidity fogging glasshouses. *Plant Cell, Tissue and Organ Culture,* 52: 109-112.

LIEVENS, B., VAES, K., COOSEMANS, J. & RYCKEBOER, J. 2001. Systemic resistance induced in cucumber against Pythium root rot by source separated household waste and yard trimmings composts *Compost Science and Utilization,* 9, 3: 221-229.

LINDERMAN, R. G. & DAVIS, E. A. 2001. Vesicular–arbuscular mycorrhiza and plant growth response to soil amendment with composted grape pomace or its water extract. *HortTechnology,* 11, 3: 446-450.

LINDERMAN, R. G. & DAVIS, E. A. 2003. Arbuscular mycorrhiza and growth responses of several ornamental plants grown in soilless peat-based medium amended with coconut dust (coir). *HortTechnology,* 13, 3: 483-487.

LINDSEY, K. L., JAGER, A. K. & VAN STADEN, J. 1998. Effect of a seaweed concentrate on acclimatization of *in vitro* grown plantlets of *Kniphofia pauciflora* and *Scilla krausii*. *South African Journal of Botany,* 64, 4: 262-264.

LINE, M. & RAMONA, Y. 2003. The making of compost teas - the next generation? *BioCycle,* 44, 12: 55-56.

LINES-KELLY, R. 2012. Biochar in Australia. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 7: pp. 61-66.

LITTERICK, A. & WOOD, M. 2009. The use of composts and compost extracts in plant disease control. *In:* WALTERS , D. (ed.) *Disease control in crops: Biological and environmentally friendly approaches.* Oxford: Wiley-Blackwell. Ch. 5: pp. 93-121.

LITTERICK, A. M., HARRIER, L., WALLACE, P., WATSON, C. A. & WOOD, M. 2004. The role of uncomposted materials, composts, manures, and compost extracts in reducing pest and disease incidence and severity in sustainable temperate agricultural and horticultural crop production - a review. *Critical Reviews in Plant Sciences,* 23, 6: 453-479.

LITTLE, A. G. & CARDOZA, Y. J. 2011. Host plant effects on generalist and specialist lepidopterous cabbage pests modulated by organic soil amendment. *Pedobiologia,* 54: 353-359.

LIU, X., CHEN, H., NI, Q. & SEUNG, L. K. 2008. Evaluation of the role of mixed amino acids in nitrate uptake and assimilation in leafy radish by using ^{15}N-labeled nitrate. *Agricultural Sciences in China,* 7, 10: 1196-1202.

LOHR, V. I., O'BRIEN, R. G. & COFFEY, D. L. 1984a. Spent mushroom compost in soilless media and its effects on the yield and quality of transplants. *Journal of the American Society for Horticultural Science,* 109, 5: 693-697.

LOHR, V. I., WANG, S. H. & WOLT, J. D. 1984b. Physical and chemical characteristics of fresh and aged spent mushroom compost. *HortScience,* 19, 5: 681-683.

LÓPEZ-GÓMEZ, B. F., LARA-HERRERA, A., BRAVO-LOZANO, A. G., LOZANO-GUTIÉRREZ, J., AVELAR-MEJÍA, J. J., LUNA-FLORES, M. & LLAMAS-LLAMAS, J. J. 2012. Improvement of plant growth and yield in pepper by vermicompost application, in greenhouse conditions. *Acta Horticulturae,* 947: 313-317.

LOPEZ-REAL, J. M., WITTER, E., MIDMER, F. N. & HEWETT, B. A. O. 1989. Evaluation of composted sewage sludge/straw mixture for horticultural utilisation. *Water Science and Technology,* 21: 889-897.

LU, W., SIBLEY, J. L., SCHAEFER, M. & YANG, X. 2005. Nursery use of municipal garbage compost. *Proceedings of the Southern Nurseryman's Association Research Conference,* 50: 68-72.

MAHAFFEE, W. F. & SCHEUERELL, S. J. 2006. Compost teas: alternative approaches to the biological control of plant diseases. *In:* BAILEY, M. J., LILLEY, A. K., TIMMS-WILSON, T. M. & SPENCER-PHILLIPS, P. T. N. (eds.) *Microbial ecology of aerial plant surfaces.* Wallingford: CABI International. pp. 165-179.

MAHER, M. J. 1991. Spent mushroom compost (SMC) as a nutrient source in peat based potting substrates. *Mushroom Science,* 13, Part 2: 645-650.

MAHER, M. J. 1994. The use of spent mushroom substrate (SMS) as an organic manure and plant substrate component. *Compost Science and Utilization,* 2, 3: 37-44.

MAHER, M. J. & PRASAD, M. 2004. Using composted green waste materials in growing media. *Combined Proceedings of the International Plant Propagators' Society,* 54: 169-173.

MAŇAS, P., CASTRO, E. & DE LAS HERAS, J. 2009. Quality of maritime pine (*Pinus pinaster* Ait.) seedlings using waste materials as nursery growing media. *New Forests,* 37: 295-311.

MANDELBAUM, R., HADAR, Y. & CHEN, Y. 1988. Composting of agricultural wastes for their use as container media: effect of heat treatments on suppression of *Pythium aphanidermatum* and microbial activities in substrates containing compost. *Biological Wastes,* 26: 261-274.

MANNING, L. K., TRIPEPI, R. R. & CAMPBELL, A. G. 1995. Suitability of composted bluegrass residues as an amendment in container media. *HortScience,* 30, 2: 277-280.

MARBLE, S. C., GILLIAM, C. H., SIBLEY, J. L., FAIN, G. B., TORBERT, H. A. & OLIVE, J. W. 2008. Composted poultry litter as an amendment for substrates with high wood content. *Combined Proceedings of the International Plant Propagators' Society,* 58: 524-532.

MARBLE, S. C., SIBLEY, J. L., GILLIAM, C. H. & TORBERT, H. A. 2011. Application of composted poultry litter as a fertilizer for landscape bedding plants. *HortScience,* 46, 10: 1367-1372.

MARCOTRIGIANO, M., GOUIN, F. R. & LINK, C. B. 1985. Growth of foliage plants in composted raw sewage sludge and perlite media. *Journal of Environmental Horticulture,* 3, 3: 98-101.

MARIANTHI, T. 2006. Kenaf (*Hibiscus cannabinus* L.) core and rice hulls as components of container media for growing *Pinus halepensis* M. seedlings. *Bioresource Technology,* 97: 1631-1639.

MASHELA, P. W., MPHOSI, M. S., SHIMELIS, H. & MOKGALONG, N. M. 2007. Interactions of *Cucumis myriocarpus*, *Lippia javanica* and *Ricinus communis* organic amendments on suppression of *Meloidogyne incognita*. *Journal of Phytopathology,* 155: 690-693.

MATSUBARA, Y., HASEGAWA, N. & FUKUI, H. 2002. Incidence of fusarium root rot in asparagus seedlings infected with arbuscular mycorrhizal fungus as affected by several soil amendments. *Journal of the Japanese Society for Horticultural Science,* 71, 3: 370-374.

MAYA, M. A. & MATSUBARA, Y. 2013. Tolerance to Fusarium wilt and anthracnose diseases and changes of antioxidative activity in mycorrhizal cyclamen. *Crop Protection,* 47: 41-48.

MAZUELA, P. & URRESTARAZU, M. 2009. The effect of amendment of vegetable waste compost used as substrate in soilless culture on yield and quality of melon crops. *Compost Science and Utilization,* 17, 2: 103-107.

MCCLINTOCK, A. & POWELL, J. 2012. Profitability of biochar in horticulture. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 6: pp. 49-60.

MCGINNIS, M. S., WARREN, S. L. & BILDERBACK, T. E. 2005. Vermicompost: improving water use efficiency in nursery crop production. *Proceedings of the Southern Nurseryman's Association Research Conference,* 50: 73-77.

MCGINNIS, M. S., WARREN, S. L. & BILDERBACK, T. E. 2009. Replacing conventional nursery crop nutrient inputs with vermicompost for container production of *Hibiscus moscheutos* L. 'Luna Blush'. *HortScience,* 44, 6: 1698-1703.

MCGINNIS, M. S., WAGGER, M. G., WARREN, S. L. & BILDERBACK, T. E. 2010. Nutrient contribution and release kinetics of vermicompost amended pine bark. *Compost Science and Utilization,* 18, 2: 97-104.

MEDINA, E., PAREDES, C., PÉREZ-MURCIA, M. D., BUSTAMANTE, M. A. & MORAL, R. 2009. Spent mushroom substrates as component of growing media for germination and growth of horticultural plants. *Bioresource Technology,* 100: 4227–4232.

MEEROW, A. W. 1994. Growth of two subtropical ornamentals using coir (coconut mesocarp pith) as a peat substitute. *HortScience,* 29, 12: 1484–1486.

MELLER HAREL, Y., ELAD, Y., RAV-DAVID, D., BORENSTEIN, M., SHULCHANI, R., LEW, B. & GRABER, E. R. 2012. Biochar mediates systemic response of strawberry to foliar fungal pathogens. *Plant and Soil,* 357: 245-257.

MENA-VIOLANTE, H. G., SAUCEDO-ARIAS, L. J., RAMIREZ-ZAVALA, B. G., GOMEZ-LIM, M. A. & OLALDE-PORTUGAL, V. 2005. Inoculation of *Bacillus subtilis* BEB-13bs improves fruit quality (firmness) in tomato (*Lycopersicon esculentum* L.). *Proceedings of the Southern Nurseryman's Association Research Conference,* 50: 81-83.

MENA-VIOLANTE, H. G. & OLALDE-PORTUGAL, V. 2007. Alteration of tomato fruit quality by root inoculation with plant growth-promoting rhizobacteria (PGPR): *Bacillus subtilis* BEB-13bs. *Scientia Horticulturae,* 113: 103-106.

METTING, B., ZIMMERMAN, W. J., CROUCH, I. & VAN STADEN, J. 1990. Agronomic uses of seaweed and microalgae. *In:* AKATSUKA, I. (ed.) *Introduction to applied phycology.* The Hague, The Netherlands: SPB Academic Publishing. pp. 589-627.

MICHITSCH, R. C., CHONG, C., HOLBEIN, B. E., VORONEY, R. P. & LIU, H.-W. 2007. Use of wastewater and compost extracts as nutrient sources for growing nursery and turfgrass species. *Journal of Environmental Quality,* 36, 4: 1031-1041.

MOHAN, V. & RADHAKRISHNAN, A. 2012. Screening of phosphate solubilizing bacterial isolates for the growth improvement of *Tectona grandis* Linn. *Research Journal of Microbiology,* 7, 2: 101-113.

MOLDES, A., CENDÓN, Y. & BARRAL, M. T. 2007. Evaluation of municipal solid waste compost as a plant growing media component, by applying mixture design. *Bioresource Technology,* 98: 3069–3075.

MØLLER, K., KRISTENSEN, K., YOHALEM, D. & LARSEN, J. 2009. Biological management of gray mold in pot roses by co-inoculation of the biocontrol agent *Ulocladium atrum* and the mycorrhizal fungus *Glomus mosseae*. *Biological Control,* 49: 120-125.

MOORE, K. K. 2005. Uses of compost in potting mixtures. *HortTechnology,* 15: 58-60.

MORALES-PAYAN, J. P. 2006. Growth of aromatic coleus (*Coleus amboinicus* Lour.) as affected by biostimulators. *Proceedings of the 33rd Annual Meeting of the Plant Growth Regulation Society of America, 9-13 July, 2006.* Quebec City, Canada: Plant Growth Regulator Society of America.

MU, J., UEHARA, T. & FURUNO, T. 2003. Effect of bamboo vinegar on regulation of germination and radicle growth of seed plants. *Journal of Wood Science,* 49: 262-270.

MUGNAI, S., PASQUINI, T., AZZARELLO, E., PANDOLFI, C. & MANCUSO, S. 2007. Evaluation of composted green waste in ornamental container-grown plants: effects on growth and plant water relations. *Compost Science and Utilization,* 15, 4: 283-287.

MULCAHY, D. N., MULCAHY, D. L. & DIETZ, D. 2013. Biochar soil amendment increases tomato seedling resistance to drought in sandy soils. *Journal of Arid Environments,* 88: 222-225.

MUNGKUNKAMCHAO, T., KESMALA, T., PIMRATCH, S., TOOMSAN, B. & JOTHITYANGKOON, D. 2013. Wood vinegar and fermented bioextracts: natural products to enhance growth and yield of tomato (*Solanum lycopersicum* L.). *Scientia Horticulturae,* 154: 66-72.

MUTHUKUMAR, T. & UDAIYAN, K. 2010. Growth response and nutrient utilization of *Casuarina equisetifolia* seedlings inoculated with bioinoculants under tropical nursery conditions. *New Forests,* 40: 101-118.

NAIR, A., NGOUAJIO, M. & BIERNBAUM, J. 2011. Alfalfa-based organic amendment in peat-compost growing medium for organic tomato transplant production. *HortScience,* 46, 2: 253-259.

NARDI, S., PIZZEGHELLO, D., MUSCOLO, A. & VIANELLO, A. 2002. Physiological effects of humic substances on higher plants. *Soil Biology and Biochemistry,* 34: 1527-1536.

NELSON, E. B. & HOITINK, H. A. J. 1982. Factors affecting suppression of *Rhizoctonia solani* in container media. *Phytopathology,* 72, 3: 275-279.

NELSON, E. B. & HOITINK, H. A. J. 1983. The role of microorganisms in the suppression of *Rhizoctonia solani* in container media amended with composted hardwood bark. *Phytopathology,* 73, 2: 274-278.

NELSON, E. B., KUTER, G. A. & HOITINK, H. A. J. 1983. Effects of fungal antagonists and compost age on suppression of Rhizoctonia damping-off in container media amended with composted hardwood bark. *Phytopathology,* 73, 10: 1457-1462.

NELSON, E. B. & BOEHM, M. J. 2002. Compost-induced suppression of turf grass diseases. *BioCycle,* 43: 51-55.

NICHOLS, M. A. & SAVIDOV, N. A. 2009. Recent advances in coir as a growing medium. *Acta Horticulturae,* 843: 333-336.

NICHOLS, M. A., SAVIDOV, N. A. & ASCHIM, K. 2010. Biochar as a hydroponic growing medium *Practical Hydroponics and Greenhouses,* 112, May/June: 40-42.

NKONGOLO, N. V., CARON, J., GAUTHIER, F. & YAMADA, M. 2000. Organic wastes for improving soil physical properties and enhancing plant growth in container substrates. *Journal of Crop Production,* 3: 97-112.

NOBLE, R. & ROBERTS, S. J. 2004. Eradication of plant pathogens and nematodes during composting: a review. *Plant Pathology,* 53: 548-568.

NOBLE, R. & COVENTRY, E. 2005. Suppression of soil-borne plant diseases with composts: A review. *Biocontrol Science and Technology,* 15, 1: 3-20.

NOBLE, R., ELPHINSTONE, J. G., SANSFORD, C. E., BUDGE, G. E. & HENRY, C. M. 2009. Management of plant health risks associated with processing of plant-based wastes: a review. *Bioresource Technology,* 100: 3431-3446.

NOBLE, R. 2011. Risks and benefits of soil amendment with composts in relation to plant pathogens. *Australasian Plant Pathology,* 40: 157-167.

NOWAK, J. 2004. Effects of arbuscular mycorrhizal fungi and organic fertilization on growth, flowering, nutrient uptake, photosynthesis and transpiration of geranium (*Pelargonium hortorum* L. H. Bailey 'Tango Orange'). *Symbiosis,* 37: 259-266.

NTOUGIAS, S., PAPADOPOULOU, K. K., ZERVAKIS, G. I., KAVROULAKIS, N. & EHALIOTIS, C. 2008. Suppression of soil-borne pathogens of tomato by composts derived from agro-industrial wastes abundant in Mediterranean regions. *Biology and Fertility of Soils,* 44: 1081-1090.

O'DONNELL, R. W. 1973. The auxin-like effects of humic preparations from leonardite. *Soil Science,* 116, 2: 106-112.

OAKES, P. 2009. Municipal solid waste processing. *BioCycle,* 50, 12: 48-49.

OFFORD, C. A., MUIR, S. & TYLER, J. L. 1998. Growth of selected Australian plants in soilless media using coir as a substitute for peat. *Australian Journal of Experimental Agriculture,* 38: 879-887.

OKA, Y. 2010. Mechanisms of nematode suppression by organic soil amendments - a review. *Applied Soil Ecology,* 44: 101-115.

ORTEGA, M. C., MORENO, M. T., ORDOVÁS, J. & AGUADO, M. T. 1996. Behaviour of different horticulutral species in phytotoxicity bioassays of bark substrates. *Scientia Horticulturae,* 66: 125-132.

ORTEGA, R. & FERNÁNDEZ, M. 2007. Agronomic evaluation of liquid humus derived from earthworm humic substances. *Journal of Plant Nutrition,* 30: 2091-2104.

OSTOS, J. C., LÓPEZ-GARRIDO, R., MURILLO, J. M. & LÓPEZ, R. 2008. Substitution of peat for municipal solid waste- and sewage sludge-based composts in nursery growing media: effects on growth and nutrition of the native shrub *Pistacia lentiscus* L. *Bioresource Technology,* 99: 1793–1800.

OUAHMANE, L., REVEL, J. C., HAFIDI, M., THIOULOUSE, J., PRIN, Y., GALIANA, A., DREYFUS, B. & DUPONNOIS, R. 2009. Responses of *Pinus halepensis* growth, soil microbial catabolic functions and phosphate-solubilizing bacteria after rock phosphate amendment and ectomycorrhizal inoculation. *Plant and Soil,* 320: 169-179.

OWINGS, A. D. 1993. Cotton gin trash as a medium component in production of 'Golden Bedder' coleus. *Proceedings of the Southern Nurseryman's Association Research Conference,* 38: 65-66.

OZORES-HAMPTON, M., VAVRINA, C. S. & OBREZA, T. A. 1999. Yard trimming-biosolids compost: possible alternative to sphagnum peat moss in tomato transplant production. *Compost Science and Utilization,* 7, 4: 42-49.

PACHOLCZAK, A., SZYDŁO, W., JACYGRAD, E. & FEDEROWICZ, M. 2012. Effect of auxins and the biostimulator Algaminoplant on rhizogenesis in stem cuttings of two dogwood cultivars (*Cornus alba* 'Aurea' and 'Elegantissima'). *Acta Scientiarum Polonorum, Hortorum Cultus,* 11, 2: 93-103.

PALMER, A. K., BROWN, J., ROSS, T., METCALF, D. A. & EVANS, K. J. 2010a. Potential for growth of *E. coli* in aerobic compost extract. *Compost Science and Utilization,* 18, 3: 152-161.

PALMER, A. K., EVANS, K. J. & METCALF, D. A. 2010b. Characters of aerated compost tea from immature compost that limit colonization of bean leaflets by *Botrytis cinerea*. *Journal of Applied Microbiology,* 109: 1619-1631.

PANE, C., SPACCINI, R., PICCOLO, A., SCALA, F. & BONANOMI, G. 2011. Compost amendments enhance peat suppressiveness to *Pythium ultimum*, *Rhizoctonia solani* and *Sclerotinia minor*. *Biological Control,* 56: 115-124.

PANE, C., CELANO, G., VILLECCO, D. & ZACCARDELLI, M. 2012. Control of *Botrytis cinerea*, *Alternaria alternata* and *Pyrenochaeta lycopersici* on tomato with whey compost-tea applications. *Crop Protection,* 38: 80-86.

PANT, A., RADOVICH, T. J. K., HUE, N. V. & ARANCON, N. Q. 2011. Effects of vermicompost tea (aqueous extract) on pak choi yield, quality, and on soil biological properties. *Compost Science and Utilization,* 19, 4: 279-292.

PANT, A. P., RADOVICH, T. J. K., HUE, N. V., TALCOTT, S. T. & KRENEK, K. A. 2009. Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (*Brassica rapa* cv. Bonsai, Chinensis group) grown under vermicompost and chemical fertiliser. *Journal of the Science of Food and Agriculture,* 89: 2383-2392.

PANT, A. P., RADOVICH, T. J. K., HUE, N. V. & MIYASAKA, S. C. 2012a. Pak choi (*Brassica rapa*, Chinensis group) yield, phytonutrient content, and soil biological properties as affected by vermicompost-to-water ratio used for extraction. *HortScience,* 47, 3: 395-402.

PANT, A. P., RADOVICH, T. J. K., HUE, N. V. & PAULL, R. E. 2012b. Biochemical properties of compost tea associated with compost quality and effects on pak choi growth. *Scientia Horticulturae,* 148: 138-146.

PAPAFOTIOU, M., ASIMAKOPOULOU, V., KOUVARI, P., KOVAEOU, I., PHSYHALOU, M., LYTRA, I. & KARGAS, G. 2001a. Cotton gin trash compost as growing medium ingredient for the production of pot ornamentals. *Gartenbauwissenschaft,* 66, 5: S229–S232.

PAPAFOTIOU, M., CHRONOPOULOS, J., KARGAS, G., VOREAKOU, M., LEODARITIS, N., LAGOGIANI, O. & GAZI, S. 2001b. Cotton gin trash compost and rice hulls as growing medium components for ornamentals. *Journal of Horticultural Science and Biotechnology,* 76, 4: 431-435.

PAPAFOTIOU, M., PHSYHALOU, M., KARGAS, G., CHATZIPAVLIDIS, I. & CHRONOPOULOS, J. 2004. Olive-mill wastes compost as growing medium component for the production of poinsettia. *Scientia Horticulturae,* 102: 167-175.

PAPAFOTIOU, M., KARGAS, G. & LYTRA, I. 2005. Olive-mill waste compost as a growth medium componentfor foliage potted plants. *HortScience,* 40, 6: 1746-1750.

PAPAFOTIOU, M., AVAJIANNELI, B., MICHOS, C. & CHATZIPAVLIDIS, I. 2007. Coloration, anthocyanin concentration, and growth of croton (*Codiaeum variegatum* L.) as affected by cotton gin trash compost use in the potting medium. *HortScience,* 42, 1: 83-87.

PAPAFOTIOU, M. & VAGENA, A. 2012. Cotton gin trash compost in the substrate reduces the daminozide spray dose needed to produce compact potted chrysanthemum. *Scientia Horticulturae,* 143: 102-108.

PAPENFUS, H. B., KULKARNI, M. G., STIRK, W. A., FINNIE, J. F. & VAN STADEN, J. 2013. Effect of a commercial seaweed extract (Kelpak®) and polyamines on nutrient-deprived (N, P and K) okra seedlings. *Scientia Horticulturae,* 151: 142-146.

PAPLOMATAS, E. J., TJAMOS, S. E., MALANDRAKIS, A. A., KAFKA, A. L. & ZOUVELOU, S. V. 2005. Evaluation of compost amendments for suppressiveness against Verticillium wilt of eggplant and study of mode of action using a novel Arabidopsis pathosystem. *European Journal of Plant Pathology,* 112: 183-189.

PERES, J. C. F., CARVALHO, L. R. D., GONÇALEZ, E., BERIAN, L. O. S. & FELICIO, J. D. 2012. Evaluation of antifungal activity of seaweed extracts. *Ciência e Agrotecnologia,* 36, 3: 294-299.

PERNER, H., SCHWARZ, D., BRUNS, C., MÄDER, P. & GEORGE, E. 2007. Effect of arbuscular mycorrhizal colonization and two levels of compost supply on nutrient uptake and flowering of pelargonium plants. *Mycorrhiza,* 17: 469-474.

PERTUIT JR, A. J., DUDLEY, J. B. & TOLER, J. E. 2001. Leonardite and fertilizer levels influence tomato seedling growth. *HortScience,* 36, 5: 913-915.

PILL, W. G., SHI, B., TILMON, H. D. & TAYLOR, R. W. 1995a. Leaching losses and plant uptake of nitrogen in soilless media containing ground kenaf (*Hibiscus cannabinus* L.) stem core. *Journal of Horticultural Science,* 70, 5: 833-840.

PILL, W. G., SHI, B., TILMON, H. D. & TAYLOR, R. W. 1995b. Tomato bedding plant production in soilless media containing ground kenaf (*Hibiscus cannabinus* L.) stem core. *Journal of Horticultural Science,* 70, 5: 713-719.

PILL, W. G., TILMON, H. D. & TAYLOR, R. W. 1995c. Nitrogen-enriched ground kenaf (*Hibiscus cannabinus* L.) stem core as a component of soilless growth media. *Journal of Horticultural Science,* 70, 4: 673-681.

PILL, W. G. & BISCHOFF, D. J. 1998. Resin-coated, controlled-release fertilizer as a pre-plant alternative to nitrogen enrichment of stem core in soilless

media containing ground stem core of kenaf (*Hibiscus cannabinus* L.). *Journal of Horticultural Science and Biotechnology,* 73, 1: 73-79.

PINAMONTI, F., STRINGARI, G. & ZORZI, G. 1997. Use of compost in soilless cultivation. *Compost Science and Utilization,* 5, 2: 38-46.

POSTMA, J., MONTANARI, M. & VAN DEN BOOGERT, P. H. J. F. 2003. Microbial enrichment to enhance the disease suppressive activity of compost. *European Journal of Soil Biology,* 39: 157–163.

PRASAD, M. & MAHER, M. J. 2001. The use of composted green waste (CGW) as a growing medium component. *Acta Horticulturae,* 549: 107-113.

PREMUZIC, Z., BARGIELA, M., GARCIA, A., RENDINA, A. & IORIO, A. 1998. Calcium, iron, potassium, phosphorus and vitamin C content of organic and hydroponic tomatoes. *HortScience,* 33, 2: 255-257.

PURMAN, J. R. & GOUIN, F. R. 1992. Influence of compost aging and fertilizer regimes on the growth of bedding plants, transplants and poinsettia. *Journal of Environmental Horticulture,* 10, 1: 52-54.

QUILTY, J. R. & CATTLE, S. R. 2011. Use and understanding of organic amendments in Australian agriculture: a review. *Soil Research,* 49: 1-26.

RADIN, A. M. & WARMAN, P. R. 2011. Effect of municipal solid waste compost and compost tea as fertility amendments on growth and tissue element concentration in container-grown tomato. *Communications in Soil Science and Plant Analysis,* 42: 1349-1362.

RAVIV, M. 1986. Promotion of "bottom breaks" in roses by spray treatment with a cytokinin-rich seaweed concentrate. *Acta Horticulturae,* 189: 209-213.

RAVIV, M. 1998. Horticultural uses of composted material. *Acta Horticulturae,* 469: 225-234.

RAVIV, M., REUVENI, R. & ZAIDMAN, B. Z. 1998a. Improved medium for organic transplants. *Biological Agriculture and Horticulture,* 16, 1: 53-64.

RAVIV, M., ZAIDMAN, B. Z. & KAPULNIK, Y. 1998b. The use of compost as a peat substitute for organic vegetable transplants. *Compost Science and Utilization,* 6, 1: 46-52.

RAVIV, M. 2005. Production of high-quality composts for horticultural purposes: a mini-review. *HortTechnology,* 15, 1: 52-57.

RAVIV, M., OKA, Y., KATAN, J., HADAR, Y., YOGEV, A., MEDINA, S., KRASNOVSKY, A. & ZIADNA, H. 2005. High-nitrogen compost as a medium for organic container-grown crops. *Bioresource Technology,* 96: 419-427.

RAVIV, M. 2008. The use of compost in growing media as suppressive agent against soil-borne diseases. *Acta Horticulturae,* 779: 39-49.

RAYMOND, D. A., CHONG, C. & VORONEY, R. P. 1998. Response of four container grown woody ornamentals to immature composted media derived from waxed corrugated cardboard. *Compost Science and Utilization,* 6, 2: 67-74.

RAYORATH, P., JITHESH, M. N., FARID, A., KHAN, W., PALANISAMY, R., HANKINS, S. D., CRITCHLEY, A. T. & PRITHIVIRAJ, B. 2008. Rapid bioassays to evaluate the plant growth promoting activity of *Ascophyllum nodosum* (L.) Le Jol. using a model plant, *Arabidopsis thaliana* (L.) Heynh. *Journal of APplied Phycology,* 20: 423-429.

REICHERT, N. A. & BALDWIN, B. S. 1996. Growth of bedding plants in a kenaf-based potting medium. *In:* JANICK, J. (ed.) *Progress in new crops.* Alexandria, VA, USA: ASHS Press. pp. 411-414.

REIS, M., MARTINEZ, F. X., SOLIVA, M. & MONTEIRO, A. A. 1998. Composted organic residues as a substrate component for tomato transplant production. *Acta Horticulturae,* 469: 263-273.

REYNOLDS, A. G., WARDLE, D. A., DROUGHT, B. & CANTWELL, R. 1995. Gro-Mate soil amendment improves growth of greenhouse-grown 'Chardonnay' grapevines. *HortScience,* 30, 3: 539–542.

RIBEIRO, H. M., VASCONCELOS, E. & DOS SANTOS, J. Q. 2000. Fertilisation of potted geranium with a municipal solid waste compost. *Bioresource Technology,* 73: 247-249.

RIPPY, J. F. M., PEET, M. M., LOUWS, F. J., NELSON, P. V., ORR, D. B. & SORENSEN, K. A. 2004. Plant development and harvest yields of greenhouse tomatoes in six organic growing systems. *HortScience,* 39, 2: 223-229.

RODRIGUEZ-NAVARRO, J. A., ZAVALETA-MEJIA, E., SANCHEZ-GARCIA, P. & GONZALEZ-ROSAS, H. 2000. The effect of vermicompost on plant nutrition, yield and incidence of root and crown rot of gerbera (*Gerbera jamesonii* H. Bolus). *Fitopatologia,* 35, 1: 66-79.

ROMAINE, C. P. & HOLCOMB, E. J. 2001. Spent mushroom substrate: a novel multifunctional constituent of a potting medium for plants. *Mushroom News,* 49, 11: 4-15.

ROSE, R. & HAASE, D. L. 2000. The use of coir as a containerized growing medium for Douglas-fir seedlings. *Native Plants Journal,* 1, 2: 107-111.

RUSSO, R., POINCELOT, R. P. & BERLYN, G. P. 1994. The use of a commercial organic biostimulant for improved production of marigold cultivars. *Journal of Home and Consumer Horticulture,* 1, 1: 83-93.

RUSSO, V. M. 2006. Biological amendment, fertilizer rate, and irrigation frequency for organic bell pepper transplant production. *HortScience,* 41, 6: 1402-1407.

RYNK, R., VAN DE KAMP, M., WILLSON, G. B., SINGLEY, M. E., RICHARD, T. L., KOLEGA, J. J., GOUIN, F. R., LALIBERTY JR, L., KAY, D., MURPHY, D. W., HOITINK, H. A. J. & BRINTON, W. F. 1992. *On-farm composting handbook,* Ithaca, NY, USA, Natural Resource, Agriculture and Engineering Service.

RYNK, R. 2001. Industries respond to the clopyralid controversy. *BioCycle,* 42, 12: 66-67.

SAMMONS, J. D. & STRUVE, D. K. 2004. Effect of Bioplex™ on transplant success of non-dormant red oak (*Quercus rubra* L.). *Journal of Environmental Horticulture,* 22, 4: 197-201.

SÁNCHEZ-MONEDERO, M. A., ROIG, A., CEGARRA, J., BEMAL, M. P., NOGUERA, P., ABAD, M. & ANTÓN, A. 2004. Composts as media constituents for vegetable transplant production. *Compost Science and Utilization,* 12, 2: 161-168.

SANDERSON, K. C. 1980. Use of sewage-refuse compost in the production of ornamental plants. *HortScience,* 15, 2: 173-178.

SANDERSON, K. J. & JAMESON, P. E. 1986. The cytokinins in a liquid seaweed extract: could they be the active ingredients? *Acta Horticulturae,* 179: 113-116.

SANDERSON, K. J., JAMESON, P. E. & ZABKIEWICZ, J. A. 1987. Auxin in a seaweed extract: identification and quantitation of indole-3-acetic acid by

gas chromatography-mass spectrometry. *Journal of Plant Physiology,* 129: 363-367.

SANGWAN, P., GARG, V. K. & KAUSHIK, C. P. 2010. Growth and yield response of marigold to potting media containing vermicompost produced from different wastes. *Environmentalist,* 30: 123-130.

SCHEUERELL, S. J. & MAHAFFEE, W. F. 2000. Assessing aerated and non-aerated watery fermented compost and *Trichoderma harzianum* T-22 for control of powdery mildew (*Sphaerotheca pannosa* var. *rosae*) of rose in the Willamette Valley, Oregon. *Phytopathology,* 90: S69.

SCHEUERELL, S. J. & MAHAFFEE, W. F. 2002. Compost tea: principles and prospects for plant disease control. *Compost Science and Utilization,* 10, 4: 313-338.

SCHEUERELL, S. J. & MAHAFFEE, W. F. 2004. Compost tea as a container medium drench for suppressing seedling damping-off caused by *Pythium ultimum*. *Phytopathology* 94, 11: 1156-1163.

SCHEUERELL, S. J., SULLIVAN, D. M. & MAHAFFEE, W. F. 2005. Suppression of seedling damping-off caused by *Pythium ultimum*, *P. irregulare*, and *Rhizoctonia solani* in container media amended with a diverse range of Pacific Northwest compost sources. *Phytopathology,* 95, 3: 306-315.

SCHEUERELL, S. J. & MAHAFFEE, W. F. 2006. Variability associated with suppression of gray mold (*Botrytis cinerea*) on geranium by foliar applications of nonaerated and aerated compost teas. *Plant Disease,* 90, 9: 1201-1208.

SCHUELER, C., BIALA, J. & VOGTMANN, H. 1989. Antiphytopathogenic properties of biogenic waste compost. *Agriculture, Ecosystems and Environment,* 27: 477-482.

SCOTT, M. A. 1988. The use of worm-digested animal waste as a supplement to peat in loamless composts for hardy nursery stock. *In:* EDWARDS, C. A. & NEUHAUSER, E. F. (eds.) *Earthworms in waste and environmental management.* The Hague, The Netherlands: SPB Academic Publishing. pp. 221-229.

SHARMA, S. H. S., LYONS, G., MCROBERTS, C., MCCALL, D., CARMICHAEL, E., ANDREWS, F., SWAN, R., MCCORMACK, R. & MELLON, R. 2012. Biostimulant activity of brown seaweed species from Strangford Lough: compositional analyses of polysaccharides and bioassay of extracts using mung bean (*Vigna mungo* L.) and pak choi (*Brassica rapa chinensis* L.). *Journal of Applied Phycology,* 24: 1081-1091.

SHEHATA, S. M., ABDEL-AZEM, H. S., EL-YAZIED, A. A. & EL-GIZAWY, A. M. 2011. Effect of foliar spraying with amino acids and seaweed extract on growth chemical constitutes, yield and its quality of celeriac plant. *European Journal of Scientific Research,* 58, 2: 257-265.

SHIAU, F. L., CHUNG, W. C., HUANG, J. W. & HUANG, H. C. 1999. Organic amendment of commercial culture media for improving control of Rhizoctonia damping-off of cabbage. *Canadian Journal of Plant Pathology,* 21, 4: 368-374.

SHIRALIPOUR, A., MCCONNELL, D. B. & SMITH, W. H. 1992. Uses and benefits of MSW compost: a review and an assessment. *Biomass and Bioenergy,* 3, 3-4: 267-279.

SIDDIQUI, Y., ISLAM, T. M., NAIDU, Y. & MEON, S. 2011. The conjunctive use of compost tea and inorganic fertiliser on the growth, yield and terpenoid

content of *Centella asiatica* (L.) urban. *Scientia Horticulturae,* 130: 289-295.

SIDDIQUI, Z. A. & KATAOKA, R. 2011. Mycorrhizal inoculants: progress in inoculant production technology. *In:* AHMAD, I., AHMAD, F. & PICHTEL, J. (eds.) *Microbes and microbial technology: agricultural and environmental applications.* New York, NY, USA: Springer. Ch. 18: pp. 489-506.

SIMINIS, H. I. & MANIOS, V. I. 1990. Mixing peat with MSW compost. *BioCycle,* 31, 11: 60-61.

SINGH, A. K., GAURI, BHATT, R. P. & PANT, S. 2012. Comparative study of carrier based materials for *Rhizobium* culture formulation. *Indian Journal of Agricultural Research,* 46, 4: 344-349.

SIVRITEPE, N. & SIVRITEPE, H. O. 2008. Organic priming with seaweed extract (*Ascophyllum nodosum*) affects viability of pepper seeds. *Asian Journal of Chemistry,* 20, 7: 5689-5694.

SLOAN, J. J., CABRERA, R. I., AMPIM, P. A. Y., GEORGE, S. A. & MACKAY, W. A. 2010. Performance of ornamental plants in alternative organic growing media amended with increasing rates of expanded shale. *HortTechnology,* 20, 3: 594-602.

SMITH, A., BROWN, K., OGILVIE, S., RUSHTON, K. & BATES, J. 2001. Waste management options and climate change. Report to the European Commission, DG Environment. Abingdon: AEA Technology.

SOHN, B. K., KIM, K. Y., CHUNG, S. J., KIM, W. S., PARK, S. M., KANG, J. G., RIM, Y. S., CHO, J. S., KIM, T. H. & LEE, J. H. 2003. Effect of the different timing of AMF inoculation on plant growth and flower quality of chrysanthemum. *Scientia Horticulturae,* 98: 173-183.

SPIERS, T. M. & FIETJE, G. 2000. Green waste compost as a component in soilless growing media. *Compost Science and Utilization,* 8, 1: 19-23.

SPRING, D. E., ELLIS, M. A., SPOTTS, R. A., HOITINK, H. A. J. & SCHMITTHENNER, A. F. 1980. Suppression of the apple collar rot pathogen in compost hardwood bark. *Phytopathology,* 70, 12: 1209-1212.

ST. JOHN, T. V., COLEMAN, D. C. & REID, C. P. P. 1983. Association of vesicular-arbuscular mycorrhizal hyphae with soil organic particles. *Ecology,* 64, 4: 957-959.

ST. MARTIN, C. C. G. & BRATHWAITE, R. A. I. 2012. Compost and compost tea: principles and prospects as substrates and soil-borne disease management strategies in soil-less vegetable production. *Biological Agriculture and Horticulture,* 28, 1: 1-33.

STAMETS, P. 2000. *Growing gourmet and medicinal mushrooms. 3rd edition,* Berkeley, CA, USA, Ten Speed Press.

STAMPS, R. H. & EVANS, M. R. 1997. Growth of *Dieffenbachia maculata* 'Camille' in growing media containing sphagnum peat or coconut coir dust. *HortScience,* 32, 5: 844-847.

STEPHENS, C. T., HERR, L. J., HOITINK, H. A. J. & SCHMITTHENNER, A. F. 1981. Suppression of Rhizoctonia damping-off by composted hardwood bark medium. *Plant Disease,* 65, 10: 796-797.

STEPHENS, C. T. & STEBBINS, T. C. 1985. Control of damping-off pathogens in soilless container media. *Plant Disease,* 69, 6: 494-496.

STEPHENSON, W. M. 1966. The effect of hydrolysed seaweed on certain plant pests and diseases. *Proceedings of the International Seaweed Symposium,* 5: 405-415.

STERRETT, S. B. 2001. Composts as horticultural substrates for vegetable transplant production. *In:* STOFFELLA, P. J. & KAHN, B. A. (eds.) *Compost utlization in horticultural cropping systems.* Boca Raton, FL, USA: Lewis Publishers, CRC Pres LLC. Ch. 10: pp. 227-240.

STEVENI, C. M., NORRINGTON-DAVIES, J. & HANKINS, S. D. 1992. Effect of seaweed concentrate on hydroponically grown spring barley. *Journal of Applied Phycology,* 4: 173-180.

STEWART, E. L. & PFLEGER, F. L. 1977. Development of poinsettia as influenced by endomycorrhizae, fertilizer and root rot pathogens *Pythium ultimum* and *Rhizoctonia solani*. *Florist's Review,* 159: 37, 79-81.

STIRK, W. A. & VAN STADEN, J. 1997. Comparison of cytokinin- and auxin-like activity in some commercially used seaweed extracts. *Journal of Applied Phycology,* 8: 503-508.

STIRK, W. A., ARTHUR, G. D., LOURENS, A. F., NOVÁK, O., STRNAD, M. & VAN STADEN, J. 2004. Changes in cytokinin and auxin concentrations in seaweed concentrates when stored at an elevated temperature. *Journal of Applied Phycology,* 16: 31-39.

SUBHAN, S., SHARMILA, P. & SARADHI, P. P. 1998. *Glomus fasciculatum* alleviates transplantation shock of micropropagated *Sesbania sesban*. *Plant Cell Reports,* 17: 268-272.

SUBLER, S., EDWARDS, C. & METZGER, J. 1998. Comparing vermicomposts and composts. *BioCycle,* 39, 7: 63-65.

SUCCOP, C. E. & NEWMAN, S. E. 2004. Organic fertilization of fresh market sweet basil in a greenhouse. *HortTechnology,* 14, 2: 235-239.

SULTANA, V., BALOCH, G. N., ARA, J., EHTESHAMUL-HAQUE, S., TARIQ, R. M. & ATHAR, M. 2011. Seaweeds as an alternative to chemical pesticides for the management of root diseases of sunflower and tomato. *Journal of Applied Botany and Food Quality,* 84, 2: 162-168.

SURRAGE, V. A., LAFRENIÈRE, C., DIXON, M. & ZHENG, Y. 2010. Benefits of vermicompost as a constituent of growing substrates used in the production of organic greenhouse tomatoes. *HortScience,* 45, 10: 1510–1515.

SZABÓ, V. & HROTKÓ, K. 2009. Preliminary results of biostimulator treatments on *Crataegus* and *Prunus* stockplants. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture,* 66, 1-2: 223-228.

SZCZECH, M., RONDOMAŃSKI, W., BRZESKI, M. W., SMOLIŃSKA, U. & KOTOWSKI, J. F. 1993. Suppressive effect of a commercial earthworm compost on some root infecting pathogens of cabbage and tomato. *Biological Agriculture and Horticulture,* 10: 47-52.

SZCZECH, M. M. 1999. Suppressiveness of vermicompost against Fusarium wilt of tomato. *Journal of Phytopathology,* 147: 155-161.

TAY, S. A. B., MACLEOD, J. K., PALNI, L. M. S. & LETHAM, D. S. 1985. Detection of cytokinins in a seaweed extract. *Phytochemistry,* 24, 11: 2611-2614.

TAY, S. A. B., PALNI, L. M. S. & MACLEOD, J. K. 1987. Identification of cytokinin glucosides in a seaweed extract. *Journal of Plant Growth Regulation,* 5: 133-138.

TERMORSHUIZEN, A. J., MOOLENAAR, S. W., VEEKEN, A. H. M. & BLOK, W. J. 2004. The value of compost. *Reviews in Environmental Science and Bio/Technology,* 3: 343-347.

TERMORSHUIZEN, A. J., VAN RIJN, E., VAN DER GAAG, D. J., ALABOUVETTE, C., CHEN, Y., LAGERLÖF, J., MALANDRAKIS, A. A., PAPLOMATAS, E. J., RÄMERT, B., RYCKEBOER, J., STEINBERG, C. & ZMORA-NAHUM, S. 2006. Suppressiveness of 18 composts against 7 pathosystems: variability in pathogen response. *Soil Biology and Biochemistry,* 38: 2461-2477.

TERRIERE, L. C. & RAJADHYAKSHA, N. 1964. Reduced fecundity of the two-spotted spider mite on metal-chelate-treated leaves. *Journal of Economic Entomology,* 57, 1: 95-99.

THIES, J. E. & RILLIG, M. C. 2009. Characteristics of biochar: biological properties. *In:* LEHMANN, J. & JOSEPH, S. (eds.) *Biochar for environmental management : science and technology.* London, UK: Earthscan. Ch. 6: pp. 85-105.

THOMAS, J., MANDAL, A. K. A., KUMAR, R. R. & CHORDIA, A. 2009. Role of biologically active amino acid formulations on quality and crop productivity of tea (*Camellia* sp.). *International Journal of Agricultural Research,* 4, 7: 228-236.

TIAN, Y., SUN, X., LI, S., WANG, H., WANG, L., CAO, J. & ZHANG, L. 2012. Biochar made from green waste as peat substitute in growth media for *Calathea rotundifola* cv. *fasciata*. *Scientia Horticulturae,* 143: 15-18.

TOGNETTI, C., LAOS, F., MAZZARINO, M. J. & HERNÁNDEZ, M. T. 2005. Composting vs vermicomposting: a comparison of end product quality. *Compost Science and Utilization,* 13, 1: 6-13.

TOMATI, U., GRAPPELLI, A. & GALLI, E. 1988. The hormone-like effect of earthworm casts on plant growth. *Biology and Fertility of Soils,* 5: 288-294.

TOMATI, U., GALLI, E., BUFFONE, R., CEGARRA ROSIQUE, J. & ROIG, A. 1993. Compost in floriculture. *Acta Horticulturae,* 342: 175-181.

TONG-JIAN, X., FANG, C., CHAO, G. & QING-YUN, S. Q.-R. A. R. W. 2013. *Bacillus cereus* X5 enhanced bio-organic fertilizers effectively control root-knot nematodes (*Meloidogyne* sp.). *Pedosphere,* 23, 2: 160-168.

TOSI, D., TESI, R. & FABBRI, A. 1989. Some aspects of composted grape and olive marcs as substrates in the pot culture of *Tagetes patula nana*. *Agricoltura Mediterranea,* 119, 3: 246-254.

TRÄNKNER, A. 1992. Use of agricultural and municipal organic wastes to develop suppressiveness to plant pathogens. *In:* TJAMOS, E. C., PAPAVIZAS, G. C. & COOK, R. J. (eds.) *Biological control of plant diseases: progress and challenges for the future.* New York, NY, USA: Plenum Press. pp. 35-42.

TREADWELL, D. D., HOCHMUTH, G. J., HOCHMUTH, R. C., SIMONNE, E. H., DAVIS, L. L., LAUGHLIN, W. L., LI, Y., OLCZYK, T., SPRENKEL, R. K. & OSBORNE, L. S. 2007. Nutrient management in organic greenhouse herb production: where are we now? *HortTechnology,* 17, 4: 461-466.

TREVISAN, S., FRANCIOSO, O., QUAGGIOTTI, S. & NARDI, S. 2010. Humic substances biological activity at the plant-soil interface: from environmental aspects to molecular factors. *Plant Signaling and Behavior,* 5, 6: 635-643.

TRIPEPI, R. R., GEORGE, M. W., CAMPBELL, A. G. & SHAFII, B. 1996. Evaluating pulp and paper sludge as a substitute for peat moss in container media. *Journal of Environmental Horticulture,* 14, 2: 91-96.

TROCHOULIAS, T., BURTON, A. J. & WHITE, E. 1990. The use of bagasse as a potting medium for ornamentals. *Scientia Horticulturae,* 42: 161-167.

TSAKONAS, A., STERGIOU, V., POLISSIOU, M., AKOUMIANAKIS, K. & PASSAM, H. C. 2005. Kenaf (*Hibiscus cannabinus* L.) based substrates for the production of compact plants. *Industrial Crops and Products,* 21: 223–227.

TÜFENKÇI, Ş., TÜRKMEN, Ö., SÖNMEZ, F., ERDINÇ, Ç. & ŞENSOY, S. 2006. Effects of humic acid doses and application times on the plant growth, nutrient and heavy metals contents of lettuce grown on sewage sludge-applied soils. *Fresenius Environmental Bulletin,* 15, 4: 295-300.

TUITERT, G., SZCZECH, M. & BOLLEN, G. J. 1998. Suppression of *Rhizoctonia solani* in potting mixtures amended with compost made from organic household waste. *Phytopathology,* 88, 8: 764-773.

TURAN, M. & KÖSE, C. 2004. Seaweed extracts improve copper uptake of grapevine. *Acta Agriculturae Scandinavica, Section B - Soil and Plant Science,* 54: 213-220.

TYLER, H. H., WARREN, S. L., BILDERBACK, T. E. & PERRY, K. B. 1993. Composted turkey litter: II. effect on plant growth. *Journal of Environmental Horticulture,* 11, 3: 137-141.

UGARTE, R. A. & SHARP, G. 2001. A new approach to seaweed management in eastern Canada: the case of *Ascophyllum nodosum*. *Cahiers de Biologie Marine,* 42: 63-70.

URBANEK KRAJNC, A., IVANUŠ, A., KRISTL, J. & ŠUŠEK, A. 2012. Seaweed extract elicits the metabolic responses in leaves and enhances growth of pelargonium cuttings. *European Journal of Horticultural Science,* 77, 4: S.170-181.

URRESTARAZU, M., SALAS, M. C., PADILLA, M. I., MORENO, J., ELORRIETA, M. A. & CARRASCO, G. A. 2001. Evaluation of different composts from horticultural crop residues and their uses in greenhouse soilless cropping. *Acta Horticulturae,* 549: 147-152.

ÜSTÜNER, Ö., WININGER, S., GADKAR, V., BADANI, H., RAVIV, M., DUDAI, N., MEDINA, S. & KAPULNIK, Y. 2009. Evaluation of different compost amendments with AM fungal inoculum for optimal growth of chives. *Compost Science and Utilization,* 17, 4: 257-265.

VABRIT, S., LEEDU, E., SUIGUSAAR, K. & BENDER, I. 2008. Effect of sewage sludge and pig manure compost on the ornamental quality of impatiens 'Candy Coral Bee' container grown plants. *Acta Horticulturae,* 779: 637-642.

VALDRIGHI, M. M., PERA, A., AGNOLUCCI, M., FRASSINETTI, S., LUNARDI, D. & VALLINI, G. 1996. Effects of compost-derived humic acids on vegetable biomass production and microbial growth within a plant (*Cichorium intybus*)-soil system: a comparative study. *Agriculture, Ecosystems and Environment,* 58: 133-144.

VAN DER GAAG, D. J., VAN NOORT, F. R., STAPEL-CUIJPERS, L. H. M., DE KREIJ, C., TERMORSHUIZEN, A. J., VAN RIJN, E., ZMORA-NAHUM, S. & CHEN, Y. 2007. The use of green waste compost in peat-based potting mixtures: fertilization and suppressiveness against soilborne diseases. *Scientia Horticulturae,* 114: 289-297.

VAN OS, G. J. & VAN GINKEL, J. H. 2001. Suppression of *Pythium* root rot in bulbous *Iris* in relation to biomass and activity of the soil microflora. *Soil Biology and Biochemistry,* 33: 1447-1454.

VAN STADEN, J., UPFOLD, S. J. & DREWES, F. E. 1994. Effect of seaweed concentrate on growth and development of the marigold *Tagetes patula*. *Journal of Applied Phycology,* 6: 427-428.

VAN STADEN, J., BECKETT, R. P. & RIJKENBERG, M. J. 1995. Effect of seaweed concentrate on the growth of the seedlings of three species of *Eucalyptus*. *South African Journal of Botany,* 61, 4: 169-172.

VAN ZWIETEN, L., SINGH, B. P. & COX, J. 2012. Biochar effects on soil properties. *In:* COX, J., DOWNIE, A., JENKINS, A., HICKEY, M., LINES-KELLY, R., MCCLINTOCK, A., POWELL, J., SINGH, B. P. & VAN ZWIETEN, L. (eds.) *Prospects for the use of biochar in Australian horticulture.* NSW Trade and Investment. Horticulture Australia Ltd. Project AH11006. Ch. 4: pp. 27-36.

VAVRINA, C. S., ROBERTS, P. D., KOKALIS-BURELLE, N. & ONTERMAA, E. O. 2004. Greenhouse screening of commercial products marketed as systemic resistance and plant growth promotion inducers. *HortScience,* 39, 2: 433-437.

VEEKEN, A. H. M., BLOK, W. J., CURCI, F., COENEN, G. C. M., TERMORSHUIZEN, A. J. & HAMELERS, H. V. M. 2005. Improving quality of composted biowaste to enhance disease suppressiveness of compost-amended, peat-based potting mixes. *Soil Biology and Biochemistry,* 37: 2131-2140.

VEGA-SANCHEZ, F. E., GOUIN, F. R. & WILLSON, G. B. 1987. Effects of curing time on physical and chemical properties of composted sewage sludge and on the growth of selected bedding plants. *Journal of Environmental Horticulture,* 5, 2: 66-70.

VEIJALAINEN, A.-M., JUNTUNEN, M.-L., HEISKANEN, J. & LILJA, A. 2007. Growing *Picea abies* container seedlings in peat and composted forest-nursery waste mixtures for forest regeneration. *Scandinavian Journal of Forest Research,* 22, 5: 390-397.

VERDONCK, O. 1988. Composts from organic waste materials as substitutes for the usual horticultural substrates. *Biological Wastes,* 26: 325-330.

VERKLEIJ, F. N. 1992. Seaweed extracts in agriculture and horticulture: a review. *Biological Agriculture and Horticulture,* 8: 309-324.

VIGILANTE, T., DIXON, K., SIELER, I., ROCHE, S. & TIEU, A. 1998. Smoke germination of Australian plants.

VINOTH, S., GURUSARAVANAN, P. & JAYABALAN, N. 2012. Effect of seaweed extracts and plant growth regulators on high frequency *in vitro* mass propagation of *Lycopersicon esculentum* L. (tomato) through double cotyledonary nodal explant. *Journal of Applied Phycology,* 24: 1329-1337.

VYAS, P. & GULATI, A. 2009. Organic acid production *in vitro* and plant growth promotion in maize under controlled environment by phosphate-solubilizing fluorescent *Pseudomonas*. *BMC Microbiology,* 9: 174; doi:10.1186/1471-2180-9-174.

WANG, Y.-T. & BLESSINGTON, T. M. 1990. Growth and interior performance of poinsettia in media containing composted cotton burrs. *HortScience,* 25, 4: 407-408.

WANG, Y.-T. 1991. Evaluation of media consisting of a cotton waste for the production of tropical foliage species. *Journal of Environmental Horticulture,* 9, 3: 112-115.

WANG, Y.-T. 1994. Using ground kenaf stem core as a major component of container media. *Journal of the American Society for Horticultural Science,* 119, 5: 931-935.

WARNOCK, D. D., LEHMANN, J., KUYPER, T. W. & RILLIG, M. C. 2007. Mycorrhizal responses to biochar in soil - concepts and mechanisms. *Plant and Soil,* 300: 9-20.

WEBBER III, C. L., WHITWORTH, J. & DOLE, J. 1999. Kenaf (*Hibiscus cannabinus* L.) core as a containerized growth medium component. *Industrial Crops and Products,* 10: 97-105.

WEERAKOON, D. M. N., REARDON, C. L., PAULITZ, T. C. & IZZO, A. D. 2012. Long-term suppression of *Pythium abappressorium* induced by *Brassica juncea* seed meal amendment is biologically mediated. *Soil Biology and Biochemistry,* 51: 44-52.

WELTZIEN, H. C. 1991. Biocontrol of foliar fungal diseases with compost extracts. *In:* ANDREWS, J. H. & HIRANO, S. S. (eds.) *Microbial ecology of leaves.* New York, NY, USA: Springer-Verlag. Ch. 22: pp. 430-450.

WILLIAMS, K. A. & NELSON, P. V. 1992. Low, controlled nutrient availability provided by organic waste materials for chrysanthemum. *Journal of the American Society for Horticultural Science,* 117, 3: 422-429.

WILSON, D. P. & CARLILE, W. R. 1989. Plant growth in potting media containing worm-worked duck waste. *Acta Horticulturae,* 238: 205-220.

WILSON, S. B., STOFFELLA, P. J. & GRAETZ, D. A. 2001a. Compost-amended media for growth and development of Mexican heather. *Compost Science and Utilization,* 9, 1: 60-64.

WILSON, S. B., STOFFELLA, P. J. & KRUMFOLZ, L. A. 2001b. Containerized perennials make good use of compost. *BioCycle,* 42, 8: 59-61.

WILSON, S. B., STOFFELLA, P. J. & GRAETZ, D. A. 2002. Development of compost-based media for containerized perennials. *Scientia Horticulturae,* 93: 311-320.

WILSON, S. B., STOFFELLA, P. J. & GRAETZ, D. A. 2003. Compost amended media and irrigation system influence containerized perennial *Salvia*. *Journal of the American Society for Horticultural Science,* 128, 2: 260-268.

WILSON, S. B., MECCA, L. K., STOFFELLA, P. J. & GRAETZ, D. A. 2004. Using compost for container production of ornamental hammock species native to Florida. *Native Plants Journal,* 5, 2: 186-194.

WILSON, S. B., MECCA, L. K., DANIELSON, H. E., GRAETZ, D. A. & STOFFELLA, P. J. 2006. Container and field evaluation of three native shrubs grown in compost-based media. *Compost Science and Utilization,* 14, 3: 178-183.

WILSON, S. B. & STOFFELLA, P. J. 2006. Using compost for container production of ornamental wetland and flatwood species native to Florida. *Native Plants Journal,* 7, 3: 293-300.

WOOTTON, R. D., GOUIN, F. R. & STARK, F. C. 1981. Composted, digested sludge as a medium for growing flowering annuals. *Journal of the American Society for Horticultural Science,* 106, 1: 46-49.

WRIGHT, R. D. & BROWDER, J. F. 2005. Chipped pine logs: a potential substrate for greenhouse and nursery crops. *HortScience,* 40, 5: 1513-1515.

WRIGHT, R. D., BROWDER, J. F. & JACKSON, B. E. 2006. Ground pine chips as a substrate for container-grown woody nursery crops. *Journal of Environmental Horticulture,* 24, 4: 181-184.

WRIGHT, R. D., JACKSON, B. E., BROWDER, J. F. & LATIMER, J. G. 2008. Growth of chrysanthemum in a pine tree substrate requires additional fertilizer. *HortTechnology,* 18, 1: 111-115.

WU, L., CHEN, J., LIN, H., VAN MANTGEM, P., HARIVANDI, A. & HARDING, J. A. 1995. Effects of regenerant wastewater irrigation on growth and ion uptake of landscape plants. *Journal of Environmental Horticulture,* 13: 92-96.

XU, D., RAZA, W., YU, G., ZHAO, Q., SHEN, Q. & HUANG, Q. 2012. Phytotoxicity analysis of extracts from compost and their ability to inhibit soil-borne pathogenic fungi and reduce root-knot nematodes. *World Journal of Microbiology and Biotechnology,* 28: 1193-1201.

YILDRIM, E., DONMEZ, M. F. & TURAN, M. 2008. Use of bioinoculants in ameliorative effects on radish plants under salinity stress. *Journal of Plant Nutrition,* 31: 2059-2074.

ZAKARIA, M. A. & LOCKWOOD, J. L. 1980. Reduction in *Fusarium* populations in soil by oilseed meal amendments. *Phytopathology,* 70, 3: 240-243.

ZALLER, J. G. 2007a. Vermicompost in seedling potting media can affect germination, biomass allocation, yields and fruit quality of three tomato varieties. *European Journal of Soil Biology,* 43: S332-S336.

ZALLER, J. G. 2007b. Vermicompost as a substitute for peat in potting media: effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Scientia Horticulturae,* 112: 191-199.

ZHAI, Z., EHRET, D. L., FORGE, T., HELMER, T., LIN, W., DORAIS, M. & PAPADOPOULOS, A. P. 2009. Organic fertilizers for greenhouse tomatoes: productivity and substrate microbiology. *HortScience,* 44, 3: 800-809.

ZHANG, R.-H., DUAN, Z.-Q. & LI, Z.-G. 2012. Use of spent mushroom substrate as growing media for tomato and cucumber seedlings *Pedosphere,* 22, 3: 333-342.

ZHANG, W., HAN, D. Y., DICK, W. A., DAVIS, K. R. & HOITINK, H. A. J. 1998. Compost and compost water extract-induced systemic acquired resistance in cucumber and Arabidopsis. *Phytopathology,* 88, 5: 450-455.

ZHANG, X. Z. & ERVIN, E. H. 2004. Cytokinin-containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinins and drought resistance. *Crop Science,* 44: 1737-1745.

ZHELJAZKOV, V. D. 2005. Assessment of wool waste and hair waste as soil amendment and nutrient source. *Journal of Environmental Quality,* 34: 2310-2317.

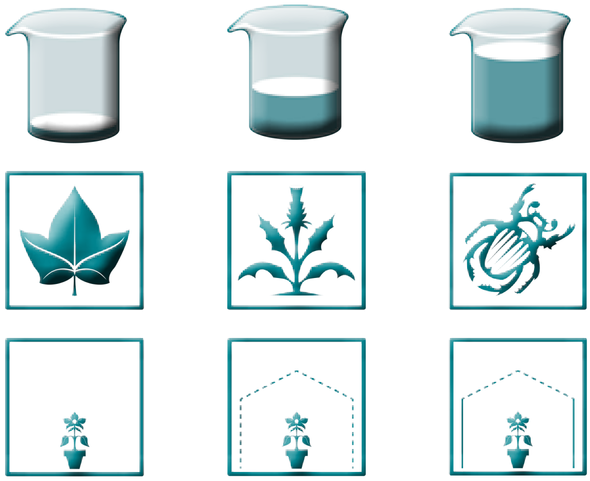
ZINATI, G. M. 2005. Compost in the 20th century: a tool to control plant diseases in nursery and vegetable crops. *HortTechnology,* 15, 1: 61-66.

ZODAPE, S. T. 2001. Seaweeds as a biofertilizer. *Journal of Scientific and Industrial Research,* 60: 378-382.

Appendix 6

Nursery Pesticide Application Best Practice Manual

Updated June 2013



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Nursery Pesticide Application Best Practice Manual

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- TGA Australia Pty Ltd Somerville VIC 3912
- Swanview Plant Farm High Wycombe WA 6057
- Rankins Nursery Pty Ltd Officer VIC 3809
- Combined Nursery Sales Baxter VIC 3911
- Chavallum Wholesale Nursery Palmwoods QLD 4555

Table of contents

INTRODUCTION

The nursery industry in Australia is very diverse, with enterprises ranging from small, owner-operator ventures to large, multi-million-dollar corporate businesses. A wide range of plant types is grown, from immature seedlings through to fully mature trees. Some production occurs in glasshouses and shade houses, while in other cases, stock is grown in open plan production areas. It is in this range of environments that pesticides need to be efficiently and safely applied for the management of pests (insects, pathogens and weeds).

The management of pests is an important part of nursery operations. A wide range of pest management measures is available, including chemical, biological, varietal and mechanical measures. All available control methods should be considered before a chemical option is employed within an Integrated Pest Management (IPM) program. Pesticides are a useful tool for managing pests. The purpose of this manual is to provide information on the effective and safe application of pesticides as part of an IPM strategy for plant nurseries.

The right spray equipment, when correctly used within a well-considered pest management program, is a critical factor in ensuring the success of that program. However, consideration must be given to the type of pest, the pesticide's mode of action and the environment in which the pesticide needs to be applied. In nurseries, special consideration should be given to the production environment, the influence of shade structures and irrigation systems and the proximity of neighbours and the workforce.

A note on legal usage of chemicals

This manual does not consider or discuss the registration status or legal usage of specific chemicals, or their active constituents, as it is the legal obligation of the nursery operator to abide by the national and local approved registrations.

Currently in Australia (excluding Victoria) if the specific crop and cropping system (e.g. nursery stock – non-food) is not registered on the label it is illegal to use that product unless a 'Minor Use' or 'Emergency' permit has been issued by APVMA. It is illegal to use a pesticide, with the same active constituent as a product that is registered, if that pesticide does not have a label registration or an APVMA permit.

Minor Use Permits allow industries that apply small volumes of pesticide to legally access the product when the manufacturer or importer decides not to register the pesticide for that specific crop or cropping system. The nursery industry is currently leading a Minor Use Pesticide program for pesticides, funded via the Nursery Products Levy, to secure access to priority pesticides[1].

[1] McDonald, J. (2012). Nursery Production Minor Use Permit Pesticide Program. Nursery Technical Papers Issue no. 11

Best management practice for pesticide application in the nursery industry

What is best practice?

Best practice in any industry is usually described as a process of continual improvement in how operations are carried out. In the area of pesticide application this means that individuals and organisations need to assess how appropriate their current operations are and put into place plans and programs that continuously improve those operations.

What is this manual designed to do?

This manual is designed to assist nursery operators in identifying and understanding the range of pesticide application equipment available and the key issues related to the use of pesticides in the nursery environment.

To assist the nursery industry in improving the safe and effective application of pesticides, this manual includes information on:

- developing spray management plans
- the types of pesticides available and their storage, handling and disposal
- the risks various pesticides may present and the selection and use of personal protective equipment to manage these risks

- suitable operating conditions for pesticide application and managing spray drift
- the advantages and disadvantages of various types of pesticide application equipment
- the calibration of pesticide application equipment
- case studies detailing examples of industry practice and critical comments
- useful contacts and references.

How to use this manual

Each section of the manual provides information on the range of products and techniques available to nursery operators for the application of pesticides.

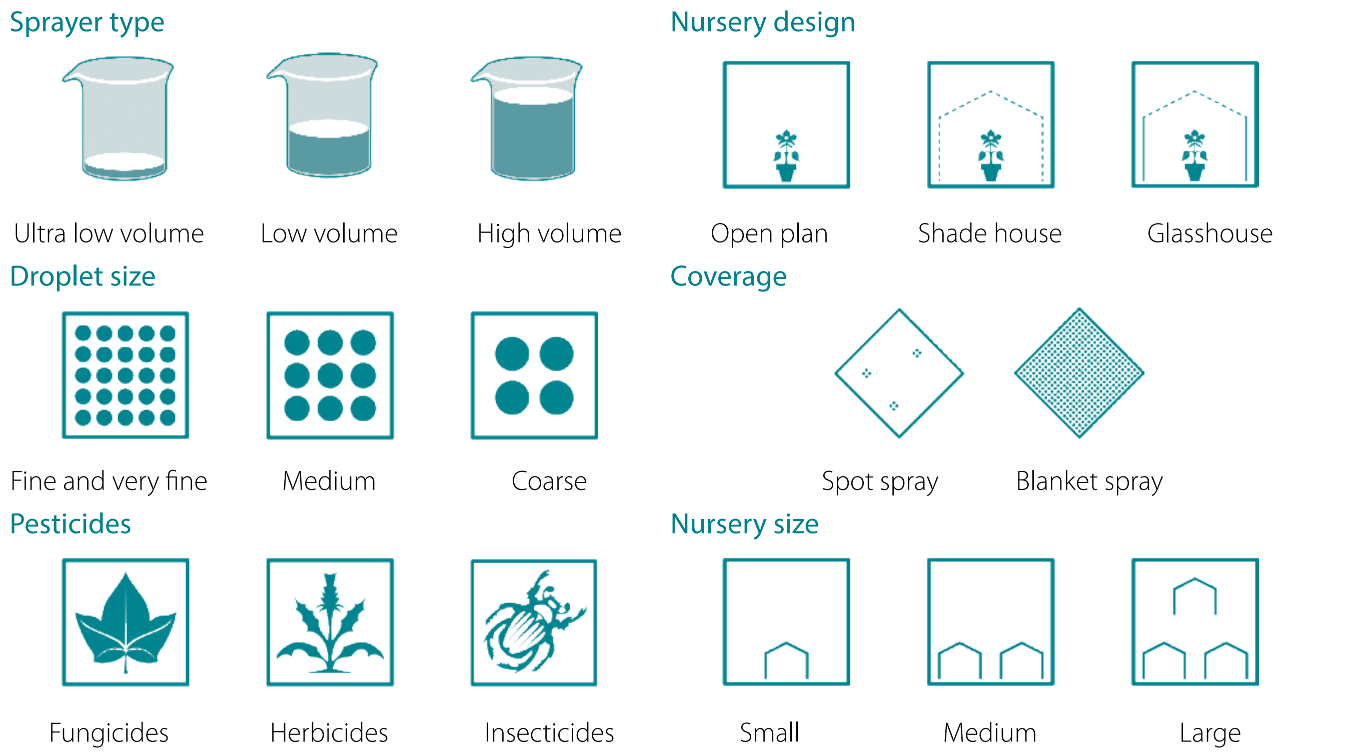
Best management practice is a process of continual improvement. This manual enables users to examine their practices with a view to improving the safe and effective use of pesticides in their situation.

Due to the diverse nature of the nursery industry, frequent changes in legislation and the development of new application equipment, it is impossible to provide examples of best practice for all the types of spraying operations that are likely to occur. This manual contains background information that individual nurseries should consider so that they can develop and improve their current practice.

Throughout the various sections of the manual, the advantages and disadvantages of a range of products and techniques are discussed. It is the responsibility of the user to determine which of these products and techniques may lead to improvement in the safe use of pesticides.

The following key is used within this manual to indicate sprayer type, droplet size, pesticide type, nursery design, expected coverage and nursery size that may be suitable for each type of application equipment discussed.

Key to symbols used in this manual



Requirements for best management practice in pesticide application

Best practice in the selection and use of pesticides begins with the correct identification of the TARGET and then the development of a pest management program, which may include the use of pesticides. If a pesticide is to be used, it must be applied to the right PLACE at the right TIME with minimal impact on people, beneficial organisms, property and the environment.

Nursery operators should ask themselves a series of questions before commencing any pest management program. These include:

1) Has the target been identified correctly?

Before proceeding with the use of any pesticide it is essential to determine the biological target. For example, different application techniques may be required to manage insect pests, weeds or plant pathogens.

2) Has the most appropriate method or methods of pest management been chosen?

As part of an Integrated Pest Management (IPM) regime a number of methods are available to the nursery operator. Issues such as cost, safety, effectiveness and chemical resistance of insects should be considered before chemical control is employed. Other methods include:

- mechanical—pruning, hand weeding, hoeing
- cultural—hygiene strategies, controlled environments, insect meshes
- biological—beneficial insects, predator releases, companion planting
- genetic—pest and disease resistant cultivars
- quarantine—use of exclusion areas, plant movement restrictions
- chemical—herbicide, fungicide, insecticides

There may be a number of pesticides registered for the management of a single pest in various industries or locations. Only products that are registered for the particular situation should be used.

When selecting a pesticide operators must consider:

- the susceptibility of the target pest
- the susceptibility of non-target organisms
- the stability of the product (e.g. whether the chemical is quickly broken down or has an ongoing or residual activity)
- the cost of the pesticide and the cost of application
- the type of formulation and safety issues
- the logistics (ease of transport, handling and storage)
- the availability of the product of choice
- the shelf life of the product.

3) Is the right amount being applied?

The correct dose of pesticide should, in most situations, be uniformly distributed across the area to be treated. This can be achieved by using an appropriate application technique with accurately calibrated equipment. Pesticides should always be applied at the rate specified on the product label. The label is a legal document, and the label information on usage conditions and other directions must be followed.

4) Is the product being applied to the right place?

It is common for pesticides to be applied to only a portion of a nursery rather than the entire area. It is important that these areas are readily identifiable so that the pesticide is applied at the correct location and accurate records of use can be kept.

5) What is the best time to apply the product?

If the product is not applied at the right time the treatment may be ineffective. Factors that influence the timing of application include:

- the lifecycle of the pest*
- the meteorological conditions
- other activities that are occurring in the area
- staff and bystander locations and re-entry periods.

*Many products are most effective at certain stages of the pest lifecycle or stage of plant growth. For example, many insect pests are only susceptible to certain products during their immature (larval or nymphal) stages. Similarly many weed species will only be affected by some herbicides while they are small, actively growing and not experiencing stress.

6) Is the appropriate personal protective equipment (PPE) being used?

Operators should consult the product label and the Safety Data Sheet (SDS), previously referred to as MSDS or Material Safety Data Sheet, before proceeding with any operation, to determine what PPE is required when mixing and applying the chosen product.

An understanding of the principles of safe mixing, loading and use of pesticides is required. Carrying out a risk assessment will assist in the identification of hazards and the management of risks.

7) Was the desired outcome achieved?

After every application, after the re-entry period has expired, assessment how well the product performed. Record this information and keep it for future reference, along with the data gathered that led to the decision to use the pesticide treatment.

8) Were there any unexpected outcomes?

Were there any detrimental effects on workers or adjacent areas? If so, were these recorded and how may they be minimised in the future?

Using this information to implement best management practice in pesticide application

All of the previous questions should be asked prior to, during and after each pesticide application. By asking these questions, recording the results and using the information contained in this manual, the practices and procedures that can assist us in moving towards best management practice in pesticide application can be implemented.

CHAPTER 1.

SPRAY MANAGEMENT PLANS

All nursery operations should have a spray management plan, including a risk assessment. Chemical users should be aware (or be made aware) of the risks associated with chemical application. A generally accepted risk assessment process has been established for effectively managing risks.

The process is:

1. Identify the hazard.
2. Assess the level of risk.
3. Control the risk.
4. Review.

Generic risk assessment templates and policies are available online or through your state workplace health and safety department (refer to the contact details on page X). These should form part of a 'Spray Management Plan' covering areas such as spray operator training, managing other nursery staff so that they do not come into contact with contaminated stock or spray drift, timing of applications, record keeping and emergency procedures.

1.1 Training

All spray operators involved in the application of nursery chemicals should be qualified according to relevant state training and accreditation requirements. For example, all spray operators should have completed a farm chemical users course (e.g. ChemCert) or other equivalent recognised chemical application course (refer to the contact details on page X). Employers have legal responsibilities to ensure that their employees are correctly trained in the use of chemicals and related equipment and ensure they are aware of, and adhere to, the record keeping requirements.

1.2 Time of application

Pesticides are most effective when they are applied at the right time. Pests are most effectively managed with pesticides when they are small or just starting to develop rather than when they are more mature. Plants should be monitored or checked regularly for pests (insects, plant pathogens and weeds) so that pest management activities can be performed at the right time.

Another factor to consider when deciding when to spray is the presence of other nursery staff, clients or members of the public. In general, it is best to arrange spraying operations sothey are undertaken at times when no one else is around, such as after closing time or on the weekends.

Weather conditions before, during and after application can all influence the timing of the spray application. Chapter 3 discusses in detail the influence of weather conditions on the likelihood of spray drift and these factors should be considered while deciding when to spray.

In general, pesticides should not be applied to plants that are stressed due to weather conditions. For example, avoid the application of pesticides during the hottest part of a summer day or if a frost is present.

1.3 Record keeping

Spray operators need to keep accurate records of all spraying activities. This should be part of any quality control strategy and is required under state and federal legislation. It is also mandatory for compliance with codes of practice covering workplace health and safety.

The spray operator should maintain up-to-date records of pesticide usage and spray operations. The operator should complete a spray report after every spray operation. The report should include the date, time, area sprayed, amount and type of pesticides applied, recorded application rates, crop details, pests present, operator(s) involved, equipment used, nozzle type, settings (e.g. spray pressure) and meteorological conditions (wind speed and direction, temperature and humidity).

Maintaining accurate records of all pesticides used at the nursery site will assist the manager in making informed management decisions.

The information recorded must include:

- calibration data, including specific nozzle information (type, pressure of operation/rotation speed etc)
- registered pesticide used, and the amount used
- personal protective equipment used and maintenance details of PPE
- environmental conditions
- area sprayed (location and size)
- pest/crop description.

Table 1 is a sample checklist for spraying operations. Another example of a recording system is the Nursery & Garden Industry Australia (NGIA) Spray Diary Recording Sheet (figure 1). This is an electronic form that allows the creation of a coding system for your nursery spray operations. For example, a shade house might be referred to as Area 1 and a glasshouse as Area 2. You can produce a code for particular operations, e.g. spraying could be S1 and mixing M1.

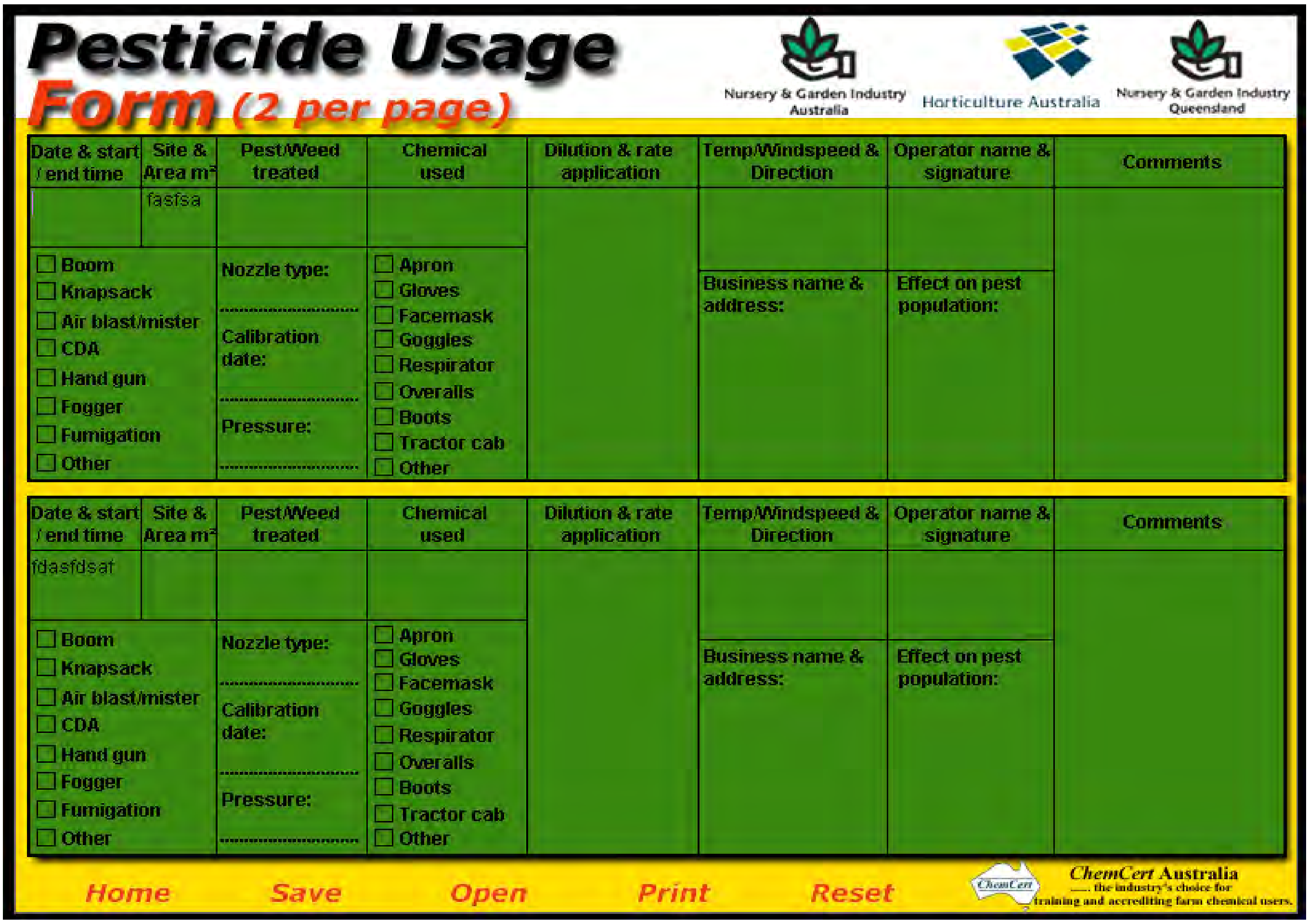


Figure 1. Nursery & Garden Industry Australia (NGIA) Spray Diary Recording Sheet

Table 1. Sample operational plan – overview checklist

Task	Tick	Notes
PLANNING – PRE SPRAY		
Chemical user		Joe Bloggs
Field owner		Fred Bloggs
Location	√	6 km SE of Country Town
Area to be sprayed, area (hectares) and type	√	Bedding plants
Nature of pest problem	√	
Are there any alternative methods to spraying?	√	No
Consult an up-to-date Awareness Zone Chart	√	Yes
Sensitive areas within Awareness Zone	√	Vineyard 1 km
Communicate to neighbours	√	Yes, by phone 5/7/13
Check user training credentials	√	ChemCert® 15/12/12
APPLICATION		
Equipment in proper working order and calibrated	√	Leak repaired
Spray equipment	√	Hand gun
Nozzle type		Dg 110-03
Nozzle number		1
Droplet size		BCPC medium
Settings	√	
Spray pressure (bar)	√	2 bar
Product label and SDS read and understood	√	Yes
Check wind direction is away from susceptible areas	√	Yes
Wind direction in °	√	From NE 040°
Windspeed in k/hr	√	10 k/hr
Temperature in °C	√	27 °C
Relative humidity %	√	50%
Cloud cover in eighths		2/8
Approximate stability class (unstable, neutral or stable)		Neutral
Is a ground surface temperature inversion present?		No
Are weather parameters within acceptable limits?	√	Yes
Are you wearing correct PPE for the job?	√	Yes
Date		13/4/2013
Time start of spraying		10.00 hr
Time end of spraying		16.00 hr
Chemical type(s)	√	
Product application rate (L/ha)		2.5 L/ha
Bulk volume rate (L/ha)	√	50 L/ha
Amount of product used		35 L
Treated area (ha)		ha
In crop/other buffer used?	√	30 m boundary
POST SPRAY EVALUATION	√	
Were results satisfactory? (note numbers controlled/escaped)	√	Yes (notes?)
Could there be any improvements?	√	No
All spray records correct, up-to-date and stored safely?	√	Yes
Full name of chemical user	Signature	Date

1.4 Emergency procedures

There are a number of hazards that exist when using registered pesticides. These can include fires, spills and poisoning. It is important that the nursery has emergency procedures in place to respond to any incident. It is also important to evaluate current practice to avoid an emergency situation. The following section discusses the areas that should be covered in planning and dealing with emergencies.

A plan for handling emergencies such as spills, accidental contamination of people and the environment should be developed as part of a risk assessment related to the use of pesticides in the nursery. Completion of a 'Managing farm safety' course will assist in understanding and carrying out a risk assessment. This knowledge can then be used to manage hazards.

> ***Both the Nursery industry EcoHort Nursery Industry Environmental Management System and the current AgSafe® Accreditation Training Manual (2002) contains detailed information on emergency procedures related to pesticide storage and handling.***

FIRES

Prevention of fires must be a primary consideration when organising the storage of products on the nursery site. Incompatible products such as flammable chemicals, oxidants and corrosive products should not be stored next to each other.

A fire management plan may include the following points:

1. Raise the alarm and evacuate the premises.
2. Notify the fire brigade and police.
3. If it is safe to do so, start fire-fighting operations with on-site equipment suitable for the purpose (e.g. hand-held fire extinguishers). Wear protective clothing.
4. Check that fire-water and spilt product is being contained.
5. If run-off occurs or there is a danger of exploding containers, consider withdrawing and allowing the fire to burn out.
6. Any person experiencing side effects from fire (e.g. dizziness) should be placed under medical care. Remove contaminated clothing.
7. On completion of activities, equipment and all clothing should be cleaned and a shower taken by all personnel involved.

SPILLS

The guiding principles in clean-up operations following an accidental spill are:

1. Isolate the affected area.
2. Wear appropriate personal protective equipment (PPE) as recommended on the label.
3. Contain the spilled chemical and prevent further contamination.
4. Decontaminate the affected area with a suitable absorbing medium or other appropriate means (refer to the SDS).
5. Dispose of the spill by safely packing the absorbing medium into proper containers.

At each chemical storage area, a 'spill response equipment kit' suitable for the purpose should be maintained. A basic kit to deal with spillage should be kept at the mixing and measuring site. A spillage kit should consist of[1]:

- sand or soil, kitty litter or vermiculite
- hydrated lime (several bags)
- square-mouthed shovel(s)
- open drums (20 L and 200 L) to collect materials
- bleach (hypochlorite) (20 L drum)
- funnels, a broom, banister brush and pan
- PPE suitable for handling concentrates, including eye protection, gloves, respirator and disposable foot protection.

> ***Emergency numbers must be clearly displayed at the sites of storage, handling and mixing. If a person has been injured or requires medical attention as result of the spill some states require the incident to be reported.***

> ***In the event of a major spill incident call '000'.***

[1] *ChemCert Australia, Chemical Users Handbook, 2013.*

POISONING

Rapid response is essential in all cases of poisoning. The speedy removal of the source of contamination and rapid first aid implementation and transport to hospital or a doctor may save a life. For information on first aid, read the appropriate label and SDS (see figures 3 and 4 for examples).

If a person who has been in direct contact with a pesticide shows signs of poisoning, take the following steps:

1. Stop any further exposure to the poison by moving the patient away from the contaminated area and from the vicinity of agricultural and veterinary chemicals. Quickly remove any contaminated clothing and wash skin.
2. Begin first aid immediately. See product label for instructions.
3. Call a doctor as quickly as possible but do not abandon the first aid treatment.
4. Keep the patient as quiet as possible and complete the first aid treatment.
5. Keep patient warm and comfortable.

Do not substitute first aid for professional treatment. First aid is only to relieve the patient before medical help is reached. Check for danger to yourself before first aid is attempted.

The national Poisons Information Hotline is 13 11 26.

CHAPTER 2.

CHEMICAL SELECTION, STORAGE, HANDLING AND DISPOSAL

The selection of chemicals and their proper storage, handling and disposal is critical to operator safety and protection of other people and the environment.

2.1 Labels

The pesticide label is a legally-binding document that has been approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA), formerly known as the National Registration Authority (NRA). It provides sufficient information to allow the safe and efficient use of the pesticide, provided the directions are followed carefully (figures 2 and 3).

The label lay-out is largely dictated by regulation and will depend on the size of the pack and the amount of information required to be provided. A minimal design would be a main panel plus an ancillary panel, but there may be two ancillary panels. If this format provides inadequate space, some information can be printed on a leaflet attached to the container, in which case the leaflet is part of the label.

First and foremost the spray operator must read, understand and adhere to the pesticide product label prior to any spraying operation.

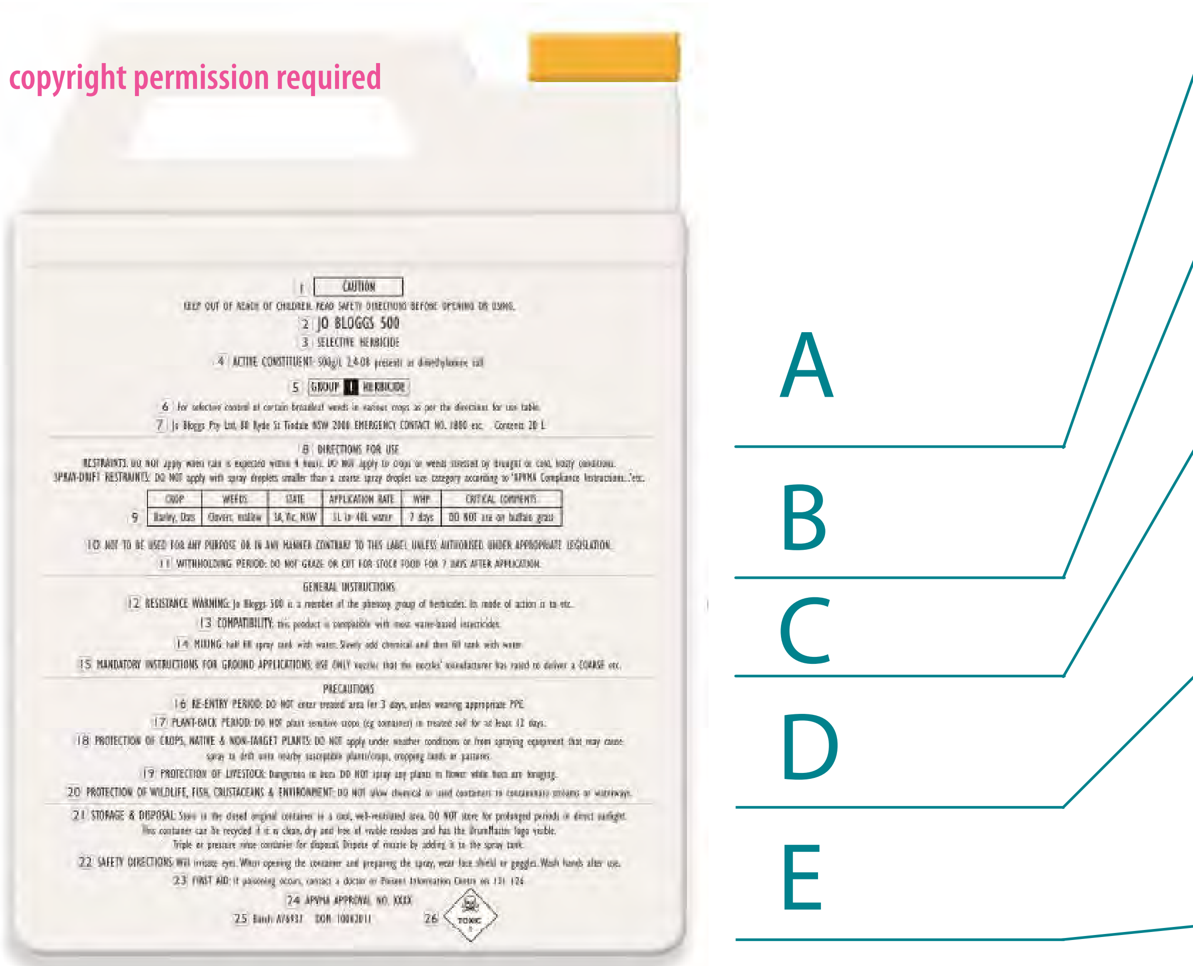


Figure 2. Typical format of a pesticide label (source:....)

Section A

1. *The signal heading*
2. *Brand name (or trade name)*
3. *Type of chemical*
4. *Active constituent*
5. *Resistance group*
6. *What the chemical does*
7. *Name, address and phone number of the business that made the chemical*

Section B—Directions of use

8. *Restraints*
9. *Directions for use table*
10. *NOT TO BE USED FOR…statement*
11. *Withholding period (WHP)*

Section C—General instructions

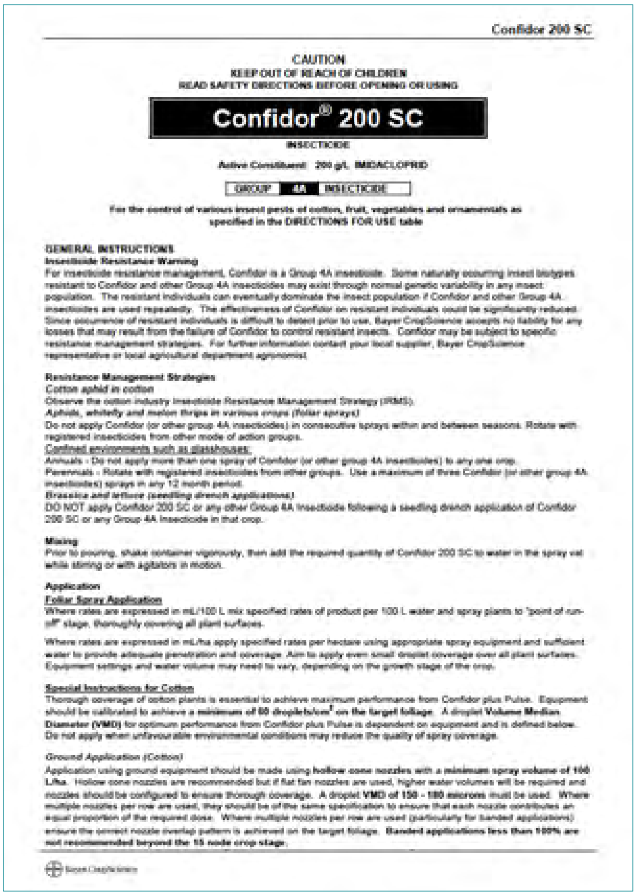
12. *Resistance warning*
13. *Compatibility*
14. *Mixing instructions*
15. *APVMA compliance instructions for mandatory droplet size categories*

Section D—Precautions

16. *Re-entry period*
17. *Plant-back period*
18. *Protection of crops, native and other non-target plants*
19. *Protection of livestock*
20. *Protection of wildlife,, fish, crustaceans and the environment*

Section E

21. *Storage and disposal*
22. *Safety directions*
23. *First aid*
24. *APVMA approval number*
25. *Batch number, date of manufacture (DOM) and expiry date*
26. *Dangerous goods/hazardous chemical information*



Confidor 200 SC

CAUTION
KEEP OUT OF REACH OF CHILDREN
READ SAFETY DIRECTIONS BEFORE OPENING OR USING

Confidor® 200 SC

INSECTICIDE

Active Constituent: 200 g/L IMIDACLOPRID

GROUP 4A INSECTICIDE

For the control of various insect pests of cotton, fruit, vegetables and ornamentals as specified in the DIRECTIONS FOR USE table

GENERAL INSTRUCTIONS
Insecticide Resistance Warning
For insecticide resistance management, Confidor is a Group 4A insecticide. Some naturally occurring insect biotypes resistant to Confidor and other Group 4A insecticides may exist through normal genetic variability in any insect population. The resistant individuals can eventually dominate the insect population if Confidor and other Group 4A insecticides are used repeatedly. The effectiveness of Confidor on resistant individuals could be significantly reduced. Since occurrence of resistant individuals is difficult to detect prior to use, Bayer CropScience accepts no liability for any losses that may result from the failure of Confidor to control resistant insects. Confidor may be subject to specific resistance management strategies. For further information contact your local supplier, Bayer CropScience representative or local agricultural department agronomist.

Resistance Management Strategies
Cotton aphid in cotton
Observe the cotton industry Insecticide Resistance Management Strategy (IRMS).
Aphids, whitefly and melon thrips in various crops (foliar sprays)
Do not apply Confidor (or other group 4A insecticides) in consecutive sprays within and between seasons. Rotate with registered insecticides from other mode of action groups.
Confined environments such as glasshouses:
Annuals - Do not apply more than one spray of Confidor (or other group 4A insecticides) to any one crop.
Perennials - Rotate with registered insecticides from other groups. Use a maximum of three Confidor (or other group 4A insecticides) sprays in any 12 month period.
Brassica and lettuce (seedling drench applications)
DO NOT apply Confidor 200 SC or any other Group 4A Insecticide following a seedling drench application of Confidor 200 SC or any Group 4A Insecticide in that crop.

Mixing
Prior to pouring, shake container vigorously, then add the required quantity of Confidor 200 SC to water in the spray vat while stirring or with agitators in motion.

Application
Foliar Spray Application
Where rates are expressed in mL/100 L mix specified rates of product per 100 L water and spray plants to "point of run-off" stage, thoroughly covering all plant surfaces.

Where rates are expressed in mL/ha apply specified rates per hectare using appropriate spray equipment and sufficient water to provide adequate penetration and coverage. Aim to apply even small droplet coverage over all plant surfaces. Equipment settings and water volume may need to vary, depending on the growth stage of the crop.

Special Instructions for Cotton
Thorough coverage of cotton plants is essential to achieve maximum performance from Confidor plus Pulse. Equipment should be calibrated to achieve a **minimum of 60 droplets/cm² on the target foliage**. A droplet **Volume Median Diameter (VMD)** for optimum performance from Confidor plus Pulse is dependent on equipment and is defined below. Do not apply when unfavourable environmental conditions may reduce the quality of spray coverage.

Ground Application (Cotton)
Application using ground equipment should be made using **hollow cone nozzles with a minimum spray volume of 100 L/ha**. Hollow cone nozzles are recommended but if flat fan nozzles are used, higher water volumes will be required and nozzles should be configured to ensure thorough coverage. A droplet **VMD of 150 - 180 microns** must be used. Where multiple nozzles per row are used, they should be of the same specification to ensure that each nozzle contributes an equal proportion of the required dose. Where multiple nozzles per row are used (particularly for banded applications) ensure the correct nozzle overlap pattern is achieved on the target foliage. **Banded applications less than 100% are not recommended beyond the 15 node crop stage.**

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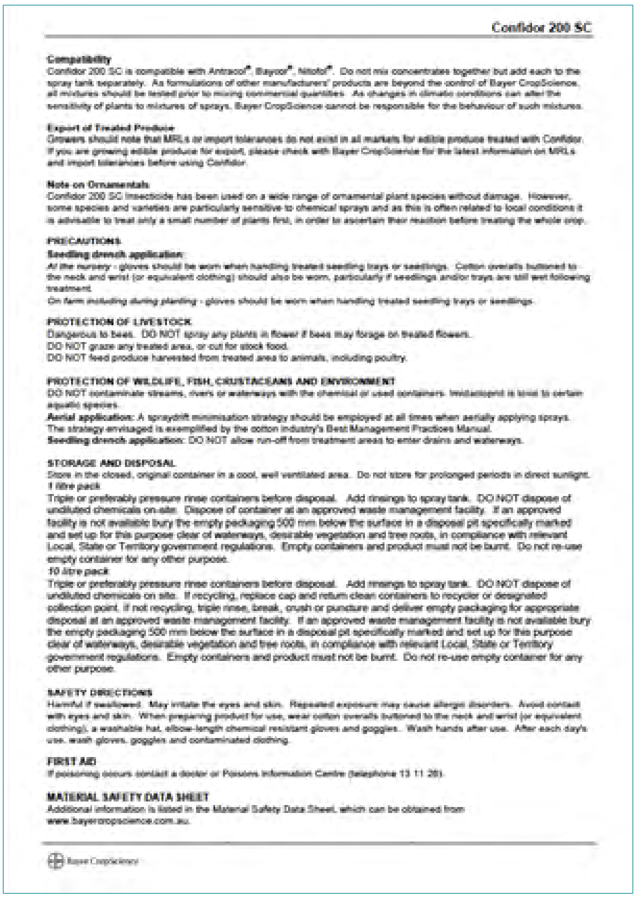
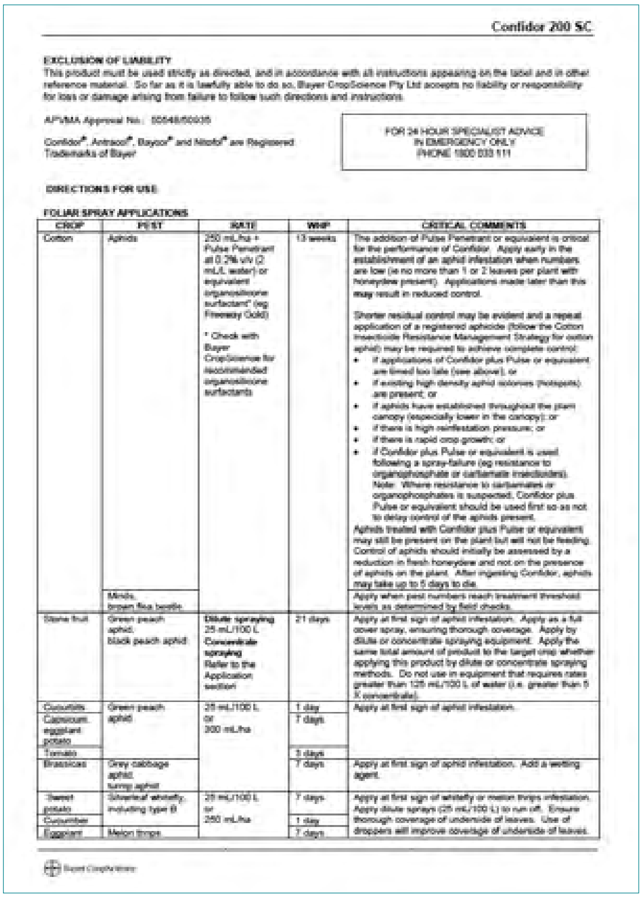
Figure 3. Sample pesticide label





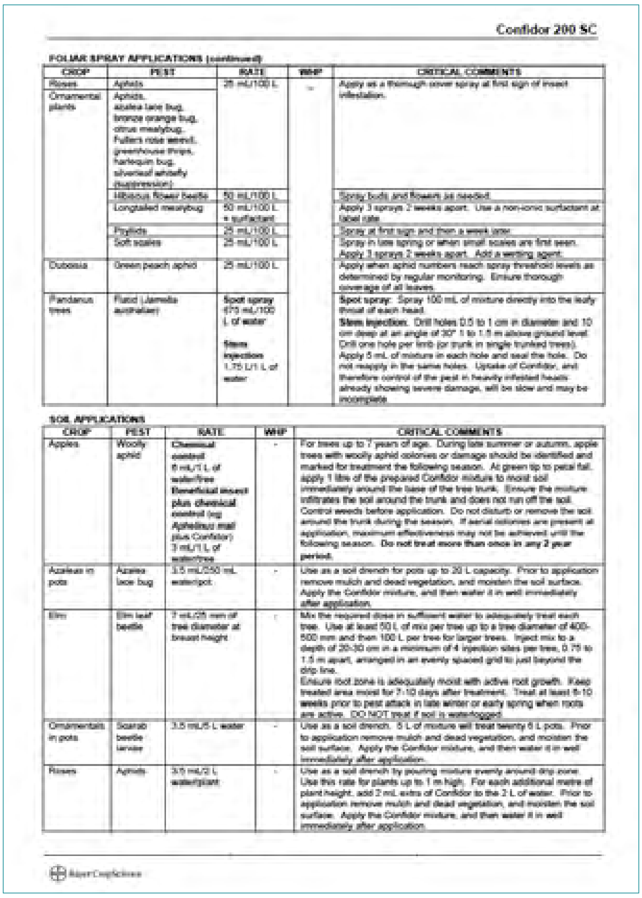
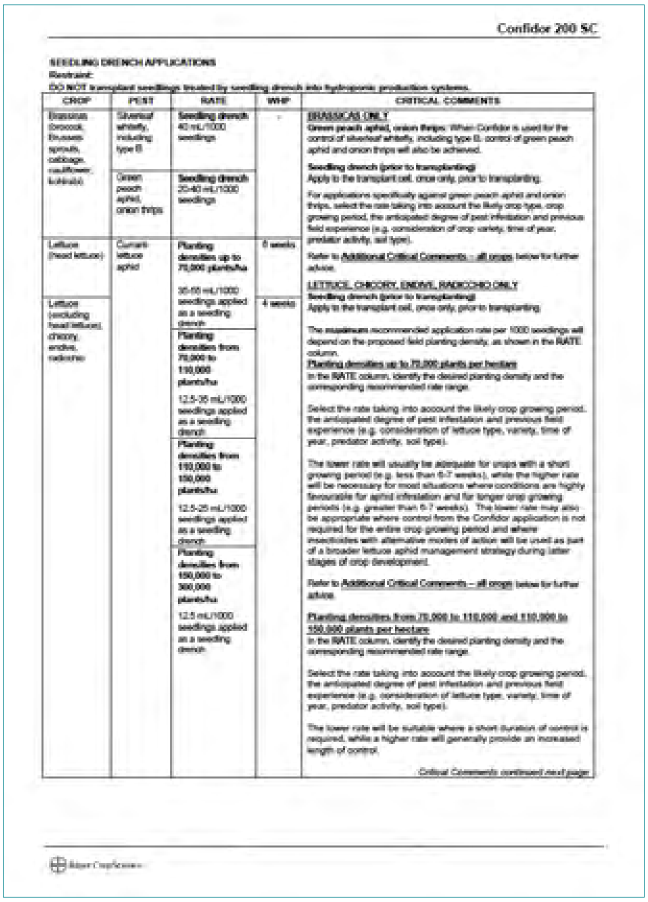


Figure 3. Sample pesticide label (*continued*)



Confidor 200 SC

SEEDLING DRENCH APPLICATIONS
Restraint:
DO NOT transplant seedlings treated by seedling drench into hydroponic production systems.

CROP	PEST	RATE	WHP	CRITICAL COMMENTS
Brassicas (broccoli, Brussels sprouts, cabbage, cauliflower, kohlrabi)	Silverleaf whitefly, including type B	**Seedling drench** 40 mL/1000 seedlings	-	**BRASSICAS ONLY** **Green peach aphid, onion thrips:** When Confidor is used for the control of silverleaf whitefly, including type B, control of green peach aphid and onion thrips will also be achieved. **Seedling drench (prior to transplanting)** Apply to the transplant cell, once only, prior to transplanting. For applications specifically against green peach aphid and onion thrips, select the rate taking into account the likely crop type, crop growing period, the anticipated degree of pest infestation and previous field experience (e.g. consideration of crop variety, time of year, predator activity, soil type). Refer to Additional Critical Comments – all crops below for further advice.
	Green peach aphid, onion thrips	**Seedling drench** 20-40 mL/1000 seedlings		
Lettuce (head lettuce)	Currant lettuce aphid	**Planting densities up to 70,000 plants/ha** 30-55 mL/1000 seedlings applied as a seedling drench	6 weeks	**LETTUCE, CHICORY, ENDIVE, RADICCHIO ONLY** **Seedling drench (prior to transplanting)** Apply to the transplant cell, once only, prior to transplanting. The **maximum** recommended application rate per 1000 seedlings will depend on the proposed field planting density, as shown in the **RATE** column. **Planting densities up to 70,000 plants per hectare** In the **RATE** column, identify the desired planting density and the corresponding recommended rate range. Select the rate taking into account the likely crop growing period, the anticipated degree of pest infestation and previous field experience (e.g. consideration of lettuce type, variety, time of year, predator activity, soil type). The lower rate will usually be adequate for crops with a short growing period (e.g. less than 6-7 weeks), while the higher rate will be necessary for most situations where conditions are highly favourable for aphid infestation and for longer crop growing periods (e.g. greater than 6-7 weeks). The lower rate may also be appropriate where control from the Confidor application is not required for the entire crop growing period and where insecticides with alternative modes of action will be used as part of a broader lettuce aphid management strategy during latter stages of crop development. Refer to Additional Critical Comments – all crops below for further advice. **Planting densities from 70,000 to 110,000 and 110,000 to 150,000 plants per hectare** In the **RATE** column, identify the desired planting density and the corresponding recommended rate range. Select the rate taking into account the likely crop growing period, the anticipated degree of pest infestation and previous field experience (e.g. consideration of lettuce type, variety, time of year, predator activity, soil type). The lower rate will be suitable where a short duration of control is required, while a higher rate will generally provide an increased length of control. *Critical Comments continued next page*
Lettuce (excluding head lettuce), chicory, endive, radicchio		**Planting densities from 70,000 to 110,000 plants/ha** 12.5-35 mL/1000 seedlings applied as a seedling drench **Planting densities from 110,000 to 150,000 plants/ha** 12.5-25 mL/1000 seedlings applied as a seedling drench **Planting densities from 150,000 to 300,000 plants/ha** 12.5 mL/1000 seedlings applied as a seedling drench	4 weeks	

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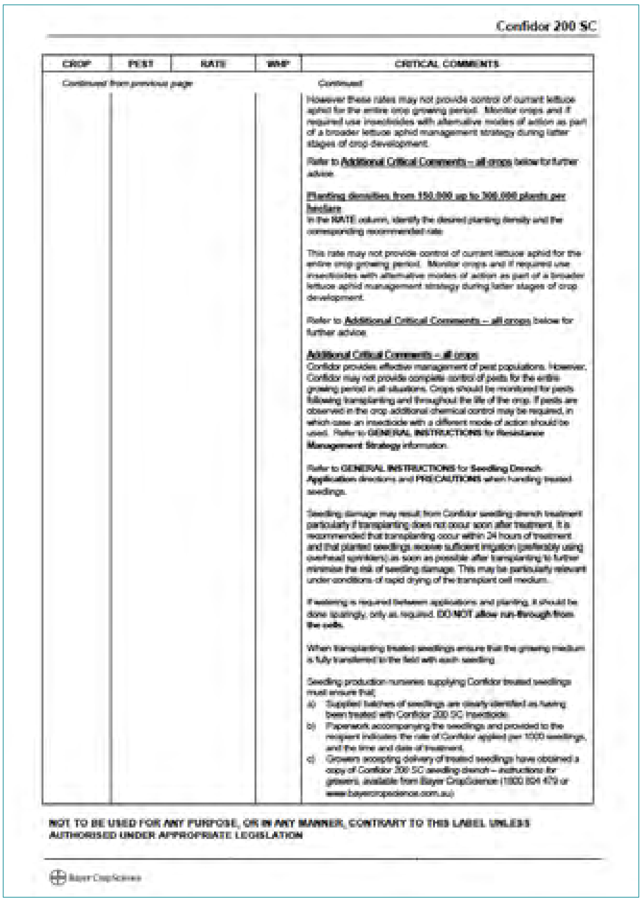

Confidor 200 SC

CROP	PEST	RATE	WHP	CRITICAL COMMENTS
Continued from previous page				*Continued* However these rates may not provide control of currant lettuce aphid for the entire crop growing period. Monitor crops and if required use insecticides with alternative modes of action as part of a broader lettuce aphid management strategy during latter stages of crop development. Refer to Additional Critical Comments – all crops below for further advice. **Planting densities from 150,000 up to 300,000 plants per hectare** In the **RATE** column, identify the desired planting density and the corresponding recommended rate. This rate may not provide control of currant lettuce aphid for the entire crop growing period. Monitor crops and if required use insecticides with alternative modes of action as part of a broader lettuce aphid management strategy during latter stages of crop development. Refer to Additional Critical Comments – all crops below for further advice. **Additional Critical Comments – all crops** Confidor provides effective management of pest populations. However, Confidor may not provide complete control of pests for the entire growing period in all situations. Crops should be monitored for pests following transplanting and throughout the life of the crop. If pests are observed in the crop additional chemical control may be required, in which case an insecticide with a different mode of action should be used. Refer to **GENERAL INSTRUCTIONS** for **Resistance Management Strategy** information. Refer to **GENERAL INSTRUCTIONS** for **Seedling Drench Application** directions and **PRECAUTIONS** when handling treated seedlings. Seedling damage may result from Confidor seedling drench treatment particularly if transplanting does not occur soon after treatment. It is recommended that transplanting occur within 24 hours of treatment and that planted seedlings receive sufficient irrigation (preferably using overhead sprinklers) as soon as possible after transplanting to further minimise the risk of seedling damage. This may be particularly relevant under conditions of rapid drying of the transplant cell medium. If watering is required between applications and planting, it should be done sparingly, only as required. **DO NOT allow run-through from the cells.** When transplanting treated seedlings ensure that the growing medium is fully transferred to the field with each seedling. Seedling production nurseries supplying Confidor treated seedlings must ensure that; a) Supplied batches of seedlings are clearly identified as having been treated with Confidor 200 SC Insecticide. b) Paperwork accompanying the seedlings and provided to the recipient indicates the rate of Confidor applied per 1000 seedlings, and the time and date of treatment. c) Growers accepting delivery of treated seedlings have obtained a copy of Confidor 200 SC seedling drench – instructions for growers, available from Bayer CropScience (1800 804 479 or www.bayercropscience.com.au)

NOT TO BE USED FOR ANY PURPOSE, OR IN ANY MANNER, CONTRARY TO THIS LABEL UNLESS AUTHORISED UNDER APPROPRIATE LEGISLATION

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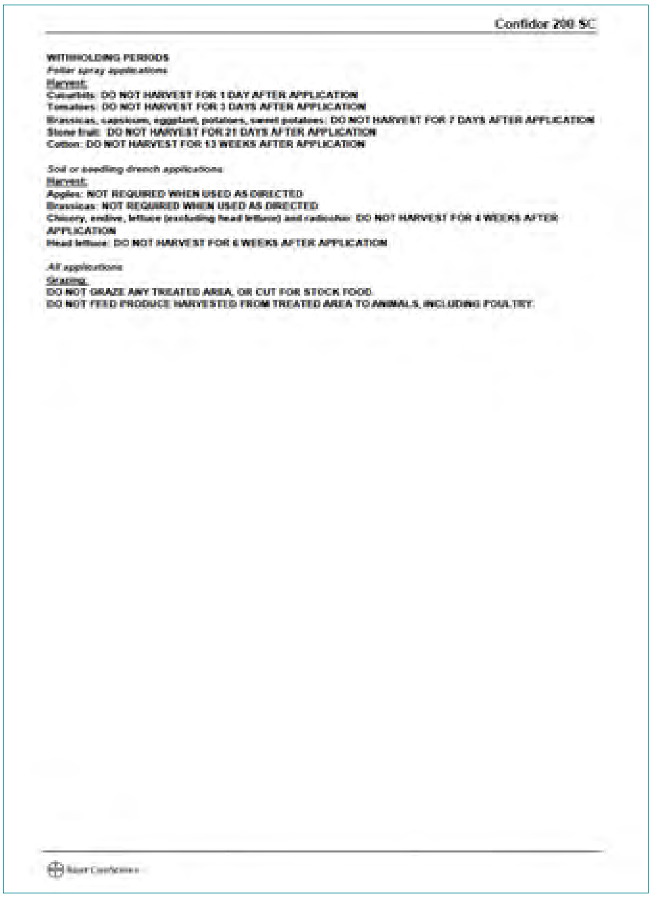

Confidor 200 SC

WITHHOLDING PERIODS
Foliar spray applications:
Harvest:
Cucurbits: DO NOT HARVEST FOR 1 DAY AFTER APPLICATION
Tomatoes: DO NOT HARVEST FOR 3 DAYS AFTER APPLICATION
Brassicas, capsicum, eggplant, potatoes, sweet potatoes: DO NOT HARVEST FOR 7 DAYS AFTER APPLICATION
Stone fruit: DO NOT HARVEST FOR 21 DAYS AFTER APPLICATION
Cotton: DO NOT HARVEST FOR 13 WEEKS AFTER APPLICATION

Soil or seedling drench applications:
Harvest:
Apples: NOT REQUIRED WHEN USED AS DIRECTED
Brassicas: NOT REQUIRED WHEN USED AS DIRECTED
Chicory, endive, lettuce (excluding head lettuce) and radicchio: DO NOT HARVEST FOR 4 WEEKS AFTER APPLICATION
Head lettuce: DO NOT HARVEST FOR 6 WEEKS AFTER APPLICATION

All applications:
Grazing:
DO NOT GRAZE ANY TREATED AREA, OR CUT FOR STOCK FOOD.
DO NOT FEED PRODUCE HARVESTED FROM TREATED AREA TO ANIMALS, INCLUDING POULTRY.

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Figure 3. Sample pesticide label (*continued*)

SAFETY DATA SHEET (SDS)

Previously referred to as an MSDS or Material Safety Data Sheet, a Safety Data Sheet (SDS) contains more detailed information about the nature of the product and how to respond if there is an emergency. An example of an SDS is provided in figure 4.

Information in the SDS includes:

- Identification details (e.g. product name and physical description/properties).
- Health hazards (e.g. health effects and first aid).
- Precautions for use (e.g. personal protection and flammability).
- Safe handling information (e.g. storage and transport).
- Other information.
- Information on toxicity.
- Information on ecological effects.

A product's SDS is available on request at the point of sale and is also downloadable from the manufacturer's website. A current SDS for each product should be made available for users. The SDS is reviewed by Safe Work Australia as part of the chemical registration process and provides useful additional information if an emergency occurs.

For an SDS to be useful three things need to happen:

1. The SDS should be read and understood before an emergency.
2. The SDS must refer to the actual pesticide formulation being used.
3. The SDS must be current and easily available to the applicator.

> ***An SDS for each product being stored or used should be available for staff to read and copies kept in or adjacent to the pesticide storage area.***

MATERIAL SAFETY DATA SHEET

Bayer CropScience

Date of Issue: August 23rd 2010

1. IDENTIFICATION OF THE MATERIAL AND SUPPLIER

Product name **Confidor® 200 SC Insecticide**
Other names None
Product codes 4952897 (1 L), 4952900 (10 L)
Chemical group Chloronicotinyl
Recommended use Agricultural insecticide
Formulation Suspension concentrate
Supplier Bayer CropScience Pty Ltd ABN 87 000 226 022
Address 391 - 393 Tooronga Road, East Hawthorn Victoria 3123, Australia
Telephone (03) 9248 6888
Facsimile (03) 9248 6800
Website www.bayercropscience.com.au
Contact Development Manager (03) 9248 6888
Emergency Telephone Number 1800 033 111 – Orica SH&E Shared Services

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
HAZARDOUS SUBSTANCE (see Risk phrase below) – NON DANGEROUS GOOD
Harmful to aquatic organisms

Hazard classification Hazardous (National Occupational Health and Safety Commission - NOHSC)

Risk phrases R22 – Harmful if swallowed.
R36/38 – Irritating to eyes and skin.
R43 – May cause sensitisation by skin contact.

Safety phrases See Sections 4, 5, 6, 7, 8, 10, 12, 13

ADG classification See Section 14.

SUSDP classification (Poisons Schedule) Schedule 5 (Standard for the Uniform Scheduling of Drugs and Poisons)

3. COMPOSITION / INFORMATION ON INGREDIENTS

Ingredients	CAS Number	Concentration (g/L)
Imidacloprid	[138261-41-3]	200
Isothiazolone antifungal agent	[55965-84-9]	0.02
Glycerin	[51-81-5]	110
Propylene glycol	[57-55-6]	25
Other ingredients, including emulsifiers, stabilizers, antifungal agents and water	(non-hazardous)	~ 665

Confidor 200 SC Insecticide Page 1 of 6

MATERIAL SAFETY DATA SHEET

Bayer CropScience

Date of Issue: August 23rd 2010

9. PHYSICAL AND CHEMICAL PROPERTIES – continued

Specific Gravity: 1.15 at 20° C
Flash Point: No flash point up to 100° C
Flammability (explosive) limits: Not applicable
Auto-ignition temperature: Not available
Partition coefficient (octanol/water): *Imidacloprid:* Log P_{ow} = 0.57 (21° C)

10. STABILITY AND REACTIVITY

Chemical stability Stable under normal conditions of use.

Conditions to avoid Avoid extreme heat.

Incompatible materials Avoid acids, alkalis, strong oxidising agents.

Hazardous decomposition products None under normal conditions. In a fire, formation of hydrogen chloride, hydrogen cyanide, carbon monoxide and nitrogen oxides can be expected.

Hazardous reactions None

11. TOXICOLOGICAL INFORMATION

POTENTIAL HEALTH EFFECTS

Inhalation May be harmful if inhaled.

Skin contact Causes skin irritation. Repeated exposure may cause allergic disorders.

Eye contact Causes eye irritation

Ingestion Harmful if swallowed. Symptoms of poisoning include:
Apathetic state, depressed muscular tone, respiratory disturbances and trembling. Muscular cramps are also possible in severe cases of poisoning.

ANIMAL TOXICITY DATA – PRODUCT

Acute:

Oral toxicity LD_{50} rat (female): approximately 1218 mg/kg
LD_{50} rat (male): approximately 1684 mg/kg

Dermal toxicity LD_{50} rat: > 4000 mg/kg

Inhalation toxicity LC_{50} rat (4 hour): > 2.238 mg/L – aerosol (highest attainable concentration) (*similar product)*

Skin irritation Not irritating (rabbit)

Confidor 200 SC Insecticide Page 4 of 6

Figure 4. Example Safety Data Sheet (SDS) for Confidor®

MATERIAL SAFETY DATA SHEET

Date of Issue: August 23rd 2010

4. FIRST AID MEASURES

If poisoning occurs, immediately contact a doctor or Poisons Information Centre (telephone 13 11 26), and follow the advice given. Show this Material Safety Data Sheet to the doctor.

Inhalation	If inhaled, remove to fresh air and keep warm and at rest. Seek medical advice if at all worried.
Skin contact	Carefully remove contaminated clothing. Wash affected areas with soap and water. Seek medical advice if at all worried.
Eye contact	Rinse eyes immediately with clean water for at least 15 minutes. Obtain medical advice.
Ingestion	Obtain immediate medical advice as above. Do not induce vomiting unless advised to do so by doctor or Poisons Information Centre. Do not give anything by mouth to an unconscious or semi conscious person.
First Aid Facilities	Provide washing facilities in the workplace.

Medical attention

Information for the physician:
The active ingredient, imidacloprid belongs to the chemical group, chloronicotinyl or neonicotinoid. Therapeutic measures: Basic aid, decontamination, symptomatic treatment.
Symptoms
Local: None expected.
Systemic: Apathetic state, depressed muscular tone, respiratory disturbances and trembling. Muscular cramps are also possible in severe cases of poisoning.
Treatment
Local: See First Aid Measures above.
Systemic: Symptomatic (nicotine-like effects). Check blood pressure and pulse rate frequently, as bradycardia and hypotonia are possible. Provide supportive measures for respiratory function and cardiac action. Give artificial respiration if signs of paralysis appear. Additional therapeutic measures involve elimination of the substance from the body or acceleration of its excretion (gastric lavage, saline laxatives, activated charcoal).
Antidote: None known.
Contraindications:
Absorption promoting agents such as alcoholic beverages and milk. Oils and fats are of no particular use, as the active ingredient has low liposolubility.

5. FIRE FIGHTING MEASURES

Extinguishing media	Water, foam, extinguishing powder, carbon dioxide, sand.
Hazards from combustion products	In a fire, formation of hydrogen chloride, hydrogen cyanide, carbon monoxide and nitrogen oxides can be expected.
Precautions for fire fighters	Firefighters should wear full protective gear, including self-contained breathing apparatus (AS/NZS 1715/1716). Keep unnecessary people away. If it can be done safely, remove intact containers from the fire. Otherwise, use water spray to cool them. Bund area with sand or earth to prevent contamination of drains or waterways. Dispose of fire control water or other extinguishing agent and spillage safely later. Do not release contaminated water into the environment.

Confidor 200 SC Insecticide Page 2 of 6

MATERIAL SAFETY DATA SHEET

Date of Issue: August 23rd 2010

5. FIRE FIGHTING MEASURES - continued

Hazchem code	Not applicable

6. ACCIDENTAL RELEASE MEASURES

Avoid contact with the spilled material or contaminated surfaces. When dealing with spills do not eat, drink or smoke and wear protective clothing and equipment as described in Section 8 - PERSONAL PROTECTION. Keep people and animals away. Prevent spilled material from entering drains or watercourses. Contain spill and absorb with earth, sand, clay, or other absorbent material. Collect and store in properly labelled, sealed drums for safe disposal. Deal with all spillages immediately. If contamination of drains, streams, watercourses, etc. is unavoidable, warn the local water authority.

7. HANDLING AND STORAGE

Handling	Keep out of reach of children. Repeated exposure may cause allergic disorders. Avoid contact with eyes and skin. Wash hands after use. After each day's use, wash gloves, goggles and contaminated clothing.
Storage	Store in the closed, original container in a cool, well-ventilated area. Do not store for prolonged periods in direct sunlight.
Flammability	Not flammable – water based product.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure standards

The NOHSC exposure standard (TWA) for glycerin mist is: 10 mg/m³
The NOHSC exposure standard (TWA) for propylene glycol is: 474 mg/ m³ (150 ppm)
Exposure standard – Time Weighted Average (TWA) means the average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day working week.

Biological limit values	None allocated.
Engineering controls	Control process conditions to avoid contact. Use in a well-ventilated area only.

Personal Protective Equipment

Eyes:	Wear goggles.
Clothing:	Wear cotton overalls buttoned to the neck and wrist and a washable hat.
Gloves:	Wear elbow-length PVC gloves.
Respiratory:	Wear a disposable mask if inhalation is likely.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	White to slightly beige liquid suspension
Odour:	Slight characteristic
pH:	7.0 – 8.5
Vapour pressure:	4 x 10^{-7} mPa at 20° C (imidacloprid)
Vapour density:	Not available
Boiling point:	Not available
Freezing/melting point:	Not available
Solubility:	Miscible with water

Confidor 200 SC Insecticide Page 3 of 6

MATERIAL SAFETY DATA SHEET

Date of Issue: August 23rd 2010

11. TOXICOLOGICAL INFORMATION - continued

Mucous membrane irritation	Not irritating (rabbit)
Sensitisation	This product is classified as "Sensitising" according to the European criteria, as it contains a very small amount of an isothiazolone antifungal agent.

Chronic:

Animal studies with imidacloprid showed no evidence of oncogenic effects, no evidence of carcinogenic effects and no teratogenic potential.

12. ECOLOGICAL INFORMATION

Imidacloprid is toxic to certain aquatic species. Dangerous to bees.
DO NOT contaminate streams, rivers or waterways with Confidor 200 SC Insecticide or the used containers.

Ecotoxicity

Imidacloprid:
Fish toxicity:
LC_{50}: 237 mg/L (96 h); golden orfe (*Leuciscus idus melanotis*)
LC_{50}: 211 mg/L (96 h); rainbow trout (*Oncorhynchus mykiss*)
LC_{50}: 280 mg/L (96 h); carp (*Cyprinus carpio*)
Aquatic invertebrate toxicity:
EC_{50}: 0.055 mg/L (48 h); *Hyalella azteca*
EC_{50}: 85 mg/L (48 h) *Daphnia magna*
Algae toxicity:
EC_{50}: > 100 mg/L (72 h); green alga (*Pseudokirchneriella subcapitata*)
Bacteria toxicity:
EC_{50}: > 10000 mg/L; activated sludge (OECD 209)
Bird toxicity:
Acute oral LD_{50}: 31 mg/kg; Japanese quail
Acute oral LD_{50}: 152 mg/kg; bobwhite quail

Environmental fate, persistence and degradability, mobility	Imidacloprid shows a medium adsorption to soil. Classified as immobile in soil. Not expected to leach.

13. DISPOSAL CONSIDERATIONS

Triple rinse or preferably pressure rinse containers before disposal. Add rinsings to spray tank. Do not dispose of undiluted chemicals on site. If recycling, replace cap and return clean containers to recycler or designated collection point. If not recycling, break, crush or puncture and bury empty containers in a local authority landfill. If no landfill is available, bury the containers below 500 mm in a disposal pit specifically marked and set up for this purpose clear of waterways, desirable vegetation and tree roots. Empty containers and product should not be burnt. Dispose of waste product through a reputable waste contractor.

Confidor 200 SC Insecticide Page 5 of 6

MATERIAL SAFETY DATA SHEET

Date of Issue: August 23rd 2010

14. TRANSPORT INFORMATION

UN number	Not applicable
Proper shipping name	Not applicable
Class and Subsidiary Risk	Not applicable
Packing Group	Not applicable
EPG	Not applicable
Hazchem code	Not applicable
Marine Pollutant	No

15. REGULATORY INFORMATION

Registered according to the Agricultural and Veterinary Chemicals Code Act 1994.

Australian Pesticides and Veterinary Medicines Authority approval number: 50548 See also Section 2.

16. OTHER INFORMATION

Trademark information	Confidor® is a Registered Trademark of Bayer.
Preparation information	Replaces August 20th 2010 edition. Reasons for revision: Hazardous ingredients, Exposure standards.

This MSDS summarises our best knowledge of the health and safety hazard information of the product and how to safely handle and use the product in the workplace. Each user should read this MSDS and consider the information in the context of how the product will be handled and used in the workplace including in conjunction with other products.

If clarification or further information is needed to ensure that an appropriate risk assessment can be made, the user should contact this company.

Our responsibility for products sold is subject to our standard terms and conditions, a copy of which is sent to our customers and is also available on request.

END OF MSDS

Confidor 200 SC Insecticide Page 6 of 6

2.2 Formulations and mixing

When a pesticide is purchased, the product consists of a mixture of components designed to keep it stable until required for use. They may also assist in its ease of handling and final effectiveness. The part that affects target pests is called the 'active constituent' and the other additives are called 'inert constituents'. These may be liquid or dry but together the total mixture is a 'chemical formulation'. Exact details of formulations are commercially sensitive because they directly influence the cost of manufacture. Formulations vary significantly but, in Australia, they are expected to have a stable shelf life of at least two years.

TYPES OF FORMULATION

Pesticides registered for use in plant nurseries are formulated in a wide variety of ways. It is not unusual to find the same active constituent available in several different formulations, each suited to a particular use and target pest situation. Formulations will vary in the hazards associated with their use, risks to the environment, efficacy in pest management and cost. Where a choice exists, it is best to select the formulation that presents the least risk to the spray operator. The level of risk is noted as the 'signal warning' on the label's central panel (see figure 2). The properties of the active constituent will usually dictate the choice of formulation that can be used to produce a stable, consistent and marketable product.

The simplest way to classify pesticide formulations is whether they are sold as a liquid or a solid. Within each of these two main categories there are a number of different formulation types.

Liquid formulations

Liquid formulations (e.g. endosulfan) are typically diluted in water to produce the final spray mix, although for some ultra low volume (ULV) applications they may be applied 'directly from the container'. The amount of formulation added to the sprayer is typically measured using a graduated cylinder or jug. The following are the general types of liquid formulations.

Solutions

These are true liquids, which contain the active constituent dissolved in either water (water-based aqueous concentrates) or a solvent that mixes (is miscible to form a liquid concentrate) with any water that may be added to make up a spray solution. The advantages and disadvantages of the 'carrier' solutions will depend on the solvents used, the concentration of the active constituent and the type of application equipment used.

Advantages of solutions	Disadvantages of solutions
• relatively easy to measure, handle, transport and store • need little agitation once mixed for application • being liquids, they cause minimal abrasive wear on spray equipment especially nozzle orifices	• the solvent system used may pose phytotoxic risks under high temperature conditions • the solvent may increase the risk of skin irritation and absorption if accidental operator exposure occurs • the solvents may cause equipment deterioration, particularly of washers and seals, which may need frequent replacement to avoid equipment leaks • some solvents employed are highly flammable and result in the product being classified as a 'dangerous good', with consequent restrictions on how it may be transported and stored

Emulsifiable concentrates (ECs)

As the name indicates, ECs contain an emulsifier in the formulation (e.g. Endosulfan 350 EC®), which enables the active constituent to be dissolved in an organic solvent and then spread evenly through the carrier water when a spray solution is made up. The final spray solution is an emulsion and is usually milky white in colour.

Advantages of emulsifiable concentrates	Disadvantages of emulsifiable concentrates
• relatively easy to measure, handle, transport and store • need little agitation once mixed for application • being liquids, they cause minimal abrasive wear on spray equipment, especially nozzle orifices	• the solvent system used may pose phytotoxic risks under high temperature conditions • the solvent may increase the risk of skin irritation and absorption if accidental exposure occurs • the solvents may cause equipment deterioration, particularly with washers and seals, which may need frequent replacement to avoid leaks • some solvents employed are highly flammable and result in the product being classified as a 'dangerous good', with consequent restrictions on how it may be transported and stored

Suspension concentrates (SCs) or flowable concentrates

This type of formulation (e.g. Confidor 200 SC®) was introduced to try and overcome some of the handling problems associated with wettable powders (WPs) or solid formulations. In SCs, the active constituent is milled to a finer size than with WPs and then packed off as a suspension of fine particles within a liquid, which is then further diluted, usually with water as the carrier liquid to make up a spray mixture.

Advantages of suspension concentrates	Disadvantages suspension concentrates
• because of the finer particle size, there is much less chance of nozzle or filter blockages than with WPs • there is no dust problem when measuring out	• the suspension may settle out in storage so packs of SCs must always be shaken vigorously before measuring out the dose required • there is a limit of about 50% in the concentration of active constituent that can be incorporated without causing stability problems in the formulation

Solid formulations

Solid formulations may range from fine powders to large granules. They typically require a balance to weigh out the correct amount to add to the spray tank. Some products may come in small pre-weighed packets that can be used as is or have special pre-calibrated mixing cylinders specifically for that formulation.

Soluble powders

As the name indicates, this type of formulation dissolves in water to form a true solution (e.g. ProGibb®).

Advantages of soluble powders	Disadvantages of soluble powders
• easy to store and transport • have lower phytotoxicity risks than ECs • can be packed in disposable packages	• must avoid breathing in the powder when measuring out doses • measuring can be difficult unless pre-packs are used

Wettable powders

WPs are designed to be dispersed in water to form a suspension, which is then applied as a spray (e.g. Dithane M-45®). Wettable powders are a convenient way of packing high concentrations of the active constituent (up to 80% of the product) in a stable condition that has commercial appeal. This advantage (to the manufacturer) is outweighed by a number of disadvantages as listed below, which have led to a decline in the popularity of WPs.

Advantages of wettable powders	Disadvantages of wettable powders
• a convenient way of packing high concentrations of the active constituent	• constant agitation in the spray vat is needed to avoid uneven dosing caused by particle settlement in the spray vat • the suspended particles are abrasive and can cause accelerated wear in nozzles and pumps • the suspended solids can block nozzles and filters, particularly if agitation in the spray tank is inadequate • many WPs require careful pre-mixing with a little water to ensure even dispersion and this process can be difficult with some alkaline bore waters • measuring out by weight can be hazardous unless pre-packs are used and then the pre-packs have to coincide with the dose required per tank of spray

Water dispersible granules

This type of formulation is a popular one as new formulation technologies have produced micro-granules that can carry high concentrations of active constituent (acceptable with low toxicity products, e.g. Simagranz®). The actual concentration put into a particular product will depend on the toxic hazards associated with the active constituent, but concentrations of up to 900 g/kg have been achieved.

Advantages of water dispersable granules	Disadvantages of water dispersable granules
• can carry high concentrations of active constituent • avoids the problems of dust generation • has pour characteristics like a liquid to make measuring easy • fine milling of the base ingredients of the formulation prior to actual granule formation ensures no problems with blockages after dispersal takes place in the spray vat • the high concentration means that these formulations are more efficient to transport and store	• a specific order of mixing may be required when more than one product is to be included in a spray solution • specific weighing or measuring jugs may be required for each product

Other formulations

Granules

Free-flowing granular formulations have been used for many years as a means of applying pesticides to manage soil-borne pests or to apply a pesticide in remote areas that depend on rainfall for later activation.

Some granules are formulated using a polymer matrix that degrades at a predictable rate, releasing small doses of active constituent over an extended period. These are known as slow or controlled release granules and they were introduced as a means of extending the period of activity for pesticides with shorter active lives. They are a replacement for the long-lasting organochlorines such as DDT and BHC, which were removed from the marketplace in 1987. Granules provide a relatively safe means of handling very toxic pesticides as the formulation involves scattering a small amount of active constituent through a much larger bulk of inert material, usually clay (e.g. SuSCon Green®).

Advantages of granules	Disadvantages of granules
• ready to use without mixing and are easy to apply • application does not involve carrying water, thus reducing soil compression and easier application in hard-to-access areas • usually have little or no dust associated with them and therefore present a low drift hazard • the application equipment needed to disperse them is relatively cheap compared with hydraulic sprayers • granules can penetrate foliage to reach the soil surface more easily than spray droplets, which can sometimes be an advantage	• more expensive than most other formulations because the amount of active constituent incorporated is at a lower concentration • may require soil incorporation or follow-up rain before becoming usefully active • may present a hazard to non-target species, especially birds • not adhering to foliage may be a disadvantage

Aerosol dispensers

These are convenient but are usually expensive. It is difficult to control placement of spray fall-out and this can pose a high risk of inhalation. The formulations often contain a flammable propellant under pressure, which represents a potential hazard if the container is punctured or incinerated (e.g. white oil).

Fumigants

These can be hazardous formulations and many have been phased out of the marketplace. They are toxic to a wide range of organisms and often do not discriminate between pests and beneficial species. They can penetrate target areas very efficiently and usually only involve a single application. Fumigants are extremely hazardous to use and most require special training in safe handling, particularly in regard to the use of appropriate protective equipment. Confining fumigating gases to the desired area of action can sometimes cause problems (e.g. methyl bromide or chloropicrin).

Water soluble crystals

This formulation type is being used for 2, 4-D based products packed in water soluble plastic packaging. These are simply dropped into the spray vat to dissolve in the carrier and form the spray solution. The user is not exposed to the pesticide at any time, increasing the safety of the operation.

Microcapsules

An alternative version of the *Bacillus thuringiensis* var. kurstaki toxin Cry1A produced in the cells of genetically modified *Pseudomonas fluorescens*, which die in such a way that they constitute a rigid capsule for the enclosed insecticidal protein. This is claimed to improve protection from UV radiation.

WATER QUALITY

The pH of the water used as a carrier for a pesticide is often overlooked when considering the factors that affect the performance of a pesticide. Some pesticides are susceptible to decomposition (or hydrolysis) in acidic or alkaline water. This can have a noticeable effect on the degree of pest control obtained because a certain amount of pesticide will have decomposed before it is actually used. The longer a spray mix is allowed to stand before use, the greater the decomposition of the active constituent. The carrier water pH has the ability to reduce the effectiveness of some pesticides in less time than it takes to spray out the tank mix!

Generally, pesticides are most stable within a pH range of 4.5–7.0, the optimum being pH 5.0–6.0. Some pesticides are not affected by pH and are stable over a pH wide range. Usually, decomposition is more rapid with increasing alkalinity. Insecticides, especially organophosphates, carbamates and synthetic pyrethroids, are generally more severely affected by alkaline water than fungicides or herbicides. Some pesticides are incompatible with alkaline materials such as lime, sulphur, calcium chloride and bordeaux mixtures, to name a few. If there is any doubt about the compatibility of certain pesticides, consult the product label.

In some cases, a minor change in the pH can significantly affect the performance of a pesticide. Carbaryl, for example, is a common insecticide used in the nursery industry and it is stable in water at pH 5.0. But in water with pH 7.0, carbaryl decomposes by 50 per cent (also known as a half-life) in 30 days, and at pH 9.0, decomposes 50 per cent in only 24 hours, cutting its effectiveness greatly. To increase pesticide effectiveness, users can follow the following recommendations:

- Do not store and reuse mixed pesticides. Mix and use for each individual job.
- Always read the pesticide label to determine if there are any recommendations for addressing carrier water pH.
- Source information from technical bulletins on products or toll-free numbers that are listed on the product labels.
- Companies that supply buffering agents are also very good sources of information on pesticide stability and products that should be used in specific situations.

ADJUVANTS

Adjuvants are substances added to a formulation or spray mix for the purpose of improving its performance or stability.

There are many different types of adjuvants, including drift retardants, sequestering agents, synergists, buffers and surfactants. 'Surfactant' is a general term used to describe surface active agents, which includes adjuvants such as wetting agents, stickers and anti-foaming agents. Some drift retardants may also be considered surfactants.

Wetting agents

These are sometimes called spreaders or wetters and are sometimes included in a formulation, but in many cases there is a label direction to add a certain quantity of a wetting agent to the spray solution, dependent on the volume being applied. Wetting agents are designed to lower the surface tension of the liquid being applied so that instead of resting as a number of individual droplets on the surfaces targeted, it spreads as an even film with a much larger area of contact. When adding a wetting agent to a pesticide, it is important to always select a non-ionic wetter unless other types of wetters (cationic or anionic) are recommended on the pesticide label. Certain spray oils are registered for use in spray mixes. Care should be taken to follow label directions and to avoid problems with phytotoxicity by not applying pesticides in the heat of the day or in full sun.

Always consult the registered label for advice and recommendations about the use of spray additives.

Synergists

These are chemicals added to a formulation to enhance the performance of the active constituent although alone they have little or no activity. Examples include piperonyl butoxide added to some pyrethroid insecticides to improve knock-down of flying insects and ammonium thiocyanate added to amitrol-based herbicides to improve uptake and weed kill.

Buffers

These are chemicals that can alter and maintain the pH of carrier water at a different level to its normal pH. Some chemicals perform more consistently under slightly acidic conditions and in many places the local water supply is a little alkaline. Acidifying buffers have the ability to lower the pH, which would be an advantage with certain organophosphates, and assist in reducing antagonism when making up mixtures with glyphosate (e.g. Roundup®).

Sequestering agents

These are used in some formulations to overcome the problems caused by hard water containing excessive amounts of calcium and magnesium salts. In a number of phenoxy herbicide formulations, ethylenediaminetetraacetic acid (EDTA) is added as it combines preferentially with the calcium and magnesium present in hard water to form soluble salts. This prevents any 2,4-D acid reactions, which would produce insoluble (solid) salts that would fall out of solution.

Stickers

These help increase the rain-fastness of a spray application, reducing the need for a repeat spray, and are often used as additives to protectant fungicide sprays specifically applied before rainfall events.

Anti-foaming agents

These can save time when recharging spray vats with high pressure water. Excess foam production can occur due to traces of wetting agent left from the previous vat load.

2.3 Transport

Some nursery chemicals are classified as dangerous goods (DG), which means they are subject to the Australian Dangerous Goods Code (available at www.ntc.gov.au/filemedia/Publications/ADG7October2011.pdf- Cited 14 May 2013). With most DG products compliance with the Code does not become a legal obligation until the loads exceed 1 t, but with some products the amount can be as low as 250 kg or L. Compliance involves appropriate documentation, defined responsibilities and vehicle placarding.

If a vehicle is used regularly to transport pesticides it should contain an emergency kit of appropriate PPE, a dry powder fire extinguisher, a shovel, a broom and a bag of neutralising agent, such as hydrated lime.

LOADING

- Nursery chemicals should never be transported in the same cabin space as people, pets and food. "Ute it. Don't boot it."
- Always check the chemical containers for corrosion and leaks.
- Check containers have complete labels.
- Distribute the load evenly and secure it to prevent movement.
- Do not leave vehicles carrying chemicals unattended.

UNLOADING

- Check the load is complete.
- Immediately clean up any spillage that may have occurred in-transit.

2.4 The storage of nursery chemicals

Chemicals should normally be obtained shortly before expected use. This will keep the stocks held at a nursery to a minimum and make secure, safe storage a straightforward task.

Storage and handling of containers of pesticide requires particular care and attention. This is an essential part of a safety audit.

CHARACTERISTICS OF A STORAGE FACILITY[2]

The storage area should be:

- located a minimum of 10 m from any dwelling and 15 m from the property boundary
- free of any flood threat or water damage
- clear of vegetation for 3 m around the facility
- constructed of fire-resistant materials
- have a sealed floor that is bunded to contain any spillage
- well ventilated and cool
- kept locked and secure
- placarded to make known its contents.

A storage area should have:

- a reliable water reservoir of clean water for washing and decontamination
- an available emergency shower, preferably fed from a separate storage tank
- the necessary equipment on hand in case of a fire, spill or accidental poisoning
- stock kept off the floor
- the stock grouped by chemical, type or dangerous good (ADG) classifications
- the stock rotated so that unused material is not accumulated
- space available to store empty containers, prior to disposal.

[2] *ChemCert Australia, Chemical Users Handbook, 2013.*

A storage and handling facility that has been well designed has four components:

1. *A storage cabinet or room*

The storage cabinet or room should be located in an area that isolates chemical fumes and dust (i.e. from any personnel), with good ventilation. Many storage lockers are available with good ventilation. Pesticides should be stored at temperatures of 5–35°C.

> ***Custom-built storage sheds with excellent ventilation, built in showers etc. are available from several manufacturers.***

2. *A mixing area*

The mixing area should contain a work surface and appropriate measuring equipment. A water supply and sink are needed for chemical preparations and clean up. A fume hood may be installed over the mixing table to remove fumes away from workers.

3. A place to store equipment and records

A separate area or room is recommended for storing protective clothing, equipment, records and SDS sheets.

4. An area for loading and rinsing spray equipment

The loading area can be part of the mixing area or it can be separate. It should be large enough to hold the largest sprayer. The purpose of this area is to collect spills while loading and emptying and to provide an area for washing down the sprayers after use. A drench shower and eye wash should be located nearby (Bartok, 1996).

All rinsate and pesticide residues from wash facilities (e.g. basins and shower) must be prevented from contaminating storm water drains, creeks and streams, the ground etc. Collect all rinsate and wash-down water and dispose of appropriately (refer to Section 2.6 on disposal).

2.5 Personal protective equipment (PPE)

Pesticides are often toxic to mammals and each product has been evaluated in terms of the risk posed to humans. This information is found on the SDS for each product and the recommendations for handling it appear by law on the label of each registered pesticide. Read both of these documents before choosing suitable personal protective equipment for the mixing and application of pesticides. Employers are responsible for the protection of their employees. The employer has a legal duty of care to ensure that workers know how to use personal protective equipment properly. It is important to identify the potential hazards and protect against them.

MODES OF PESTICIDE CONTAMINATION

Pesticides present different risks of poisoning depending on the active chemistry and the carrier. There are several pathways by which pesticides may come in contact with humans—respiratory (by breathing in), dermal (through the skin), ingestion (via the mouth) and insinuative (through puncture or injection).

Each product poses different levels of risk for each pathway and so planning protection will require consideration of the risk posed by every pesticide that will be used. Each product's SDS contains information on the risk posed by each mode of contamination. Different risks may also be posed by various methods of application and these should be identified by carrying out a risk assessment.

RESPIRATORY EXPOSURE AND PROTECTION[3]

Contaminants can be breathed in through mouth or nose and are absorbed into tissues via the lungs. Respiratory hazards take the form of:

Particulates

- dusts—solid particles moved by air
- mists—liquid droplets suspended in air
- fumes—thermally generated particles.

Gases and vapours

- gases—chemicals that mix with air at room temperature
- vapours—substances that evaporate from liquids and solids at room temperature.

Respiratory protection is provided through properly fitted face masks that remove contaminants by filtering them from the airstream breathed by the user. The Australian/New Zealand Standard AS/NZS 1715–2009 'Selection, use and maintenance of respiratory protective devices' provides comprehensive guidance on how to select the correct type of respiratory protective device (RPD).

Protection from particles

Particulate filters to remove material between 0.6 and 2.0 microns in size from the airstream. They filter the air through fibres, which are often electrostatically charged, to attract contaminants as well as mechanically block their movement. Filters clog over time and should be replaced when breathing through them becomes difficult.

Filters are categorised to match specific groups of contaminants.

Filter type	Contaminant
P1	mechanically generated dusts and mists
P2	mechanically and thermally generated dusts, mists or fumes
P3	highly toxic dusts, mists and fumes

[3] 3M Occupational Health and Environmental Safety Division (2011). 3M ™ Administrative Respiratory Protection Program. St Paul, MN, USA. URL: http://multimedia.3m.com/mwsaweb-server?66666UuZjcFSLXTtNxfcNxMyEVuQEcuZgV-s6EVs6E666666-- (Cited 14 May 2013).

Protection from gases and vapours

Gas and vapour filters contain activated charcoal which absorbs organic contaminants and removes them from the airstream. The charcoal, usually found in plastic cartridges, is chemically treated to enable it to attract and bind particular chemical groups and so must be matched to the contaminants expected in the environment where they are used.

Filter type	Contaminant
A	organic vapours (solvents)
B+E	acid gases
Form	formaldehyde
G	low vapour sprays (most agricultural pesticides)
K	ammonia

Filter classes

Filters of all kinds come in four classes that describe their capacity, i.e. the amount of contaminant they can remove from air.

Filter class	Capacity to remove contaminants
Class Aus	low concentration of contaminant for short durations
Class 1	higher concentrations or longer duration of use
Class 2	higher concentrations or longer duration of use
Class 3	highest concentration of contaminant or longest duration of use

Respirator cartridges

The cartridges fitted to respirators usually consist of both a particulate and a gas/vapour filter. Cartridges containing activated charcoal should be taken off the equipment between uses and stored in a clean, airtight container (such as a re-sealable plastic bag) to avoid deterioration through exposure to water and other vapours. They must be replaced when they are no longer absorbing the gas or vapour, usually apparent when the operator can detect odours while wearing the equipment. Effectiveness of the equipment can be crudely tested by applying a drop of strong smelling perfume or nail polish thinner (acetone) to the air intake of the cartridge before use. If this can be detected by the wearer then the cartridge/s must be replaced.

Powered full helmets

Powered helmets have the advantage of providing filtered air under positive pressure, which increases safety and removes the work of the lungs having to draw in air against filter resistance as in cartridge respirators. A full helmet is necessary for high-risk situations and for spray applicators with beards. All powered air purifying respirators should comply with AS/NZS 1716:2012[4] and should be fitted with filters appropriate to the particular task.

DERMAL EXPOSURE AND PROTECTION

Material can be absorbed through the skin, particularly if there is moisture on the skin, such as sweat. Overalls, gloves, boots, aprons, goggles and face shields are used to mechanically prevent pesticides from reaching the skin. Gloves and boots should be non-absorbent and without lining so that pesticides do not permanently contaminate equipment. Overalls need to be washed between uses and should be removed and replaced if they become visibly wet with spray. Fresh water, soap and showering facilities need to be available where pesticides are mixed and used so that skin can be cleaned immediately in the event of contamination.

Areas of high blood flow such as eyes, ears, face, head and groin have increased absorption rates and particular care should be taken in protecting them. These areas are often scratched or rubbed by operators even when wearing protective gloves, which can lead to contamination of otherwise protected areas.

INGESTION

Pesticide material can splash into the mouth, be accidentally eaten, fall onto food or droplets may fall without notice into the mouth and be swallowed. Take care to use a face shield when mixing pesticide concentrates as splashing can occur.

INSINUATIVE EXPOSURE

Puncture wounds, such as a high pressure spray that breaks the skin or injects material under it, can lead to pesticide exposure. This is more common in glasshouse management than in most other plant industries due to the use of mechanical foggers.

HEARING PROTECTION

Exposure to the noise of mechanical equipment, especially that of small engines such as those found in foggers, misters and the like can damage hearing. Ensure that operators and other staff have suitable ear protection, such as expanding foam earplugs or earmuffs. Consult resellers/manufacturers to determine what equipment is appropriate for the particular task.

[4] *AS/NZS 1716:2012 Respiratory Protective Devices. URL: http://infostore.saiglobal.com/store2/Details.aspx?ProductID=1507382*

[5] *AS/NZS 1716:2012 Respiratory Protective Devices. URL: infostore.saiglobal.com/store2/Details.aspx?ProductID=1507382*

Table 2. Personal protective equipment required for handling pesticides

Protected Area	Equipment Item	Comments
Body	Overalls 	Buttoned at the wrist and neck. These must be clean at the start of each day, splash proof and worn outside the boots.
	Apron 	A full-length plastic apron gives added frontal protection when mixing concentrates.
Eyes	Goggles 	To give complete eye protection.
Face	Face shield 	To give protection against face splash.
Feet	Footwear 	Never use absorbent materials such as leather. Use rubber or PVC, preferably with steel toe cap.
Hands	Gloves 	Chemical-resistant, preferably unlined and elbow length (e.g. nitrile PVC gloves).
Head	Washable cotton hat, overall hood 	Head covering to prevent scalp/hair exposure.
Respiratory system	Respirator 	Half or full-face respirator incorporating a cartridge filter system. Refer to the Australian Standard AS/NZS 1716:2012 Respiratory Protective Devices to select the correct respirator and cartridge.[5]

Table 3 illustrates the relative risks associated with various types of pesticides, method of application and choice of application equipment. Some operations present a much higher risk to people and property than others.

For each of the various levels of risk a range of personal protective equipment has been suggested. In all instances chemical labels should be read fully and adhered to and the SDS consulted for further information.

Table 3. Personal protective equipment during spraying operations

Risk	Situations	Choice in products: Herbicide	Choice in products: Insecticide/ Fungicide	Method of spray	Choice of equipment	PPE for spraying
Low to moderate	Open area	e.g. glyphosate (S5) (e.g. Roundup®)	e.g. NPVs, Bt (e.g. Gemstar®, Dipel®)	High volume (>200 L/ha)	Shielded sprayer, hydraulic boom, knapsack.	Overalls, boots, goggles
Moderate to high	Shadehouse	e.g. fluazifop-P,butyl (S6) (e.g. Fusillade®)	e.g. carbaryl (S5), mancozeb (S5) (e.g. Dithane/ M45®)	Low volume (10–200 L/ha)	Hydraulic boom, spinning disc (herbi), airshear	Overalls, gloves, boots, washable hat, appropriate respirator (where indicated on label), face shield, goggles
High to very high	Enclosed area (glasshouse)	e.g. paraquat (S7) (e.g. Gramoxone®)	e.g. endosulfan (S6) (e.g. Thiodan®)	Ultra low volume (<10 L/ha)	Electrostatics, spinning disc (ulva), foggers (ULV/CDA)	Overalls, gloves, boots, full-face respirator (or goggles and ½ face respirator), face shield, washable hat, goggles
	Mixing	Most pesticides				Overalls, gloves, boots, full-face respirator (or goggles and ½ face respirator), face shield, washable hat and apron

MAINTENANCE OF PERSONAL PROTECTIVE EQUIPMENT

- All PPE should be cleaned as soon as possible after each use. It must not be contaminated with residues from a previous occasion.
- Soaking overalls in a slightly alkaline bleach solution (such as ammonium or sodium hydroxide) will prevent residues becoming 'fixed' in the fabric and break down any organophosphate or carbamate pesticide residues that may be present.
- A similar solution may be used to wipe over other items of PPE prior to storage.
- It is wise to check all items prior to storage for signs of wear and tear so that replacements can be obtained before the next occasion the equipment is needed.
- Respirator cartridges should always be removed and stored in a clean air-tight container (such as a resealable zip-lock plastic bag) to prevent a reduction in useful life (see page 23).
- The usage period of respirator cartridges containing activated charcoal should be recorded and they should be tested for efficiency regularly (see page 23).
- Care should be taken to service the inhalation and exhalation valves in the body of cartridge respirators.

The spray operator must wear protective clothing as recommended on the label when mixing and applying pesticides.

Protective clothing and equipment should be checked before use, cleaned and checked after every day's use and then stored in a clean dry area away from pesiticides.

Mixing the concentrate when preparing to spray can be the most hazardous time for the operator.

2.6 Disposal

It is the responsibility of the user to see that wastes such as unused chemicals and empty containers are disposed of properly. Empty containers can be a hazard to curious children and animals. Improperly disposed of chemicals can result in water contamination and crop damage. The current AgSafe® *Accreditation Training Manual* (2002) has further information on this topic.

There are services available that can be used to dispose of chemical waste and containers. Such services include drumMUSTER and ChemClear[6].

The following steps are guidelines for disposing waste properly:

- Purchase only the required amount of pesticide needed for one season to avoid disposal problems associated with excess product.
- Always read the label for disposal instructions.
- Wear the appropriate protective clothing during the disposal of any unwanted pesticide or pesticide mixture.
- Treat contaminated clothing and protective equipment, contaminated soil or materials used to clean up spills in the same manner as nursery chemical waste. The current AgSafe® *Accreditation Training Manual* (2002) has further information on this topic.
- Use accredited disposal schemes, such as drumMUSTER, where available[6].

The label must remain on the container at all times.

drumMUSTER

drumMUSTER is the national program for the collection and recycling of empty, cleaned, non-returnable crop production and on-farm animal health pesticide containers. Containers will be inspected for visible signs of pesticide residue or any liquid before being accepted for re-use or recycling. For the drumMUSTER website refer to the contact details on page X.

DISPOSING OF UNUSED MIXED PRODUCT

Small amounts of excess pesticide mixture are frequently left at the end of an application and are also created when rinsing spray tanks or empty pesticide containers. This material must be disposed of properly. Check the pesticide SDS for specific risks of contamination. This material must never be allowed to enter streams or drainage from the property! Excess spray can be disposed of by spraying over the crop, although care should be taken that authorised rates of application are not exceeded by the addition of this application to the treatment previously applied. Alternatively, a mulched area might be used, with the same provision concerning registered rates of application per area.

Areas where mixing and cleaning of equipment are performed create risks of pesticide spillage. They should be bunded to prevent run-off or drainage to watercourses and suitable materials kept nearby for the neutralisation of spilled material. Wash water collected from this area must be retained to allow pesticide breakdown.

[6]*www.chemclear.com.au; www.drummuster.com.au*

CLEANING SPRAY EQUIPMENT

Rinsing

Spraying equipment should be cleaned in the same manner as pesticide containers to remove spray residues that may clog equipment or present a safety hazard. This should be performed directly after use to prevent drying or caking, which may be difficult to remove later. The inside of the spray tank must be rinsed out and the rinsate run out through the nozzles or other applicator until the tank is empty. This should be repeated at least twice and the outside of the equipment inspected for visible residues.

Neutralising

Plastic and fibreglass spray tanks and the plastic spray lines absorb trace quantities of pesticides during use. This can later create hazardous vapours or contaminate spray mixes of other materials. This can create risks for operators and target plants, depending on the pesticides used. Ideally, use separate spray tanks for different groups of pesticides used, i.e. herbicides, insecticides and fungicides, or members within these categories used for different management activities. Consulting the records of pesticides previously applied with equipment can avoid expensive mistakes, damaging sensitive crops or endangering staff.

While separate equipment may be an option for large plant nurseries, most operators will want to neutralise the residues in equipment from time to time so that they can safely use it for a variety of purposes.

Table 4. Recommendations for use of cleaning agents[7]

Chemical used	Cleaning agent per 100 L water	Instructions
All herbicides	Commercial cleaning agent	Follow directions of cleaning agent label.
Phenoxy herbicides (2,4-D, Dicamba, MCPA etc)—salt and amine formulations Small traces of 2,4-D can damage sensitive plants. Preferably do not use the same sprayer to apply other chemicals to sensitive plants. Hoses may need to be replaced.	1–2 L household ammonia per 100 L water or	Thoroughly agitate, flush small amount through system and let remainder stand in sprayer overnight. Flush and rinse with clean water several times before use.
	500 g washing soda or	Same as above but let stand for at least 2 hours.
	1 kg trisodium phosphate per 100 L water or	Same as above but let stand for at least 2 hours.
	250 g fine activated charcoal and half a cup of detergent (liquid or powder) per 100 L water	Make a sudsy solution. Agitate, operate sprayer for 2 minutes, let remainder stand for 10 minutes, then flush through sprayer. Rinse.
Phenoxy herbicides—ester formulations	500 g washing soda + 4 L kerosene + 125 g powder detergent	Rinse inside of tank and flush small amount through system. Let stand for at least 2 hours. Flush and rinse.
Sulfonylurea herbicides	500 ml sodium hypochlorite (chlorine) bleach (6% solution)	Flush through the boom for at least 10 minutes including spraying out the jets. Make sure all spray lines, filters etc are well cleaned. Rinse out. Repeat the operation for at least another 10 minutes. Allow the sprayer to stand for at least 12 hours.
Other herbicides	125 g powder or liquid detergent to make a sudsy solution	Rinse with clean water afterwards.
Insecticides and fungicides	125 g powder or liquid detergent to make a sudsy solution	Rinse with clean water afterwards. Organophosphate and carbamate insecticide may be detoxified by adding household ammonia to the cleaning solution at 1 L per 100 L water.

[7] *Source: Chandlers IAMA, Hardi International, format based on Chemcert, Spray Application and Risk Management in Vineyards, 2003.*

RINSING CONTAINERS

Rinsing and cleaning containers are the first steps in proper disposal. State laws require users to follow label instructions that specify that containers must be rinsed. Local shire and municipal councils will only accept properly rinsed and cleaned containers at their approved refuse landfills, after inspection of the containers. Under current regulations in most states, containers that have not been properly rinsed can be classified as hazardous wastes[8].

Containers should be rinsed directly after emptying their contents as residues are more difficult to remove when dry. Proper rinsing of nearly all types of pesticide containers will remove more than 99% of any pesticide residue remaining in the container. Rinsing into the spray tank also conserves valuable pesticide.

Two commonly used procedures are effective for proper rinsing of pesticide containers: 1. pressure rinsing and 2. triple-rinsing. Clean water must always be used to rinse containers.

Pressure rinsing

Some spray equipment manufacturers supply a special rinsing attachment that enables drums and bags to be rinsed using a pressure nozzle. This method is generally faster and easier to carry out than triple-rinsing (AgSafe® *Accreditation Training Manual*, 2002). There are two basic forms: 1. the 'piercing nozzle' and 2. 'sucker-flusher' probes. The piercing nozzle makes its own hole and is inserted into the bottom or side of the container. In this case the rinsate flows out through the regular opening. Sucker-flusher probes enter through the normal aperture and suck fluid from the bottom of the container while spraying pressurised water from nozzles on the side of the probe back from the head.

The steps to follow when pressure rinsing are:[8]

1. Remove the cap from the container. Empty contents into the tank and allow to drain for an extra 30 seconds after the flow reduces to drops.
2. For piercing nozzles, insert the pressure nozzle by puncturing through the lower side of the container. Do not, however, puncture plastic containers (such as 20 L drums) if they are part of a manufacturer's re-use program; these should be triple-rinsed. For sucker-flusher probes, insert through the regular opening and do not invert the container (i.e. ignore step 3).
3. Hold the container upside down over the sprayer tank so the rinsate will run into the sprayer tank.
4. Turn the water on and rinse for the length of time recommended by the manufacturer (normally at least 30 seconds) or until the rinsate coming from the container is clear. Move the nozzle or probe about so that the stream of water reaches all parts of the container to rinse all inside surfaces.
5. Rinse the container cap when there is a clear stream of water coming out of the container, or alternatively, rinse separately in a bucket of water and pour this into the spray tank.
6. Check the container thread and the outside surfaces of the container and, if contaminated, rinse with a hose into the spray tank.
7. Look inside the container to ensure that thorough cleaning has occurred.
8. Let the container dry completely (this may take several days), then replace the cap.
9. Store containers where they can remain clean and dry until they can be taken to a collection or disposal site.

[8]http://www.drummuster.com.au/wp-content/blogs.dir/3/files/2011/08/drummuster-effective-rinsing-brochure.pdf?phpMyAdmin=afc50bbf10et2e46ef05

Triple-rinsing

Triple-rinsing is a three-stage manual rinsing process, involving the following steps:

1. Remove the cap from the container.
2. Empty the contents into the spray tank and allow the container to drain for an extra 30 seconds after the flow reduces to drops.
3. Fill the container with water to between 20% and 25% of its capacity.
4. Replace the cap securely.
5. Shake, rotate, roll or invert the container vigorously for at least 30 seconds, so that the rinse reaches all inside surfaces. For 200 L drums, rolling between two people is advised.
6. Remove the cap. Add the rinsate from the container into the sprayer tank. Let it drain for an extra 30 seconds after the flow reduces to drops.
7. Repeat steps 3–6, two more times.
8. Check the container thread and the outside surfaces of the container and, if contaminated, rinse with a hose into the spray tank.
9. Look inside the container to ensure it is thoroughly clean.
10. Wash the cap.
11. Let the container dry completely (this may take several days), then replace the cap.
12. Store containers where they can remain clean and dry until they can be taken to a collection or disposal site.

2.7 Environmental protection

Any pesticide material that does not reach or remain on the target may pollute the atmosphere, water and soil. These are important natural resources and operators have a legal responsibility to avoid contaminating them. Potential sources of pesticide pollution include:

- drift of droplets in air away from the target area
- pesticide transported by water from the target area:
  - leaf run-off due to excess spray volume or overly large droplets
  - irrigation or rainfall on recently sprayed areas
- droplets falling on soil where there is incomplete canopy cover by target foliage
- rinsate from equipment washing and spray mixing
- leaching from pesticide treated potting mixture.

ATMOSPHERIC CONTAMINATION

Pesticide droplets that are carried in the air away from the target can cause significant damage to other, non-target plants and unprotected people, soil and water. This is commonly referred to as 'spray drift' and is the main theme of chapter 3 of this manual.

SOIL CONTAMINATION

Pesticides contacting the soil may be adsorbed on soil minerals and organic matter or remain in a soluble form that can be moved by water. Contaminants may leach into the water directly or may be carried on soil particles, particularly during storms and irrigation. Contaminated soil also creates hazards through direct skin exposure to the soil, inhalation of pesticide in dust or vapours moving into the air. Persistent pesticide contamination in soil can move into the surrounding environment over time, thus creating an ongoing source of pollution.

WATER CONTAMINATION

Water rapidly spreads pollution through the environment. Pesticides can remain active even at very low concentrations, creating adverse impacts on environmental and community health. Many pesticides are toxic to mammals and pose a direct health hazard. Water in populated areas is tested regularly for contamination and the likelihood of poor management being identified and prosecuted is high. Further, many birds and aquatic life forms (e.g. fish and crustaceans) are extraordinarily sensitive to insecticides and herbicides. Pesticide pollution exposes operators to prosecution under state laws governing environmental protection.

Pesticide residues can also be carried by water to the watertable. These contaminants are no longer exposed to the normal biological and physical factors such as micro-organisms, heat, light and air that degrade pesticides. Thus, groundwater contamination can be very persistent.

PESTICIDE DEGRADATION

While pesticides may have a shelf-life of two or more years in storage as concentrated form, dilute sprays in the natural environment are expected to degrade more swiftly. This is a major consideration in the creation of product advisory information during registration.

Factors that increase the breakdown of pesticide molecules include:

- exposure to direct sunlight (UV)
- soil and plant micro-organisms
- high temperature
- filtering, through sand, vegetation or organic matter
- aeration (if in water)
- plant metabolism.

Table 5 contains data on the breakdown and persistence of some pesticides in the environment. While this illustrates the general differences between types of chemical, actual performance will depend strongly on soil type, water quality and other environmental factors.

MANAGING PESTICIDE CONTAMINANTS IN SOIL AND WATER

Assess the pathway of drainage water from areas of pesticide application. What sensitive areas are in the downstream environment? Consult each SDS to determine the specific risks each pesticide poses, including all soil and potting-mix treatments. What flows of water are expected under normal operation and during floods?

Due to their intense management of production areas, nurseries are more able to manage water than most other plant industries. When designing drainage for a production area consider ways to maximise the factors that increase pesticide degradation. For example, if soil is well drained, seal the floor of the production area with a plastic sheet under the gravel to prevent water travelling down into the soil profile. Expose water leaving the target area to unpasteurised soil and sunlight and ideally filter it slowly through a sand bed. If water can be collected, do so in shallow, aerated ponds, with reeds or other water plants. If water is otherwise of suitable quality, it may be economical to treat it and recycle it for re-use as irrigation water, which further decreases risks posed to the surrounding community.

The quality of water leaving commercial properties is likely to come under increasing scrutiny in the near future, and careful planning of growing areas now may help to avoid costly liability later.

To reduce the risk of polluting soil and water with pesticide:

- Plan to leave most spray on the target:
  - » avoid run-off, don't over-spray or use the largest droplet sizes, which can roll off leaves
  - » avoid drift from the target area.
- Ensure the correct rate per area or concentration is being applied at the correct frequency and use properly calibrated equipment.

Table 5. Physical properties and predicted mobility of selected pesticides, From: http://npscolorado.com/xcm177.pdf

Trade name	Common name	Soil sorption index	Water solubility	Soil half-life	Predicted mobility Surface runoff	Predicted mobility Leaching
Herbicides		(K_{oc})	(ppm)	(days)		
Aatrex	atrazine	100	33	60	medium	small
Banvel	dicamba	2	500,000	14	small	large
Basagran	bentazon	35	2,300,000	20	medium	large
Bladex	cyanazine	190	170	14	medium	medium
Buctril	bromoxynil	190	<1	5	medium	small
Curtail	clopyralid	1	300,000	30	small	large
Dacthal	DCPA	5000	<1	100	large	small
Dual	metolachlor	200	530	20	medium	medium
Eptam	EPTC	280	375	30	medium	medium
Eradicane	EPTC	280	375	30	medium	medium
Far-Go	triallate	2400	4	82	large	small
Goal	oxyfluorfen	100,000	<1	35	large	small
Gramoxone	paraquat	100,000	1,000,000	500	large	small
Lasso	alachlor	170	240	15	medium	medium
Prowl	pendimethalin	24,300	<1	90	large	small
Roundup	glyphosate	24,000	900,000	47	large	small
Sencor	metribuzin	41	1220	30	medium	large
Stinger	clopyralid	1	300,000	30	small	large
Sutan	butylate	126	46	12	medium	medium
2,4-D Amine	2,4-D amine	20	796,000	10	small	medium
Tordon	picloram	16	200,000	90	small	large
Treflan	trifluralin	7000	<1	60	large	small
Velpar	hexazinone	54	33,000	90	medium	large
Insecticides						
Ambush	permethrin	86,600	<1	32	large	small
Asana XL	esfenvalerate	5300	<1	35	large	small
Counter	terbufos	3000	5	5	medium	small
Cygon	dimethoate	8	25,000	7	small	medium
Diazinon	diazinon	500	40	40	medium	medium
DiSyston	disulfoton	1600	25	5	medium	small
Dyfonate	fonofos	532	13	45	large	medium
Endocide	endosulfon	2040	32	120	large	small
Furadan	carbofuran	22	351	50	small	large
Kelthane	dicofol	8,000,000	1	60	large	small
Malathion	malathion	1800	145	1	small	small
Orthene	acephate	2	818,000	3	small	small
Parathion	parathion	5000	24	14	large	small
Penncap-M	methyl parathion	5100	60	5	medium	small
Pounce	permethrin	86,000	<1	32	large	small
Pydrin	fenvalerate	5300	<1	35	large	small
Sevin	carbaryl	200	114	10	medium	small
Temik	aldicarb	30	6000	30	small	large
Thimet	phorate	2000	22	90	large	small

- If the soil is naturally well drained, use an impermeable layer under the production area to avoid groundwater contamination and consider recycling run-off to filters, ponds etc.
- Prevent erosion of soil that may receive spray.
- Pesticide-treated potting soil is contaminated. Do not allow water to run through it and then to waste. Reuse or allow it to break down where it cannot drain into an uncontrolled waterway. Drainage systems should be designed to collect and hold run-off water on site.

2.8 The law and nursery chemicals

Laws exist at both the federal and state level to regulate the use of pesticides. These are aimed at ensuring the safety of operators, the environment and the community. In general, responsibility for pesticides prior to the point of sale is regulated by federal legislation and the responsibility for transport, storage and application after sale is regulated by separate legislation in each state and territory.

DISCLAIMER

This manual attempts only to outline the areas of legislation concerned with pesticide management and does not seek to provide information on the specific laws or their application in the states and territories of Australia. Laws and practices vary between states, as do the application of some federal standards.

These are subject to constant revision and up-to-date information should be sought for each inquiry. To ensure you are aware of the Acts and Regulations that may affect the way you operate, contact your state Nursery Industry Development Officer for more details.

Other reliable sources of information include:

- commonwealth, state and territory departments of agriculture, primary industries or lands or environment
- certified agricultural safety trainers e.g. ChemCert.

See contact details on pages 112–114 for ways to obtain further information on agricultural pesticide use legislation for each state in Australia.

DUTY OF CARE

People handling pesticides, and their employers, have a duty of care to comply with all safety requirements of storage, handling and use. Duty of care legislation in contract or common law covers acts or omissions that cause harm. It is the responsibility of workplace managers to ensure safe practice and they are directly responsible for the compliance of employees in the workplace. They are also responsible for the safety of all equipment used, employee protection from exposure to risk and protection of the environment.

FEDERAL LAW

Australian Pesticide and Veterinary Medicines Authority (APVMA)

For a pesticide to be sold or legally used in a nursery in Australia it must be registered by APVMA. APVMA examines each product in the areas of:

- human toxicology
- environmental impact
- occupational health
- efficacy.

APVMA invites public comment before granting clearance or otherwise. It may also administer 'minor use', 'permit' and 'off-label' schemes, usually in conjunction with relevant state departments, to supervise small market uses not large enough to support the cost of generating normal data submission packages and label extensions.

National Standards (AS)

Australian Standards exist for storage and handling pesticides. Each state has legislation that covers these areas and recognition and application of the national standards varies widely between states. The current relevant Australian Standards are:

- AS 1940 (2004) *The storage and handling of flammable and combustible liquids*
- AS 2507 (1998) *The storage and handling of agricultural and veterinary chemicals*
- AS/NZS 4452 (1997) *The storage and handling of toxic substances*
- AS/NZS 3833 (2007) *The storage and handling of mixed classes of dangerous goods, in packages and intermediate bulk containers*

STATE AND TERRITORY LAW

Once clearance has been given for sales to proceed, a pesticide is subject to the legislation of each state. This involves a number of different legal Acts with their accompanying Regulations. In some cases the formal legislation is supported by 'codes of practice' or 'compliance guidelines', which are documents designed to assist in understanding what the law requires.

It is important that nursery operators are aware of the regulations that may affect or limit the types of operations they may wish to carry out in each state or territory. The current AgSafe® *Accreditation Training Manual* (2002) provides an excellent summary of this area on a state-by-state basis.

Examples of SOME areas where legislation exists relating to the nursery industry include:

- the use of particular pesticides and how they may be applied
- the operation of particular pieces of equipment, and where they may be operated
- workplace health and safety Regulations and who may apply pesticides
- health Acts and Regulations that determin how and where pesticides may be stored, used and disposed of
- environmental protection Acts that encompass water, air and noise management
- noise pollution Regulations for powered equipment
- numerous others, depending on the location of the nursery.

In some regions within specific states special, more restrictive regulations apply to the use of agricultural chemicals. For example in Victoria, Agricultural Chemical Control Areas (ACCAs) exist where the use of some chemicals is prohibited unless authorisation and a permit has been received that includes notifying the local authority of the time, date and exact location of the proposed chemical application.

Occupational health and safety Legislation

There is also considerable legislation that regulates pesticide use, even though not directly addressing it. Of particular interest for managers and operators are laws concerning occupational health and safety. These laws generally cover:

- identification of hazards
- risk management
- risk reporting
- activities in the workplace
- emergency response (safety, first aid, spill management)
- facilities
- personal protective equipment
- hazardous substances
- training monitoring and records.

Workplace managers are directly responsible for employee compliance to these laws.

A process of legislative harmonisation is currently underway nationally to bring states under the standardised *Work Health and Safety Act 2011*. The main object of this process is to provide for a balanced and nationally-consistent framework to secure the health and safety of workers and workplaces. The national legislation has already been adopted by some states and territories while others are operating under temporary transitional arrangements and others are unwilling to sign up to the proposed Act. It is recommended that advice be sought from the relevant state or territory government to determine the progress of the harmonisation process at the time of reading. Links to all agencies are available from http://www.safeworkaustralia.gov.au or by calling 1300 551 832.

Table 6. Occupational health and safety legislation in Australian states

State/territory	Acts and Regulations
Australian Capital Territory	*Work Health and Safety Act 2011*
New South Wales	*Work Health and Safety Act 2011*
Northern Territory	*Work Health and Safety (National Uniform Legislation) Act 2011*
Queensland	*Work Health and Safety Act 2011*
South Australia	*Work Health and Safety Act 2012*
Tasmania	*Work Health and Safety Act 2012*
Victoria	*Occupational Health and Safety Act 2004*
Western Australia	*Occupational Safety and Health Act 1984*

CHAPTER 3.

SUITABLE CONDITIONS FOR PESTICIDE APPLICATION AND MANAGING SPRAY DRIFT

Spray drift is a major consideration in relation to the safe use of pesticides.

Spray drift is the movement of a pesticide (as droplets in the air) outside the intended target area. This off-target movement of pesticide has the potential for injury or damage to humans, plants, animals, the environment or property.

Spray drift does not include off-target movement of a chemical due to post-spray volatilisation or movement in water, soil or organisms, although this chemical movement can also be very damaging (see sections 2.5 to 2.7).

It is recognised that nearly all spray application of pesticide results in some spray drift. However, if uncontrolled and excessive, spray drift can cause:

- damage to crops in neighbouring areas
- contamination of neighbouring crops resulting in illegal residues on produce
- loss of expensive chemical and reduced efficacy on target pests
- death of beneficial organisms such as bees, and predators and parasites of pest organisms
- environmental contamination
- adverse publicity and community concern.

Spray drift is usually the result of:

- spraying in unsuitable weather conditions
- using spray equipment inappropriately (i.e. use inconsistent with manufacturer's instructions or training guidelines)
- using an unsuitable (e.g. unregistered or unapproved) pesticide formulation for a particular use or in a particular area
- failing to identify and allowing spray to drift onto susceptible non target areas
- using a droplet size that is too small.

In plant nursery operations drift can occur internally to other parts of the nursery (e.g. neighbouring plants or areas where other staff are working) or externally to the nursery (e.g. neighbouring houses or fields). It is important to consider the potential for both internal and external drift before undertaking the application of pesticides.

3.1 Managing spray drift

There are four main methods that can be used to reduce spray drift in the nursery. These are:

1. Control droplet size when applying sprays or use solid formulations such as granules.
2. Use appropriate application techniques.
3. Select the correct meteorological conditions.
4. Use buffer zones (including vegetative and artificial structures).

DROPLET SIZE

Droplet size is probably the single most important factor in managing potential pesticide spray drift. Because large droplets fall towards the ground significantly faster than small droplets, the airborne transport of droplets is significantly reduced if small droplet production is kept low.

However, all droplets used for spraying pesticides are small! Droplets are measured in micrometres (µm). It is easy to refer to droplets of 10, 100 or 500 µm, forgetting that 10 µm and even 100 µm droplets may not be visible to the naked eye.

As an example, the full stop at the end of this sentence is approximately 300 µm in diameter. A micrometre is 1/1000 of a millimetre (mm) and thus a 500 µm droplet is half a millimetre in diameter. A 500 µm diameter droplet is considered a large droplet in spray application technology.

Droplet behaviour under optimum spraying conditions

In general terms we can say that droplets in the following size ranges will behave as described below:

Approximate droplet size	Expected behaviour under suitable spraying conditions
Less than 50 µm	If water based, will evaporate quickly and will typically be lost before reaching the target.
Droplets 50–150 µm	Will move with air movement (wind), and may move off-target. However, if managed well under good spraying conditions, they can improve target penetration and coverage.
Droplets < 200 µm	Considered 'driftable' because they may reduce in size due to evaporation (if water based), and hence move with the wind.
Droplets > 350 µm	May bounce or run off without the addition of adjuvants, hence may not be useful for spraying foliage.

Droplets between 100 and 350 microns are considered the MOST USEABLE fraction of the spray cloud when spraying foliage (e.g. useful for many insecticide sprays).

ESTIMATORS OF DROPLET SIZE IN THE DROPLET CLOUD

Unfortunately, no practical spray nozzles are currently available to produce droplets that are all the same size. All commercial nozzles generate a range of droplet sizes. It is therefore difficult to exactly describe the output from a spray nozzle in terms of droplet size produced. Some pesticide labels describe the droplet size to be used by an applicator in terms of the volume median diameter (VMD).

The VMD divides the droplet spectrum into two equal parts. One half of the total spray volume is made up of droplets larger than the VMD and the other half made up of droplets smaller than the VMD. A diagrammatic representation of VMD is shown in figure 5. If droplets from a spray nozzle could be lined up in order of size, the VMD indicates the droplet size that would divide the sample in half by volume.

Two different nozzles may produce the same VMD but may actually produce quite a different droplet cloud. One nozzle may produce droplets that all fall in a very narrow band around the VMD while the other nozzle may produce a broad spectrum of droplet sizes.

Most hydraulic nozzle manufacturers' catalogues now indicate droplet size produced using the spray quality categories of very fine (the smallest), fine, medium, coarse and very coarse (the largest). Refer to table 7 for the designation of droplet size ranges in microns. An example from the Spraying Systems Co. catalogue is shown in figure 6[9]. This scheme of describing droplet size was originally devised by the British Crop Protection Council (BCPC) during the mid 1980s as a means of standardising the relationship between a variety of measurement systems and describing the entire droplet spectrum generated by a spray nozzle. Currently, air induction nozzles are not included in the classification scheme. To reduce drift, select nozzles and pressure settings that produce a coarse or very coarse spray.

[9] http://www.spray.com/cat75/automatic-m/index.html

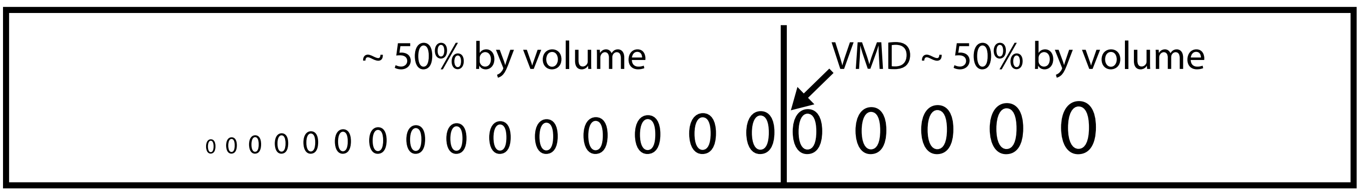


Figure 5. Illustration of the volume median diameter (VMD)

3.2 Understanding spray quality classifications

A number of nozzle manufacturers provide information on the spray quality from their hydraulic nozzles (for ground application) at various pressures according to the British Crop Protection Council (BCPC) and American Society of Agricultural & Biological Engineers (ASAE S572.1) standards.

Table 7. ASABE droplet categories, average sizing and potential uses

ASAE category	Colour code	VMD of droplet cloud	Potential uses
Extremely fine (XF)	purple	< 60 µm (microns)	insecticide
Very fine (VF)	red	61–144 µm	insecticide
Fine (F)	orange	145–235 µm	fungicide
Medium (M)	yellow	236–340 µm	herbicide/insecticide
Coarse (C)	blue	341–403 µm	herbicide
Very coarse (VC)	green	404–502 µm	herbicide
Extremely coarse (XC)	white	503–665 µm	herbicide
Ultra coarse (UC)	black	> 500 µm	herbicide

Examples of spray quality charts for various nozzle types

PRE-ORIFICE

HARDI ISO LD	bar					
	1.5	2.0	2.5	3.0	4.0	5.0
LD-110-01	M	M	M	M	M	F
LD-110-015	M	M	M	M	M	M
LD-110-02	M	M	M	M	M	M
LD-110-025	C	C	M	M	M	M
LD-110-03	C	C	C	C	M	M
LD-110-04	C	C	C	C	C	M

LOW PRESSURE AIR INDUCTION

HARDI ISO MINIDRIFT	bar					
	1.5	2.0	2.5	3.0	4.0	5.0
MINIDRIFT-015	C	C	C	C	M	M
MINIDRIFT-02	VC	C	C	C	C	M
MINIDRIFT-025	VC	VC	C	C	C	M
MINIDRIFT-03	VC	VC	VC	C	C	C
MINIDRIFT-04	VC	VC	VC	VC	C	C

HIGH PRESSURE AIR INDUCTION

HARDI ISO INJET	bar					
	3.0	4.0	5.0	6.0	7.0	8.0
INJET - 01	VC	VC	VC	C	C	C
INJET - 015	VC	VC	VC	VC	VC	C
INJET - 02	VC	VC	VC	VC	VC	VC
INJET - 025	VC	VC	VC	VC	VC	VC
INJET - 03	VC	VC	VC	VC	VC	VC
INJET - 04	VC	VC	VC	VC	VC	VC

HYBRID PRE-ORIFICE

Turbo TeeJet®	bar									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0
TT110-01VP	C	M	M	M	F	F	F	F	F	F
TT110-015VP	C	C	M	M	M	M	M	F	F	F
TT110-02VP	C	C	C	M	M	M	M	M	M	F
TT110-025VP	VC	C	C	M	M	M	M	M	M	M
TT110-03VP	VC	C	C	C	C	M	M	M	M	M
TT110-04VP	XC	VC	C	C	C	C	C	C	M	M

AIR INDUCTED TWIN JET

Air Induction Turbo TwinJet®	bar								
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
AITTJ110-02VP	VC	VC	VC	C	C	C	C	C	C
AITTJ110-025VP	VC	VC	VC	C	C	C	C	C	C
AITTJ110-03VP	XC	XC	VC	VC	VC	C	C	C	C
AITTJ110-04VP	XC	XC	VC	VC	VC	C	C	C	C

HYBRID AIR INDUCTION

Turbo TeeJet® Induction	bar									
	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	7.0
TTI110-015VP	UC	UC	UC	UC	XC	XC	XC	XC	XC	XC
TTI110-02VP	UC	UC	UC	UC	UC	UC	XC	XC	XC	XC
TTI110-025VP	UC	UC	UC	UC	UC	UC	XC	XC	XC	XC
TTI110-03VP	UC	UC	UC	UC	UC	UC	XC	XC	XC	XC
TTI110-04VP	UC	UC	UC	UC	UC	UC	XC	XC	XC	XC

UC	XC	VC	C	M	F	VF
Ultra Coarse	Extra Coarse	Very Coarse	Coarse	Medium	Fine	Very Fine

Figure 6. BCPC classification scheme used to define spray quality by spraying systems (F=fine, M=medium, C=coarse, VC=very coarse)[9]

An example of the use of these classifications is provided below, which is an excerpt from the Spraying Systems TeeJet® catalogue[9].

Figure 7. Spray qualities at various pressures for XR nozzles (V=very fine, F=fine, M=medium, C=coarse)

Spray Quality and Nozzle Outputs

Typical of 110° conventional flat fan nozzles (not reduced drift fan nozzles).
Note: Check with your nozzle supplier for the actual spray quality for their nozzles.

Nozzle code		11001	110015	11002	11003	11004	11005	11006	11008
ISO colour		Orange	Green	Yellow	Blue	Red	Brown	Grey	White
Pressure - Bar	1.5	0.29	0.42	0.56	0.85	1.13	1.41	1.70	2.26
	2.0	0.33	0.49	0.65	0.98	1.31	1.63	1.96	2.61
	2.5	0.37	0.55	0.73	1.10	1.46	1.82	2.19	2.92
	3.0	0.40	0.60	0.80	1.20	1.60	2.00	2.40	3.20
	3.5	0.43	0.65	0.86	1.30	1.73	2.16	2.59	3.45
	4.0	0.46	0.69	0.92	1.39	1.85	2.31	2.77	3.69
		Nozzle output = litres/minute							

Spray Quality	Fine	Fine/Medium	Medium	Medium/Coarse	Coarse

With hydraulic nozzles it is possible for one type of nozzle to produce a range of spray qualities depending on the pressure of operation. The higher the pressure, the smaller the droplets produced will be, hence the finer the spray quality it is assigned.

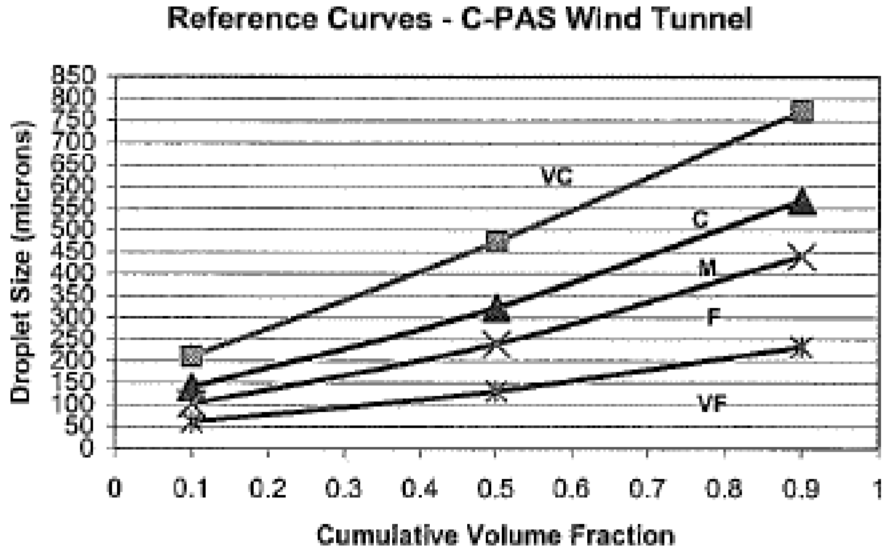
WHAT ARE THE BCPC and ASAE S572.1 CLASSIFICATIONS?

The BCPC and ASAE S572.1 classifications describe spray quality (the range of droplet sizes produced by a nozzle). This spray quality is determined by comparing a nozzle's output of different sized droplets (droplet spectrum) at a given pressure against the outputs of a set of standard reference nozzles. This is done using a laser-based instrument and, due to the comparative nature of the standard, nozzles will achieve the same classification regardless of testing technique.

There are three key measurements used in determining the spray quality classification. These describe the proportion of volume through the nozzle resulting in different size categories.

Key measurements	Proportion of volume in different size categories
D[v,0.1]	10% of the spray volume produced by the nozzle results in droplets smaller than this size (diameter in microns).
D[v,0.5]	Also known as the volume mean diameter (VMD). 50% of the spray volume produced by the nozzle is in droplets smaller than this size (diameter in microns). 50% of the spray volume is in droplets larger than this size.
D[v,0.9] =	90% of the spray volume produced by the nozzle is in droplets smaller than this size (by diameter in microns).

These three measurements are plotted on a graph to produce boundaries for each spray quality classification. A reference curve from a Malvern laser instrument, as shown in figure 8, is used for this purpose.



Droplets smaller than a particular size (microns). For example 0.1 is the D[v,0.1], 0.5 is the D[v,0.5] also known as the VMD and 0.9 is the D[v,0.9].

Figure 8. Example of BCPC reference curves used to determine spray quality

USING THE REFERENCE CURVES TO UNDERSTAND NOZZLE OUTPUTS

By using the reference curves in conjunction with the spray quality classifications, nozzle outputs can be better understood. For example, a nozzle that has been assigned a FINE spray quality will produce droplet sizes within a particular range.

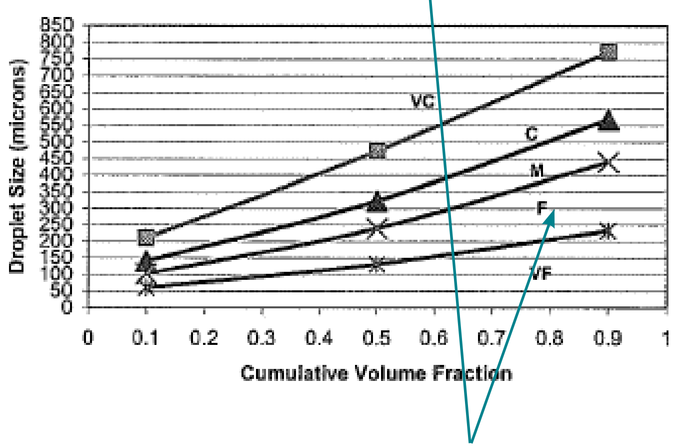
Figure 9 shows that a fine nozzle will have a D[v,0.1] of 60–100 µm. This means that 10% of the spray volume is in smaller droplets than these sizes. A fine nozzle will also have a D[v,0.5] or VMD of 131–239 µm.

Where a particular nozzle can produce a FINE spray quality at a range of spray pressures, the droplet sizes produced will be largest when operated at the lowest pressure required to stay within the FINE classification (towards 239 µm).

If the nozzle is operated at the highest possible pressure to stay within a FINE spray quality the droplet sizes produced will be smaller. It is possible that the VMD could be as small as 131 µm.

By understanding how droplets of various sizes behave in differing conditions, the reference charts can be used to estimate the spread of droplet sizes produced when operating nozzles to deliver spray. Pesticide applications can be better planned using this information.

HYBRID PRE-ORIFICE	Turbo TeeJet®	bar									
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0
	TT110-01VP	C	M	M	M	F	F	F	F	F	F
	TT110-015VP	C	C	M	M	M	M	M	F	F	F
	TT110-02VP	C	C	C	M	M	M	M	M	M	F
	TT110-025VP	VC	C	C	M	M	M	M	M	M	M
	TT110-03VP	VC	C	C	C	C	M	M	M	M	M
	TT110-04VP	XC	VC	C	C	C	C	C	C	M	M



A nozzle that has been assigned a FINE spray quality will produce droplet sizes within a particular range.

Figure 9. Using the reference curves and spray quality charts

USING THE BCPC SPRAY QUALITY CLASSIFICATIONS TO SELECT NOZZLES

When selecting a nozzle for a particular purpose, an understanding of what the classifications mean in terms of the types of droplets each classification includes is required. The behaviour of various droplet sizes can then be used to select the appropriate nozzle for particular situations. For example, in a situation where drift would be of particular concern, it is important that after determining the desired droplet size for the target (which should be close to the VMD) a nozzle is selected with the largest possible size of 'fine' droplets D [v,0.1].

DROPLET SIZES FOR DIFFERENT TARGETS

Regardless of the target, the objective should be to obtain the best coverage possible while minimising the off target losses, such as drift or run-off, as much as practically possible. The understanding of the droplet sizes required for different targets is gradually improving. Recommendations for the application of different pesticides onto different targets are continually being developed so it is important to keep up-to-date with developments.

Label instructions need to be followed for the correct application of particular product types. Where this information is not provided the general principles provided in table 8 can be applied.

Table 8. General guide to application of different product type

Product Types	Spray classification	Comment
Insecticides		
Contact	Fine–Medium	If using the finer end of the droplet spectrum.
Systemic	Fine–Medium	If using medium, stay at the finer end.
Fungicides		
Protectant	Very fine–Fine	Be aware of droplet spectrum and evaporation.
Curative/eradicant	Fine–Medium	If using medium stay at the finer end.
Herbicides		
Soil Applied	Coarse	Use appropriate water volumes to ensure coverage.
Contact	Medium	Medium preferred where conditions allow.
Systemic	Medium–Coarse	Use at the coarse end and monitor conditions.

NOZZLE TYPE

Nozzle selection is an important factor when considering spray drift. It is well known that spray drift can be minimised—and spray efficiency maximised—by selecting an appropriate nozzle for a spray job. Most pesticide labels do not provide recommendations for a specific nozzle for a particular job. However the ASAE categories (extremely fine, very fine, fine, medium, coarse, very coarse, extremely coarse and ultra coarse) enable the spray performance of most common hydraulic systems to be characterised. The system allows operators more choice in selecting a nozzle type, size and pressure for a particular task, provided the selected combination produces the droplet size that falls within the specified category. Notice that in the example shown in figure 6 that the droplet size generated by a Spraying Systems Turbo TeeJet® increases as orifice size is increased and spray pressure is reduced.

SPRAY PRESSURE

Spray pressure should be as low as possible, consistent with nozzle specifications and coverage requirements. Check the manufacturer's nozzle catalogues for recommended pressure of operation.

When the pressure at the nozzle is increased, most hydraulic nozzles generate a finer droplet spectrum. To reduce drift potential, use low pressures.

Many nozzle manufacturers now provide low pressure nozzles that can be operated as low as 100 kPa (where 100 kPa = 1 bar = 15 psi). This will be marked on the nozzle with the other specifications as 'LP'.

It is important to note that:

- spray volume should be controlled by changing nozzles not by changing pressure, i.e. selecting nozzles with a greater throughput to increase volume
- all sprayers should be fitted with an accurate, easy to read pressure gauge.

NOZZLE SPRAY ANGLE

A flat fan nozzle that has a wider spray angle will normally produce a thinner sheet of spray solution, which results in smaller droplets than will be produced by a narrower angle nozzle operating at the same pressure. For example a 110° flat fan can normally be expected to generate a finer droplet spectrum than an 80° flat fan operated at the same pressure with the same orifice size (and flow rate). In terms of drift control, the benefits of a lower nozzle height provided by a wide-angle nozzle, can outweigh the disadvantages associated with smaller droplet spectrum produced due to the wider angle nozzle.

SPRAY VOLUME

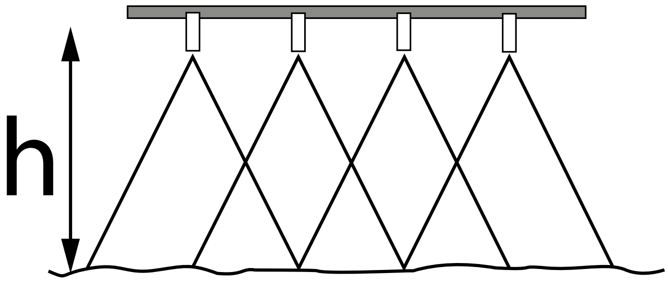
A larger nozzle orifice increases the droplet size when operated at the same pressure as a smaller nozzle orifice. It will also increase the rate of flow and thus the amount of spray used per unit of time. This results in the use of more carrier fluid per area at the same speed of application, and the concentration of pesticide should be lowered accordingly.

APPLICATION TECHNIQUES

Release height

Release height of the spray is an important factor that influences the potential for spray drift. The higher droplets are released, the greater the potential for drift. Release height of sprays should be as low as possible, consistent with nozzle specifications and target coverage requirements (see diagram below).

When boom sprayers are fitted with flat fan nozzles, boom height should not exceed the optimum height as specified by the nozzle manufacturer. The height (h) required to sufficiently overlap spray patterns varies depending on the angle of spray emission (e.g. 80°, 110°) from the nozzles. With most 110° flat fan nozzles, a minimum height of 35 cm, and a maximum of 50 cm, above the target is usually recommended.



Boom stability

On boom sprayers, adequate boom stabilisation is essential to prevent sway and dipping, which alter the height and evenness of spray. This is especially important for operation on uneven ground. Boom height may be lowered to produce less spray drift, although modification to nozzle number, type and orientation is usually required to maintain an even spray pattern across the boom. The use of wide-angle flat fan nozzles (e.g. 110°) usually permits lower boom heights to be used effectively.

3.3 Meteorology

The weather plays an important role in controlling the fate of pesticides applied as sprays. It is essential that operators engaged in spraying are aware of the immediate environmental parameters. Low cost, hand-held anemometers and psychrometers are available to monitor wind velocity and humidity respectively. The purchase of meteorological station data loggers is recommended for larger enterprises that regularly apply pesticides.

The spray operator must observe wind direction, wind speed, temperature and humidity, and check that they are within acceptable limits before spraying takes place.

The operator should record wind direction, wind speed, temperature and humidity prior to and during every spray operation.

RAINFALL AND IRRIGATION

It is important to time spray applications to avoid periods of rain or irrigation. Spraying onto leaves or other surfaces that are already wet dilutes most pesticide formulations and may lead to an increase in run-off, wasting the product and causing pollution. Wetting the sprayed surface after application can cause similar results depending on the 'rain-fastness' of the pesticide. Read product labels to determine appropriate practices. As a general rule, protectant pesticides (e.g. bordeaux mixture), which sit on target surfaces and contact pests directly remain vulnerable to washing off. Additives can be mixed with some formulations of pesticide to improve their durability on the target surface. Systemic pesticides are absorbed by plants if sufficient time for absorption is allowed prior to wetting and can remain active after wetting.

WIND

Direction

Droplets, particularly small ones, move with the air. Therefore, measuring the wind direction prior to and during application is essential. Importantly, the wind can be used to direct sprays away from identified susceptible areas. Do not spray when the wind is blowing towards susceptible areas.

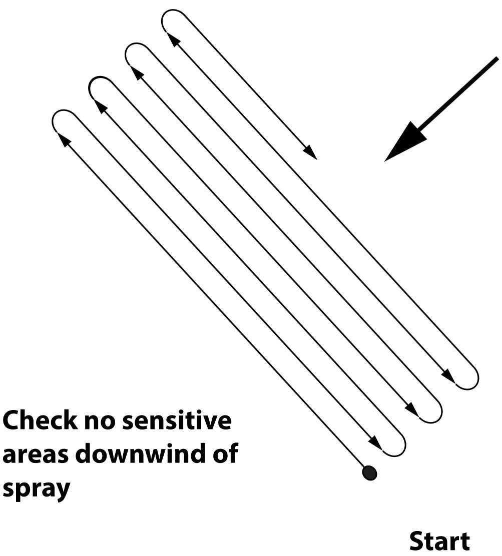
Spraying should, where possible, be carried out with a crosswind, working into wind towards the unsprayed area (see adjacent diagram). All spray operators should be alert to changes in wind direction during spraying and modify or cancel a spray program as necessary.

Wind speed

Wind speed should be about 3–15 km/hr for most spraying operations. Droplets, particularly medium and large droplets, move greater distances in stronger wind conditions so some forms of pesticide drift can be reduced if application is undertaken during low wind speed conditions. However, spraying should not normally take place if the wind is light and variable in strength or direction.

TEMPERATURE

Whenever possible, spraying should be avoided in high ambient air temperatures. Water-based sprays are prone to evaporation, which decreases droplet size. Small droplets fall more slowly and may even remain suspended in the air, increasing the likelihood of drift and decreasing the amount delivered to the target. This is particularly true when air temperatures are high and the relative humidity is low. Initial droplet size may be increased to compensate for this, or an adjuvant can sometimes be added to the formulation to decrease evaporation. In open areas, high temperatures also mean the onset of unstable atmospheric conditions, which make it difficult to control the movement of droplets.



HUMIDITY

Spraying of water-based sprays should not take place under conditions of high temperature and low humidity, i.e. when the wet bulb depression (a measure of evaporation potential) is greater than about 10°C. Thermometer-based whirling psychrometers or electronic hand-held instruments are available that can quickly assess relative humidity and temperature, both under shade structures and in the open.

ATMOSPHERIC STABILITY

Stability is a term used to describe the vertical movement and mixing of air in the atmosphere (see figure 10). If the atmospheric conditions are unstable, such as occurs on a summer afternoon, the dispersion rate of pesticide sprays may be high. Spray droplets or vapours can be lifted up rather than settling, resulting in increased off-target drift.

In conditions of moderate stability where there is air movement, turbulence is created when air moves over the ground or plant canopy. This mixes air into the leaves of the plants and can assist in even delivery of pesticide droplets to targets within a leaf canopy.

Air moving slowly (less than 5–10 km/h) toward the target, without updraughts, represents ideal spraying conditions for many hydraulic spray operations.

Under very stable conditions with little air movement, such as very early mornings, large droplets fall more vertically and an increased proportion of pesticide is deposited on upper leaf surfaces. Without air movement to swirl them into the canopy, very fine droplets may even fall so slowly as to evaporate before impact and remain suspended in the air, leading to increased risk of drift during later air movement.

Temperature inversions

If the sky is clear at night, the ground can lose heat rapidly. The ground then cools the air layers adjacent to the soil surface, particularly if humidity (and thus heat capacity of the air) is low. Under these conditions, air close to the ground becomes cooler than air above. Since this phenomenon is opposite to the normal condition of the atmosphere (temperature decreasing with height), the condition is called 'surface temperature inversion.'

Temperature inversions tend to suppress the vertical movement of air and therefore, in effect, present a

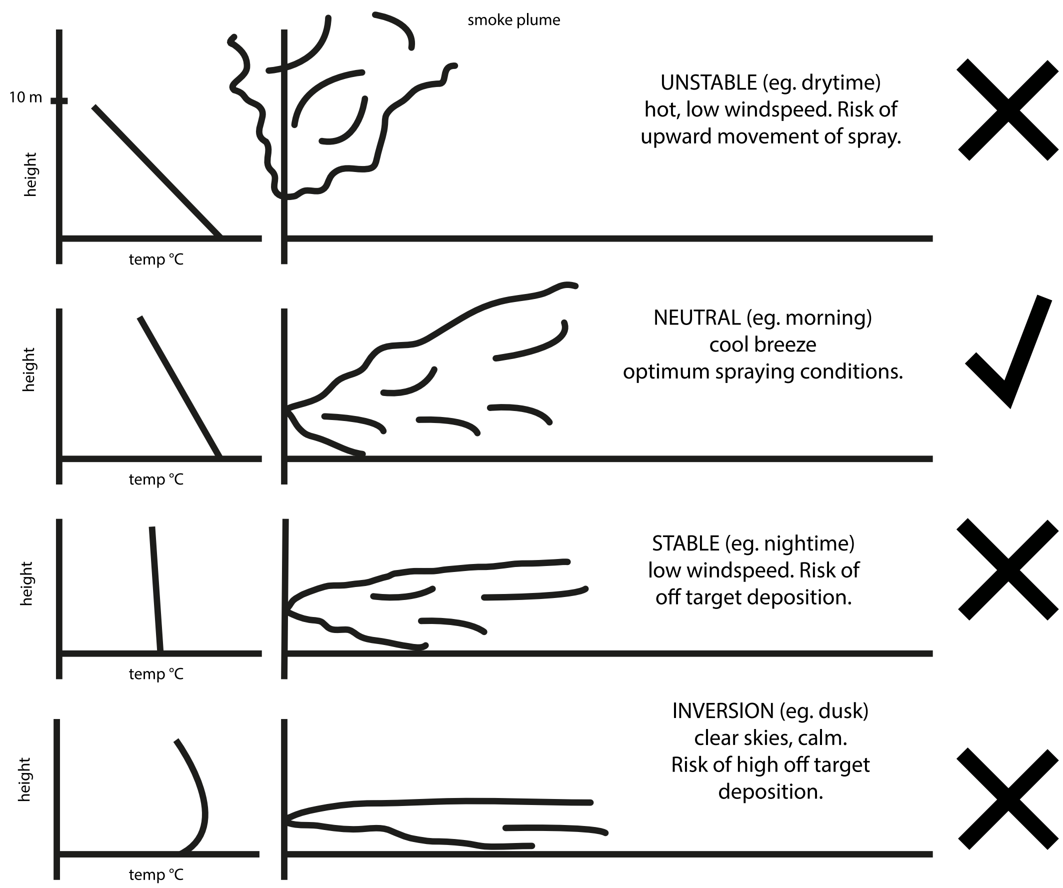


Figure 10. Basic guide to air stability showing the behaviour of smoke or dust under various stability conditions

barrier to the transport of small droplets to the crop canopy. Inversions usually form under very low wind speed conditions.

Spraying should be avoided under such circumstances, since small droplets are capable of remaining airborne for long periods after drifting above an inversion layer. This has been known to cause severe damage several kilometres away from where spraying took place.

Assessing conditions

Spraying should therefore ideally take place in neutral atmospheric conditions with slight air movement. The stability of the atmosphere can be assessed using smoke, or driving a vehicle along a dusty track. Movement of material up into the air indicates instability and concentration of smoke or dust within a thin layer indicates the presence of a surface temperature inversion.

3.4 Vegetative buffers

Trees and shrubs planted downwind of an agricultural area or nursery boundary can be used to capture droplets moving out of the sprayed area and thereby reduce spray drift. Their use has been trialled by several commercial nurseries.

PRINCIPLES OF BUFFERS

If a dense barrier is presented to airflow, air tends to flow up and over the barrier. This is illustrated in figure 11a, where the airflow deviation over a solid board (0% porosity) placed in a wind tunnel is shown. The region directly behind the barrier is characterised by low pressure and turbulent eddies. Dense, low porosity structures are less effective in trapping the droplets moving with the air except in the immediate region behind the barrier because small droplets (under 100 µm) move readily in the airstream and are carried above and around the barrier.

A porous barrier, however, allows some air to pass though its structure while still deflecting some airflow over the top. This is illustrated in figure 11b where a nylon mesh with 50% porosity (50% solid and 50% open) was placed in a wind tunnel. The figure shows that there was less deviation of air over the top of the barrier compared to the solid barrier. The airflow behind the barrier was also straighter and less turbulent than behind the solid barrier. With a porous barrier, droplets can be carried through a buffer and this increases the chance of capture within the buffer

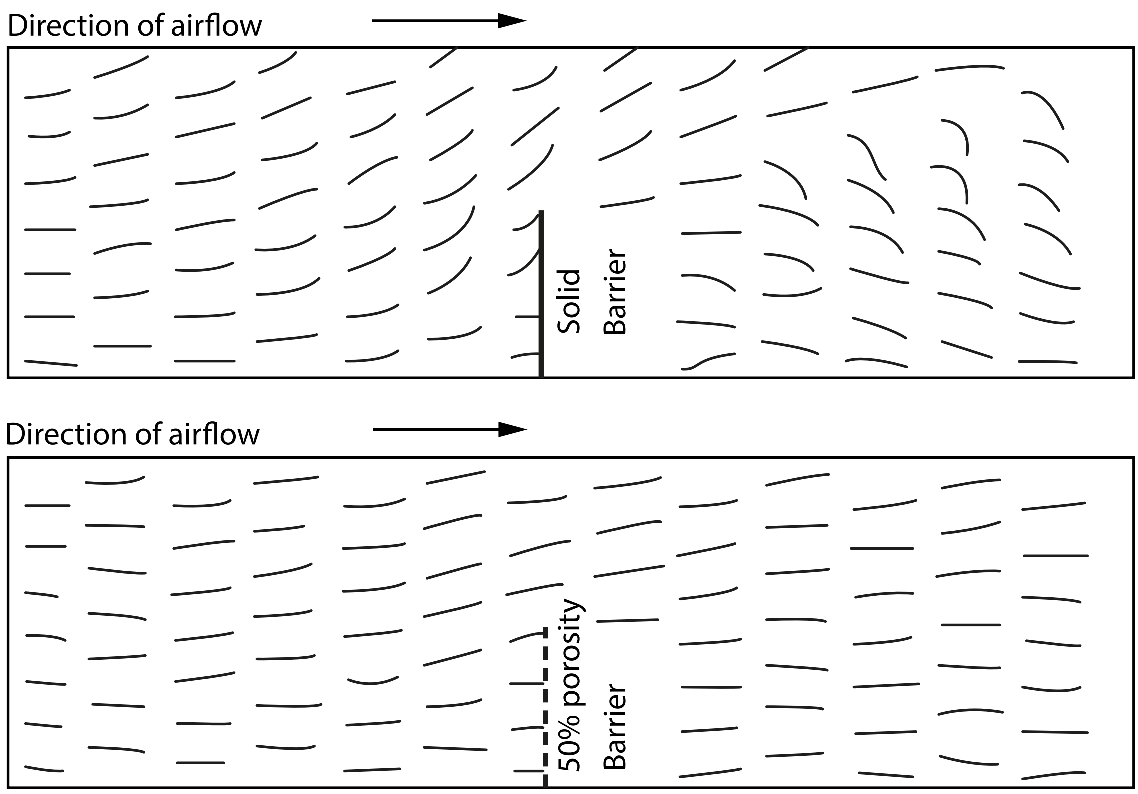


Figure 11a and 11b. Effect of barrier porosity on airflow characteristics structure. A porous barrier can effect a greater removal of spray droplets than a solid barrier.

Using vegetation as a buffer

In designing vegetative buffers, the primary aim is to maximise the catching surface for the spray droplets while also minimising the amount of airflow passing around the buffer. This is not designed to be a complete windbreak, but more of a strainer or filter. The aim of a vegetative buffer is to use the natural surfaces (leaves, stems, flowers and seeds) of the trees or shrubs to catch pesticide droplets as they move in the air through the vegetation. Vegetative elements that present a small frontal area to the moving droplets are the most successful at catching droplets. Trees such as the river she-oak (*Casuarina* spp.) that have thin, needle-like foliage and numerous small branches are particularly suitable. Large leaves that are covered in small hairs can also be very efficient at removing droplets. Most natural surfaces are not smooth. Plants may have a complex rough surface comprising small protruding spikes or hairs and leaf veins. All these factors help to increase the catch efficiency of the plant. Movement of the leaves caused by the flow of air around shrubs and trees also increases the efficiency of small droplet capture.

Constructed buffers

Due to the intense land use of nurseries, it can be more convenient to erect artificial buffers using shade cloth and timber posts. These require no growing time and have the added benefit of retaining humidity and reducing the vulnerability of stock to wind damage. Contact your state Nursery Development Officer for information on construction details, or read the Nursery Paper *Windbreaks, an investment in quality and profitability.*[10]

Height of buffers

Because turbulence causes dispersion of a spray cloud, and it 'spreads' vertically as well as horizontally, a vegetative barrier must be higher than the release height of the spray. The greater the density of the buffer (the lower the porosity), the higher a barrier needs to be in relation to the spray release height. Wind tunnel tests have shown that the minimum height of the barrier should be at least one and a half (1.5) times the release height of the spray for a barrier with 50% porosity. If the porosity is reduced to 40%, the minimum height of the barrier increases to double (2 times) the release height.

For a solid barrier the required height approaches infinity, so solid barriers are not suitable unless they entirely enclose the sprayed area (as per a poly or glasshouse). As a general guide, the minimum height of the buffer should be double the release height (see figure 12). For example, if spraying is conducted by hand at a release height of one metre, then the buffer height should be at least two metres.

Width of buffers

The wider the buffer, the greater their ability to reduce spray drift. With a wide buffer it is possible to increase the number of surfaces available for droplet collection without significantly reducing the airflow through the buffer. A wide buffer is impractical in many rural–urban interfaces, so a compromise may sometimes be needed.

Distance of buffers from spraying

The closer the vegetative buffer is to the release point, the greater the proportion of spray that will be intercepted. Figure 13 shows that a vegetative buffer at position A would tend to intercept a greater proportion of a spray cloud than a buffer located at position B. However, the

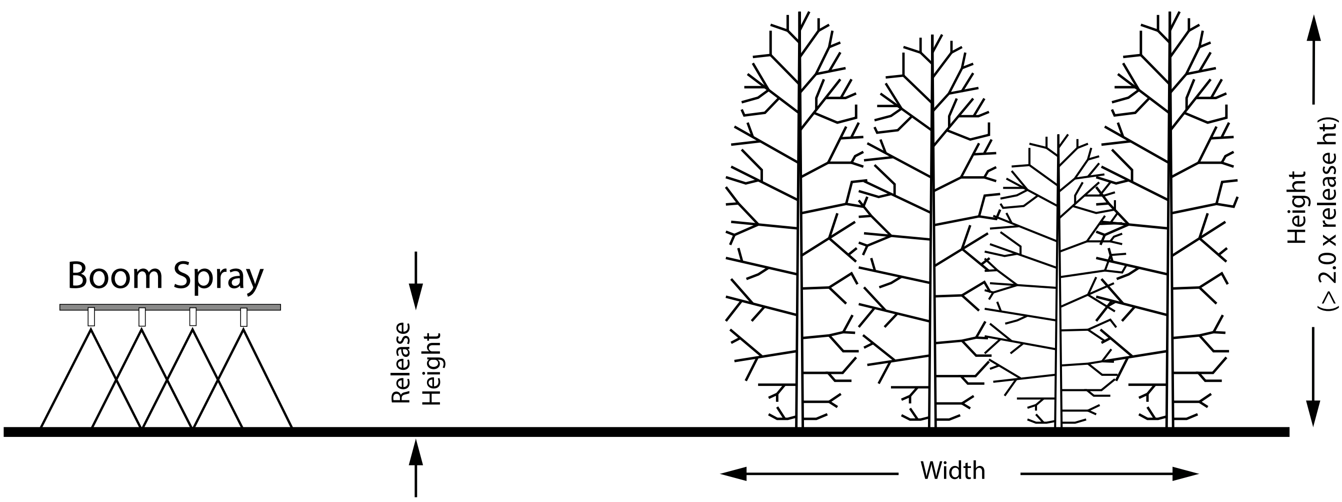


Figure 12. Optimum vegetative buffer dimension

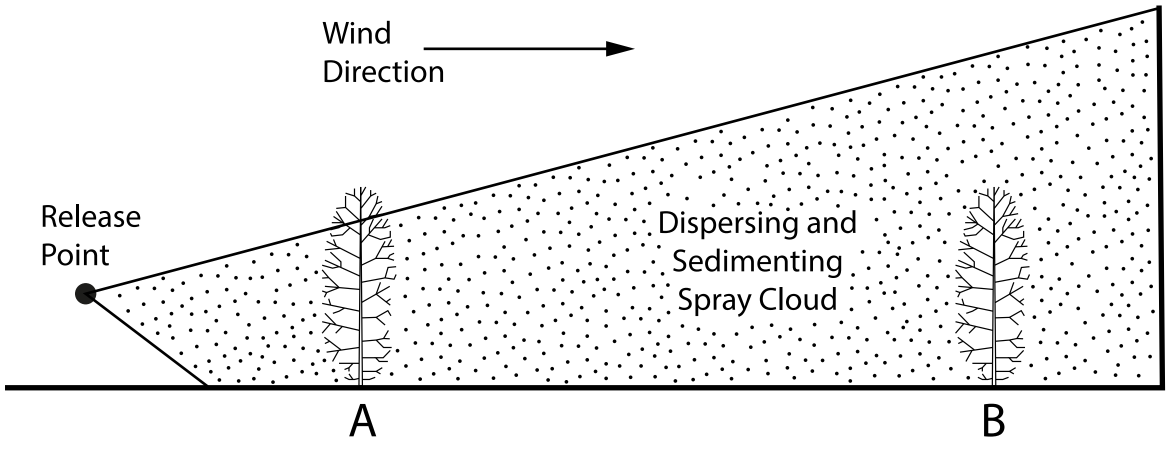


Figure 13. Effect of distance from release point

concentration through the spray cloud is not constant and usually tends to be greatest near ground level. A buffer at position B could still be expected to intercept a reasonable proportion of the airborne droplets.

[10] http://www.ngia.com.au/files/nurserypapers/NP_1999_11.pdf

PLANNING GUIDELINES IN QUEENSLAND

In 1997 the Department of Natural Resources in Queensland introduced the *Planning Guidelines: Separating Agricultural and Residential Land Uses*[11]. The guidelines have the following objectives:

1. To protect the use of reasonable and practicable farming measures that are practiced in accordance with the *Environmental Code of Practice for Agriculture* and associated industry-specific guidelines.
2. To minimise scope for conflict by developing where possible, a well-defined boundary between agricultural and residential areas and not interspersing agricultural and residential areas.
3. To minimise the impacts of residential development on agricultural production activities and land resources.
4. To minimise the potential for complaints about agricultural activities from residential areas.
5. To provide residents with acceptable environmental conditions in residential areas that are located adjacent to agricultural production areas.

The Queensland guidelines specify a minimum spray drift buffer width of 20 metres planted with trees and at least 10 metres clear of vegetation to either side of the vegetated area to give a total buffer width of 40 metres[11]. A schematic cross-section of this arrangement is shown in figure 14. A 20-metre clear area, (10 metres either side of the buffer) is included in the design to provide a fire break, allow access to the buffer for maintenance and limit solid structures immediately next to the buffer elements. Provided the requirements of the guidelines can be met by other means, the guidelines do allow buffer layouts to be altered. The Queensland guidelines provide a sound minimum basis for the construction of buffer areas between conflicting land uses.

[11] http://www.dsdip.qld.gov.au/resources/policy/plng-guide-sep-ag.pdf

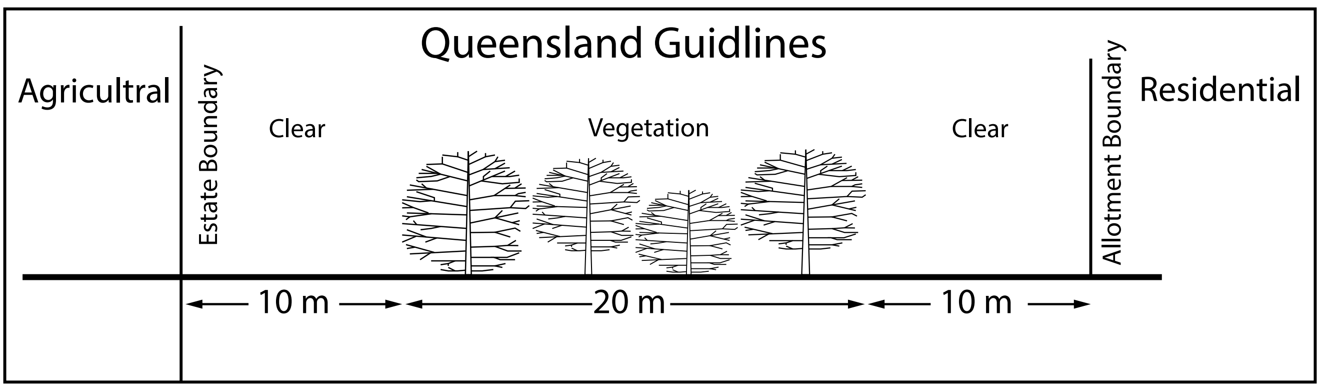


Figure 14. Schematic illustration of vegetative buffer required for spray drift mitigation as defined by *Planning guidelines: Separating agricultural and residential land uses* (DNR 1997)

SUMMARY

In summary, operators can manage off-target movement of sprays in the nursery if they:

- *Identify all areas around an area to be sprayed that could be susceptible to spray drift damage.*
- *Communicate on a regular basis with neighbours regarding proposed spray schedules and activities.*
- *Maintain a copy of relevant safety data sheets (SDS) for all pesticides stored and used.*
- *Read, understand and follow the pesticide product label prior to mixing and spraying.*
- *Observe and record wind direction, wind speed, temperature and humidity prior to and during application.*
- *Avoid spraying when air is moving toward susceptible areas.*
- *Avoid spraying if the wind is light and variable in strength or direction.*
- *Spray water-based sprays when temperatures are the lowest (in a 24 hr cycle).*
- *Avoid spraying water-based pesticides under conditions of high temperature and low humidity.*
- *Spray when atmospheric conditions are neutral.*
- *Avoid spraying during highly stable conditions or when surface temperature inversion exists.*
- *Spray with a crosswind and progress upwind.*
- *Ensure spray equipment is correctly calibrated and appropriate nozzle systems are selected.*

CHAPTER 4.

PESTICIDE APPLICATION EQUIPMENT AND TECHNIQUES

A wide variety of pesticide application equipment is available. Assess the suitability of the equipment for the specific task and choose appropriate application techniques.

4.1 Sprayer types

Sprayers used in plant nurseries are commonly classified according to the volume of spray they apply per sprayed area. Application type and delivery volumes are determined by the choice of nozzle. It is the nozzle that delivers the spray solution as spray droplets are distributed over the treatment area.

Nozzle selection is one of the most important considerations when selecting a sprayer. In this manual, nozzle types have been separated into three categories according to the way they are used when fitted to pesticide application equipment used in nurseries: 1. high volume, 2. low volume and 3. ultra low volume.

HIGH VOLUME

High volume sprayers are the most common types of sprayer used in nursery operations. Application rates range from about 200 L/ha to over 2000 L/ha. High volume sprayers are typically used where the label refers to spraying to run-off. Hydraulic nozzles such as flat fan and hollow cones or adjustable hand guns are typically used on high volume sprayers. These sprayers may range from small units such as the Silvan Selecta® range, up to large, purpose-built units such as the QuikSpray 9TBE®.

LOW VOLUME

Low volume sprayers are used as an alternative to high volume hydraulic sprayers for pesticide application in plant nurseries, particularly where label rates are expressed as a volume of chemical per unit volume of spray solution (e.g. 300 mL per 100 L of water). Although they may be more expensive, they may also provide better target coverage. Some low volume sprayers may also reduce the time required for spraying and, therefore, cost of labour. Low volume equipment typically uses

air-shear or spinning discs (commonly referred to as CDA or 'controlled droplet applicator' nozzles) to generate droplets. Examples of air-shear include the Silvan Turbomiser® and the Hardi® backpack mister. The ULVA+® and HERBI4® sprayers are examples of CDA technology.

ULTRA LOW VOLUME

Ultra low volume sprayers used in nursery applications are commonly called foggers and they apply very low volumes (less than 10 L/ha) of chemical mix. In some cases, the pesticide is applied neat or directly from the container without any mixing with water. The use of ultra low volume systems is only possible if the spray is delivered as very small droplets. Examples include the Curtis Dyna-Fog® and the PulsFog®.

4.2 Sprayer components

Sprayers come in a large range of types and sizes, from small, hand-held sprayers to large, self-propelled machines. While there is such a large variety, there are some basic components that are found on nearly all types of sprayers (see figure 15). The basic components used in liquid application systems include:

- nozzles to generate droplets
- a method of holding the nozzle so that the spray is directed towards the target (e.g. boom)
- a frame or chassis and drive
- a tank to hold the chemical
- a method to make liquid flow (e.g. pump)

- an agitation system to keep the spray solution well mixed
- pressure regulators and control valves
- a filtration system (suction and pressure in-line filters)
- auxiliary equipment, such as a clean water tank, diaphragm check valves and spray management valves.

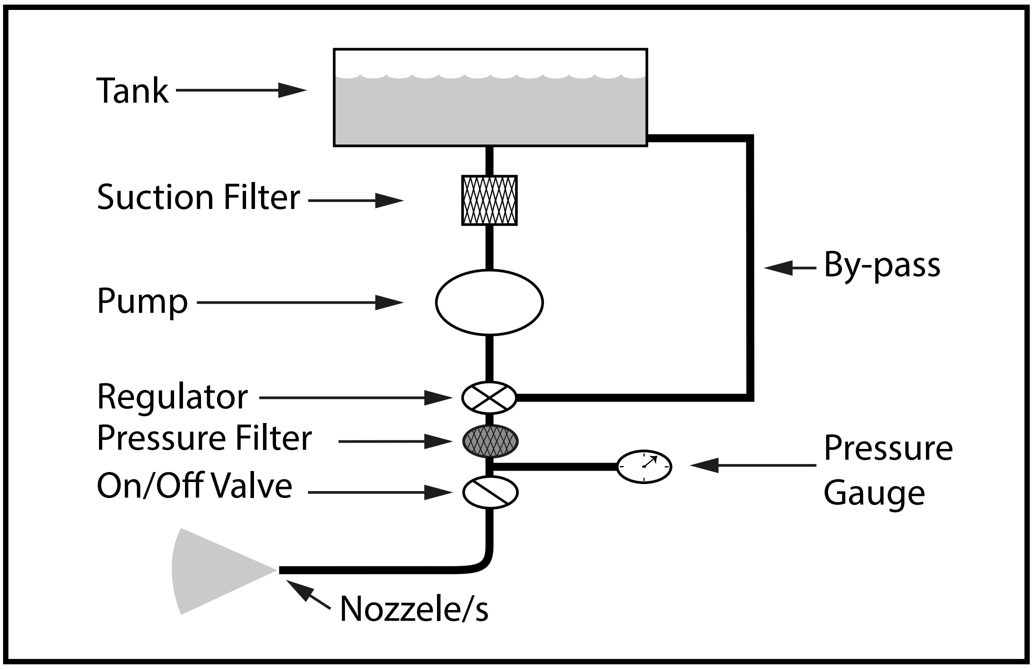


Figure 15. A typical layout of application equipment (high and low volume) used in the nursery industry

TANK

The spray tank should be of an appropriate size for the type of sprayer used and the volume of pesticide mixture required for the area to be sprayed. The shape of the tank should allow for easy access for filling and ease of drainage and cleaning. A small sump in the tank is generally recommended so that a minimum amount of liquid remains within the tank after the majority of the spray solution has been used.

Materials used in tank construction need to be resistant to chemicals, non-corrosive, not easily damaged, resistant to sunlight and easy to repair. A gauge showing volumes at various percentages of fill is important.

PUMP (LIQUID FLOW)

The spray liquid is usually forced through the nozzle using a pump to generate pressure. Some hand-held systems such as the ULVA® and HERBI® use gravity for the liquid to flow (tank positioned higher than nozzle). A wide variety of pumps are available for application systems. Examples include diaphragm, centrifugal, piston, roller, and gear pumps. Pumps used in nursery situations are commonly powered by a 12 V battery, a separate petrol motor on the sprayer or a tractor driven power take-off (PTO).

When selecting a pump, the following factors should be considered:

- The operating pressure required
- the output (L/min) of liquid required
- power requirement to drive the pump
- type of chemicals to be used
- durability of the pump
- costs.

AGITATION SYSTEM

Many chemical formulations consist of fine powders or particles that need to be held in suspension in the chemical mix. If the mix is left to stand, these particles may settle on the bottom of the tank. A system to agitate or mix the chemical is therefore required. This is usually achieved by recirculating some of the spray mix back to the spray tank. The pump output should be greater than that required to operate the nozzle to allow recirculation back into the tank during spraying. Once flow to the nozzles is stopped, the total flow from the pump is redirected back into the spray tank. Sometimes special fittings are used on the bypass system to increase the agitation in the tank.

Other methods of agitation include mechanical systems, such as a rotating paddle, or manual agitation, by physically shaking the tank of small hand-held equipment. Pesticide labels should always be consulted to determine any specific requirements for agitation.

PRESSURE REGULATORS AND CONTROL VALVES

Liquid flow rate and pressure to nozzles must be controlled to ensure that sprayer output is consistent. This is generally achieved by use of pressure regulators and/or control valves. These may be operated manually or electronically, particularly for the larger sprayers. All systems MUST be fitted with a pressure gauge. The gauge should be positioned as close as practicable to the nozzles and be clearly visible to the operator. On tractor mounted equipment, two separate pressure gauges may be necessary, one visible to the operator and the other nearer to the nozzles used for calibration and set-up of equipment.

FILTRATION SYSTEM

Filters are required to prevent nozzle blockage. Blockage results in wasted time, increased risk of chemical exposure if nozzles or filters require cleaning in the field and poor coverage in the field if individual nozzle blockages are not detected. Factors such as the water source, pesticide formulation and pump agitation capability influence the type of filtration system required for the sprayer.

There are typically several stages of filtration in liquid application equipment. These stages and typical mesh sizes are listed below. Mesh size is defined as the number of openings along a linear inch. Thus 100 mesh has 100 openings along a linear inch, or 10 000 openings per square inch.

Filter stage	Typical mesh size
Tank inlet filter	50 mesh
Suction filter	40–80 mesh
Pressure line filter	40–80 mesh
Nozzle filter	50–100 mesh

For hydraulic nozzle operation, the manufacturer's recommendations should be followed. The fitting of pressure in-line filters with easy access and colour-coded filters is recommended. For positioning of the pressure in-line filter, refer to figure 15.

AUXILIARY EQUIPMENT

Auxiliary equipment such as a fresh water tank and chemical handling equipment can be added to a sprayer system for increased safety and easier preparation of chemicals. Smaller chemical tanks such as chemical induction hoppers can be added to the side of the larger tanks at an accessible height to allow safe pouring of chemicals. Clean water tanks are important for hand washing and use in emergencies when clean water may be unavailable in the field.

4.3 Spraying equipment

Symbols describing spraying equipment

To assist in ease of use and economy of space within the manual, symbols have been used to indicate certain aspects of spray application. These symbols are listed and described on page 2. The symbols have been included with the general descriptions and advantages and disadvantages of each piece of pesticide application equipment described in this chapter.

Where one or more symbols have been included with the description of the equipment, this indicates that this piece of equipment is suitable for the use or uses that each of those symbols indicates.

For instance, some sprayer types are suitable for use at a range of volumes and may have all three sprayer type symbols included with their descriptions, whereas others may only be suitable for use at one volume, such as many of the ultra low volume sprayers. Some sprayers may produce a wide range of droplet sizes, while others may produce a narrow range of droplet sizes.

Some sprayers will be useful in a range of nursery operations, whereas others may be limited to glasshouse, polyhouse or outdoor use.

The symbols on page 2 are used to indicate what sprayer type, droplet size, pesticide type, nursery design, expected coverage and nursery size may be suitable for each type of application equipment discussed.

If in doubt about any of the symbols used in this chapter, please refer back to this key.

Always refer to the manufacturer's catalogue when selecting or fitting appropriate accessories such as nozzles, handpieces, etc for pesticide application.

Be sure to check the output and nozzle specifications to ensure that they are appropriate for the task intended.

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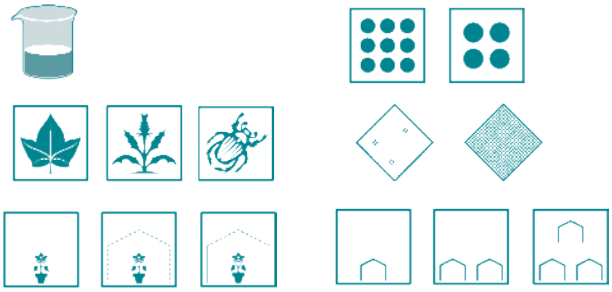
Hydraulic nozzles



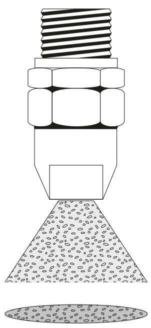
Hydraulic nozzles come in a wide variety of designs. Droplets are formed by forcing the spray liquid under pressure through specially designed holes, or 'orifices', in the body of the nozzle. The most common types of hydraulic nozzles are the flat fan and hollow cone nozzles. The spray patterns produced by these two nozzle types are shown in the diagrams below. In general, flat fan nozzles produce a slightly larger droplet size than the hollow cone nozzle and can be operated at lower pressures than hollow cone nozzles.

The droplet size produced by hydraulic nozzles increases as the orifice size is increased (allowing higher flow rates) or as the operating pressure is decreased. Decreasing pressure also decreases the angle of the spray pattern.

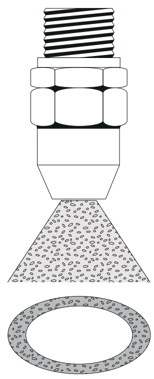
Most manufacturers of hydraulic nozzles now produce low drift nozzles that are designed to produce larger droplet sizes under typical operating conditions. The larger droplet sizes can assist in reducing drift, but may also reduce coverage on plant surfaces due to the lower number of droplets that are generated per volume of spray liquid. Drift reduction nozzles produce larger droplets through minor charges to the nozzle design. Typically, these changes are in the form of a pre-orifice or by air inclusion in the liquid.

Hydraulic nozzles are usually mounted at or near the end of a hand lance or hand gun, or along a boom.

Flat fan nozzle

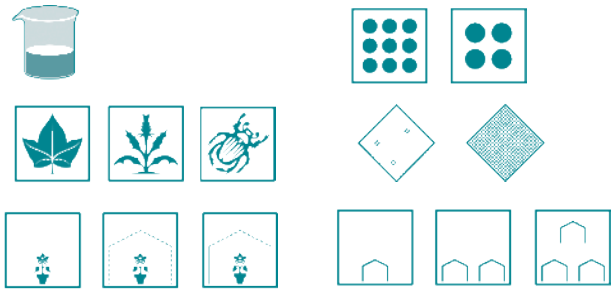


Hollow cone nozzle



Advantages	Disadvantages
• versatile • low cost • nozzles are easy to use—no moving parts • nozzles can be used for a wide range of situations • nozzle components are easily changed • parts are of a simple design • the wide droplet spectrum allows for some operator error	• difficult to get uniform coverage • nozzles are prone to wear • nozzles require regular calibration • pressure and distance to target must be known • air assistance is sometimes required for efficient small droplet capture on targets • nozzles generate a wide droplet spectrum that can lead to wastage and/or pesticide drift

Hand gun



The hand gun is the most commonly used spray nozzle in nursery situations. They are usually operated at a high pressure of 10–30 bar (150–450 psi), although lower pressure versions are available. Due to this high pressure, hand guns are able to throw the spray liquid long distances, which enables the operator to stand in walkways and direct the spray to the far side of racks or bays. However, this increased throwing distance encourages the production of large droplet sizes. These large droplets may lead to poor coverage, particularly on lower leaf surfaces, excessive use of pesticide mixture, run-off and contamination of the environment. The use of too high a pressure can also result in very fine droplets being produced (misting). These fine droplets are prone to drift away from the application area and may also contaminate the operator. The high pressure may also result in damage to foliage nearest to the release point from the hand gun.

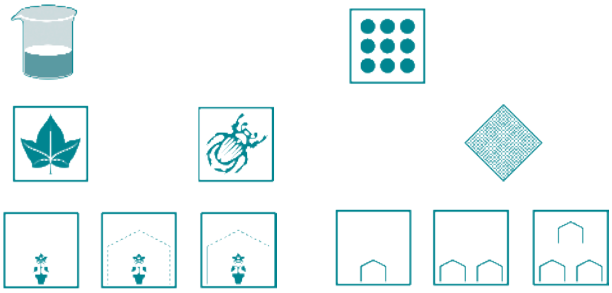
Spray guns may have either a fixed swirl chamber or an adjustable swirl chamber that allows a change of spray angle and thus the spread of the spray. Adjustable nozzles can provide spraying flexibility, however a greater degree of operator knowledge is required to correctly use these nozzles. Changes to flow rate, operating pressure, width of the spray, throwing distance and droplets sizes will all influence the effectiveness of pest management. For details of these influences refer to chapter 3 of this manual.

The trigger on adjustable nozzle guns allows the operator to change the flow rate and nozzle performance. While this has practical advantages, it makes these systems difficult to calibrate when using products that need to be applied on a volume per unit area basis (e.g. L/ha) rather than a volume per volume or concentration basis (e.g. 300 mL per 100 L of spray solution).

Sprayer units fitted with a high-pressure hand gun can be mounted on tractors, trailers or hand-pushed carts, which increases manoeuvrability. One significant disadvantage of the hand gun is that the coverage is dependent upon the individual spray operator. Some product labels recommend that the volume of spray has to be applied until run-off occurs on the plant. This definition of 'run-off' is an ambiguous term and the amount applied by different operators can vary considerably across a target area. Run-off also results in loss of spray into the environment.

Advantages	Disadvantages
• versatile—can be used for all spraying operations • nozzles may be adjusted to suit operating conditions • relatively inexpensive • can be used in various sizes of nursery	• difficult to calibrate • highly subject to operator error • difficult to achieve uniform coverage • high risk of run-off and environmental contamination

Air shear sprayers



Air shear nozzles use high-speed air (up to 300 km/hr) to convert the spray solution into droplets. The spray liquid is fed at low pressure to the nozzle through a suitable restrictor and the jet of liquid emerging at the nozzle orifice is then sheared by the high speed air into droplets that are carried to the target in the air stream produced by the sprayer.

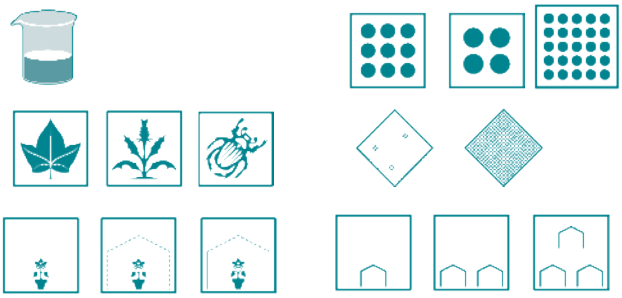
Droplet sizes generated from air shear nozzles are usually fine to very fine. The most important variable determining droplet size is the air:liquid ratio. Larger droplets are obtained with increased liquid flow and/or through a reduction in air velocity. The spray liquid should be spread into a sheet to maximise the effect of airflow and obtain efficient break-up into droplets. Variation in droplet size depends to some extent on the design and position of the spray liquid orifice in relation to the airstream.

Air shear systems may have a high power requirement because of the need to produce high-speed air for the efficient formation of small droplets. Such systems range from backpack misters to large tractor powered units such as the Turbomiser®. Hearing protection is generally required when operating these systems due to the noise generated by the motor and fan. Newer models of backpack misters tend to be quieter and may be preferable to older models.

The air used in the production of the droplets can also be used to constrain droplets within the airstream and to direct the droplets towards the target. This can increase the droplet capture and coverage on the target. Various deflectors and diffusers can be used to manage and direct the droplet-laden air to the targets.

Advantages	Disadvantages
• small droplets can result in good coverage under suitable conditions • air movement can aid penetration into canopy and droplet capture on targets • spray covers a large area quickly • changing air/liquid flow can alter droplet size • low quantities of carrier fluid required	• cost of equipment • high level of operator knowledge required • small droplets are prone to drift • high power requirement • not suitable for spot spraying • can be noisy

Controlled droplet applicators (CDA)



Controlled droplet application (CDA) is a method of producing droplets using spinning discs or cages. CDA sprayers produce a narrower range of droplet sizes compared to hydraulic nozzles. The droplet sizes produced by CDA sprayers can be increased or decreased by changing the rotational speed of the disc or the flow rate of the liquid, or a combination of both. The selection of the disc or cage type is also important for managing droplet size.

Rotational speed for battery operated equipment, such as the HERBI4® or ULVA® CDA sprayers can be affected by the number of batteries or the charge of the batteries. Flow rate can also be affected by the viscosity of the liquid. In some models the flow rate can be changed by changing the metering orifice.

- To produce smaller droplets—increase rotational speed, or decrease flow rate, or a combination of both.
- To produce larger droplets—decrease rotational speed, or increase flow rate, or a combination of both.

For optimum outcomes and management of the droplet sizes, refer to the manufacturer's handbook. The selection of disc or cage types is important in managing the droplet spectrum produced by the sprayer.

Small discs spinning at high speeds can produce fine droplets that considerably increase the target coverage when applying insecticides and fungicides. Many of these systems, such as the ULVA +®, use a fan with the spinning disc to direct droplets towards the desired target. This can further increase coverage by improving penetration and target capture of the spray droplets. ULVAs have smaller discs that spin at higher speeds and are better suited to insecticide and fungicide operations in controlled environments such as glass or poly houses. HERBIs, on the other hand, have larger discs that normally spin at lower speeds and produce larger droplets. They are typically used for herbicide application.

Advantages

- a narrow range of droplets can be produced
- uniform droplet size
  - HERBI® units minimise small droplets (minimising drift)
  - ULVA+® units minimise large droplets (minimising waste and carrier volumes)
- air assistance can be used to increase coverage/ penetration
- nozzle systems can be tailored for the production of certain droplet sizes (e.g. high speed small discs produce fine droplets, low speed large disc generate larger droplets)
- generally light weight and low energy use

Disadvantages

- most nozzle systems require relatively complex motorised components
- for effective use, specialist knowledge and a high level of understanding is required
- accurate droplet formation requires the correct disc or cage, rotational speed and liquid flow rate
- may be difficult to calibrate, as swath width may vary depending on wind conditions and operating height
- battery driven models may need regular recharging or battery replacement

Electrostatics

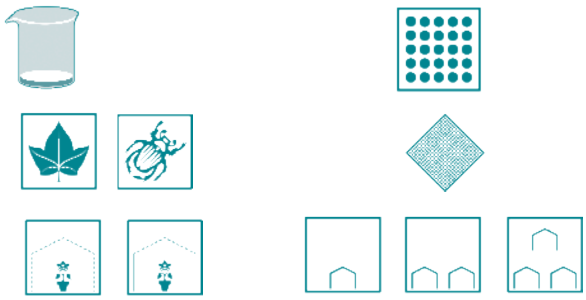
In electrostatic sprayers the spray material is given a static electric charge as it travels through the nozzle. In theory this can help to create droplets that are more uniform in size, which disperse more evenly because they repel each other, since all droplets carry a like charge.

Several styles of electrostatic sprayers are available They require an independent power supply to charge the tank. Other units are cart-mounted with an integral compressor powered by a petrol engine or electric motor. Electrostatic sprayers work best if the sprayer-to-target distance is less than 4–5 m.

Penetration of spray into a dense canopy and coverage onto the under leaf surfaces can be poor because the droplets are attracted to the nearest surface, which may well be the outer foliage of the plant. Electrostatic charging is only effective for small droplets. The charging may also not be sufficient to overcome other effects such as wind, so they are best used in controlled environments such as glasshouses or polyhouses.

Advantages	Disadvantages
• small droplets potentially give a more uniform coverage on both upper and lower leaf surfaces	• high operator hazard as spray can be attracted to operator and equipment • very high level of knowledge required for successful use • high level of maintenance

Cold foggers



Cold foggers, also known as mechanical foggers, use high-pressure pumps and atomising nozzles to produce very small fog-sized particles of less than 15 µm. Distribution of the spray material is through a hand-held gun or external fan unit. With the fan unit, the distance and the area that can be treated depend on the capacity of the fan. Multiple units or multiple settings may be needed to cover large areas.

Often it is difficult for fine droplets to penetrate dense canopies, however, many studies have shown good pest management has been achieved using foggers.

Safety is important when using a mechanical fogger employing a high-pressure pump. Hands and arms must be kept away from the outlet because at 2000–3000 psi spray particles can penetrate the skin very easily. Information should also be gathered on the length of time that fog stays suspended in a still or controlled environment to determine the period for safe re-entry to the area.

Advantages	Disadvantages
• blanket spray • suitable for glasshouse/polyhouse application if appropriate products are used • very small droplets can result in good coverage	• drift • operator hazard • can’t spot spray • small droplets may not penetrate dense plant canopies

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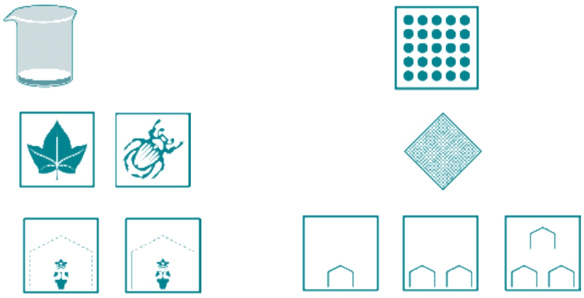
Thermal foggers



Thermal foggers require a specially formulated carrier that is mixed with the pesticide to improve uniformity of droplet size and distribution of the spray material. The carrier also decreases molecular weight, allowing the particles to float in the air for up to six hours. This can be a disadvantage when access to the treated area is required.

A thermal fogger uses a system similar to that used in jet engines. The pesticide is injected into the extremely hot, fast moving air stream, where it is vaporised into fog-sized particles. Moving from one end to the other, a hectare can be covered in as little as 30 minutes. Air circulation systems in a building will improve the uniformity of coverage and foliage penetration.

The temperature and humidity in the greenhouse can also affect the spray droplets. Under high temperatures and low humidity, the spray droplets will tend to fall out of the air quicker and increase the level of deposits on the upper leaf surfaces.

Due to the level of noise generated by thermal foggers, hearing protection should be worn when using equipment!

Advantages	Disadvantages
• blanket spray • suitable for glasshouse or polyhouse use • very small droplets can result in good coverage, particularly when combined with air movement	• drift • operator hazard from small droplets and noise • spot-spraying is impossible • small droplets may not penetrate dense plant canopies without air movement

Wick wipers

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Rope wick applicators are a convenient way of applying herbicides to manage weeds in plant nurseries. They produce no drift and therefore can be used close to other plants. They are ideal for weed management on paths, particularly in retail situations where the opportunities for spot spraying may be limited.

Rope wick applicators are used for wiping translocated herbicides (e.g. glyphosate) onto the foliage of susceptible weeds. They consist of a container from which the pre-mixed spray solution is able to soak an absorbent surface without dripping excess liquid.

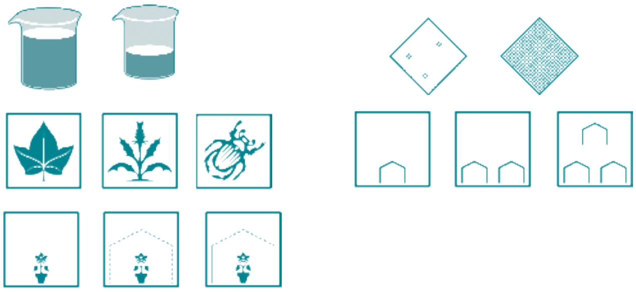
The main problems with wick wipers are the difficulties in avoiding dripping, or conversely, having too dry a wick, and accumulation of dirt on the surface of the applicator. The hand carried rope wick applicator is mainly used for spot treatment of weeds on paths and between beds where the likelihood of the wick contacting nursery plants is minimal.

Advantages	Disadvantages
• no drift • low cost • easy to use	• translocated herbicides only • products recommended for use in wick wipers are usually non-selective

NOZZLE HOLDERS : HYDRAULIC SPRAYERS

On many nursery sprayers the nozzle-holding device is hand-held by the spray operator. Nozzle-holders can incorporate structures such as shields to minimise drift or otherwise modify the spray pattern and management (e.g. diaphragm check valves).

Hand held nozzles



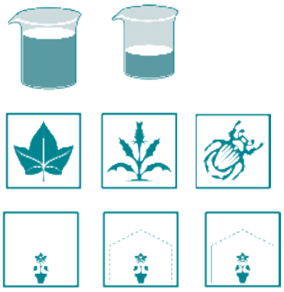
For most sprayers used in nursery situations the nozzle is held by hand and manually directed towards the target. The nozzle may either be a hydraulic hand gun or hydraulic nozzle at the end of a lance. More than one hydraulic nozzle may be used on a small boom arrangement. They usually have a trigger or tap to enable the operator to quickly and easily start and stop liquid flow to the nozzle.

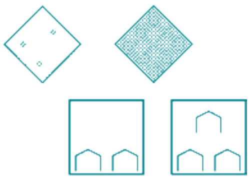
The nozzles can be at the end of a long flexible hose connected to the remainder of the sprayer components, which can then be parked at a convenient location. This approach allows greater freedom for the operator to move around the nursery. The hose is usually manually rolled and unrolled but some units (e.g. QuickSpray®) have a radio controlled unit to remotely coil and uncoil the hose.

When applying the pesticide mixture to the target, the operator needs to carefully move the nozzle in such a way that uniform coverage of the target is achieved over the entire treatment area.

Advantages	Disadvantages
• flexible operation—able to manoeuvre around nursery structures such as irrigation risers and building supports	• difficult to calibrate • operator exposure due to direct handling of nozzle and hoses • uniform deposits difficult to achieve

Boom Sprayers (vehicle mounted)





Vehicle-mounted boom sprayers can be used to treat larger areas within the nursery more uniformly than is possible with hand-held equipment.

A boom is a structure on which more than one nozzle is mounted. The boom is usually attached to the other components and driven along roadways with the boom directed over the target area (plant bed). Most booms are mounted at the rear of the spray tank, although some are in front so that the operator can see the position of the nozzles in relation to the rows. The front mounted boom position can result in increased risk of operator exposure to the pesticides.

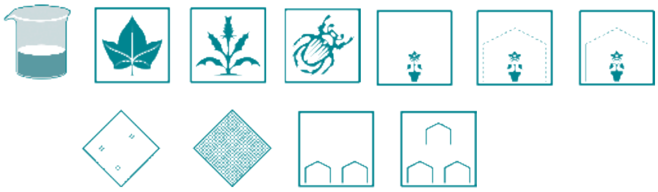
For nursery sprayers a single-, or occasionally, a double-wing boom is used. During spraying, the outer sections are often mounted so that they can be moved out of the way of any obstructions. Manufacturers have used various methods to pivot and fix the boom sections for easy handling. Normally, the booms are unfolded by hand, but on some sprayers, positioning of the boom can be managed hydraulically without the operator leaving the tractor or vehicle.

A wide range of hydraulic nozzles can be fitted to the boom. The nozzle body may be screwed into openings along the boom, but often the boom incorporates special nozzle bodies clamped to the horizontal feed pipe. A diaphragm check valve should be used with each nozzle to prevent dripping of liquid when pressure to the boom is low (i.e. the vehicle is stationary). Nozzles are evenly spaced along the boom and the height of the boom should be adjusted according to the type of nozzle being used and the manufacturer's recommendations.

The pattern from each nozzle has to be overlapped to achieve as uniform a distribution of spray as possible across the whole boom. Some operators use a double overlap. If the boom is set too high drift potential is increased and excessive overlap can occur, resulting in very uneven distribution. The subsequent 'peaks' and 'troughs' occur with both fan and hollow cone nozzles, but are generally more pronounced with hollow cone nozzles. Uneven distribution also results if the boom is set too low.

Advantages	Disadvantages
• quick to cover the target area • greater uniformity in deposition than hand guns • nozzles can be changed to suit situation	• booms can be difficult to manoeuvre around the nursery (e.g. irrigation risers, building structures) • nozzles wear and should be replaced regularly

Vertical boom



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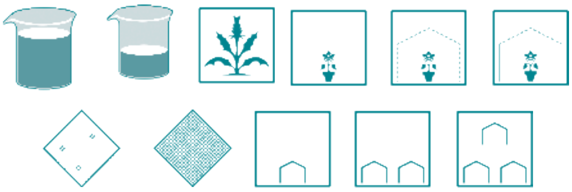
A vehicle mounted boom fitted with controlled droplet applicator (CDA) heads has various names including 'vertical boom' and 'vertical mister'. Each head consists of four spinning discs and a fan. These are driven by hydraulic pressure generated by a pump under the tank that attaches to the tractor's power take-off (PTO). The heads are normally operated at around 2000 rpm to generate droplets that are then moved toward the target in the air-stream created by the fans.

Heads can be fitted facing forward or backward to suit the orientation of the target. The entire unit, including tank, is usually mounted on the three point-linkage of a small tractor.

When using vertical booms care must be taken to determine that the fans create sufficient air movement so that spray droplets penetrate into the plant canopy. This is an important part of calibration with this equipment.

Advantages	Disadvantages
• quick to cover the target area • greater uniformity in deposition than handheld CDA equipment • attitude and airflow can be adjusted to suit target	• tractor mounted equipment can be difficult to manoeuvre around the nursery • risk of drift if airflow not entirely intercepted by target • greater requirement for operator knowledge • difficult to spot spray small areas

Shielded sprayers



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Shields are sometimes placed around the spray nozzle to prevent droplets (usually of herbicide) travelling away from the target area. With sprayers generating air movement they may also be used to direct droplets in the air stream toward the target. This technique is particularly suited for weed management around the nursery such as weeds growing in walkways and near buildings.

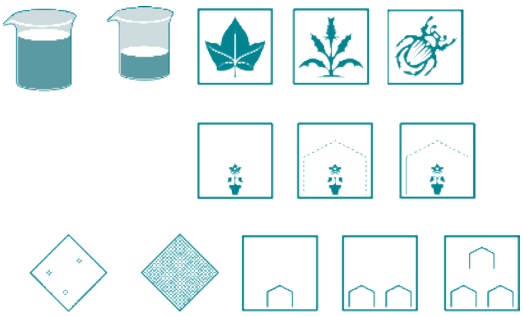
Shielded sprayers can be suitable for applying non-selective chemicals because they can minimise the off-target losses. When shields are fitted to knapsack sprayers a flat fan nozzle should be used, with a spray angle that is appropriate for the shield design. Even when using a shielded sprayer the correct hydraulic nozzle should be selected for the target, only spray during suitable conditions and operate at a pressure that minimises the formation of small droplets.

Advantages	Disadvantages
• low drift • suitable for herbicide application • can decrease chemical use by spot spraying	• generally not used for insecticides/fungicide application to plant nurseries • large units can be relatively expensive • the weight of the shield on hand held units

FRAME/CHASSIS AND DRIVE

The sprayer requires some form of frame or chassis to hold all the sprayer components together. This needs to be of sufficient strength to carry the load (including a full spray tank). A method of driving the sprayer over the treatment area is also required. This can be achieved by foot, tractor, 4WD motorbike or self-contained drives.

Trailer



Trailer sprayers come in a large variety of sizes and shapes. The size of the trailer typically relates to the area requiring treatment. The larger the area, the larger the spray components and hence, the larger the trailer. Trailer sprayers are often fitted with one or more hydraulic hand guns or a wand on a short boom fitted with nozzles.

Advantages	Disadvantages
• versatile • flexible	• difficult to turn in small areas • bulky

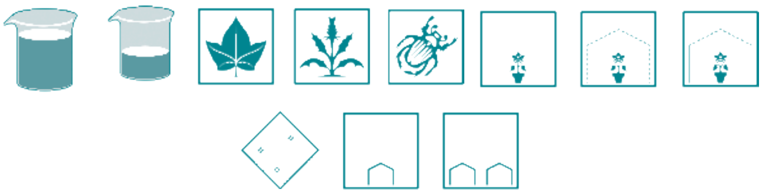
Tractor three-point linkage

The entire sprayer unit may be mounted on the three-point linkage of a tractor. This method is more common in large nurseries. The Silvan Turbomiser® is a commonly used example of a tractor-mounted droplet delivery system. The same principles apply as with smaller scale equipment. In this case, as an air shear sprayer, it is not suitable for herbicide application because of the large number of small droplets produced that create a high potential for drift.

Tractors can be fitted with cabins and suitable air filters to decrease operator exposure to pesticides during application.

Advantages	Disadvantages
• quicker to cover large target areas • small droplets in a moving airstream can improve target capture	• only suitable for larger operations • may require more horsepower to operate than available on many small tractors • drift needs to be considered

Backpack/knapsack or hand-held hydraulic sprayer



Knapsack sprayers are carried by the operator, usually on the back. The pump is usually a piston or diaphragm driven by a lever that the operator moves up and down during use. Small petrol motor-driven pumps or electric pumps operating on a rechargeable 12V battery may be used on some units. Most lever-operated knapsack sprayers are fitted with a simple lance with usually one or two nozzles at the end. Hydraulic nozzles are typically used.

When using lever-operated knapsacks, the operator works the pump several times with the tap closed so that pressure is built up in the pressure chamber. The tap is opened and the operator continues to pump steadily with one hand while spraying with the other. Ideally a pressure control valve is also fitted adjacent to the tap. Spray management valves (SMVs) can be fitted to ensure that the pressure at the nozzle remains constant. Most older-style knapsacks deliver low pressures of 1–5 bar, but some newer models are capable of 8–9 bar.

Compression sprayers

Some units have a small tank that can be carried by hand or slung over the shoulder by a strap. These are referred to as compression sprayers. A hand pump, usually built into the tank, is used to pressurise the tank to a level suitable for correct operation of the nozzle. An SMV should be fitted to ensure constant pressure during spray operations. A pressure relief valve should also be fitted into these sprayers to release pressure for refilling.

All systems that rely on manual pumping suffer from fluctuating pressure levels. The operator may over-pump the sprayer and create excessive pressure or may under-pump, which results in insufficient pressure being produced. These changes in operating pressure alter the flow through the nozzle and therefore the droplet size generated. A constant pressure SMV positioned just before the nozzle can overcome these variations in pressure.

Advantages	Disadvantages
• suitable for spot spraying • for small operations • a range of nozzles can be used for target and pesticide combinations	• operator hazard—may leak, weight on back • variable pressure (unless SMV used), variable flow rate • must be calibrated for each operation

CHAPTER 5.

CALIBRATION

The objective when applying pesticides is to deliver the required amount of active constituent of the chemical to the desired target area. Regular calibration allows the operator to check that each of the components of the sprayer is operating within acceptable limits. It will also prevent over-dosing or under-dosing the target areas and reduce unnecessary contamination of the environment.

Over-dosing occurs when more than the recommended amount of a pesticide or mixture of pesticides is applied to the target area. This can result from hydraulic nozzle wear and other faults, such as increased pressure and varying travel speed, resulting in increased flow rates.

Over-dosing results in:

- wasting pesticides or products, time and money
- possible damage to crops (phytotoxicity)
- the possibility of exceeding the product's maximum residue limit (MRL)
- extra wear and tear on equipment
- possibly reducing the effectiveness of the product
- increased risk to non-target area
- increased risk of developing pest resistance to pesticides.

Under-dosing occurs when less than the recommended amount of active constituent is delivered to the target. This can be caused by blocked nozzles or filters and varying travel speed. This problem is difficult to detect with the eye and often goes unnoticed until a major blockage occurs.

Under-dosing results in:

- wasting chemicals, time and money
- reduced effectiveness of the product or pesticide
- increased risk of development of resistance to insecticides and fungicides
- possible production losses due to pest damage or competition.

Regular calibration of equipment will help to identify and reduce these problems.

> ***Do not rely on experience to know how far a tank will spray.***
>
> ***Equipment calibration is the only way to check the sprayer's application rate per area and identify problems in the uniformity of output.***

5.1 Calibration technique

Calibrating a piece of equipment for the application of pesticides as droplets involves four steps. These four steps are used in calibrating all types of sprayers, including hand-held equipment, boom sprayers, air-assisted hydraulic and air shear sprayers, misters and even agricultural aircraft. The form used by Nursery and Garden Industry Queensland is provided on page 68 to assist with the relevant calculations. The basic principles of calibration are discussed for collecting information. In the final section, these principles are applied to the major types of equipment.

> ***It is important that accurate records are kept of the calibration process.***

Before commencing calibration

It is important to ensure that the sprayer is operating correctly before taking any measurements of the sprayer's performance. The equipment must be checked and adjusted if necessary before calibration. The operator or supervisor should check the:

- the sprayer is clean
- the pesticide label recommendations in relation to rates and safety requirements

- the pressure gauge is operational (if fitted)
- pressure regulator setting (if one is fitted)
- spray lines and filters for leaks, blockages
- nozzle and sprayer description
- environmental conditions
- that the equipment is the most suitable for the job.

Steps for generalised sprayer calibration

A. Measure sprayer output (L/min)

The sprayer output is calculated by collecting and measuring the output of the nozzle(s) at the operating pressure required, into a container for one minute. The output from all nozzles should be measured. To reduce any errors, this procedure should be performed at least three times, then an average reading calculated.

The measured output of a nozzle is only acceptable if it varies by less than 10% from the manufacturer's new nozzle specifications. If the measured output of a nozzle varies by more than 10% from the manufacturer's new nozzle specifications, that nozzle should be replaced.

Enter the result at A on the calibration sheet (page 68).

B. Calculate the area sprayed in square metres per minute (m^2/min)

Calculating the area sprayed during the calibration requires two activities:

1. The first information required is the sprayer/nozzle's swath width in metres. Swath width is the width of spray coverage that is effectively delivered by the nozzle(s) to the target area, i.e. how wide the sprayer can effectively spray. For many plant nursery situations, the swath width can be taken as the width of the beds being sprayed.
2. The second measurement is the distance travelled (in metres) by the sprayer during one minute (see diagram below). This is measured while actually spraying with water.

The area sprayed in metres squared per minute (m^2/min) is calculated from the swath width and distance travelled using the formula on the calibration sheet.

Enter the result at B on the calibration sheet (page 68).

C. Calculate the sprayer's application rate in litres per hectare (L / ha)

This step determines the sprayer's output over a given area. For liquids this is known as the application rate in litres per hectare (L/ha). Registered pesticides must be applied at the application rate specified on the label. The sprayer application rate is calculated by using the data collected in steps A and B.

Enter the result at C on the calibration sheet (page 68).

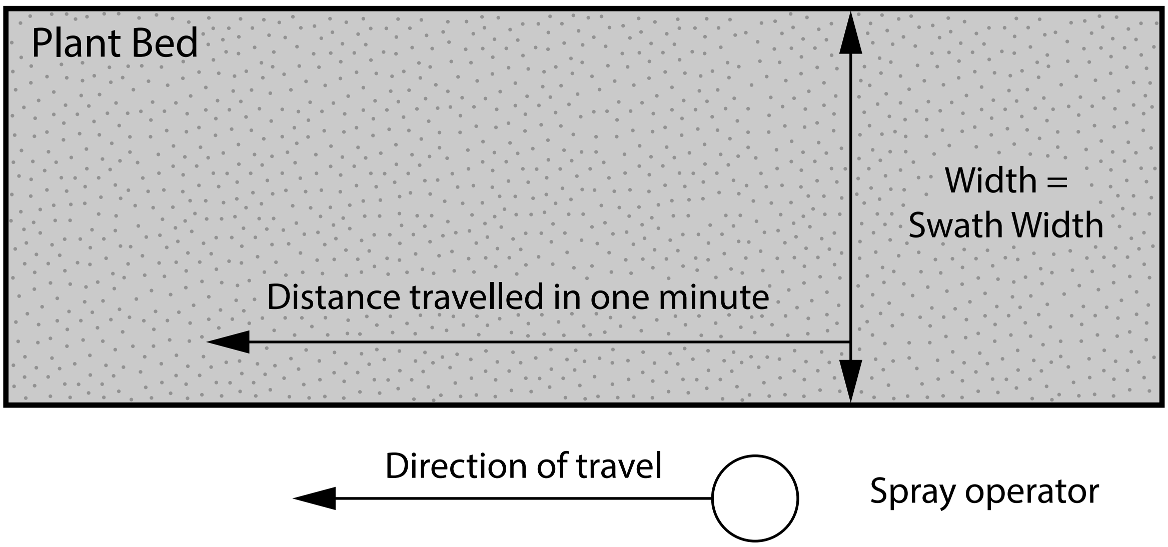
D. Calculate the amount of chemical required per spray tank volume

This is a critical step in the calibration procedure, as it ensures that the recommended label rates of pesticides are applied to target areas by determining the amount of chemical to be added to the spray tank to make up the volume that is to be used.

To calculate the amount of pesticide to add to the required tank volume the following information is needed:

- Sprayer application rate (L/ha) (calculated in step C)
- Registered product label rate (L/ha or g/ha or kg/ha or L/100 L or g/100 L or kg/100 L as stated on the label)
- Tank volume (L) for the amount of spray being prepared.

Enter the result at D on the calibration sheet (page 68).



check addition of labels for C and D and additions to the instructions on page 69

Date: ……………….. Name:………………………..

Nursery & Garden Industry Queensland

CALIBRATION SHEET

ACCREDITED NURSERY NIASA Setting the Standards

APPLICATION RATE

A = LIQUID FLOW (NOZZLE OUTPUT) FOR 1 MINUTE

NOZZLE OUTPUT/FLOWRATE = […………...] L/Min (A)

B = AREA (WIDTH X DISTANCE)

WIDTH (SWATH WIDTH) = [ ] (W)

DISTANCE TRAVELLED = [ ] (D)

W X D

[………] X [. ……..] = […………...] m^2 (B)

APPLICATION RATE

A ÷ B x 10 000 (C)

[ ] ÷ [ ] x 10 000 = [ ] L/ha

AMOUNT OF CHEMICAL TO ADD TO THE TANK.

SPRAY TANK SIZE = [ ] Litres

APPLICATION RATE = [ ] L/ha (Above Answer)

CHEMICAL RATE = [ ] L/ha (Label Rate)

TANK SIZE ÷ APPLICATION RATE x CHEMICAL RATE (D)

[ ] ÷ [ ] x [ ] = [ ] L

5.2 Hand-held sprayer calibration

Calibration checklist for hand-held equipment

- Ensure the sprayer is clean and filled with the required volume of water for the exercise.
- Check and record the operating parameters (e.g. nozzle type, travel speed and height, product rate and water rate).
- Adjust the pressure setting to the required operating pressure or fit a spray management valve (SMV). Record the pressure.
- Check the equipment for possible leaks and blockages.
- Use a measuring cylinder or jug and collect the output from the nozzle(s) when the sprayer is operating at the required pressure for one minute. For high pressure nozzles, it may be easier to place a small length of hose (e.g. 1 m) over the nozzle.
- Record the volume collected for each nozzle.
- Measure the nozzle output(s) for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials.
- Check that all nozzles are not more than 10% above the manufacturer's new nozzle specifications. If they are more than 10% above, replace them. If they are below, this indicates there is probably a blockage in the nozzle or the filters.
- Record the total output from the nozzle(s) measured and record the result at A on the calibration sheet.
- Record the swath width of the sprayer. When spraying beds with a hand-held nozzle the swath width may be taken as the bed width.
- Measure the distance travelled in one minute. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Calculate the area and record the result at B on the calibration sheet.
- Calculate and record the sprayer's application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume. Record the result at D on the calibration sheet.

5.3 Boom sprayer calibration

Check list for boom sprayer calibration

- Ensure the sprayer is clean and filled with the required volume of water for the exercise.
- Adjust the PTO revs and pressure setting to the required operating pressure.
- Check and record the operating parameters such as nozzle type, operating speed (gear, engine revs and PTO revs), boom height, product rate and water rate).
- Check the equipment for possible leaks and blockages.
- Use a measuring cylinder or jug and collect the output from each of the nozzles when the sprayer is operating at the required pressure for one minute.
- Record the volume collected for each nozzle.
- Measure the nozzle outputs for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials.
- Check that all nozzles are not more than 10% above the manufacturer's new nozzle specifications. If they are more than 10% above, replace them. If they are below, this indicates there is probably a blockage in the nozzle or the filters.
- Record the total output from all of the nozzles measured and record the result at A on the calibration sheet.
- Record the swath width of the sprayer. When spraying beds with a hand-held nozzle the swath width may be taken as the bed width.
- Measure the distance travelled in one minute. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Calculate the area and record the result at B on the calibration sheet.
- Calculate and record the sprayer's application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume. Record the result at D on the calibration sheet.

5.4 Calibration of misters (+ CDA)

Check list for mister calibration (+ cda equipment)

- Ensure the sprayer is clean and the tank is filled with the required volume of water for the exercise.
- Check and record the operating parameters e.g. engine (head rotation speed), travel speed and height, product rate and water rate.
- Adjust the engine speed (or the head rotation) setting to that required for operating.
- Check the equipment for possible leaks and blockages.
- Detach the spray liquid feed from the reservoir at a point before it enters the nozzle (CDA head). Use a measuring cylinder or jug to collect the output from the pipe when the sprayer is operating at the required speed for one minute.
- Record the volume collected for each feed pipe (on large misters and CDA machinery there may be several).
- Measure the feed pipe output(s) for one minute and record the result two more times.
- Work out the average output per minute for each nozzle from the three trials. Then work out a total output for the equipment when all are functioning together. Enter this as A on the calibration sheet.
- Record the swath width of the sprayer. In this case, swath width is the maximum horizontal distance spray travels while still achieving effective coverage of the target. This can be determined accurately with the use of water sensitive paper placed on the target during a water test spray to check the number and size of droplets travelling to the target. Water sensitive paper and information on using it should be available from major pesticide suppliers.
- Measure the distance travelled in one minute by the equipment. This distance should be measured while moving the nozzle in the desired fashion to achieve uniform coverage of the bed.
- Enter the swath width and distance travelled then calculate the area and record at B on the calibration sheet.
- Calculate and record the sprayers application rate at C on the calibration sheet.
- Record the label application rate.
- Record the spray tank volume.
- Calculate and record the amount of chemical required per spray tank volume at D on the calibration sheet.

CHAPTER 6.

CASE STUDIES

The following section contains short case studies. These provide real examples of the current practices from the nursery industry in relation to purchase, storage and handling of agricultural pesticides. For each of the areas in which information was gathered, a rating has been used to indicate the level of performance relative to best practice for the nursery industry. Critical comments have also been provided for each case study to assist in understanding the development of best practice.

Key to the ratings used in the industry case studies contained in this section

RATINGS	
Must be improved	☆
Could be improved	☆ ☆
Reasonable practice	☆ ☆ ☆
Towards best practice	☆ ☆ ☆ ☆

Case Study 1	**Production description:** Main products include ornamentals (gingers and heliconias, natives, gardenias, murrayas, durantas, allamandas, cordylines, crotons). Produced in shadehouses, igloo and open areas. **Operation type:** Wholesale only.	*OVERALL RATING* ☆½
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Hand pump sprayers for spot application. **Calibration:** Information not supplied.	☆☆☆
2. Chemical handling, storage & disposal	**Transport:** Ute.	☆☆
	Storage: Locked refrigerator cabinet.	☆☆
	Personal protective equipment: For insecticides and all mixing operations a washable hat, overalls, boots, gloves and respirator are used. For herbicides and fungicides a washable hat, overalls and boots are used.	☆☆☆
	Disposal: Use remaining product on other produce (not usually an issue).	☆☆
3. Spray drift	**General operating parameters:** Information not supplied.	☆
	Typical spraying conditions: Wind speed: nil–5kph. Temperature: less than 32°C. Humidity: Information not supplied.	☆☆
	Spray drift management strategies: No strategies in place.	☆
4. Overall management of spraying operations	**Training:** Information not supplied.	☆
	Record keeping: Information not supplied.	☆
	Emergency procedures: Information not supplied.	☆

CRITICAL COMMENTS (by management area)

1. Calibration of equipment essential and records of calibration and usage must be kept.
2. Chemical handling
   i) Use of an old refrigerator cabinet is not recommended and it has no ventilation.
   ii) Eye protection, goggles or faceshield should be worn particularly when measuring or mixing concentrates.
3. Records must be kept of all pesticide use and application methods and conditions.
4. Training of staff is required, as are records, and emergency procedures for managing spills must be in place.

Case Study 2	**Production description:** Main produce includes gardenias, lavenders and herbs. Open areas used for production only. Glasshouse used for propagation. **Operation type:** Wholesale only.	***OVERALL RATING*** ☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** High volume PTO sprayer with hand gun, Silvan 400 Lt. **Calibration:** Variable cone nozzle on hydraulic hand gun.	☆☆
2. Chemical handling, storage & disposal	**Transport:** Van.	☆
	Storage: In chemical store (no details given).	☆☆
	Personal protective equipment: Washable hat, overalls, boots, gloves, goggles/face shield and respirator are used for insecticides (Bugmaster®, Malathion, Rogor), herbicides (Round up®, Gesatop®, Tryquat®), fungicides (Kocide®, Bravo®, Octave®) and mixing operations.	☆☆
	Disposal: Only mix enough product for job requirements.	☆☆☆
3. Spray drift	**General operating parameters:** Information not supplied.	☆
	Typical spraying conditions: Wind speed: Not measured. Temperature: less than 28°C. Humidity: Not measured.	☆☆☆
	Spray drift management strategies: Drift is not an issue, therefore no strategies in place.	☆
4. Overall management of spraying operations	**Training:** All operators trained with farm chemical user course and apprenticeships.	☆☆☆½
	Record keeping: Handwritten onto a spread sheet.	☆☆☆
	Emergency procedures: Dial 000, SDS on hand, atropine on site and Ipecac syrup.	☆☆☆

CRITICAL COMMENTS (by management area)

1. Hydraulic pressure variable nozzle hand guns are difficult to calibrate and this usually results in uneven dosing of the target with pesticide and run-off to waste.
2. Products need to be separated from driver/passengers during transport and the chemical store locked and clearly placarded.
3. Operating parameters need to be measured and recorded. Spray drift is always an issue and must be carefully considered.
4. Having atropine and Ipecac syrup on site is not recommended as it should only be administered under medical supervision.

Case Study 3	**Production description:** Main product lines include annual flowers, vegetables, seedlings and herbs. Produces in shadehouse, glasshouse and open areas. **Operation Type:** Wholesale only.	***OVERALL RATING*** ☆☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** QuickSpray (2 x retractable reels (600L tank) and 2 x 1600 cc Kubota's (200 L tanks). **Make and model:** Quickspray® 9TBE600, Kubota B5100E® and B6100E. **Calibration:** Regular calibration and equipment maintenance.	☆☆½ ☆☆☆☆
2. Chemical handling, storage & disposal	**Transport:** Tray truck.	☆☆☆
	Storage: Chemical storage shed.	☆☆☆
	Personal protective equipment: Tyvek suits, boots, gloves (nitrile), goggles/face shield and respirator are used for all insecticide, herbicide, fungicide and all mixing operations.	☆☆☆☆
	Disposal: Use excess on other crops. Operators don't mix large quantities, but prefer to go back and re-fill if more is required.	☆☆☆½
3. Spray drift	**General operating parameters:** Information not supplied.	☆
	Typical spraying conditions: Wind speed: less than 10 km/hr. Temperature: less than 26°C. Humidity: Not applicable.	 ☆☆☆ ☆☆☆☆ ☆
	Spray drift management strategies: Not necessary due to our location. We never spray when windy and most crops are under cover.	☆☆
4. Overall management of spraying operations	**Training:** All operators are trained in the farm chemical users course.	☆☆☆☆
	Record keeping: Spray request form—date, operator/s, purpose of spray, crops to spray, litres required, locations, chemical, rate, amount, wetter, unit speed, unit (equipment), weather, hours. All details recorded.	☆☆☆☆
	Emergency procedures: Emergency showers, sand bags, safety protocols and first-aid officer on site during all spray operations.	☆☆☆½

CRITICAL COMMENTS (by management area)
1. High volume hydraulic spraying can result in waste of pesticide and run-off to the environment. 2. The pesticide storage area needs to be locked, well ventilated and placarded. 3. Spray drift is always an issue requiring consideration and careful planning, even high volume hydraulic sprayers produce some fines (small droplets prone to drift). 4. Emergency contact numbers and product SDS sheets need to be available.

Case Study 4	**Production description:** Main product lines include house plants, exotic shrubs (gardenias and natives). Produces in shadehouse, glasshouse and open areas. **Operation type:** Wholesale only.	*OVERALL RATING* ☆☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Annovi Reverbi AR 30 pressure sprayer with 300 L tank, 2 hoses and reels with 2 turbo gun 400s. Granule applicator (supplied with product) and knapsack sprayer used for some herbicide operations. **Calibration:** Information not supplied.	☆☆☆
2. Chemical handling, storage & disposal	**Transport:** By suppliers vehicle – flat bed truck with secure chemical box bolted to tray.	☆☆☆☆
	Storage: Secure locked room, shelved, ventilated and signed.	☆☆☆☆
	Personal protective equipment: PPE used for spraying insecticides (Orthene Xtra®, Vertimec®, Pirimor WG®, Confidor® 200 SC, Kelthane®, Talstar® 80 SC) and fungicides (Rovral® aquaflo, Fosject®, Wettabel Sulphur, Bravo® 720) (including their related mixing operations) includes overalls with hood, boots, gloves and power helmet. Overalls with hood, boots, gloves and respirator are used for herbicide (Ronstar, Rout, Weedmaster) operations. The same equipment is used for mixing herbicides plus goggles/face shield.	☆☆☆
	Disposal: Extra pesticide is sprayed on other crops.	☆☆☆½
3. Spray drift	**General operating parameters:** 2.75 L/min @ 10 bar	
	Typical spraying conditions: Do not have facilities to measure conditions. Spraying ceases when considered to be ineffective or to produce too much drift.	☆
	Spray drift management strategies: Do not spray when wind is too strong or blowing from particular direction.	☆☆
4. Overall management of spraying operations	**Training:** All spray operators are ChemCert accredited.	☆☆☆☆
	Record keeping: Will use computer records in future. Presently use record sheets (weather conditions, PPE, name of mix, trade name, quantity, vat volume, area to be sprayed, plants to be sprayed, plant code, size, signature).	☆☆☆
	Emergency procedures: Office is always open when any spray application occurs. Spill kits are supplied to contain any spills, safety showers on site.	☆☆☆

CRITICAL COMMENTS (by management area)

1. Calibration information for all sprayers is required and calibration needs to be repeated regularly.
2. Records of respirator cartridge usage need to be kept. Respirators and all other PPE should be carefully stored away from pesticides.
3. Environmental conditions before and during spraying should be measured. A pressure of 10 bar will produce a lot of small droplets, which may drift out of the target area.
4. Emergency numbers and SDS information for products should be available.

Case Study 5	**Production description:** Indoor plants. Produces in shadehouses. **Operation type:** Wholesale only.	***OVERALL RATING*** ☆☆½
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Optima Croplands **Make and model**: Silvan 300 L tank. Pump and motor (HR30TG) 5½ Honda motor. **Calibration:** Output of machinery? 6L every 46 seconds.	☆☆
2. Chemical handling, storage & disposal	**Transport:** Delivery truck.	☆☆☆
	Storage: In a chemical shed.	☆☆½
	Personal protective equipment: For insecticide (Endosulfan, Lannate®, Verdimec®) and fungicide (Copper, Dithane®, Sulphur) operations a washable hat, overalls, boots, gloves, sunglasses and respirator are used. For herbicide operations (Roundup®) overalls, boots, gloves and respirator are used. Overalls, boots, gloves, face shield, respirator and apron are used for mixing operations.	☆☆☆½
	Disposal: Respray over the crop or target area.	☆☆☆
3. Spray drift	**General operating parameters:** Information not supplied.	
	Typical spraying conditions: Wind speed: less than 30 km/h. Temperature: less than 32°C. Humidity: 65% or higher.	 ☆ ☆☆☆ ☆☆☆
	Spray drift management strategies: Fibre glass walls and trees.	☆☆½
4. Overall management of spraying operations	**Training:** All operators have been trained through ChemCert.	☆☆☆☆
	Record keeping: Record keeping sheets (date, crop type, pest or problem, area treated, amount of mix used, notes, results, name of operator, signature).	☆☆☆☆
	Emergency procedures: Bucket, shovel, plastic bags and broom are all kept for spills. Shower is close by.	☆☆☆

CRITICAL COMMENTS (by management area)
1. Spraying equipment needs to be calibrated and records kept. 2. The pesticide storage area needs to be well ventilated, locked and well placarded. 3. Operating conditions, including equipment settings need to be recorded for all operations.

Case Study 6	**Production description:** Outdoor trees, shrubs and groundcovers. Produces in shadehouse and open areas. **Operation type:** Wholesale only.	***OVERALL RATING*** ☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Hydraulic spray pump, PTO-driven, Hardi mistblower®. **Calibration:** Information not supplied.	☆☆☆
2. Chemical handling, storage & disposal	**Transport:** Delivered by supplier.	☆☆☆☆
	Storage: Chemical shed.	☆☆
	Personal protective equipment: Overalls, boots, gloves, goggles/face shield and respirator used for all insecticide, herbicide and fungicide applications.	☆☆☆
	Disposal: Extra product used on stock gardens.	☆☆½
3. Spray drift	**General operating parameters:** Information not supplied.	
	Typical spraying conditions: Wind speed: When leaves are blowing across ground. And when spray may drift towards sensitive areas. Temperature: Done early morning. Humidity: N/A	☆ ☆
	Spray drift management strategies: Shadehouses near perimeter of nursery.	☆☆
4. Overall management of spraying operations	**Training:** All operators have been ChemCert accredited.	☆☆☆☆
	Record keeping: New industry spray diary.	☆☆☆
	Emergency procedures: SDS sheets available, emergency shower.	☆☆½

CRITICAL COMMENTS (by management area)
1. The term 'mistblower' is confusing, it might refer to an air-shear sprayer or an air assisted hydraulic sprayer (most likely the second). 2. The storage area for pesticides needs to be locked and well ventilated. 3. Records must be kept of operating conditions and the calibration of equipment. 4. A spill kit is also required along with emergency contact numbers.

Case Study 7	**Production description:** Main product lines include plant seedlings (vegetables, potted colour, specialised flowers, pot plants), herbs, tropical foliage plants, trees and shrubs. 70 acre orchard. Produces in shadehouse, glasshouse and open areas. **Operation type:** Wholesale only and retail.	***OVERALL RATING*** ☆☆☆½
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Small pneumatic sprayers, knapsack for small use areas, 450 L spray carts from tractor, PTO-driven. **Make and model:** Mostly all Hardi equipment. **Calibration:** Information not supplied.	☆☆ N/A
2. Chemical handling, storage & disposal	**Transport:** Supplier's vehicle (truck or heavy ute).	☆☆☆☆
	Storage: Locked, brick shed, plus separate locked compartment for some chemicals. The shed is specially constructed for spillage and has concrete bunding.	☆☆☆☆
	Personal protective equipment: For insecticide (Orthene, Pounce®, Lannate®), herbicide (Rout®, Gramoxone®), fungicide (Zibeb®, Saprol®, Kocide®) and mixing (not insecticides) operations the PPE used includes washable hat, disposable overalls, boots, gloves, goggles and respirator. The same is used for Roundup® and mixing insecticides minus the washable hat, and potentially no goggles for the Roundup®.	☆☆☆½
	Disposal: Excess spray is sometimes dispersed over grassed wasteland away from drains, creeks etc. or collected in a sump from rinsing operations.	☆☆☆
3. Spray drift	**General operating parameters:** Ceramic nozzles, at 100 psi (5 L/min).	☆☆
	Typical spraying conditions: Wind speed: By observation. Weather station phoned daily. Temperature: less than 27°C if possible. Humidity: Difficult in houses, but good drying day essential. When chemical can't dry, we won't spray. We phone for dew point if in doubt.	☆☆☆½
	Spray drift management strategies: Shadehouses have sidewalls mostly. Vegetation screens are planted for open areas.	☆☆☆
4. Overall management of spraying operations	**Training:** All spray operators are ChemCert accredited.	☆☆☆☆
	Record keeping: Record sheet (date, crops, chemical, rate/litre, reason, start & finish time, operators signature).	☆☆☆☆
	Emergency procedures: Showers, eye wash and workplace health and safety officer on site. Spillage bucket, SDS and emergency contact numbers available. **Extra notes:** All personnel using pesticides have blood samples taken at the firm's expense annually by a visiting doctor. The list of chemicals used is forwarded to the doctor. No person to date has been found to be in any danger.	☆☆☆☆ ☆☆☆☆

CRITICAL COMMENTS (by management area)
1. Calibration of all equipment is essential and records should be kept. 2. The same PPE for all products is recommended as good practice to avoid confusion. 3. A full record of operating conditions is necessary for all applications of pesticide. 4. The overall management is very good.

Case Study 8	**Production description:** Main product lines include roses and topiary. Produces in shadehouse and open areas. **Operation type:** Wholesale only.	***OVERALL RATING*** ☆☆½
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Quickspray unit. **Calibration:** Information not supplied.	☆☆
2. Chemical handling, storage & disposal	**Transport:** Delivered by company of purchase.	☆☆☆☆
	Storage: In a steel locked shed.	☆☆½
	Personal protective equipment: Overalls, boots, gloves, goggles/ face shield and respirators are used for insecticides (Confidor®, Lorsban® Talstar®), herbicides (Basta®, Rout®, Afalon®), fungicides (Dithane®, Ridomil®, Topas®) for mixing and spraying operations.	☆☆☆
	Disposal: We don't have any, all our chemicals are always bought on demand.	Not assessable
3. Spray drift	**General operating parameters:** No information given.	
	Typical spraying conditions: Wind speed: We have to judge wind speed. Temperature: Generally we do not spray above 30°C. Humidity: Not Applicable.	☆
	Spray drift management strategies: No strategies as we do not spray when weather conditions are unsuitable.	☆½
4. Overall management of spraying operations	**Training:** All are either qualified or trained in the farm chemical users course.	☆☆☆
	Record keeping: All records are kept in a book, for every spray application.	☆☆☆
	Emergency procedures: We have a shower, fire extinguisher and emergency phone number.	☆☆½

CRITICAL COMMENTS (by management area)
1. Calibration of equipment must be carried out frequently and records kept. 2. The pesticide storage area needs to be well ventilated, appropriately signed and locked. 3. Records of operating conditions need to be kept and the management of spray drift carefully considered. 4. A spill management kit should be available at the mixing and loading site/s.

Case Study 9	**Production description:** Main products include fuscias, hibiscus, hydrangeas, bougainvillea, Australian natives and outdoor shrubs. Produce in shadehouse, glasshouse (propagation only), open areas and igloo. Total area 2.3ha. **Operation type:** Wholesale only.	*OVERALL RATING* ☆☆½
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** High volume sprayer, AR 30 SP (Annovi Reverberi) pressure pump – powered by Kubota. **Calibration:** Information not supplied.	☆☆
2. Chemical handling, storage & disposal	**Transport:** Truck.	☆☆
	Storage: Locked shed.	☆☆☆
	Personal protective equipment: Disposable overalls, rubber boots, disposable gloves and respirator used for insecticide (Maverick®, Confidor®, Supracide®), herbicide (Glyphosate®, Spray seed®, Ronstar®) and fungicide (Baycor 300®, Alliette®, Ridomil®) operations.	☆☆☆½
	Disposal: Only mix required amount of chemical. Any excess is sprayed onto stock plants as a preventative.	☆☆☆½
3. Spray drift	**General operating parameters:** Information not supplied.	
	Typical spraying conditions: Wind speed: Information not supplied. Temperature: Summer months early morning or evening. Humidity: Information not supplied.	☆
	Spray drift management strategies: Information not supplied.	☆
4. Overall management of spraying operations	**Training:** All spray operators participate in the industry training refresher every 2–3 years.	☆☆☆
	Record keeping: Chemical record book (date, chemical used, rate & quantity mixed, plants sprayed, operator).	☆☆☆
	Emergency procedures: No procedures.	☆

CRITICAL COMMENTS (by management area)
1. Calibration of spraying equipment and the keeping of records are both essential. 2. A well-ventilated and signed pesticide storage area required. Transport truck needs to be adequately managed. 3. Measurement of operating conditions when spraying and keeping records is important. 4. Emergency procedures including contact numbers and an emergency spill kit need to be available.

Case Study 10	**Production Description:** Product lines include semi-advanced and advanced plants, produced in open areas only. **Operation Type:** Wholesale only.	***OVERALL RATING*** ☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer types:** Contract sprayers using hand lances and boom sprayer. Also 4WD bike with CDA equipment. **Make and model:** Quickspray (400 Lt) 3Pt. Linkage Silvan boom and 1200 Undavina CDA. **Calibration:** Information not supplied.	☆☆☆½ ☆
2. Chemical handling, storage & disposal	**Transport:** Chemical company delivers via trucks.	☆☆☆☆
	Storage: Lockable cabinet in locked shed.	☆☆☆½
	Personal protective equipment: For all insecticide (Endosulfan®, Folimat 800, Mavrik®), herbicide (Roundup®, Gesatop 560®, Ronstar®), fungicides (Bravo 720®, Bacor 300® and Copper oxy) and mixing operations overalls, boots, gloves, goggles/face shield and respirator or power helmet are used.	☆☆☆
	Disposal: Very rare to have remaining product, but if necessary it is emptied onto grassy area near washdown site if not used up on another suspect crop, or if herbicide stored in drums in spray shed.	☆☆☆
3. Spray drift	**General operating parameters:** Information not supplied.	
	Typical spraying conditions: Wind speed: Information not supplied. Temperature: less than 30°C. Humidity: 50% or higher.	☆☆½
	Spray drift management strategies: Boundary plantings and windbreaks.	☆☆☆
4. Overall management of spraying operations	**Training:** Some operators have been trained in the Farm chemical users course.	☆☆
	Record keeping: Spray record sheet (date, area ref., crop, weed/pest/ disease targeted, chemicals & additives used, recommended rate, litres of spray applied, temperature, signature).	☆☆☆½
	Emergency procedures: SDS sheets easily accessible, colour tags to be worn when spraying eg. if S6 – yellow tag. Up to date first aid cabinet – IPECAC and atropine tablets, long life milk. Trained first aiders on site.	☆☆☆☆

CRITICAL COMMENTS (by management area)
1. Calibration of spraying equipment needs to be carried out regularly and records kept. Contractors should be asked to supply records of their activities. 2. The pesticide storage cabinet should be well ventilated and signed. 3. Operating conditions during spraying should be measured and recorded. 4. All operators should be ChemCert accredited. Ipecac syrup and atropine should not be available as they can only be used under direct medical supervision.

Case Study 11	**Production description:** Main product lines include annuals and vegetables. Specialises in one species of flowering plant. Produces in shadehouse, glasshouse and open areas. **Operation Type:** Wholesale only.	***OVERALL RATING*** ☆☆
MANAGEMENT AREA	CURRENT OPERATION	RATING
1. Application equipment & techniques	**Sprayer Types:** 200 L spray machine Hardi pump. Also 8/t Hozelock handspray used at times (for glasshouse and open areas only). **Calibration:** Information not supplied.	☆☆½ ☆
2. Chemical handling, storage & disposal	**Transport:** Ute.	☆☆
	Storage: In certified storage which complies with American and Australian Standards.	☆☆☆
	Personal protective equipment: Overalls, boots, gloves and respirators are used for insecticide (Ambush®, Mavrik®, Pirimor ®), herbicide (Roundup ®, Gesatop ®) and fungicide (Dithane®, Bavistan®, Exparen®) operations. Mixing information not included.	☆☆½
	Disposal: Excess is shared between growers or disposed of in a separate chemical drainage system.	☆
3. Spray drift	**General operating parameters:** Information not supplied.	
	Typical spraying conditions: Wind speed: Moderate. Temperature: less than 30°C. Humidity: Humidity in Melbourne not an issue.	☆½
	Spray drift management strategies: All staff are notified of spraying to vacate area. No Entry signage erected.	☆☆
4. Overall management of spraying operations	**Training:** All operators are trained in the farm chemical users course or in the house training manual.	☆☆☆
	Record keeping: Record sheets include spray list, chemicals used, chemical manifest, water treatment, drenching sheet.	☆☆☆
	Emergency procedures: No information supplied.	☆

CRITICAL COMMENTS (by management area)

1. Calibration of all pesticide application equipment is essential and records must be kept.
2. Disposal: It is not advisable to store pesticide mixtures; mixing can be the most hazardous time when using pesticides and mixing and use protocols need to be in place.
3. Environmental conditions at the time of pesticide application must be measured and recorded.
4. Emergency numbers and a spill kit need to be available.

REFERENCES AND FURTHER READING

Barret, M, Boldra, C, Chalmers, I, Henderson, R and Keighly, V. 2002. *Agsafe Accreditation Training Manual*. Canberra: Agsafe Limited. agsafe.com.au

Bartok, JW Jr. 1996. *Guidelines for safe pesticide storage*, Greenhouse Management & Production, May, pp.56–57.

ChemCert Australia, 2013. *Chemical Users Handbook*, Sydney Australia.

Day, LG, Hock, WK and MacAlpine, G. 1999. *Agsafe Accreditation Training Manual*, A Subsidiary of Avcare Limited, Canberra.

Department of Natural Resources, Queensland, 1997. *Planning Guidelines: Separating Agricultural and Residential Land Uses*. DNRQ 97088, http://www.dsdip.qld.gov.au/resources/policy/plng-guide-sep-ag.pdf

drumMUSTER, 2002. *Effective Rinsing of Farm Chemical Containers*. http://www.drummuster.com.au/wp-content/blogs.dir/3/files/2011/08/drummuster-effective-rinsing-brochure.pdf?phpMyAdmin=afc50bbf10et2e46ef05

Houseworth, LD. 1998. *pH Balanced*, American Nurseryman, May, pp. 44–45.

McDonald, J. 2012. *Nursery Production Minor Use Permit Pesticide Program*. Nursery Technical Papers Issue no. 11

NGIA. 2011. *EcoHort: Nursery Industry Environmental Management System* fact sheet. (Cited 22 June, 2013) www.ngia.com.au/Category?Action=View&Category_id=126

Radcliff, JC. 2002. *Pesticide Use in Australia*. Australian Academy of Technological Sciences and Engineering, Ian McLennan House, Victoria.

3M Occupational Health and Environmental Safety Division, 2011. *3M™ Administrative Respiratory Protection Program*. St Paul, MN, USA. (Cited 14 May 2013) URL: http://multimedia.3m.com/mws/-mediawebserver?66666UuZjcFSLXTtNxfcNxMyEVuQEcuZgVs6EVs6E666666--

APPENDIX 1. CONTACT DETAILS

DISPOSAL OF USED PESTICIDE CONTAINERS & CHEMICALS

DRUM MUSTER

Phone: 1800 008 707

Website: www.drummuster.com.au

ChemClear

Phone: 1800 008 707

Website: www.chemclear.com.au

LEGISLATION

Australasian Legal Information Institute

Website: www.austlii.edu.au

COMLAW

www.comlaw.gov.au

NEW SOUTH WALES

Nursery & Garden Industry, NSW and ACT (NGINA)

344–348 Annangrove Road

Rouse Hill, NSW, 2155

Phone: 02 9679 1472 Fax: 02 9679 1655

Email: info@ngina.com.au

Website: www.ngina.com.au

Environmental Protection Agency (EPA)

Website: www.environment.nsw.gov.au/pesticides/index.htm

New South Wales Legislation

Website: www.legislation.nsw.gov.au

NORTHERN TERRITORY

Nursery & Garden Industry, Northern Territory (NGINT)

PO Box 348

Palmerston, NT 0831

Phone: 08 8983 3233 Fax: 08 8983 3244

Email: ngint@ntha.com.au

Department of Primary Industries and Fisheries

Phone: 08 8999 5511

(Ask for Chemical Services)

www.nt.gov.au/d

Northern Territory Legislation

Website: www.dcm.nt.gov.au

QUEENSLAND

Nursery & Garden Industry, Queensland (NGIQ)

Cnr Orange Grove & Riawena Roads

PO Box 345, Salisbury QLD 4107

Phone: 07 3277 7900 Fax: 07 3277 7109

Email: info@ngiq.asn.au

Website: www.ngiq.asn.au

Department of Agrculture Fisheries and Forestry Queensland (DAFFQ) Call Centre

Phone: 13 25 23 (Ask to speak to the appropriate policy officer within the DAFF Animal and Plant Health Service.)

Website: www.dpi.qld.gov.au

Queensland Legislation

Website: www.legislation.qld.gov.au

SOUTH AUSTRALIA

Nursery & Garden Industry, South Australia (NGISA)

505 Fullarton Road

Netherby, SA 5062

Ph: +61 8 8372 6822 Phone: 08 8271 1012

Fax: 08 8372 6833

Email: gfuller@ngisa.com.au

Website: www.ngisa.com.au

Bioscecurity South Australia

Website:www.pir.sa.gov.au/biosecuritysa/ruralchem

South Australia Legislation

Website: www.legislation.sa.gov.au

TASMANIA

Department of Primary Industries, Parks, Water and Environment

Phone: 1300 368 550

Spray drift complaints: 1800 005 244

Website: www.dpiw.tas.gov.au/inter.nsf/ThemeNodes/EGIL-52N435?open

Nursery & Garden Industry, Tasmania

9 Takari Place

MORNINGTON TAS 7018

PO Box 3009

ROSNY PARK TAS 7018

Phone: 03 6244 7977 Fax: 03 6244 7977

Email: ngit@bigpond.com

Tasmania legislation

Website: www.thelaw.tas.gov.au

VICTORIA

Nursery Industry Association of Victoria

3/307 Wattletree Road, Malvern East VIC 3145

PO Box 2280, Wattletree Road LPO, East Malvern VIC 3145

Phone: 03 9576 0599 Fax: 03 9576 0431

Email: ngiv@ngiv.com.au

Website: www.ngiv.com.au

Department of Environment and Primary Industries

Phone: 136 186

www.dpi.vic.gov.au/agriculture/farming-management/chemical-use

Victoria legislation

Website: www.legislation.vic.gov.au

WESTERN AUSTRALIA

Nursery & Garden Industry, Western Australia (NGIWA)

PO Box 135

MOUNT HELENA WA 6082

Phone: 0419 930 008

Email: reception@ngiwa.com.au

WA Department of Agriculture

Phone: 08 9368 3333

Website: www.agric.wa.gov.au/PC_92826.html?s=1865313585

Western Australia legislation

www.slp.wa.gov.au/legislation/statutes.nsf/default.html

PRODUCTS & SERVICES

Nursery & Garden Industry Australia

Unit 58 Quantum Corporate Park

5 Gladstone Road

CASTLE HILL NSW 2154

PO Box 7129

BAULKHAM HILLS BC NSW 2153

Phone: 02 8861 5100 Fax: 02 9659 3446

Email: info@ngia.com.au

For information on FMS, EcoHort, NIASA and BioSecure HACCP.

Agsafe Limited

Level 2, AMP Tower, 1 Hobart Place, Canberra City, ACT 2601

GPO Box 816, Canberra City ACT 2601

Phone: 02 6230 4799 Fax: 02 6230 6710

Email: info@agsafe.com.au

Website: agsafe.com.au

ChemCert Australia Inc.

For all enrolment and courses inquiries:

Freecall: 1800 444 228

Website: www.chemcert.com.au

Cornell University Pesticide Active Ingredient information

Website: pmep.cce.cornell.edu/profiles/index.html

Extonet Pesticide Information Profiles

Website: extoxnet.orst.edu/pips/ghindex.html

Standards Australia

Level 10, The Exchange Centre

20 Bridge Street, Sydney

GPO Box 476

Sydney NSW 2001

Freecall within Australia: 1800 035 822

Fax: 02 9237 6010

Website: www.standards.org.au

Standards Australia Publications Distributor - SAI Global

Office hours: 8 am to 5 pm (AEST/AEDT)

Call within Australia: 131 242

Faxes within Australia: 1300 65 49 49

Email: sales@sai-global.com

Web shop: www.saiglobal.com/shop

Poisons information hotline 13 11 26.

Australian Pesticides and Veterinary Medicines Authority (APVMA)

The APVMA is the regulator of pesticides and veterinary medicines up until the point of retail sale. For regulation policy issues, chemical use issues or for the regulation of other chemical products, please view information on the responsible organisations.

18 Wormald Street, Symonston, ACT, 2609, Australia

PO Box 6182, Kingston, ACT, 2604, Australia

Phone: +61 2 6210 4701

Email: contact@apvma.gov.au

Website: www.apvma.gov.au

Adverse experiences

To report an unintended effect from the use of registered agricultural or veterinary chemicals.

FreeCall: 1800 700 583 (within Australia). Charges apply for calls made from mobile phones

Fax: +61 2 6210 4776

Email: aerp@apvma.gov.au

Agricultural chemical products, active constituents and permits

Phone: +61 2 6210 4748 Fax: +61 2 6210 4776

Email: pesticides@apvma.gov.au

Fees, Levies and Invoice queries

Phone: +61 2 6210 4852 Fax: +61 2 6210 4874

Email: finance@apvma.gov.au

Feedback and complaints

Phone: +61 2 6210 4746 Fax: +61 2 6210 4776

Email: feedback@apvma.gov.au

APPENDIX 2. GLOSSARY OF PESTICIDE TERMS

COMMON ABBREVIATIONS

AVPMA	Australian Pesticides and Veterinary Medicines Authority
EC	Emulsifiable concentrate—a liquid pesticide formulation
IPM	Integrated pest management
MRL	Maximum residue level
OC	Organochlorine pesticide
OP	Organophosphate pesticide
SC	Suspended concentrate—a liquid pesticide formulation
SDS	Safety data sheet
SP	Soluble powder pesticide formulation
SP	Synthetic pyrethroid pesticide
ULV	Ultra low volume sprays, usually oil based

DEFINED TERMS

Acetone	A volatile solvent, such as that used in many nail polish removers.
Acidic	A low pH (< 7) e.g. vinegar is mildly acidic, sulphuric acid is very acidic.
Active constituent	That part of a farm chemical formulation that is biologically active on the pest target.
Adjuvant	A secondary 'helper' chemical added to improve the effectiveness of a pesticide spray.
Aerosol	Fine droplets, small enough to stay suspended in air.
Alkaline	A high pH (> 7) e.g. bore water is mildly acidic, sodium hydroxide (table salt) is very alkaline.
Anionic	Negatively charged (ions).
Anti-foaming agent	A substance added to a formulation to prevent excessive foam forming during the mixing of ingredients.
Buffering agent	A chemical which, when added to a solution, has the ability to resist changes to pH or hydrogen ion concentrations. Acidifying buffers are used to counter alkaline bore water supplies that can improve spray solution stability and performance.
Cationic	Positively charged (ions).
Diffusion	The spreading and penetration of particles by natural movement into space that may be enclosed, as in the case of respirator filter elements.
Dispersal	The process of spreading a population, usually by seeds or spores.
Efficacy	A measure of how well a product does the job it was designed to do.

Emulsifiable concentrate	A chemical formulation consisting of an active constituent dissolved in an organic solvent together with an emulsifier to facilitate the formation of an even, milky emulsion when mixed with water.
Flowable concentrate	Sometimes called suspension concentrates. These are suspensions of finely milled solid active particles mixed with and suspended, usually, in water that can be measured out by liquid volume.
Formulation	The make-up of the farm chemical as purchased. It consists of the active constituent(s) together with a number of other components that are added to assist handling, efficacy, safety and stability.
Hydrolysis	The breakdown of the active ingredient over time, when mixed in poor quality water.
Integrated pest management	The coordinated use of all available pest management methods to keep pest populations below economic injury levels.
Larva	An immature or young insect that has a pupal or resting stage.
Lifecycle	The successive life stages of a plant or animal as they progress from birth to death.
Maximum residue limit	The maximum legal amount of chemical residue expressed in parts per million that is permitted to be present in marketed produce. No chemical is given clearance for use on a crop or animal unless an MRL has previously been established.
Mode of action	How the agrochemical actually works, e.g. nerve poison.
Non-ionic	A molecule that does not ionise when placed in water. Nearly all wetting agents used in agriculture are non-ionic.
Nymph	An immature insect that does not have a pupal or resting stage, e.g. green vegetable bug.
pH	A measure of acidity. Low pH is acidic (< 7), high pH is alkaline (> 7).
Phytotoxic	A damage response to applying agrochemical, such as a chemical burn.
Resistance	The appearance of a high level of tolerance to a pesticide in a pest species. This is likely to occur when the pest population has been subject to high selection pressure by repeated exposure to pesticides with a similar mode of action.
Selective chemicals	Pesticides that have the ability to selectively target a pest without affecting the crop in which the pest is present.
Sequestering agent	In formulations, adjuvants designed to differentially combine with certain metallic elements, isolate them in soluble compounds and prevent the precipitation of solid particles that could block filters and nozzles.
Soluble powder	A chemical formulation that is packaged as a powder and dissolves completely in water to form a spray solution.
Stable/stability	Meteorological conditions when little or no wind occurs. Not suitable for spraying.
Stickers	An adjuvant added to a product to reduce run-off.
Solution	A liquid containing one or more compounds in a completely homogenous state. Usually refers to chemicals dissolved in and mixed with water (i.e. an aqueous solution).

Surfactant	Short for 'surface active agent'. This term is used to describe wetting agents, stickers and spreaders. Usually non-ionic when used with farm chemicals.
Suspension concentrate	See flowable concentrate.
Synergist	A chemical that increases the biological effect of another when the two are mixed.
Synthetic pyrethroids, organophosphates and carbamates	Insecticides that acts as a nerve poison. They work the same way on humans as they do on insects.
Target	The place where the spray should be directed, which depends on how the product actually works (i.e. its mode of action).
Translocated herbicides	Once applied, these products will move within the plant to the site of action.
Water miscible	Another liquid that is able to mix completely with water to form a homogenous mixture.
Wettable powder	A chemical formulation designed to form a suspension when mixed with water to make up a pesticide spray solution.
Wetter	See 'surfactant'.

APPENDIX 3. PESTICIDE ACTIVITY GROUPS AND STRATEGIES TO AVOID PESTICIDE RESISTANCE

The following pages are a list of the major groups of pesticide chemicals published by Avcare Australia. These are grouped by target into insecticides, fungicides and herbicides, and each is described in terms of its activity on the target organism, usually the disruption of a metabolic pathway. Also included is a description of management strategies to avoid pests developing resistance to pesticides and practical examples from the nursery industry.

Table 8. Insecticides listed by activity group.

Avcare

National Association for Crop Production and Animal Health

Avcare Insecticide Resistance Action Committee (AIRAC) Mode of Action Classification for Insecticides

Group	Primary Target Site	Chemical Subgroups
1A	Acetyl choline esterase inhibitors ** all members of this class may not be cross resistant*	carbamates*
1B		organophosphates*
2A	GABA-gated chloride channel antagonists	cyclodienes
2B		polychlorocycloalthanes
2C		fiproles
3A	Sodium channel modulators	pyrethroids and pyrethrins
4A	Acetyl choline receptor agonists/antagonists	chloronicotinyls
4B		nicotine
4C		cartap, bensultap
5A	Acetyl choline receptor modulators	spinosyns
6A	Chloride channel activators	avermectin, emamectin benzoate
6B		milbemycin
7A	Juvenile hormone mimics	methoprene, hydroprene
7B		fenoxycarb
7C		pyriproxifen
8A	Compounds of unknown or non specific mode of action (fumigants)	methyl bromide
8B		phosphine generating compounds
9A	Compounds of unknown or non specific mode of action (selective feeding blockers)	pymetrozine
9B		cryolite
10A	Compounds of unknown or non specific mode of action (mite growth inhibitors)	clofentezine, hexythiazox

Table 9. Fungicides listed by activity group.

Fungicide Mode of Action Groups

GROUP	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
A	*Benzimidazole*	*Benzimidazole*	benomyl	Benlate®
			carbendazim	various
			thiabendazole	Tecto®
			thiophanate-methyl	Topsin M®
B	*Dicarboximide*	*Dicarboximide*	iprodione	Rovral®
			procymidone	Sumisclex®
C	*DMI*	*Imidazole*	imazalil	Fungaflor ®, Magnate®
			prochloraz	various
		Piperazine	triforine	Saprol®
		Pyrimidine	fenarimol	Rubigan®
		Triazole	bitertanol	Baycor®
			cyproconazole	Alto®
			cyproconazole (+ chlorothalonil)	Bravo Plus®
			cyproconazole (+ iodocarb)	Garrison®
			diclobutrazole	Vigil®
			difenoconazole	Score®, Bogard®
			flusilazole	Cane Strike®, Nustar®
			flutriafol	Vincit®, Armour®, Impact®
			hexaconazole	Anvil®
			myclobutanil	Systhane®, Mycloss®
			paclobutrazol	Cultar®
			penconazole	Topas®
			propiconazole	Tilt®, Bumper®
			tebuconazole	Raxil®, Folicur®
			triadimefon	Bayleton®
			triadimenol	Bayfidan®, Shavit®
			triticonazole	Premis®

Note: - Some products are mixtures of fungicides from different activity groups. These appear only once in the chart.
- If multiple trade names exist, the trade name entry is listed as various.

® Trademark

Avcare

Fungicide Mode of Action Groups

GROUP	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
D	*Phenylamide*	*Acylamine*	benalaxyl (+ mancozeb)	Galben M®
			furalaxyl	Fongarid®
			metalaxyl	Ridomil®
			metalaxyl (+ copper oxychloride)	Ridomil® Plus
			metalaxyl (+ mancozeb)	Ridomil® MZ
			metalaxyl-m	Ridomil® Gold
			metalaxyl-m (+ mancozeb)	Ridomil® Gold MZ
		Oxazolidinone	oxadixyl (+ mancozeb)	Recoil®
			oxadixyl (+ propineb)	Fruvit®
E	*Morpholine*	*Morpholine*	tridemorph	Calixin®
F	*Phosphoro-thiolate*	*Organo-phosphorous*	pyrazophos	Afugan®
G	*Oxathiin*	*Anilide*	carboxin	Vitavax®
			oxycarboxin	Plantvax®
H	*Hydroxy-pyrimidine*	*Pyrimidinol*	bupirimate	Nimrod®
			dimethirimol	Milcurb®
I	*Anilinopyrimidine*	*Anilinopyrimidine*	cyprodinil	Chorus®
			pyrimethanil	Scala®
J	*Hydroxyanilide*	*Hydroxtanilide*	fenhexamid	Teldor®
K	*Strobilurin*	*Strobilurin*	azoxystrobin	Amistar®
			kresoxim-methyl	Stroby®
			trifloxystrobin	Flint®
L	*Phenylpyrroles*	*Phenylpyrroles*	fludioxinil	Maxim®

Note: - Some products are mixtures of fungicides from different activity groups. These appear only once in the chart.
- If multiple trade names exist, the trade name entry is listed as various.
® Trademark

Avcare

Fungicide Mode of Action Groups

GROUP	ACTIVITY GROUP	CHEMICAL GROUPING	ACTIVE CONSTITUENT	TRADE NAME
Y	*Multi-site activity*	*Carbamate*	iodocarb	
			propamocarb	Previcur®
		Phosphonate	fosetyl-al	Aliette®
			phosphorous acid	*various*
		Inorganic	copper (cuprous oxide) copper (hydroxide) copper (oxychloride)	*various*
			iodine	Ultra Dyne C®
			mercury	Shirtan®
			sodium metabisulphite	Uvas Quality Grapeguard®
			sulphur	*various*
		Dithiocarbamate	mancozeb	*various*
			metiram	Polyram®
			thiram	*various*
			propineb	Antracol®
			zineb	*various*
			zineb (+ copper oxychloride)	Copper Curit®
			ziram	*various*
		Phthalimide	chlorothalonil	Bravo®, Rover®
		Chlorophenyl	quintozene	Terrachlor®
		Quinone	dithianon	Delan®
		Hydroxyquinoline	8-hydroxy quinoline sulphate	Chinosol®
		Pyradinamine	fluazinam	Shirlan®
		Cyclic imide	captan	Captan WG, Merpan®
X	*(Unspecified)*	*Cinnamic acid derivative*	dimethomorph (+ mancozeb)	Acrobat® MZ
		Sulfamide	dichlofluanid	Euparen®
			tolyfluanid	Euparen Multi®
		Dinitrophenyl	dinocap	Karathane®
		Organophosphate	tolclofos-methyl	Rizolex®
		Guanidine	dodine	*various*
			guazatine	Panoctine®
		Thiadiazole	etridiazole	Terrazole®
		Quinoxaline	oxythioquinox	Morestan®
			pencycuron	Monceren®

Note: - Some products are mixtures of fungicides from different activity groups. These appear only once in the chart.
- If multiple trade names exist, the trade name entry is listed as various.

® Trademark

Table 10. Herbicides listed by activity group

2000 Herbicide Modes of Action

Avcare

Herbicides act by interfering with specific processes in plants - this is their mode of action. Herbicide product labels carry a letter code A,B,C, ... N representing their specific mode of action group. ***To effectively manage herbicide resistance get to know your herbicide groups and follow these simple steps.***

▪ Design your anti-resistance strategies around integrated weed management guidelines. ▪ Check this chart for herbicides in the same group (*the resistance risk is the same*). ▪ Where possible reduce reliance on high risk groups. ▪ Rotate between groups across years. ▪ Seek advice and further information about anti-resistance strategies. ▪ Keep accurate records of your herbicide applications on a paddock basis.

CRC Weed management systems

GRDC Grains Research & Development Corporation

High Risk

GROUP A Inhibitors of fat (lipid) synthesis – ACC'ase inhibitors.

- **Aryloxyphenoxypropionates ("Fops"):** Correct®, Falcon®, Fusilade®, Fusion®, Hoegrass®, Puma S®, Shogun®, Targa®, Topik®, Tristar®, Verdict®, Wildcat®, diclofop
- **Cyclohexanediones ("Dims"):** Achieve®, Fusion®, Select®, Sertin®, Sertin® Plus

GROUP B Inhibitors of the enzyme acetolactate synthase – ALS inhibitors.

- **Sulfonylureas:** Ally®, Brush-Off®, Cut-Out™, Glean®, Harmony® M, Logran®, Londax®, Monza®, Oust®, Renovate®, Titus®, metsulfuron, chlorsulfuron
- **Imidazolinones:** Arsenal®, Flame®, OnDuty®, Spinnaker®
- **Sulfonamides:** Broadstrike®, Eclipse®

Moderate Risk

GROUP C Inhibitors of photosynthesis and photosystem II.

- **Triazines:** Agtryne® MA (also contains MCPA - Group I), Bladex®, Gesagard®, Gesaprim®, Igran®, atrazine, simazine, terbutryn
- **Triazinones:** Lexone®, Sencor®, Velpar®, metribuzin
- **Ureas:** Afalon®, Cotoran®, Graslan®, Karmex®, Tribunil®, Probe®, Tupersan®, Ustilan®, diuron, linuron
- **Nitriles:** Buctril® 200, Buctril® MA (also contains MCPA - Group I), Jaguar® (also contains diflufenican - Group F), Totril®, bromoxynil
- **Benzothiadiazoles:** Basagran®
- **Acetamides:** Ronacil®
- **Uracils:** Hyvar®, Krovar®, Sinbar®
- **Pyridazinones:** Pyramin®
- **Pheny-pyridazines:** Tough®

GROUP D Inhibitors of tubulin formation.

- **Dinitroanilines:** Relay®, Surflan®, Stomp®, Treflan®, Yield®, trifluralin
- **Benzoic acids:** Chlorthal®
- **Pyridines:** Visor®

GROUP E Inhibitors of mitosis.

- **Thiocarbamates:** Avadex® BW, Eptam®, Ordram®, Saturn®, Tillam®, Vernam®, molinate
- **Carbamates:** chlorpropham
- **Organophosphorus:** bensulide

GROUP F Inhibitors of carotenoid biosynthesis.

- **Nicotinanalides:** Brodal®, Jaguar® (also contains bromoxynil - Group C), Tigrex® (also contains MCPA - Group I)
- **Triazoles:** amitrole
- **Pyridazinones:** Solicam®
- **Isoxazolidinones:** Command®, Magister®
- **Pyrazoles:** Talpan®

GROUP G Inhibitors of protoporphyrinogen oxidase.

- **Diphenyl ethers:** Affinity®, Blazer®, Goal®, Spark™
- **Oxidiazoles:** Ronstar®

GROUP H Inhibitors of protein synthesis.

- **Thiocarbamates:** Saturn®

GROUP I Disrupters of plant cell growth.

- **Phenoxys:** 2,4-D, 2,4-DB, MCPA, Barrel®, (also contains bromoxynil and dicamba – Group C and Group I), Buctril® MA (also contains bromoxynil – Group C), Tigrex® (also contains diflufenican - Group F), Tillmaster® (also contains glyphosate - Group M)
- **Benzoic acids:** Banvel®, Cadence®, dicamba
- **Pyridines:** Garlon DS®, Lontrel®, Tordon® 242, Tordon® 75-D, Starane®, triclopyr

Low Risk

GROUP J Inhibitors of fat synthesis.

- **Alkanoic acids:** Propon

GROUP K Herbicides with multiple sites of action.

- **Amides:** Devrinol®, Dual Gold®, Enide®, Kerb® WP, Ramrod®, napropamide, metolachlor
- **Carbamates:** Asulox®, Betanal®, Carbetamex®, asulam
- **Amino propionates:** Mataven L®
- **Benzfurans:** Tramat®, ethofumesate
- **Phthalamates:** Alanap®
- **Nitriles:** dichlobenil

GROUP L Inhibitors of photosynthesis at photosystem I.

- **Bipyridils:** Gramoxone®, Reglone®, SpraySeed®, paraquat, diquat

GROUP M Inhibitors of EPSP synthase.

- **Glycines:** Roundup®, Tillmaster® (also contains 2,4-D - Group I), Touchdown, glyphosate

GROUP N Inhibitors of glutamine synthetase.

- **Glycines:** Basta®

Groups are listed by resistance risk. The listing of trade names above does not represent an exhaustive record of registered products. Products listed are primary registered products only and are arranged in alphabetical order. Active ingredient names are additionally included where multiple products are registered.

Table 11. Insecticide resistance management strategies

Insecticide resistance management strategies

Insecticide Resistance Management Strategies

Developed by the Avcare Insecticide Resistance Action Committee and Industry Researchers

Introduction

The Avcare Insecticide Resistance Action Committee (AIRAC) has developed insect resistance management strategies in conjunction with growers, researchers and agronomists to minimise the development of insect resistance to insecticides. These strategies attempt to provide growers with the widest possible range of methods for sustainable insect control.

Principles of Resistance Management

The broad principles on which resistance management strategies are based rely on the minimisation of selection pressure to insecticides or groups of insecticides and are as follows.

Alternation of Chemistry

Constant use of insecticides from one chemical grouping will increase the risk of rapid build up of resistance to that chemical group. Alternation of chemical groups will slow down the process of selection for resistance.

Use of Cultural Practices

Incorporation of cultural techniques for controlling an insect pest will reduce selection pressure on the insecticides. Any resistance management strategies should incorporate all available methods of control for the insect pest concerned.

Understanding of the Insect/Mite Life Cycle

A good understanding of the life cycle of the pest is essential so that control methods can be effectively targeted. An insecticide should always be targeted at the insect growth stage that is most susceptible for that insecticide.

Application

Label Recommendations

Insecticide labels have been carefully developed to ensure the most effective control of the pest. The label should be carefully read and adhered to at all times.

Rates

Full recommended rates of registered insecticides should always be used to ensure the most effective control of the pest.

Coverage

The majority of insecticides require good coverage of the target area to ensure the best possible chance of contact and subsequent control of the pest.

Avcare recommended resistance strategy examples

Insecticide Resistance Management Strategies
Developed by the Avcare Insecticide Resistance Action Committee and Industry Researchers

Crop(s): Strawberries

Insect(s): Two Spotted Mite

Guidelines:

- Monitor mite activity and treat infestations before thresholds are reached - i.e. spray earlier rather than later. A threshold of 6 mites per leaf could be followed.
- Do not apply sequential applications of products from any one chemical group. Rotate between miticides from different groups.
- Any one product should not be used more than twice in a growing season
- If possible incorporate the use of predatory mites for the control of this pest.

Insecticide Resistance Management Strategies
Developed by the Avcare Insecticide Resistance Action Committee and Industry Researchers

Crop(s): Various

Insect(s): Green Peach Aphid

Guidelines:

- Rotate between registered insecticides that have different modes of action (e.g. groups 1 & 4).
- Do not apply consecutive applications of insecticides that have the same mode of action within and between seasons.
- The modes of action (groups) and registered insecticides for control of green peach aphid are listed below.

Group*	Primary Target site	Chemical Subgroup	Example chemical
1A	Acetyl choline esterase inhibitors	Carbamates	pirimicarb
1B		Organophosphates	methamidophos
4A	Acetyl choline receptor agonists/antagonists	Chloronicotinyls	imidacloprid

***Groups are the International Resistance Action Committee Insecticide Groups based on mode of action of the insecticides.**

Notes:

1. Seek advice from the manufacturers and/or government advisory services to determine local resistance levels for particular Group 1 and Group 4 insecticides.
2. Adhere to the maximum number of applications if recommended on the insecticide label.

Appendix 7

Australian Government

Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR THE CONTROL OF APHIDS, SCALE AND SILVERLEAF WHITEFLY IN NURSERY STOCK (NON-FOOD)

PERMIT NUMBER - PER12543

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 28 JUNE 2013TO 31 MAY 2015.

Permit Holder:
NURSERY & GARDEN INDUSTRY AUSTRALIA
C/O AGAWARE CONSULTING P/L
21 Rosella Avenue
STRATHFIELDSAYEVIC3551

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
MOVENTO 240 SC INSECTICIDE
Containing: 240 g/L SPIROTETRAMAT as their only active constituent.

Directions for Use:

Crop	Insect Pests	Rate
Nursery stock (non-food): Seedlings & plugs, potted colour, trees & shrubs, foliage plants, palms, grasses and fruit trees (non-bearing).	Aphids, Scale insects and Silverleaf whitefly.	Foliar: apply 200-400 mL/ha or 20-40 mL/hL plus specified spray adjuvant. Container drench: apply 50-100mL plus specified spray adjuvant.

Critical Use Comments:
Aphids & Whitefly: monitor crops and commence application when thresholds are reache. Use higher rates where rapid buildup or crop growth is observed.
DO NOT apply more than 3 applications within a 12 month period per crop. DO NOT re-apply within 7 days of previous applications.

Scale: target post hatch crawler stage only. Follow up treatment may be necessary to control later hatchings 21 to 35 days later. DO NOT apply more than 2 applications within a 90 day period and DO NOT exceed a maximum of three sprays per crop in any 12 month period.

Jurisdiction:
ACT, NSW, QLD, SA, TAS, NT, WA only.
(Note: Victoria is not included in this permit because their 'control-of-use' legislation means that a permit is not required to legalise this off-label use in VIC).

Additional Conditions:
THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

TO AVOID CROP DAMAGE:
Products containing spirotetramat have demonstrated phytotoxicity and undesirable commercial effects in some plant species. The addition of surfactant may contribute to those effects.

Due to the large number of plant genera included under this permit the products have NOT been evaluated for crop safety on all species or in all situations where treatment may be undertaken. It is critical that a sample area be treated and assessed fully prior to whole crop treatment. This will help minimise potential for any undesirable effects. However, this action cannot guarantee crop safety as application method, environmental and crop conditions may vary from test treatment to whole of crop treatment. Any instances of phytotoxic effects should be reported to the permit holder and the APVMA.

Issued by

Delegated Officer

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR THE CONTROL OF SPECIFIED INSECT PESTS IN NURSERY STOCK (NON-FOOD)

PERMIT NUMBER - PER13382

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM28 AUGUST 2012 TO 31MAY 2015.

Permit Holder:
NURSERY & GARDEN INDUSTRY AUSTRALIA LTD
C/O AGAWARE CONSULTING PTY LTD
21 Rosella Avenue
STRATHFIELDSAYEVIC3551

Persons who can use the product under this permit:
Personsgenerally.

CONDITIONS OF USE

Product to be used:
DURIVO INSECTICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 100g/L CHLORANTRANILIPROLE and 200g/L THIAMETHOXAM as their only active constituent.

Directions for Use:

Crop	**Pest**	**Rate**
Nursery stock (non-food) - Seedlings and Plugs, Potted colour, Treesand Shrubs, Foliageplants, Palms, Grassesand Fruit trees (non-bearing)	Diamondback moth *(Plutella xylostella)*, Cabbage white butterfly *(Pieris rapae)*, Heliothis *(Helicoverpa* spp.*)*, Loopers *(Thsanoplusia orichalcea*), Leafhoppers (*Cicadelidae*spp.), Whitefly, Thripsand Aphids.	15-50mL/1000 seedlings.

Jurisdiction:
ALL States except Vic.
(Note: Victoria is not included in this permit because their 'control-of-use' legislation means that a permit is not required to legalise this off-label use in VIC).

Additional Conditions:
THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

TO AVOID CROP DAMAGE:
The sensitivity of some species and varieties of the crops to be treated under this permit has not been fully evaluated. It is advisable, therefore, to only treat a small number of plants to ascertain their reaction before treating the whole crop.

Issued by

Delegated Officer

Note: this permit was amended to include Whitefly and Thrips on 3 December 2012 (Permit Version 2)

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR THE CONTROL OF VARIOUS FUNGAL DISEASES IN NURSERY STOCK

PERMIT NUMBER - PER13459

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 14 MAY 2013 TO 31 MAY 2015.

Permit Holder:
NURSERY & GARDEN INDUSTRY AUS.C/O AGAWARE CONSULTING P/L
21 Rosella Avenue
STRATHFIELDSAYEVIC3551

Persons who can use the product under this permit:
Persons generally

CONDITIONS OF USE

Product to be used:
AERO FUNGICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 550g/kg METIRAM and 50g/kg PYRACLOSTROBIN as their only active constituent.

Directions for Use:

Crops	Diseases	Rate
Nursery stock (non-food): Including seedlings and plugs, potted colour trees and shrubs, foliage plants, palms, grasses, and fruit trees (non-bearing).	Alternaria (*Alternaria*spp.) Anthracnose (*Colletotrichum* spp.) Phytophthora (*Phytophthora* spp.) Powdery Mildew (*Oidium* spp.) Downey Mildew *(Peronsopora spp.)*	200-300g/100L

Critical Use Comments:
- Adhere to ALL product label restraints and mandatory no spray zone instructions.
- Use preventively. Begin application when conditions favour disease development, prior to or at the first signs of disease.
- DO NOT apply more than 2 applications per crop. Sprays should be applied 10 to 14 days apart. Continue the spray program using fungicides from different activity (MoA) group.
- Thorough coverage of foliage is essential: apply to the point of run-off.
- Use in accordance with CropLife Australia Resistance Management Strategy and in accordance with best practice.

Withholding Period:
Grazing: DO NOT graze or cut for stock food.

Jurisdiction:
ALL States except Vic
(Note: Victoria is not included in this permit because their 'control-of-use' legislation means that a permit is not required to legalise this off-label use in VIC).

Additional Conditions:

THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

TO AVOID CROP DAMAGE:
The sensitivity of some species and varieties of the crops to be treated under this permit has not been fully evaluated. It is advisable, therefore, to only treat a small number of plants to ascertain their reaction before treating the whole crop.

Re-entry Period:

- DO NOT enter treated areas to conduct very low/low exposure activities such as propping, irrigation, scouting and weeding until spray has dried, unless wearing cotton overalls buttoned to the neck and wrist (or equivalent clothing) and chemical resistant gloves. Clothing must be laundered after each days use.
- DO NOT enter treated areas to conduct high exposure activities such as harvesting, pruning, training and tying for 2 days, unless wearing cotton overalls buttoned to the neck and wrist (or equivalent clothing) and chemical resistant gloves. Clothing must be laundered after each days use.

Safety Directions:
Will irritate the skin.May irritate the eyes. Avoid contact with eyes and skin. If product on skin, immediately wash area with soap and water.When opening the container and preparing spray wear cotton overalls buttoned to the neck and wrist (or equivalent clothing) and elbow-length PVC gloves. When using the prepared spray (by low pressure handwand), wear cotton overalls buttoned to the neck and wrist (or equivalent clothing), elbow-length PVC gloves and half face piece respirator. Wash hands after use. After each day’s use, wash gloves and contaminated clothing.

Issued by

Delegated Officer

Australian Government
Australian Pesticides and
Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR INCLUSION IN POTTING MEDIA FOR CONTROL OF A RANGE OF PESTS IN NURSERY STOCK

PERMIT NUMBER - PER13942

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 5 FEBRUARY 2013 TO 31 MAY 2015

Permit Holder:
NURSERY & GARDEN INDUSTRY AUSTRALIA
C-/ AgAware Consulting Pty Ltd
21 Rosella Avenue
STRATHFIELDSAYE VIC 3551

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
SUSCON MAXI SOIL INSECTICIDE
Containing: 50 g/kg IMIDACLOPRID as its only active constituent.

Directions for Use:

Crop	Pest	Rate
Nursery stock (non-food) – seedlings & plugs, potted trees & shrubs, foliage plants, palms, grasses and fruit trees (non-bearing).	Aphids, Lace bugs (Tingidae) Mealy bugs (Pseudococcidae) Leafhoppers (Cicadellidae and Delphacidae) Scale insects (Coccidae, Diaspididae and Eriococcidae) Psyllids (Psyllidae) Ants (Formicidae) Scarab beetle larvae (Scarabidae) Fungus gnats (Sciaridae) Silverleaf white fly (*Bemisia tabaci*) Greenhouse white fly (*Trialeurodes vaporariorum*)	Small cell trays (5 L capacity) 830 g/m^3 potting media Medium pots (5.1 – 100 L capacity) 415 g /m^3 potting media Large containers (101 – 1,000 L capacity) 208 g/m^3 potting media

Critical Use Comments:
- Mix the required amount of SUSCON MAXI per cubic metre of potting media for the container category being used.
- Mix thoroughly before filling pots/tubes etc and transplanting. Irrigate moderately after potting to activate the insecticide.
- DO NOT allow significant leaching and run-off at least 3 irrigations or 10 days, whichever is longer.

Jurisdiction:
WA, VIC, SA, QLD, TAS, ACT and NT only.

Additional Conditions:

This PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Safety Directions:

Ensure that the following safety directions are followed when **mixing** and **using** the product;

- The product will irritate the eyes, nose, throat and skin.
- Avoid contact with eyes and skin.
- When opening the container and loading, wear cotton overalls buttoned to the neck and wrist (or equivalent clothing), elbow-length PVC gloves, goggles and disposable dust face mask covering mouth and nose.
- If product gets in eyes, wash it out immediately with water.
- Wash hands after use.
- After each day's use, wash gloves, goggles and contaminated clothing.

Issued by

Delegated Officer

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

FOR CONTROL OF SLIVERLEAF AND SWEET POTATO WHITEFLY ON NURSERY STOCK AND TOMATO AND PEPPER SEEDLINGS

PERMIT NUMBER – PER13953

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 1 MARCH 2013 TO 31 MAY 2015

Permit Holder:
NURSERY & GARDEN INDUSTRY AUSTRALIA
C-/ AgAware Consulting Pty Ltd
21 Rosella Avenue
STRATHFIELDSAYE VIC 3551

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Product to be used:
CONFIDOR 200 SC INSECTICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 200 g/L IMIDACLOPRID as their only active constituent.

Directions for Use:

Crop	Pest	Rate
Nursery stock (non-food) and plug stock/tube stock (non-food) and Tomato and Pepper seedlings (excluding seedlings for hydroponic production)	*Bemisia tabaci* species* Sweet potato whitefly (native) AN biotype Silverleaf whitefly B biotype Silverleaf whitefly Q biotype	40 mL product per 1,000 seedlings applied as a seedling drench.

**Bemisia tabaci* is a species complex composed of numerous biotypes (strains), which may differ from each other both genetically and biologically. The native AN biotype and B and Q biotypes have been reported in Australia.

Critical Use Comments:

- Application should be aimed at the early nymph stages.
- Apply 7 to 10 days after the first appearance of adult whiteflies on foliage, or monitor populations and apply based on the numbers of nymphs observed.
- DO NOT apply if products containing imidacloprid or other 4A group insecticides have been used on seedlings prior to this treatment.
- DO NOT apply more than one application of Confidor (imidacloprid) or other group 4A insecticide per crop.
- Apply as a foliar drench in sufficient volume to provide adequate penetration and coverage/drenching of foliage and soil; particularly the underside of leaf area, as nymphs (and adults) are predominantly on the underside of leaves. Ensure even distribution across all seedlings.
- Apply by dedicated nursery spray equipment, such as a calibrated hydraulic boom. Users must take care during application to minimise any run-off either during or following application. This should include applying only sufficient volumes of prepared solution to fill the cell thereby avoiding excessive application volumes that may result in run-off.
- Apply to seedlings well within 24 hours prior to shipment from a propagation nursery.
- The sensitivity of some species and varieties of the crops to be treated under this permit has not been fully evaluated. It is advisable, therefore, to only treat a small number of plants to ascertain their reaction before treating the whole crop.
- The application of Confidor (imidacloprid) is not permitted for use on tomato and pepper seedlings grown in hydroponic situations.

Planting of treated crop: Persons using the product must ensure the receiver of the treated seedlings has been made aware that ideally, planting out should occur within 24 hours of treatment due to:

- Watering of seedling trays following application may wash chemical from the cells. If watering is required between application and planting, care should be taken to avoid or minimise leaching from the cells.
- Experience with this use pattern in other crops has shown that there is a potential for crop burn when planting is delayed after treatment and cells begin to dry out. This is thought to occur because the developing young roots of the seedling do not have access to alternative water sources, leading to excessive uptake of Confidor (imidacloprid). This situation appears to be exacerbated in warmer conditions. To help minimise the potential for such damage in this case, it is recommended to transplant seedlings within 24 hours of treatment and provide irrigation soon after to ensure seedlings have access to an alternative water source.

Occupational Health and Safety: Persons handling treated trays and seedlings following treatment must wear chemical resistant gloves and wash hands after handling. Persons using the product must ensure the receiver of the treated seedlings has been made aware that the seedlings have been treated with Confidor (imidacloprid) and that those persons handling trays and seedlings should wear chemical resistant gloves and wash hands after handling.

Residues in food crops (Tomatoes & Peppers only): Persons using the product must ensure the receiver of the treated seedlings has been made aware that the treated tomato and pepper seedlings have been treated with Confidor (imidacloprid) and that no further treatments of imidacloprid should be made to ensure maximum residue limits for imidacloprid in these commodities are not exceeded.

Resistance Management: Persons using the product must ensure the receiver of the treated seedlings has been made aware that seedlings have been treated with Confidor (imidacloprid) to assist the receiver to adhere to the silverleaf whitefly resistance management strategy. To help avoid resistance build-up, Confidor (imidacloprid) should be rotated with other approved products from different chemical groups. Confidor or any other Group 4A insecticide should not be re-applied to each crop, either as a soil or foliar applied treatment.

Protection of wildlife:
Imidacloprid is toxic to certain aquatic species. If run-off should occur action must be taken to retain and dispose of that run-off in an appropriate manner so that it does not contaminate drains or waterways. DO NOT apply if the crop is exposed to heavy rains or irrigation expected to occour within 24 hours of application.

Jurisdiction:
NSW & QLD only.

Additional Conditions:

This PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

OTHER MATTERS

Pest Monitoring: Persons using the product must ensure the receiver of the treated seedlings has been made aware that they should monitor for target pest during early crop establishment and throughout the life of the crop. If the target pest is observed feeding on the crop and additional chemical applications are being considered, an insecticide with a different mode of action should be used.

Transmission of tomato yellow leaf curl virus (TYLCV)

Bemisia tabaci (sweet potato whitefly and silverleaf whitefly) are the vectors of TYLCV. The treatment of seedlings under this permit will not necessarily prevent transmission of the virus to treated plants. Treatment of seedlings under this permit is only intended to control silverleaf whitefly, which is the vector for TYLCV. Additional measures may be necessary to control silverleaf whitefly and hence reduce the potential for transmission of TYLCV in the nursery before application of Confidor (imidacloprid), and in the field as the crop develops and Confidor activity diminishes.

Issued by

Delegated Officer

Australian Government
Australian Pesticides and Veterinary Medicines Authority

PERMIT TO ALLOW MINOR USE OF AN AGVET CHEMICAL PRODUCT

TO CONTROL MYRTLE RUST
IN ORNAMENTALS AND NON-FRUIT BEARING PLANTS OF THE MYRTACEA FAMILY IN HOME GARDENS

PERMIT NUMBER - PER14225

This permit is issued to the Permit Holder in response to an application granted by the APVMA under section 112 of the Agvet Codes of the jurisdictions set out below. This permit allows a person, as stipulated below, to use the product in the manner specified in this permit in the designated jurisdictions. This permit also allows any person to claim that the product can be used in the manner specified in this permit.

THIS PERMIT IS IN FORCE FROM 28 JUNE 2013 TO 30 SEPTEMBER 2018.

Permit Holder:
NURSERY & GARDEN INDUSTRY AUSTRALIA LTD
C/- AgAware Consulting Pty Ltd
21 Rosella Avenue
STRATHFIELDSAYE VIC 3551

Persons who can use the product under this permit:
Persons generally.

CONDITIONS OF USE

Products to be used:
RICHGRO COPPER FUNGICIDE & LEAF CURL SPRAY
PLUS OTHER REGISTERED PRODUCTS
Containing: 500 g/kg COPPER OXYCHLORIDE as their only active constituent.

SEARLES MANCOZEB FUNGICIDE
PLUS OTHER REGISTERED PRODUCTS
Containing: 750 g/kg MANCOZEB as their only active constituent.

SHARP SHOOTER TRIFORINE ROSE SPRAY CONCENTRATE
PLUS OTHER REGISTERED PRODUCTS
Containing: 19 or 20 g/L TRIFORINE as their only active constituent.

Directions for Use:

Crop	Disease	Active	Rate of application per Litre water
Ornamentals and Non-fruit bearing plants[1] of the Myrtaceae family. [1]At least 6 months prior to first harvest	Myrtle rust (*Uredo rangelii*)	copper oxychloride	3 g/L
		mancozeb	2.5 g/L
		triforine	15 ml/L

Critical Use Comments:
Apply by knapsack or powered hand-gun.
Apply in sufficient volume to ensure thorough coverage of all plant surfaces.

Plant Damage
Due to the wide range of susceptible species covered under this permit, these chemicals have not been exhaustively tested for potential damage to plants following treatment. Treat a sample area and assess appropriately prior to whole crop treatment to help minimise potential for phytotoxic damage. This action cannot guarantee crop safety as application, environmental and crop conditions may vary from test treatment to whole of crop treatment. This is particularly important for plants in flower.

Management strategy:
Triforine is slightly curative as well as a protectant. It can be applied when disease is noticeably affecting plants or prior to this when warm, wet and humid conditions prevail.

Both mancozeb and copper oxychloride are protectants and should be applied before disease is noticeably affecting plants when warm, wet and humid conditions prevail.

Fungicide	Activity	Chemical group	Minimum re-treatment interval between consecutive applications
TRIFORINE	Systemic, slightly curative and protectant	3	7 days
MANCOZEB	Protectant	M3	7 days
COPPER OXYCHLORIDE	Protectant	M1	7-14 days

Jurisdiction:
NSW, QLD, NT, WA, SA, TAS, ACT & VIC.

Additional Conditions:
THIS PERMIT provides for the use of a product in a manner other than specified on the approved label of the product. Unless otherwise stated in this permit, the use of the product must be in accordance with instructions on its label.

PERSONS who wish to prepare for use and/or use products for the purposes specified in this permit must read, or have read to them, the details and conditions of this permit.

Issued by

Delegated Officer