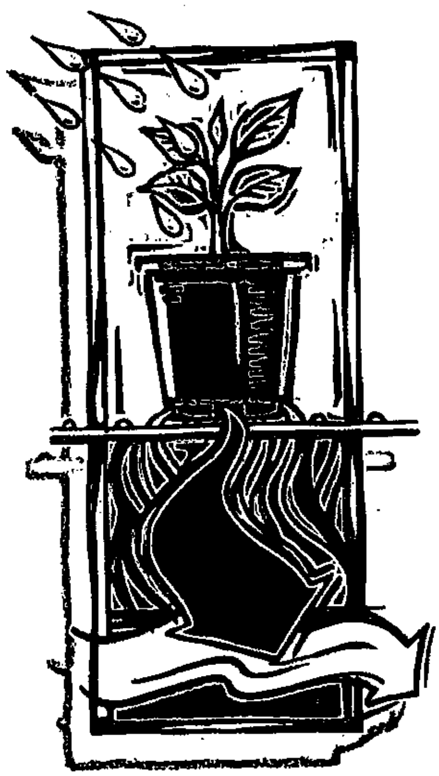
managing NURSERY *runoff*



TECHNIQUES TO REDUCE NUTRIENT LEACHING FROM POTS

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NSW Agriculture

MANAGING NURSERY RUNOFF

Techniques to reduce nutrient leaching from pots

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Contents

1

INTRODUCTION

Chapter summary

- Water which drains from pots after rain or an irrigation is called leachate and it carries with it nutrients from fertiliser applied to the potting mix. Nursery runoff is a mixture of leachate and the water that falls between the pots, on pathways and other non-productive ground. Sometimes, this runoff water contains high levels of nutrients - particularly nitrogen - which can contaminate ground and surface waters.

- Nursery operators need to improve the way they fertilise and irrigate to minimise contamination of waterways and to meet environmental regulations.

- Many nurseries currently overwater their stock - some by as much as 10 times the amount needed - using inefficient overhead sprinkler systems. Water savings of 75 per cent can be achieved by replacing sprinklers with drip or sub-irrigation systems. Savings can also be achieved with sprinkler systems by making sure the sprinkler area is completely covered with pots, by improving application uniformity and by watering no more than is needed.

- Many nurseries also use higher rates of fertiliser than are necessary or use inappropriate fertiliser types. There are four main fertiliser types - controlled release fertilisers (CRFs), inorganic fertilisers, liquid fertilisers and organic fertilisers. Each has different release characteristics which influence nutrient leaching and runoff.

Nutrient runoff

Environmental legislation intended to protect Australia's water resources is certain to have a major impact on the nursery industry over the next few years. Recent concerns about the occurrence of algal blooms, increasing nutrient loads and reduced flow rates in our rivers has focussed attention on the impact of agriculture on these systems. Of major interest has been the contribution of nutrients in wastewater discharged from intensive horticultural industries.

The nursery industry has responded positively to the challenge of reducing its environmental impact. Steps have been taken to formulate a national water management strategy which will be the basis for planning future research and education initiatives. The industry has funded several research programs concerned with water quality issues. The first of these was undertaken by Drs Cresswell and Huett and was a study of nutrient discharge from nurseries. The findings from this study, presented in this publication, are of benefit to the nursery industry because they address:

- environmental concerns about nutrient runoff from nurseries; and
- inefficiencies in current fertiliser and water use practices.

Many nurseries are located close to a watercourse and can affect it with nutrients in runoff.

Water quality requirements

At the time of writing, the exact nature of the legislation regulating the disposal of nursery wastewater in Australia was unclear. It was apparent, however, that each State would administer its own Act and that as a result some differences in requirements could exist between States.

From discussions with the Environmental Protection Authority (EPA) in NSW and Victoria, a general approach appears likely. This could see the nursery being required to conform to a set of Best Management Practices (BMPs). These BMPs would ideally be developed by the industry with the guidance of the EPA. This cooperative approach is favoured to prevent unrealistic requirments being imposed on industry. However, despite the apparent willingness of most regulating authorities to develop workable rules it must be understood that the guiding legislation is designed to prevent the contamination of surface and subsurface waters. Accordingly, stringent guidelines on permissible concentrations of many organic and inorganic compounds in waste water can be expected.

Acceptable levels for nutrients in waterways and reservoirs are set out in the Australian Water Quality Guidelines (ANZECC 1992), and also in NSW in the *Clean Water Act*, 1972 (see Table 4, Chapter 2). The limit of 10mg/L of N (as nitrate) is of particular concern for horticultural enterprises as levels well in excess of this have been found in studies of runoff from agricultural land in Western Australia and from nurseries in the USA and Europe.

Nutrients in runoff

Nutrient runoff consists of the water which drains from pots after rain or an irrigation (leachate) and the water that falls between pots and onto other non-producing areas of the nursery, such as pathways roads and buildings. The leachate is the smallest fraction but contributes most of the nutrients present in the runoff water.

The management of nutrient loads in runoff, therefore, involves reducing both the volume and the nutrient content of the leachate. Runoff volumes can be reduced further by minimising the quantity of water falling on non-productive ground during an irrigation.

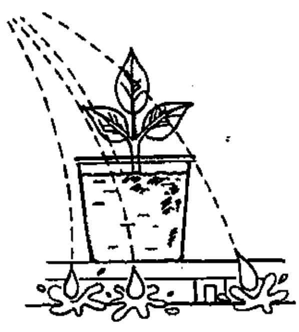
Nursery water use

In Australian nurseries, irrigation rates commonly exceed the daily water use of plants (around 3-6 mm/day depending on season) by as much as 10-fold. This tendency to overwater plants probably came about at the time relatively inexpensive permanent plastic irrigation systems became available. This new technology meant that watering could be automated. Watering was now controlled by a clock where previously it had been done by hand and according to need. Shortcomings in the way sprinkler systems dispensed water also encouraged over watering of plants.

Sprinkler irrigation

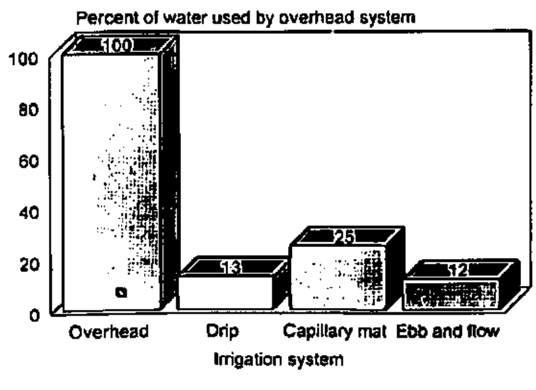
Overhead sprinklers are a very inefficient means of getting water to pots. They have two major weaknesses:

1. Water is distributed to an area of bench or ground regardless of whether pots are present. Pots normally cover only 20-50% of the area under sprinkler irrigation which means that most of the applied water is wasted. Water savings of 75% or more can be achieved by simply replacing sprinklers with drip, capillary mat or ebb and flow systems (Figure 1). The main disadvantage of these other systems is that they are more expensive to install and maintain.



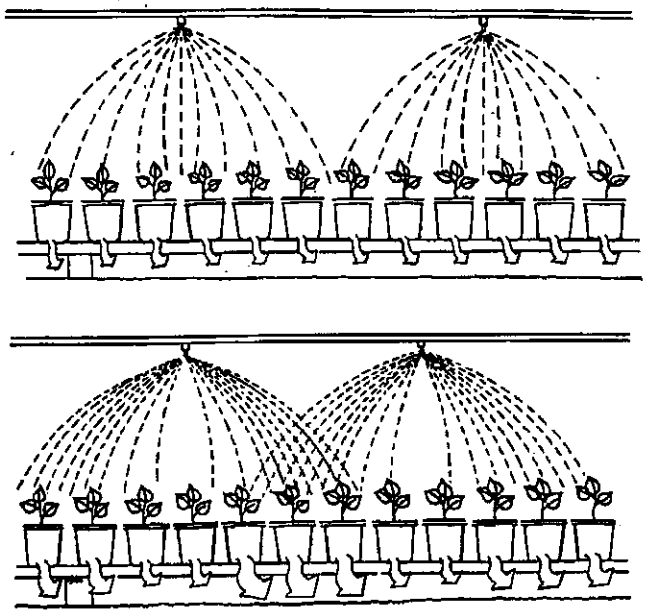
Most of the water applied by overhead sprinklers misses the pot.

Figure 1. Relative water use for different types of nursery irrigation systems, after Neal and Henly (1992).



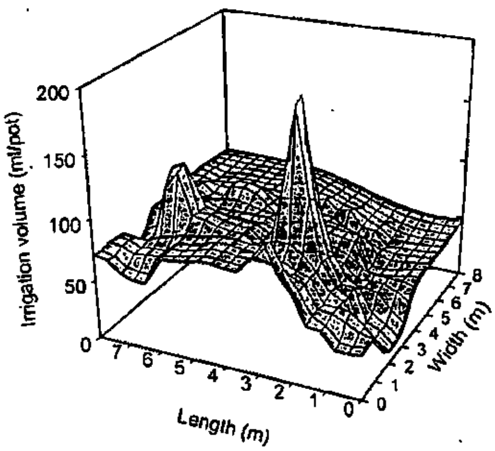
Even distribution is important in water use efficiency.

Uneven distribution means some spots are too wet or too dry.



2. Sprinklers do not distribute water evenly and this leads to dry areas. This problem is accentuated if the system is poorly designed or maintained (Figure 2). Uneven application is generally dealt with by watering until the driest pots are wet. This practice means that more water than necessary is applied (up to 6-7 times) .

Figure 2. Uneveness in sprinkler range and poor overlap of spray areas can create dry spots, where pots are underwatered.



Use of fertilisers in nurseries

High fertiliser rates are used in nurseries to maintain rapid growth of plants under conditions of excessive leaching. Fertiliser practice in nurseries is discussed in Handreck and Black (1984) and a brief introduction is given here. There are 4 main types of fertilisers used in nurseries (Table 1):

- controlled release fertilisers (CRF's) are the most widely used;
- soluble inorganic fertilisers;
- liquid fertilisers; and
- organic based fertiliser, derived from fowl litter and other sources.

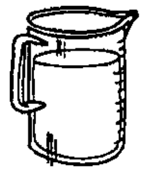
Table 1. Types of Fertilisers and their Characteristics.

Inorganic fertilisers: Inorganic nutrient salts including calcium nitrate, ammonium nitrate, potassium nitrate. They are normally soluble in water and readily leached. They are rapidly available to plants and must be applied at low rates to avoid injury.

Organic based fertilisers: These are usually animal manures, the most popular being pelletised poultry manure. Other waste materials with useful amounts of nitrogen are also used including sewage sludge, feather meal and blood and bone.

Controlled release fertilisers: CRF's are prills of inorganic fertiliser coated with a membrane which reduces the rate at which the fertiliser is dissolved in water so that the nutrients are released over a number of weeks or months. This characteristic makes them less susceptible to leaching. Osmocote® and Nutricote® are probably the best known CRF's, but other products are available including slow release urea (IBDU), Woodace® and Macrocote®. Most are available with different nutrient release characteristics.

Liquid fertilisers: Nutrient salts are dissolved in water and applied directly to the growing medium or to the foliage as a spray. They are prone to leaching and should be applied directly to pots to avoid waste.



Seasonal conditions

Climatic differences between winter and summer in Australia cause marked changes in the water requirements of plants. Cold overcast conditions in winter lead to low water use and hot, dry, windy, sunny conditions in summer promote heavy water use by plants. Nurseries with inflexible watering regimes are likely to be over or under watered during seasonal extremes. Irrigation volume should be adjusted to meet the seasonal variation in the water requirements of plants.

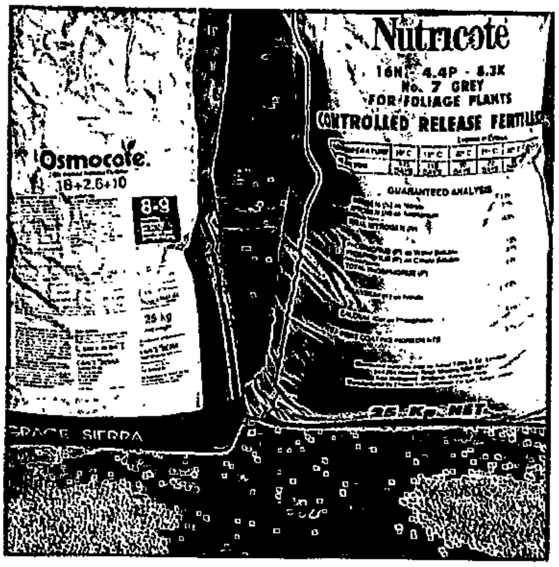
Seasonal temperatures also affect the rate of nutrient release from fertilisers. CRF's are made for European conditions where temperatures are usually lower than in Australia.

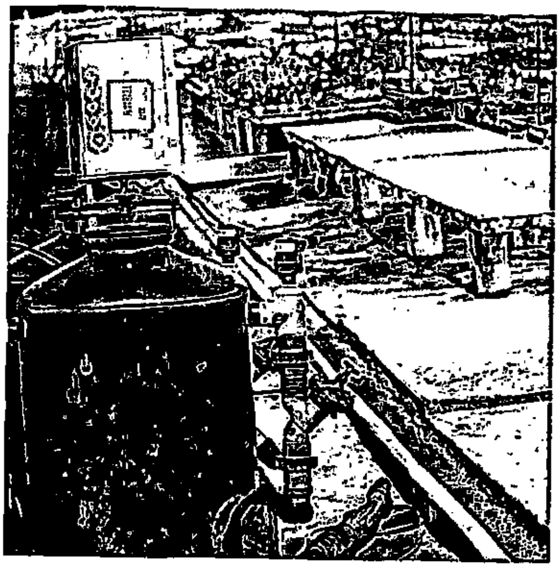
Chapters ahead

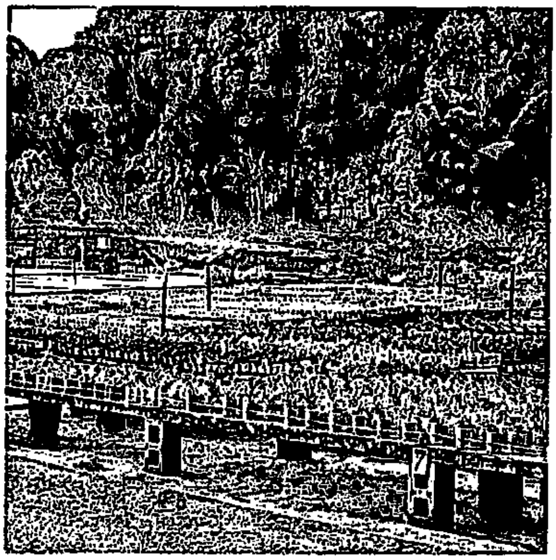
The next chapter presents results from a survey of nutrient discharge from Sydney nurseries.

The publication then explores factors influencing nutrient loss including:

- over watering;
- water and nutrient retention properties of growing media;
- the effectiveness and efficiency of CRF's.







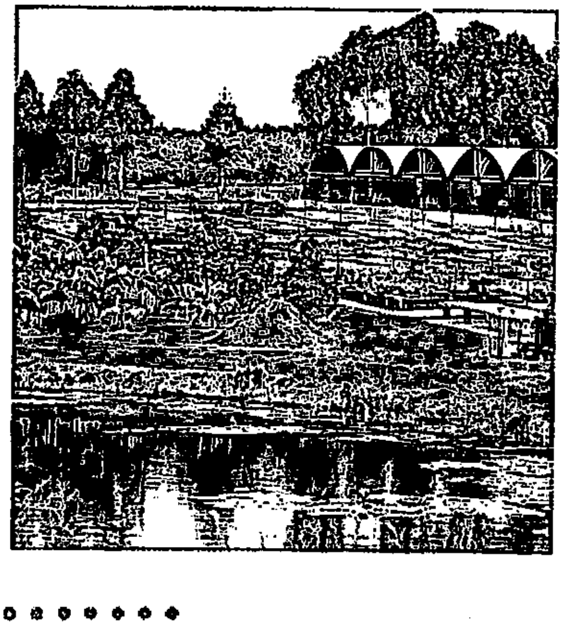
ABOVE: Channelling run-off into a holding tank.

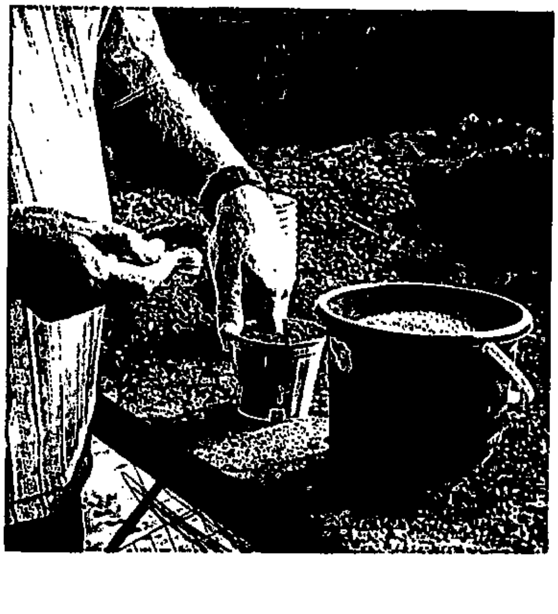
ABOVE LEFT: Examples of controlled release fertilisers (CRFs) commonly used in plant nurseries.

LEFT: Overhead irrigation in operation.

BELOW LEFT: Capturing nursery runoff is necessary to protect waterways.

BELOW: Controlled release fertiliser (CRF) being added at potting up stage.





2

SURVEY OF NUTRIENT LEACHING IN SYDNEY NURSERIES

Chapter summary

- A survey involving 13 Sydney nurseries was undertaken in 1992/93 to determine the level of nutrients draining from pots in leachate.

- Overwatering was found to be widespread but nutrient concentrations in leachate varied substantially between nurseries. In some cases the drainage water was fit to drink, in others it was so loaded with nutrients as to be toxic to plants.

- Concentrations of nitrogen, phosphorus, iron and manganese in leachate regularly exceeded water quality guidelines. Of course, leachate is diluted with fresher nursery drainage water, greatly reducing nurient concentrations.

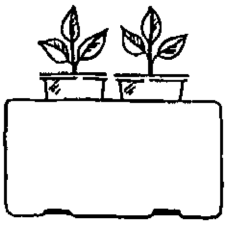
- Nutrient leaching losses were highest in the first few weeks after potting up. This was because:
  - fertilisers, even CRFs (controlled release fertilisers), release nutrients more rapidly in the first weeks, and
  - smaller plants use less water and fertiliser.

- Nutrient losses were much higher in summer than in winter. This was because the nursery operators in the survey irrigated for much longer and more frequently in summer, resulting in 60 per cent more leachate than in winter. It may also have reflected faster nutrient release from CRFs in hotter weather and greater propagating activity in summer.

Purpose

A survey was undertaken of nutrient leaching in nurseries in the Sydney metropolitan area with the primary purpose of establishing the extent and nature of nutrient losses. This information was needed to raise awareness within the industry of the impact of this process on the environment and on individual business profitability.

The survey also provided an opportunity to identify management practices responsible for excessive nutrient leaching. This knowledge was used to develop strategies for reducing leaching, and these were subsequently investigated experimentally. Results from this work are considered in later chapters.



Leachate was collected in polystyrene boxes placed underneath pots.

Methods

Drainage water from pots (leachate) was collected from 13 wholesale nurseries in Sydney in March and April 1992. Further sampling was done at three of the largest nurseries in August and September 1992 and January and February 1993 (Table 2). On each occasion, both irrigation and drainage water were collected weekly, over 4 consecutive weeks.

Table 2. Sampling program of Sydney nursery survey.

Period surveyed	Number of Nurseries	Number of leachate traps
March-April 1992	13	69
August-Sept. 1992	3	18
January-Feb. 1993	3	10

Leachate was collected in polystyrene boxes (leachate traps) placed underneath pots within existing nursery production areas. Production information including type of fertiliser and rate of application, potting mix formulation, method of irrigation, plant species and maturity was obtained from each nursery. Potting mix samples were also collected for physical and chemical testing.

Main findings

The quantities of leachate collected in any given sampling period varied substantially indicating large differences in water application rates, even between neighbouring nurseries. As plant water requirements could not have differed by this much, some nurseries were clearly overwatering. High leaching fractions (discussed in Chapter 3), and the sodden condition of growing areas generally would suggest that the practice is widespread, even in otherwise well managed nurseries.

Nutrient composition of leachate

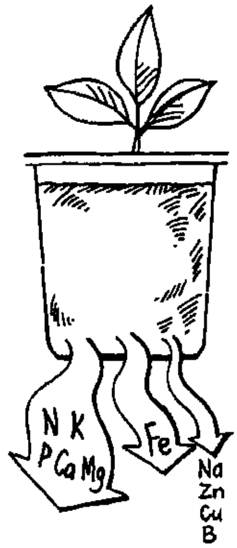
Leachate composition varied widely within and between nurseries. In some instances, nutrient concentrations were high enough to be toxic to plants and in other instances so low that the drainage water was fit for drinking (Table 3). The most nutrient rich leachate was generally obtained from pots containing fresh media and from propagation areas, and the least nutrient rich leachate from larger container plants which had not received fertilisers for some time.

Nutrient losses from propagation areas are high because of the heavy fertiliser and water use needed to maximise growth of seedlings or cuttings given the small root volume available in trays, tubes and cells. Losses from freshly potted media tend to be high because soluble fertilisers used in preparing the potting mix tend to leach out in the first few irrigations and because most fertilisers regardless of whether they are coated (CRFs) or organic in nature provide an initial flush of soluble nutrients. These points are discussed in more detail in Chapter 3.

Table 3. Nutrient concentrations in leachate collected from wholesale nurseries in Sydney*.

Element	Concentration (mg/L)		
	Maximum	Minimum	Mean
Calcium	900	<1	64
Sulphur	1712	<1	61
Potassium	457	2	60
Nitrogen (NO_3)	776	<1	48
Sodium	476	<1	36
Magnesium	741	<1	26
Phosphorus	152	<1	5
Iron	7	<0.05	0.6
Zinc	3	<0.01	0.3
Manganese	10	<0.01	0.2
Copper	1	<0.1	0.1
Boron	1	<0.05	0.1

**Based on 388 leachate samples collected during summer and winter.*



Concentrations of N, P, Fe and Mg in leachate regularly exceeded guidelines.

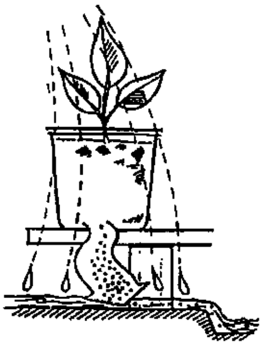
Environmental hazard

Concentrations of nitrogen, phosphorus, iron and manganese in leachate from most nurseries regularly exceeded New South Wales and National water quality guidelines (Table 4).

Table 4. Nutrient concentrations in leachate (mg/L) collected from pots and water quality guidelines applicable to nursery runoff.

Nutrient	Nursery leachate*	Clean Waters Act, NSW	National Water Quality Guidelines	
			River/stream	Lake/reservoir
Nitrogen	48 (776)	10	100-750	100-500
Phosphorus	5 (152)		10-100	5-50
Iron	0.6 (7)	0.3		
Zinc	0.3 (3)	5		
Manganese	0.2 (10)	0.05		
Copper	0.1 (1)	1		
Boron	0.1 (1)	1		

**Mean and maximum concentration recorded in Sydney survey.*



Nutrient rich leachate is diluted by fresher water draining from the nursery.

Fortunately, the concentrations of nutrients present in nursery runoff water are lower than in the leachate from individual pots. This is because the nutrient rich leachate is diluted by fresher water draining from the nursery (50-80% of the water from overhead sprinklers normally falls between pots and onto paths and other non-producing areas). Nutrients are also removed from runoff water by chemical processes as it percolates through soil, and by biological processes as it passes within the influence of weeds, turf and trees (nutrient scrubbing).

Dilution and nutrient scrubbing can greatly reduce nutrient concentrations in runoff water as can be seen by comparing the nutrient composition of leachate and nursery dam water (Table 5). These results show that in addition to saving water, use of storage facilities will help minimise the environmental impact of any runoff water leaving the nursery.

Table 5. Nutrient concentrations (mg/L) in leachate and in dam water collected from nurseries practising some recycling.

	NO_3-N	P	S	K	Ca	Mg	Na	Fe	Cu	Zn	Mn	B
Leachate	48	5	61	60	64	26	36	0.6	0.1	0.3	0.2	0.1
Dam	3	.3	16	9	16	8	26	0.3	.09	.01	.08	0.5

Nutrient losses

The quantities of nutrients leached from potting media (Table 7) are high relative to the amounts normally applied to containerised plants as fertiliser. Average fertiliser inputs of N, P and K for nurseries in the survey are shown in Table 6. Given the leaching rates recorded in this study, an average preplant application of N, P and K would be entirely lost in 11, 20 and 5 months respectively. When other losses are considered such as plant uptake, N draw-down, volatilisation and chemical fixation, the useful life of the fertiliser is shortened considerably. From this assessment it seems likely that growth of nursery plants is often limited by nutrient deficiency, particularly in the latter stages of production. This may explain why nitrogen deficiency symptoms are common in nursery plants.

Table 6. Mean rate of N, P and K applied as fertiliser in Sydney nurseries.

Nutrient	Rate (g/m^3)
Nitrogen	801
Phosphorus	180
Potassium	409

When are losses greatest

Nutrient leaching losses are highest in the first few weeks after potting-up (Figure 3). Several factors may be contributing to this:

- nutrient supply exceeds the plant requirement at this early stage of development.
- supply is far greater than the plants capacity to absorb nutrients given its limited root system.

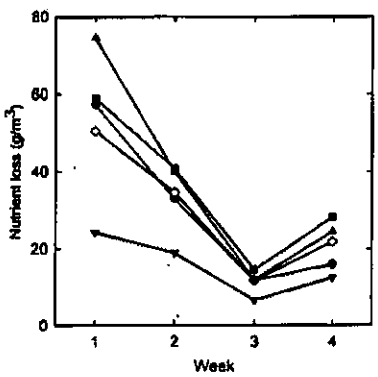
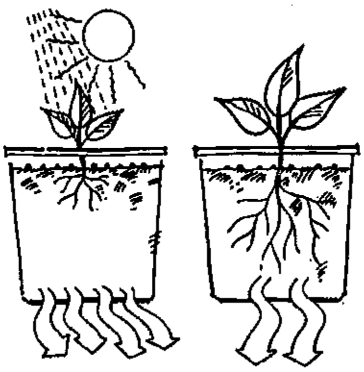


Figure 3. Pattern of nutrient leaching in the first weeks after potting-up. Nitrogen (•), calcium (■), magnesium (▼), potassium (◇), and sulphur (▲).

Smaller plants use less water and nutrients, so nutrient leaching losses are high if application rates aren't reduced.



The roots of larger plants absorb more water and nutrients.

- leaching is more severe. Small plants also use less water and so the potting mix remains wetter between irrigations. If water application rates are not reduced, then more of the applied water will drain from the pot after an irrigation taking with it soluble nutrients.
- nutrients are more available for leaching. Organic fertilisers and CRF's release nutrients more rapidly in the first weeks. In the case of the CRF's, this could be because of damage to the coating on some prills.

Damaged prills release nutrients more rapidly.

Seasonal influence on leaching

Nutrient losses through leaching are generally much higher in summer than in winter (Table 7). On average, 5 times the nitrogen, 6 times the phosphorus and more than 3 times the potassium is lost. This is despite the fact that seasonal differences in the concentrations of these nutrients in leachate are relatively small. The explanation is that a greater volume of leachate is produced in summer because plants are irrigated for longer and more frequently. During the survey period around 60% more water was collected in leachate traps in summer than in winter.

Table 7. Mean and seasonal monthly leaching losses of nutrients from nursery containers.

Element	Mean rate of loss	Summer rate (g/m^3/month)	Winter rate
Calcium	86	180	38
Sulphur	75	158	38
Nitrogen	15	155	31
Potassium	80	113	29
Sodium	48	72	19
Magnesium	31	58	16
Phosphorus	9	6	1
Manganese	0.3	2	<0.1
Iron	0.9	0.8	0.2
Zinc	0.4	0.5	<0.1
Boron	0.2	0.4	<0.1
Copper	0.3	0.2	<0.1

Other factors which may contribute to higher leaching losses in summer are:

- accelerated nutrient release from CRFs at high temperatures.
- increased potting and propagating activity in the warmer months.

The clear influence of irrigation volumes on nutrient leaching points to the need to improve irrigation management. For many nutrients, a reduction in irrigation volume would provide a proportional reduction in leaching losses.

Conclusions

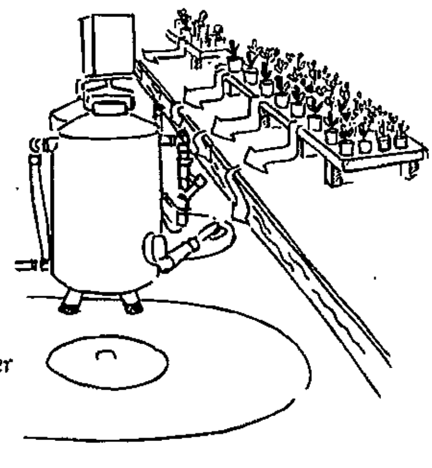
Significant amounts of fertiliser are currently removed from nursery media in drainage water. Nutrient concentrations in this water commonly exceed water quality guidelines which may soon be adopted nationally in Australia.

The quantities of nutrient lost this way are large relative to fertiliser inputs and leaching may therefore routinely lead to deficiencies in crops.

Over watering appears to be the main reason for unacceptably high nutrient leaching losses from nursery containers. Consequently, a major effort should be made to improve water use efficiency in nursery production systems. Where overhead sprinklers are used, attention should be given to obtaining better uniformity of water application.

Reducing nutrient leaching should mean that fertiliser rates can be lowered without adversely affecting plant growth or quality.

Containing and recycling nursery runoff water offers a way of cutting water costs and reducing the volume and the nutrient concentration of waste water.



Containing and recycling run-off water can cut costs.

3

NUTRIENT LEACHING LOSS FROM NURSERY CONTAINER MEDIA

Chapter summary

- Following the results of the survey presented in the previous chapter, the authors set up a controlled experiment to look more closely at nutrient leaching loss.
- Under a typical summer irrigation level of 25mm a day, they found up to 40 per cent of the nutrients in CRFs and 80 per cent in Dynamic Lifter® were being wasted in leachate over 10 weeks.
- The percentage of water applied which leaches from the pot (called the "leaching fraction") often exceeds 80 per cent from high output overhead sprinklers.
- A reduction in leaching fraction to 12 per cent will prevent salt from building up in pots and prevent growth depression.
- Over a 10 week period, 10-40 per cent of the nitrogen (N) and potassium (K) are leached from 3-5 month CRFs.
- Nutrient leaching is most intense in the first week after plants are potted up. Fertiliser added to the potting medium during preparation accounts for about half this loss and the CRF added at potting up accounts for the other half.
- In the first week after potting up, nitrate-N concentrations in excess of 50mg/L have been recorded in leachate collected directly from pots. Allowing for a 1:5 dilution with water falling between pots and on paths, the final nitrate-N concentrations in nursery runoff water could still exceed the 10 mg/L limit of the *Clean Waters Act*.

Over watering causes nutrient loss

Plants absorb nutrients from the water fraction of the container medium. However, dissolved nutrients which are primarily derived from fertiliser, are readily leached.

Amount of leaching

Only 12% of applied water should leach out.

A small amount of leaching is necessary to prevent fertiliser salts accumulating on the surface of the pot. The extent of leaching can be gauged by comparing the volume of water which drains from a pot with that applied. While a leaching fraction of 12% is recommended, values exceeding 80% are common in Australian nurseries using overhead sprinkler irrigation.

Coated fertilisers

Controlled release fertilisers are the best nutrient source to minimise nutrient leaching losses. The slow release properties of CRF's are a function of the resin coating. Soluble fertiliser within the resin coated capsule diffuses through the membrane into the water fraction of the medium where it can be absorbed by plant roots. The properties of the membrane will determine the rate of release of nutrients from the fertiliser capsule. Frequent leaching will accelerate the release of nutrients from CRF's and also accelerate nutrient loss in runoff.

Amount of nutrient loss

Nitrogen, phosphorus and potassium readily leached in summer.

Under high summer irrigation (25 mm per day), up to 40% of the nutrients in CRF's and 80% in Dynamic Lifter® are leached over 10 weeks (Tables 8 and 9). Phosphorus was less readily leached than N and K and total nutrient leaching from 3-5 month formulations of Osmocote and Nutricote was similar.

These high nutrient losses have serious implications for plant growth and nutrient discharge from the nursery (Chapter 5).

Table 8.Nutrient leached (% total applied) over 10 weeks in summer (adjusted for nutrient losses from the potting mix).

Treatment	N	P	K
Nutricote (4-5 month)	38-39	2-7	12-34
Osmocote (3-4 month)	10-39	12-13	22-37
Dynamic Lifter	1-14*	7-15	82

* *A further 30% was lost through volatilisation as ammonia.*

The low proportion of P leached (2-15%) (Table 8) indicates that it is relatively resistant to leaching (Table 9).

Dynamic Lifter had very high K leaching losses (82%), and apparently low N losses. The low N leachate loss was due to the high volatilisation of N as ammonia gas (NH_3). This effect is most severe when Dynamic Lifter is applied to the surface, and is reduced substantially when it is incorporated into the media or soil.

Table 9. Nutrients leached (mg/10cm pot) from fertiliser treatments (adjusted for the same amount of N), over 10 weeks (mean summer and autumn). This gave a CRF fertiliser treatment rate of approximately 5 kg/m^3 potting mix.

Treatment	N	P	K	Ca	Mg
Nutricote (4-5 month)	321	8	83	192	99
Osmocote (3-4 month)	260	10	100	182	98
Dynamic Lifter	183†	52	262	145	92
Control* (potting mix)	149	2	30	142	79

**The control was a standard potting mix which had soluble fertiliser incorporated when it was being prepared.*

† A further 30% lost through volatilisation of ammonia.

The high Ca and Mg leaching losses were derived from fertilisers added to the potting medium during preparation. Nitrogen is mainly leached as nitrate (NO_3^-) and this attracts the cations causing high leaching of K, Ca and Mg. Where NO_3^- losses are high, K, Ca and Mg losses will also be high. The high Ca leaching loss leads to acidification of the potting medium over time.

Peak nutrient losses

Peak nutrient losses occur in the first week after potting-up (Figure 4). Most of the major plant nutrients such as N, K, Mg, and Ca show this trend. Phosphorus is the exception being more resistant to leaching with peak loss occurring 2 weeks after potting up.

More than half of the nutrients released in the first and second weeks (Figure 4) were from soluble fertiliser incorporated into potting media during preparation. Dynamic Lifter has the same leaching pattern as the control (soluble fertiliser) with most of the loss occurring by week 3.

When nutrient loss from CRF's is adjusted for the control, nutrient loss from the former during week 1 is approximately 4 times the relatively constant rate of loss during weeks 4 to 10. The high rates of N loss in leachate immediately after potting were also reported by Hershey and Paul (1982). The spike of nutrient release, both from the CRF and the fertiliser added during preparation of the potting medium, accounts for the high concentrations of nutrients in leachate over summer (Tables 3 and 10).

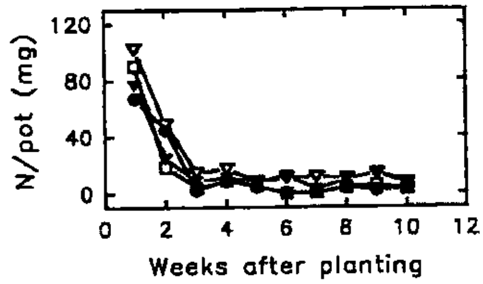


Figure 4. Amount of N leached/10 cm pot with several fertiliser sources applied to the prepared medium at potting-up. Nutricote (▽), Osmocote (▼), Dynamic Lifter (□), Control (•).

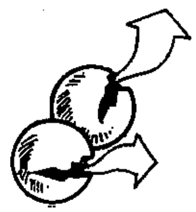
Table 10. Maximum nutrient concentrations (mg/L) in summer leachates, which occur in the first week* after potting-up. Fertiliser treatments were adjusted to the same N rate which is equivalent to a CRF rate of approximately 5 kg/m^3 potting mix.

Treatment	NO_3^- -N	NH_4^+ -N	P*	K	Ca	Mg	Na
Nutricote (4-5 month)	64	58	1.3	61	75	37	19
Osmocote (3-4 month)	50	61	1.4	66	76	40	19
Dynamic Lifter	43	98	9.6	194	102	54	68
Control (potting mix)	33	31	0	33	66	27	18

**Maximum concentration for P occurred in second week.*

Leachate nutrient concentrations approximately doubled when fertiliser rates were doubled. The nutrient concentrations recorded in Table 10 are for leachate collected directly from pots and not runoff. Dilution of 1:5 occurs from irrigation and rainfall falling between pots, tables and within walkways. Nitrate-N concentrations in runoff will exceed the 10 mg/L limit set by the Clean Waters Act from freshly potted plants.

Factors causing high nutrient loss



Damaged prills cause a spike of nutrient release.

Damaged CRF prills

Freshly potted plants which have received a single pre-plant application of CRF produce high nutrient loss. The spike of release is probably due to the presence of damaged CRF prills. Cracks in the resin coating which develop during manufacture and transportation, allow water to penetrate quickly and rapidly dissolve the nutrients.

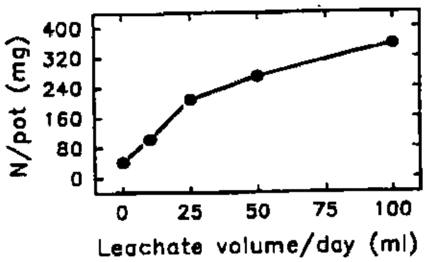
Soluble fertilisers

Soluble fertilisers added during preparation of potting media account for at least half of the nutrients leached after transplanting. Urea in particular, as well as a broad range of macro- and micro-nutrients are incorporated prior to composting and are a source of nutrients for leaching. It is standard practice to add N fertiliser prior to potting up to compensate for the 'nitrogen draw-down' effect common in pinebark-sawdust media (Handreck and Black 1984).

Summer irrigation rates

Nutrient leaching in summer is 2-6 times higher than in winter (Table 3 Chapt 2). The suceptiblity of the major plant nutrients to leaching results in high nutrient loss under high summer irrigation rates. Excessive irrigation is a major cause of excessive nutrient leaching, even where CRF's are used. The quantities of nutrient leached increase with increasing leachate volume as demonstrated for N in Figure 5. These volumes are much lower than the 230-260 ml/pot/day leached from pots where high output overhead sprinklers were used.

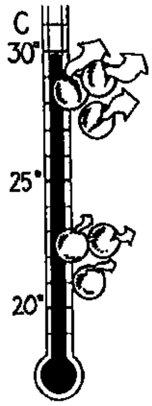
Figure 5. Influence of leachate volume (ml/pot) on nitrogen leached over 4 weeks from a 10 cm pot with plants fertilised with a CRF at 5 kg/m^3.



High temperatures affect fertiliser release rates

Most CRF's are designed for temperate European conditions (Lamont *et al* 1987, Handreck and Black 1984)).

The rate of nutrient release for Osmocote is standardised for 21°C and for Nutricote 25°C (Lamont *et al* 1987). In summer in Australia, maximum daily temperatures regularly exceed 25°C and container temperatures exceed 30°C (Table 11). CRF's release nutrients at least one third faster under Australian conditions. To moderate this effect, nursery operators my choose longer term formulations (Handreck and Black 1984).



CRFs release nutrients faster at higher temperatures.

Table 11. Media temperatures in 10 cm pots at Alstonville when mean daily maximum temperature was 25-26°C.

Month and Year.	Mean pot max temp.	No. of days pot > 30°C	No. of days pot > 35°C
Nov-Dec 1992	32°C	47	23
March-April 1993	31°C	18	15

Reductions in leaching

Measurements made on NSW nurseries indicate that where overhead sprinklers are used, leaching fractions generally exceed 50% and often exceed 80%. The project demonstrated that a 12% leaching fraction was sufficient to prevent growth depression due to salt accumulation. This leaching fraction reduced nutrient loss (Fig. 5) and water use by 75%. Similarly in the USA, Biernbaum (1992) reduced CRF application rates with similar growth rates by reducing the leaching fraction to 12%.

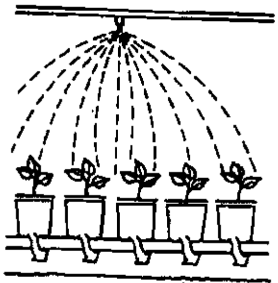
Reduced leaching would increase the period over which an adequate nutrient supply was available from CRF's. That is, efficient irrigation management increases the effective life of CRF's, plant growth rates improve and turnover rates increase.

Strategies for reducing irrigation volume, leaching and nutrient loss

Most of the following strategies are discussed in detail by Rolfe *et al* (1994) and Biernbaum (1992).

Pulse watering

Applying water as a series of short pulses instead of a continuous irrigation is more effective in rewetting pots. A half hour watering cycle could be changed to two 10 minute waterings spaced an hour apart. The time gap between applications allows water to be absorbed by the potting medium and minimises leaching.



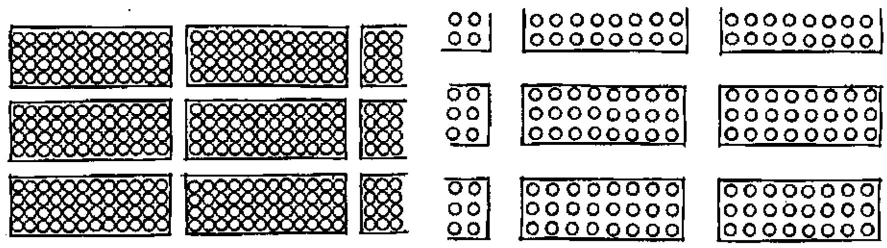
Applications rates can be reduced by applying water more uniformly.

Uniformity of spray

Application rates can be reduced by applying water more uniformly. This requires correct matching of nozzel type and spacing with water pressure. Maintenance and replacement of worn sprinkler heads is essential. This will reduce the occurrence of dry areas or pockets and the need to excessively water the whole nursery to wet these drier areas.

Pot spacing

The quantity of water falling outside pots can be minimised by closer spacing of pots and reducing the area of pathways.



By placing pots close together, the volume of drainage water can be minimised.

Widely spaced pots mean more water will fall between them.

Wetting agents

Wetting agents can be used to improve rewetting of potting media.

Watering by pot weight

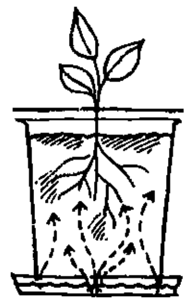
Excessive watering can be avoided by irrigating on demand. The timing of irrigation should be linked to a target pot weight. The target weight can be established in two ways, using portable scales.

(i) Weighing several representative pots that are judged by the appearance of plants to require water. This point can be moist or dry depending on the growers preference (Biernbaum 1992). Whenever this weight is reached irrigation is applied.

(ii) Allow some established plants to wilt slightly then record pot weight. The difference in weight between a recently watered plant at container capacity and a plant near wilting point is an estimate of available water in the pot

Water availability to plants can be estimated by weighing representative plants.

(Biernbaum 1992). Plants should be watered when the pots are two thirds of the way to wilting point weight. This gives a safe margin for variation in watering needs of other plants in the nursery. This will result in water being applied when 60-70% of the available water in the pot has been used (Biernbaum 1992).



Trays under pots help maintain water and nutrient supply.

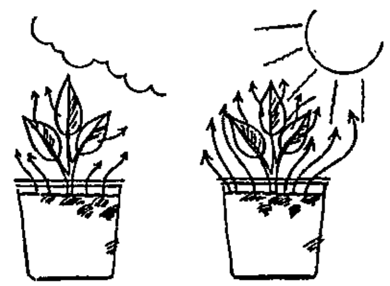
Use trays under plants

Trays placed under pots are a low cost method of maintaining water and nutrient availability to potted plants. Trays will retain some of the nutrient-rich leachate and act as supplementary source of water.

Matching irrigation volume with climatic conditions

Seasonal adjustments should be made to the rate of water application to account for high evaporation rates in summer and low rates in winter.

In winter, evaporation rates are lower so plants need less water.



In summer, evaporation rates are higher so plants need more water.

Water retention capacity of potting media

Potting media with high water retention capacity should be used to reduce irrigation frequency. This is discussed in detail in the next chapter, Chapter 4.

Review use of soluble fertilisers

There is scope for reviewing the benefits of soluble fertiliser in potting media, given that most of the soluble fertiliser is leached in the first week after potting-up. Research suggests that CRF's can provide an adequate nutrient release to meet plant requirements and nitrogen draw-down.

4

NURSERY POTTING MEDIA

Chapter summary

- Drainage losses from media following an overhead irrigation are high.
- Substantial savings in water and fertiliser can be achieved by using more water retentive media.
- Media which comply with the Australian Potting Mix standard can differ markedly in the capacity to retain water.
- Media water retention can be improved using a wetting agent.
- Water retention is best at irrigation application rates within the range 10-20 mm/hr.
- Increasing the cation exchange capacity of media with additives can reduce nutrient leaching and the requirement for fertiliser.

Properties of modern potting media

Modern growing media used to produce containerised plants are generally made from soilless ingredients, have an open structure (air filled porosities > 13%) and are free draining.

Soilless media are preferred because they are light, cheap (often made from available waste materials), relatively free of many soil pathogens and easier to manage in pots than soil. The media used in pots must be open and free draining to cope with over-watering which is common in nurseries relying on overhead sprinklers. Without these properties, the growing medium would quickly become water logged and plant performance would suffer.

Unfortunately, media which drain quickly are also likely to dry out quickly. Use of open, free draining media in nursery production, therefore, encourages frequent and heavy watering and strong nutrient leaching.

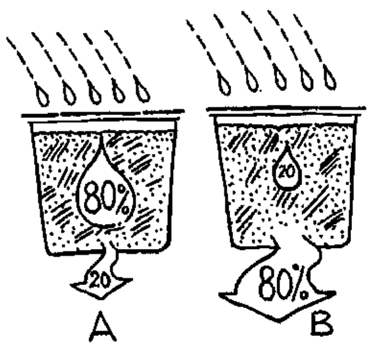
An important first step in improving water and fertiliser use efficiency in nurseries which use overhead irrigation is to reduce water application rates. To accomodate this change, media which have a better capacity to retain both water and nutrients will be required.

Water retention

The primary purpose of any irrigation program is to replace the water lost from the growing medium through plant uptake or by evaporation. This is not as simple as it seems.

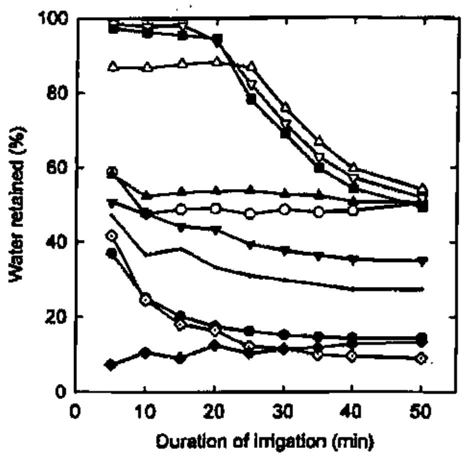
Anyone who has hand watered a pot plant knows that much of the applied water quickly drains through the mix without being absorbed. This effect is more severe in mixes which are open or which shrink away from the sides of the pot when dry. When plants in a nursery are irrigated with overhead sprinklers some water is also wasted in this way. This means that more water must be applied than was actually lost from the potting mix since the last irrigation. Use of media which are difficult to wet up therefore leads to greater water consumption and increased runoff.

Tests performed on a number of commercially produced media indicate that the capacity for water retention can be quite variable, even between mixes which conform with the Australian Standard for potting mixes (Figure 6, over page). The most water retentive medium tested, absorbed around 80% of the water which was applied over the first 25 minutes of the irrigation. Only 20% was therefore lost as drainage. If the water deficit in a 1 L pot on a warm day is in the order of 100ml,



Potting media vary considerably in their ability to retain water. Some retain four times as much as others.

Figure 6. Water retention characteristics of potting mixes under overhead irrigation.



125 ml of irrigation water would be needed to replace the 100ml pot deficit. In the case of the least water retentive medium, which only retained 20% of the applied water, 500 ml of irrigation water would be required to replace the 100ml pot deficit.

A nursery changing from the least efficient to the most efficient potting mix would therefore save 500-125 = 375 ml of water per pot, a reduction in water use of 75%, for the nursery.

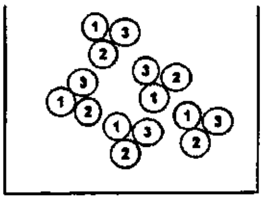
Identifying water efficient media

The ability of a potting mix to retain water from an overhead irrigation cannot be reliably predicted from wettability, air filled porosity, bulk density, water holding capacity or any of the other properties specified in the Australian Standard for Potting Mixes (1993).

Until a simple laboratory test is developed, nursery operators must field evaluate any new mix. This can be done by measuring the volume of leachate which drains from test mixes within the first 10-15 minutes of an irrigation. Mixes which release the least amount of leachate are the most efficient.

For a fair comparison, all mixes should be at a similar moisture content at the time of testing. This can be achieved by allowing fully wet mixes without plants to dry for 2-3 days prior to testing. To minimise the effect of uneven water distribution from sprinklers on leaching rates, at least 5 pots (replicates) of each mix should be used and they should be arranged as shown in Figure 7.

Figure 7. Pot layout plan for evaluation of 3 mixes using 5 replicate pots of each.



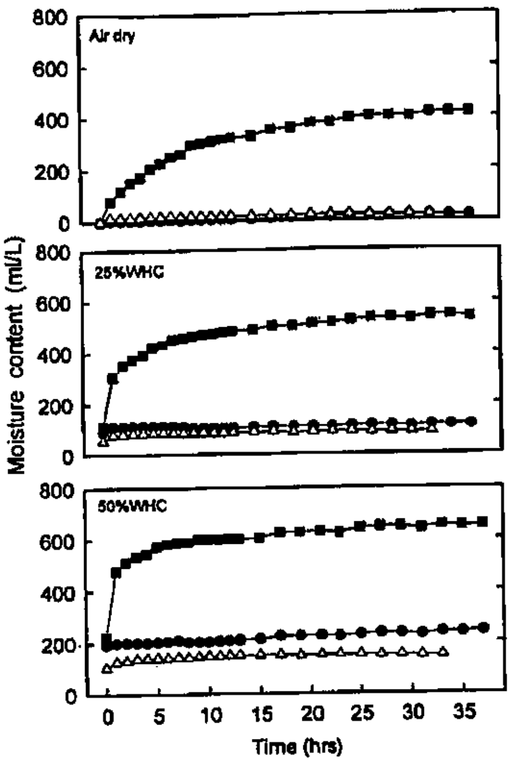
Strategies for conserving water

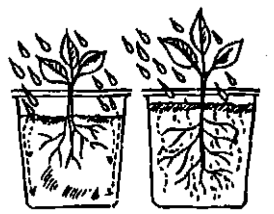
Selecting appropriate media

Only media which comply with the Australian Standard for Potting Mixes (1993) should be used in nursery plant production. Plants can be grown on media which fail the standard, but their use makes water, nutrient and disease management more difficult.

When choosing a mix for a particular aspect of nursery production it is important to consider the method of irrigation which is to be employed. If it is bottom watering, as is the case with sand bed or ebb and flow systems, a mix with good capillary wetting properties is needed. Although peat is useful for improving the water holding capacity (WHC) of a mix, its capillary wetting capacity is very poor

Figure 8. Capillary wetting of coir dust (■), sphagnum (•) and sedge peat (Δ) at 3 initial moisture levels - air dry and 25% and 50% of maximum water holding capacity





Mixes which shrink when dry allow water to channel down the inside of the pot.

(Figure 8). Coir fibre dust (coconut husk waste), on the other hand, is extremely easy to wet in this way and would be a useful amendment to mixes where bottom watering is used.

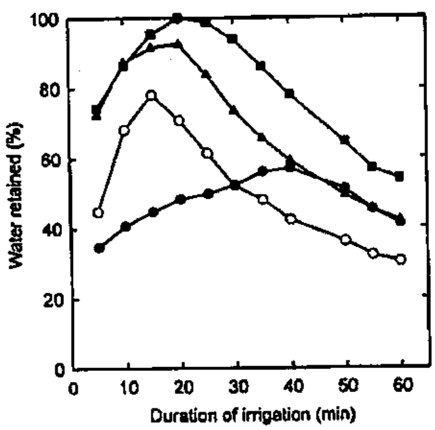
If pots are watered from the top, as with overhead sprinklers or with drippers, the mix should have good water retention properties. Mixes which are difficult to rewet or which shrink when dry should not be used. Shrinkage allows irrigation water to channel down the inside of the pot by-passing the mix and increasing leaching losses.

Improving existing media

Adding materials which are easily rewet and have a high water holding capacity should improve the water retention efficiency of a mix. However, the effect of such a change may not always be predictable. For example, the capacity of a wood waste based potting mix to retain water was improved by adding coir dust at rates of 20% and 40% V/V but was surprisingly reduced at a rate of 10% V/V (Figure 9).

It would seem prudent, therefore, to trial any reformulated mix against its parent before it is adopted within a nursery.

Figure 9. Influence of coir dust additions on media water retention. Nil (o), 10% v/v (•), 20% v/v (▲) and 40% v/v (■),



Wetting Agents

Wetting agents are surfactants which promote wetting by reducing the surface tension of water. They are now being promoted in Australia as an aid in rewetting of nursery media. Some of these products have been evaluated by Kevin Handreck and his findings are published in Australian Horticulture (Handreck 1992a and b).

Some media, particularly those containing sphagnum peat and pinebark, can become quite difficult to rewet once they have dried out (they are said to be hydrophobic). This problem is generally managed by irrigating pots frequently to avoid drying - a practice which is wasteful of water and which encourages nutrient leaching. If these mixes do become too dry, long periods of pulse watering are often needed to bring them back to a satisfactory moisture level. A more effective way of dealing with hydrophobicity is to use a wetting agent. By assisting rewetting of potting media (Fig 10), these products can substantially reduce nursery water useage.

Wetting agents can be applied when a mix is first made or even watered in after plants have been potted up. Manufacturer's recommendations should be followed closely to obtain best results. Plant phytotoxicity and even some loss of water retention efficiency is possible if rates are too high (Figure 10).

Wetting agents have been shown to increase water holding capacity without reducing airfilled porosity and even improve capillary wetting of some media. This latter effect is important with media used in sub-irrigation systems.

Polymer gels

In recent years, water holding gels (crystals) have been heavily promoted in Australia as a means of reducing water consumption in nurseries. These products are usually starch or synthetic polymers which have the ability to absorb and retain as much as 800 times their own weight in water. They are usually added to potting media to increase water holding capacity so that less frequent watering is necessary. This benefit has not always been demonstrated in research trials.

Tests performed on one of the polymer gels (Aquasorb®) revealed that it actually reduced the water retention efficiency of a mix (Figure 11). The results suggest that the gel absorbed water too slowly to exploit the brief period when water was moving freely through the mix. Faster uptake may have occurred if the product had been

Figure 10. Influence of a wetting agent on potting media water retention. Nil (o), 1 mL/L (▲), and 2 mL/L (■).

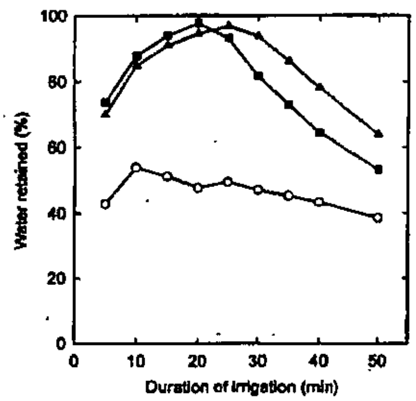


Figure 11. Influence on water retention of adding a polymer gel (Aquasorb®) to a potting mix. Nil (o), 1 g/L (■), and 2 g/L (▲).

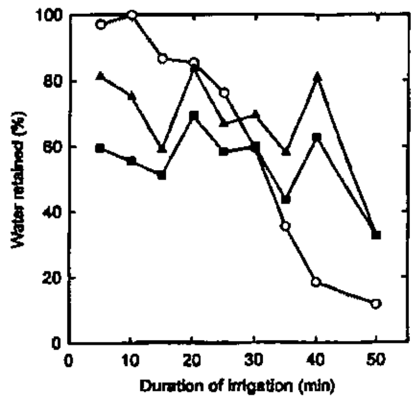


Figure 12. Effect of irrigation intensity on media water retention.

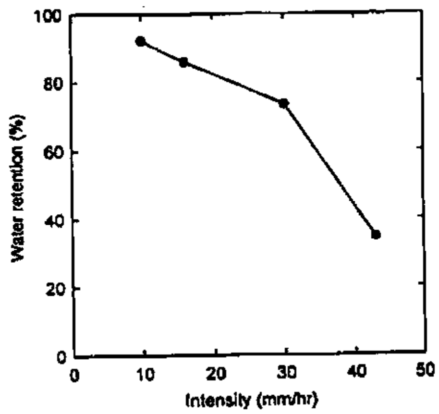


Table 12. Cation exchange characteristics of organic growing media and soil.

Medium	Sum of Cations meq/L
Potting mix[1]	56 (22)
Clay soil	100-300

1 Mean and standard deviation of 42 wood waste and peat based media.

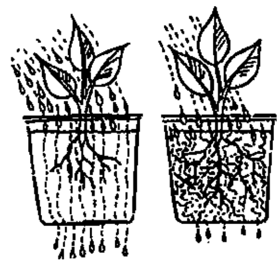
used with a wetting agent. The gel did increase the mixes capacity to hold water but this would not be a benefit in most nurseries where watering is both frequent and excessive. Gels are more likely to be useful where watering is done on demand than where overhead sprinklers are used.

Irrigation

Regardless of media type, water retention is improved by reducing the intensity of an overhead irrigation. The relationship between irrigation intensity and water retention for a sawdust, peat, sand mix is shown in figure 12.

Best results were achieved over the range 10-20 mm/hr which is much lower than is common in most nurseries where application rates generally exceed 25 mm/hr. At high rates of water application, efficiency may be improved by reducing the duration but increasing the frequency of irrigation, a practice called 'pulse watering'.

Information on the design and management of nursery irrigation systems can be obtained from Rolfe *et al* 1994.



Water retention is improved by reducing the intensity of irrigation.

Improving nutrient retention

Soilless media used in nursery production are generally low in fertility and fertilisers are required to maximise plant growth. The organic component of a potting mix can reduce nutrient availability, particularly of N and P. The reduction in N availability is known as 'nitrogen draw-down'.

Most organic based potting media have a modest capacity to retain nutrients, compared with a fertile soil. This is related to low numbers of negatively charged sites on exposed surfaces, the cation exchange capacity (CEC), (Table 12). These negative sites attract and loosely hold positively charged ions (cations) such as Mg^{+2}, K^{+2} and $NH_4{}^{+2}$.

When CEC is low, soluble fertilisers can be readily leached and potting media are prone to rapid changes in pH. This not only influences nutrient loads in runoff water but also causes fluctuations in nutrient availability to plants which itself can reduce growth rates and product quality.

Table 13. Cation exchange properties media additives used to improve nutrient retention.

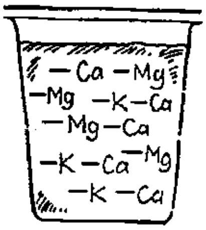
Material	Cation sum BaCl2 meq/L	NH4Cl meq/L
Potting mix[1]	56	
Zeolite	119	472 (1920)[2]
Vermiculite	89	86
Kaolite	45-59	-
Kandite	17	27
Black soil (alluvium)	29	33

1 Mean value from a survey of 42 wood waste and peat based media.

2 A higher estimate of the CEC of zeolite is obtained using an ammonium chloride extractant.

Improving existing media

The capacity of a potting mix to retain nutrients can be improved by incorporating materials which increase the CEC. A list of minerals which are used for this purpose is given in Table 13.



Increasing CEC helps a potting mix retain nutrients.

In trials on a commercial nursery, leaching of K from containers was significantly reduced when zeolite (10% v/v) was added to the pinebark based mix. However, savings in K were balanced by losses of other cations which were presumably displaced from exchange surfaces. Zeolite did little to reduce leaching losses of N because nitrate (an anion) and not ammonium (a cation) is the dominant N form used in nursery fertilisers.

Less K fertilisers are needed to sustain plant growth when zeolite is included in a mix (Fig 13). This may be because there is less leaching of K. However, zeolite is also a satisfactory short term source of K for plants.

In overseas studies, zeolite preloaded with N and other plant nutrients has been successfully used as a fertiliser.

Conclusions

In nurseries using overhead irrigation substantial savings in water and nutrients appear possible through the development of media with better water and nutrient retention properties.

At the moment, there is no simple way of identifying water efficient media other than by on-farm trials. However, commercial media with excellent properties have

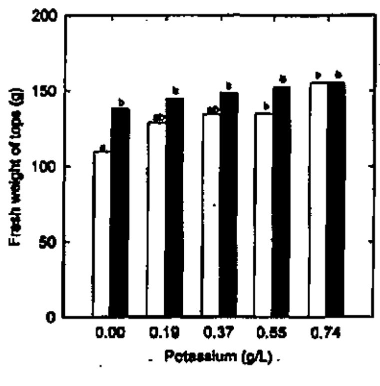


Figure 13. Influence of Zeolite addition on the response of marigold seedlings to potassium (K). Treatments with the same letter do not differ significantly (P = 5%).

been identified which indicates that water efficient media can be produced at a competative price. Further research is needed to give potting mix manufacturers the necessary tools to consistently make these products.

Preliminary work suggests that wetting agents are useful for improving media water retention. However, further studies are needed to establish how long the benefit lasts after the treatment.

More work is also required to establish whether polymer gels have a role in improving water use efficiency in nurseries.

Insufficient research has been done with media additives designed to increase CEC. Under existing nursery conditions, typified by generous fertiliser rates and excessive leaching, the benefits of using these materials are likely to be small. However, the strategy is sound, and these products do have a place in nursery production systems where water and fertilisers are managed more objectively.

Until recently, the main force driving the development of potting mixes has been a requirement that they are forgiving of overwatering. As a consequence, very open mixes with excellent drainage have become the industry standard. With recent water restrictions and moves towards nurseries paying the real cost for water, a market for media which perform well under less generous water conditions is rapidly developing. This new trend may well see a return to tighter mixes.

5

FERTILISER MANAGEMENT IN NURSERIES

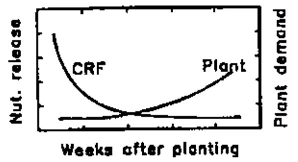
Chapter summary

- Osmocote and Nutricote are equally effective in supporting plant growth. They will produce about 70% of the growth of a treatment where optimum nutrition is provided (such as a continuous liquid feed).
- Soluble fertilisers are rapidly leached from potting media and can only maintain plant growth with frequent applications.
- A combination of CRF's with a range of release periods and minimum leaching is required to maintain adequate nutrient availability to plants.
- Split CRF applications are more effective in maintaining nutrient supply than single doses.

Plant nutrient uptake

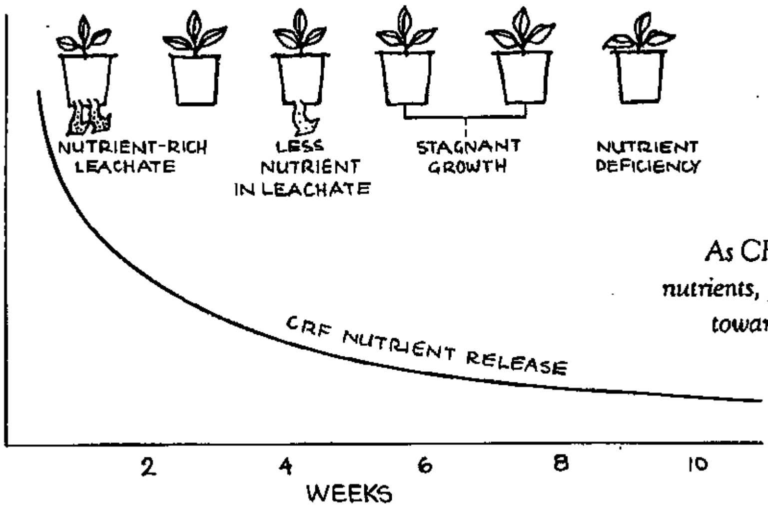
Ideally, nutrients should be released from CRF's at a rate which coincides with the nutrient demand by the plant. In practice, a single application of CRF gives a spike of release in the first week after potting-up, followed by a more stable and lower rate of release until the product is depleted of nutrients. Release rates over this latter period are influenced by the volume and frequency of water applied and pot temperatures. The challenge to manufacturers is to develop products with release patterns which match plant demand more closely (Figure 14).

Figure 14. A generalised pattern of CRF nutrient release pattern and plant nutrient requirements.



This figure indicates that a nutrient deficit is likely as plants near maturity using single dose CRF applications. Plants adjust their growth rates to the nutrient availability and will slow growth where there is a deficit. A reduction in growth as the plant is maturing is not easily detected by eye, because plants will only exhibit nutrient deficiency symptoms when there is a severe deficit.

High pot media temperatures and high irrigation rates in summer substantially reduce the life of CRF's. Rapid release under these conditions increases the likelihood of a nutrient deficit as the plant is nearing maturity.



As CRFs release less nutrients, plants will progress towards deficiency.

Plant growth in response to fertiliser types

The growth performance of containerised nursery plants in response to different fertiliser treatments has been tested in Australian and American studies. In the Australian study, the fertiliser treatments were compared with a frequently applied liquid fertiliser designed to optimise nutrient supply (Figure 15 and Table 14).

Fertiliser treatments were adjusted to the same rate of N, 800 g N/m^3 potting mix equivalent to 5 Kg/m^3 Nutricote (16N:4.4P:8.3K) (4-5 month). This was consistent with the general rate of application found in the survey of Sydney nurseries (Table 4, Chapt. 2). Other treatments were Osmocote (19N:2.6P:10K) (3-4 month) and Dynamic Lifter (3.0N:2.5P:1.6K).

The CRF's achieved 50-70% and Dynamic Lifter around 30% of the growth from the liquid fertiliser treatment.

Despite the spike of nutrient release during the week after potting up (Chapter 3), plant growth for all fertiliser treatments was poor relative to a continuous liquid

Figure 15. Comparison of growth as measured by the dry weight of plant tops, for 10 week groundcover species fertilised with Nutricote (△), Osmocote (▲), Dynamic Lifter (◇), and liquid fertiliser (■).

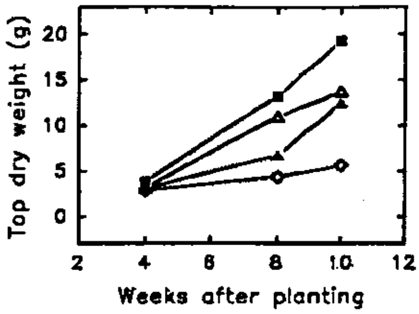


Table 14. Performance of fertiliser treatments at a recommended rate of about 5kg/m^3 expressed as a % top growth of a liquid control.

Treatment	4 week species	10 week species
Nutricote (4-5 month)	50	68
Osmocote (3-4 month)	50	68
Dynamic Lifter	32	27

feed over 4 weeks. Most of the nutrient spike was leached. Dynamic Lifter does not have the slow release characteristics of the CRF's. Its place in nursery fertiliser programs is similar to that of soluble fertilisers in providing rapid nutrient availability.

It is interesting to note the improved performance of the CRF's for the 10 week species compared to 4 week species relative to the liquid feed treatment. The improved performance of Osmocote and Nutricote may be due to plant recovery from a set back. Plant growth may have been slowed in the early stages by:

- Salinity effect due to the high rate of nutrient release (nutrient spike) in the first week.
- Inadequate nutrient release in weeks 2 to 4.

Maintaining nutrient supply

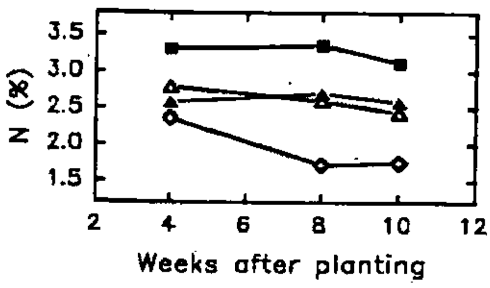
Collecting young, mature leaves for analysis can help determine the effectiveness of a fertiliser program.

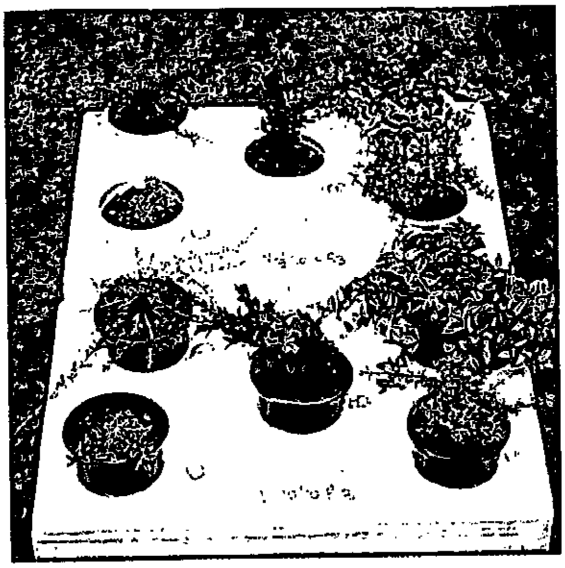
Another indicator of the effectiveness of a fertiliser in maintaining an adequate nutrient supply to plants is the nutrient concentrations in the plant tops (Figure 16). Concentration reflects nutrient availability.

A stable N concentration was maintained in plant tops from liquid feed and CRF treatments. In contrast, Dynamic Lifter had released most of its nutrients by week 4 which led to a decline in plant nutrient concentrations.

The differences in growth performance (Fig. 15), indicates that while the level of nutrient supply from CRF's is stable (Fig. 16) it is not high enough to fully meet plant nutrient demand, which the liquid fertiliser treatment achieved.

Figure 16. Nutrient concentrations (% dry wt) in plant tops over time for 10 week species fertilised with Nutricote (△), Osmocote (▲), Dynamic Lifter (◇), and liquid fertiliser (■).





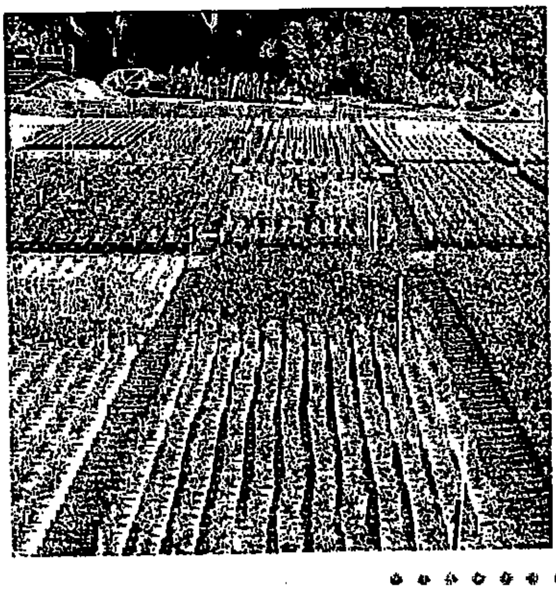
ABOVE: Examples of different plant growth from (top box) Nutricote fertiliser and (lower box) liquid fertiliser.

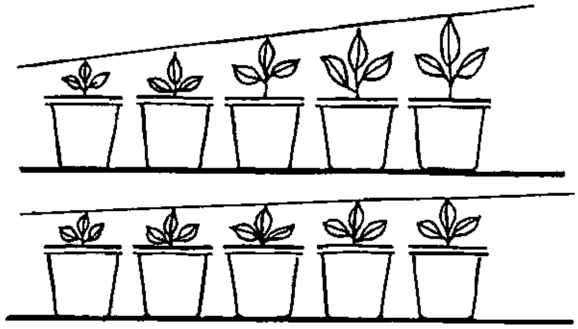
ABOVE RIGHT: Pine bark and sawdust: some of the ingredients making up potting mix.

RIGHT: A nursery plant showing placement of CRFs in the middle of the pot and how the root ball has grown down through this layer.

BELOW RIGHT: An example of good pot spacing - closely packed with minimum pathways.

BELOW: Leaching due to excess watering.





Plant growth will vary according to how well the fertiliser meets plant nutrient demand.

Raising nutrient supply levels

An optimum nutrient supply will maintain high growth rates and adequate nutrient concentrations in plant tops. The N concentrations in tops (Fig. 16) for liquid feed > Osmocote = Nutricote > Dynamic Lifter demonstrates this point follows the same order as for growth rate.

A sustainable and adequate nutrient supply is required to improve plant growth as was reported in other studies (Worrall *et al* 1987). The highest yields from CRF's are obtained when average available N concentrations are maintained at 100-200 mg/L (Jarnell *et al* 1983) equivalent to the N concentrations in the liquid feed treatment applied in this study.

Higher fertiliser treatment rates were tested to see if they improved growth performance (Table 15), compared with recommended rates (Table 14).

Table 15. Performance of fertiliser treatments at double the recommended rate, expressed as a % of a liquid feed control.

Treatment	4 week species	10 week species
Nutricote (x2) (4-5 month)	58	62
Osmocote (x2) (3-4 month)	60	82
Dynamic Lifter (x2)	43	32
Nutricote (x2) (+ 40d)	84	74

Doubling the rate of CRF's did benefit the 4 week species, improving growth by 10%. This is consistent with the possibility of a nutrient deficit or an uptake problem in the 2 to 4 week period after potting up. However, it does negate a salinity effect from the spike of nutrient release in the first week after potting up. The response of 10 week species to the high fertiliser rate varied from a slight reduction to an almost 15% improvement (Osmocote) and is inconclusive as a guide to growth responses. Any improvement in growth achieved from doubling recommended CRF rate is at the expense of a large increase in nutrient leaching (Chapter 3).

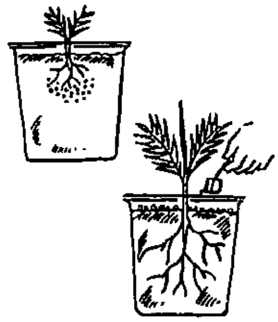
The biggest improvement in growth was from the addition of a 40d formulation to the Nutricote treatment. The 34% improvement for the 4 week species again suggests that the levels of nutrient release over the 2 to 4 week period from a standard 4 month CRF formulation may be inadequate.

Strategies for improved CRF performance

Soluble (rapid release) fertilisers are of limited benefit as a supplement to CRF's because they are leached rapidly from potting media. Improved CRF performance is more likely to be achieved by combining CRF's with various release characteristics and by splitting applications.

Combining short and medium term CRF formulations

Combining short and medium term CRF formulations at potting-up gave a marked improvement in growth. The improvement appears to come from higher rates of release in the 2-4 week period because substantial nutrient release occurred in week 1 from both the soluble fertiliser added to the medium pre-potting and from damaged CRF prills.



Splitting fertiliser applications will help maintain nutrient levels.

Split applications of CRF's

Splitting applications of CRF's, particularly for medium to long term species, will assist to maintain nutrient levels throughout the growing period (Cox 1993). This approach is particularly applicable during the hotter spring, summer and autumn months when CRF's are depleted more rapidly and a nutrient deficit occurs towards plant maturity.

6

CONCLUSIONS

Chapter summary

- There are three main strategies you can adopt to reduce leaching loss in your nursery. They are:
  - improve delivery of fertiliser and water to pots,
  - improve retention of fertiliser and water in the growing medium, and
  - recycle waste water.

- Not all changes in these areas involve spending lots of money and yet benefits can include:
  - up to 30% saving in fertiliser,
  - up to 80% saving in water,
  - improved plant growth and quality, and
  - reduced nutrient load in runoff water.

- The first step is to sample your runoff and dam water for nutrient loads to check the efficiency of your fertiliser and irrigation practices. Then you will have a better idea of which areas in your current system need attention.

Fertiliser and water savings

Research into fertiliser use efficiency and nutrient leaching from container media indicates that substantial savings in fertiliser and water can be made in most nurseries relying on overhead sprinklers. Many of these changes do not require a large capital expenditure and may lead to better growth and plant quality.

Strategies

In the preceding chapters, some of the main factors which determine the degree of leaching loss in nurseries have been identified and simple measures to minimise their impact have been recommended. In this concluding chapter we have grouped these measures into three strategies.

1. Improve delivery of fertiliser and water to pots
   - provide liquid feeds through drip irrigation lines in preference to overhead sprinklers.
   - improve uniformity of sprinkler application by using best available nozzles, at appropriate spacing and line pressures.
   - maximise number of pots within sprinkler area.
   - investigate use of subirrigation in any new production area.
2. Improve retention of fertiliser and water in the growing medium.
   - use minimum rates of fertiliser to achieve desired growth rate and quality.
   - use controlled release fertilisers in preference to liquid, soluble fertilisers or poultry manure.
   - split fertiliser applications.
   - use media with higher CEC
   - reduce volume of irrigation water applied to minimise leaching fraction to around 12%.
   - reduce irrigation intensity to optimise rewetting of media.
   - use pulse watering - reduce duration but increase frequency of irrigation.
   - irrigate when needed adjusting application rates for seasonal differences in water requirement and where possible for daily differences.
   - use media with good water retention properties.
   - use wetting agents with media which are difficult to rewet.
3. Recycle waste water
   - collect waste water into storage areas for sterilisation and reuse. Particular attention should be given to the water from propagating areas and to the first part of the runoff following heavy rain.
   - seal growing areas and drains to minimise infiltration of waste water into soil.
   - filter sediments from runoff water using reed beds, hay bales, etc.
   - monitor storage water quality and adjust fertiliser program to make use of recycled nutrients.

Benefits

The ability to comply with environmental regulations will be an essential requirement for the success of nursery businesses in the future. This will not be possible without adopting best management practices and this process will be costly. However, in changing to more environmentally sound practices, nurseries currently relying on overhead sprinklers can expect to obtain commercial and environmental benefits.

The main commercial benefits are:

- savings in fertiliser (up to 30%)
- savings in water (up to 80%)
- improved plant growth and quality, hence faster turnover rates

The main environmental benefits are:

- reduced nutrient load in runoff water.
- reduced volume of runoff water.

The first step

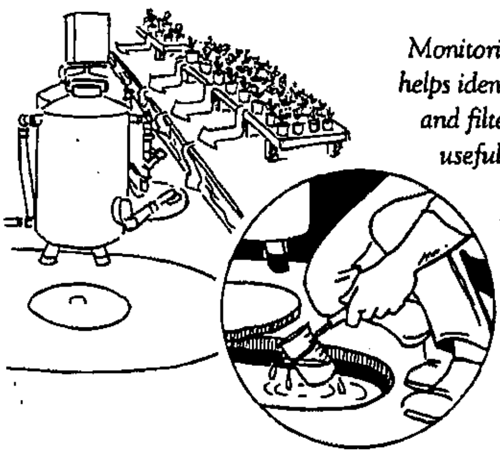
Before upgrading your system, we suggest you examine the effectiveness of your current fertiliser and water use practices.

Samples of runoff and dam water should be analysed to determine nutrient loads. The results can be compared with water quality criteria reported in this publication. Leaching fractions following an irrigation should be estimated at a number of sites within the nursery. The efficiency of overhead sprinkler systems should also be assessed using methods described in Rolfe *et al* (1994).

This baseline information will help you to identify the areas of greatest waste in the current system allowing you to better target limited resources.

A regular program of monitoring will give feedback on the benefits of change as well as a better understanding of the production environment.

Good record keeping and good management go hand in hand.



Monitoring drainage water helps identify areas of waste, and filtering improves its usefulness for reuse.

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Glossary of Terms

4 week species — Fast growing ground cover plant reaching commercial maturity approximately 4 weeks after transplanting.

10 week species — Ground cover plants that have reached commercial maturity by approximately 10 weeks after transplanting.

Anion — -ve charged ion. Examples include nitrate (NO_3-) and sulphate (SO_4-).

Cation — +ve charged ion. For example calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and ammonium (NH_4^+).

Cation exchange capacity (CEC) — The capacity of a growing medium to attract and hold +ve charged ions. Nutrients held on the negatively charged exchange sites are less subject to leaching.

Controlled release fertilisers (CRFs) — Any soluble fertiliser which has been coated with a semi-permeable membrane to slow down nutrient release.

Dry weight — Weight after material has been dried in an oven at 80°C.

Fertiliser use efficiency — Percentage of applied fertiliser nutrients which is utilised by plants.

Field or container capacity — Water content of a growing medium after it has been fully wet and allowed to drain.

Irrigation efficiency — Percentage of the applied irrigation water which is retained by the growing medium.

Leachate — Drainage water from pots after irrigation or rain.

Leaching fraction — Percentage of the applied irrigation water which drains from a pot.

Nitrogen drawdown — The capacity of the organic component of a growing medium to reduce the availability of nitrogen for plant use. This happens because N is used by microorganisms involved in the decomposition of organic matter high in carbon. Pinebark and

	sawdust have a high N drawdown capacity and it is standard practice to add an N source like urea to media when these materials are present.
pH	Logarithmic scale indicating concentrations of hydrogen ions in solution. pH 7 is neutral, values below 7 are classed as acid and above 7 as alkaline. Nutrient availability is influenced by pH. Plants generally grow best at a pH of 5-6.5.
Plant nutrients	Elements essential for growth and reproduction of plants. The macroelements are: carbon (C), hydrogen (H), oxygen (O), sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and chlorine (Cl). The micro or trace elements are: Iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), boron (B) and molybdenum (Mo).
Plant tops	The above ground portion of the plant, including stems, branches, leaves and flowers.
Polymer gels	Long-chain cross linked organic molecules added to growing media to increase water holding capacity. They absorb water during an irrigation and release it to roots as the medium dries. Conflicting results have been reported in the literature and so no general claim about their usefulness can be made.
Volatilisation	N loss as ammonia (NH_3) - can be more severe when fertiliser is surface applied and is negligible when incorporated into the growing medium.
Wetting agents	Chemical additive used to promote wetting in potting media by decreasing water surface tension.
Wilting point	Moisture content of a growing medium at which plants begin to wilt.

Notes