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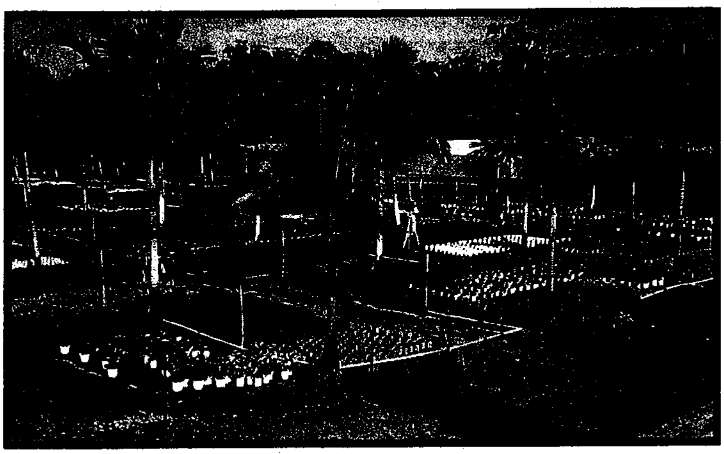
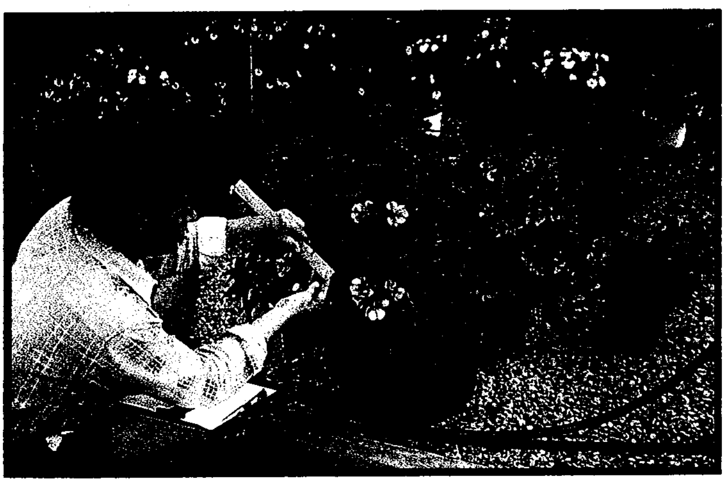
Do Our Own Research

THE DOOR MANUAL FOR PLANT NURSERIES





QUEENSLAND GOVERNMENT

DPI QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

QUEENSLAND NURSERY INDUSTRY ASSOCIATION

HRDC

THE UNIVERSITY OF QUEENSLAND

The **DOOR** *way to practical solutions*

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FOREWORD

Over the past thirty to forty years, the Queensland agricultural and horticultural industries have become increasingly dependent on the public sector for research solutions to their industry problems. This research has proved useful for many of the single commodity industries, such as wheat and sugarcane, macadamias and mangoes, but less so for the nursery industry.

In the nursery industry, generic research conducted by government institutions is often not specific enough to be highly valued and adopted by the individual operator. Operators need practical solutions to their particular problems. Such problems almost invariably involve sets of conditions common to few other enterprises. This uniqueness reflects the almost infinite variation of options available in terms of species grown, media used, fertiliser, amendments and chemicals applied and the way water is supplied.

The Queensland Government is strongly advocating increasing industry self-reliance in many aspects of agriculture. The objective of Do-Our-Own-Research (DOOR)—enhancing the capacity of nursery operators to do their own research—is thus strongly aligned with government policy. More important, however, is the assessment by industry itself that the DOOR approach is in many circumstances the only cost-effective way to find solutions or to develop new opportunities.

DOOR advocates a significant paradigm shift in technology transfer in horticultural research. The DPI acknowledges the significance of the ground-breaking work of Professor Shankariah Chamala in making this development possible.

DOOR represents a relatively unexplored way of generating new, statistically sound research information in the nursery industry. Its potential is immense. The DOOR approach has application in a number of other industries and may provide important support at a time of declining Research, Development and Extension investment by the public sector.

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PREFACE

The aim of the manual is to enhance nursery operators' understanding and skills development in the following areas:

- critically evaluating opportunities and problems in the nursery environment,
- gathering relevant information,
- deriving and prioritising potential solutions to problems and opportunities,
- becoming familiar with the scientific method employed in testing potential solutions,
- carrying out statistically sound and rigorous research, and
- developing recommendations that flow from the research information generated.

Additional material and resources for facilitators and operators are provided in the appendixes.

We would like to acknowledge the help of everyone who made this manual possible, including Dominie Wright for writing most of the keypoints, Bev Traynor for the original layout, Naomi McIntosh for the final design and layout, and everyone who read and criticised the manuscript.

This manual was developed by the following members of the DOOR project team: Mal Hunter, Garth Hayes, Cynthia Carson, Stuart Scott, Jim Page, Janet Giles and Vesna Popovic (DPI Queensland); Shankariah Chamala and Emma Durrough (student observer) (University of Queensland); Wayne Bacchi and Barry Naylor (Nursery Industry Advisors); David Hawthorne, Herbert Hartwig, Kevin Body, Stephen Collins, Ian Waters, Ian Greet, Matthew Plummer, Jim Goody, Rob Burfein, Brad Skinner, Ian Heymink, Martin Hickey, Lex McMullin and Carmel Hennessey (Queensland Nursery Industry Association participants).

M. N. Hunter and G. W. Hayes

INTRODUCTION

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1.4 STATISTICALLY SOUND RESEARCH

The time is ripe for nursery operators to do their own statistically sound research, confident that they can find relevant answers at a level of precision they may have thought beyond their grasp.

The answers they get will be directly relevant to their own operations and provide a solid base on which to make good decisions. This is what DOOR is about: the development of practical solutions to problems by the people who are on site.

1.4.1 USING STATISTICS

Researchers at any level must be able to detect differences between treatments and compare the results of research. The greater the ability to separate these differences, the more valuable the research will be.

Instinctively, most operators would be able to detect differences of more than 30 or 40 per cent in plant characteristics. But, to get the most value out of more sensitive research, an operator has to be able to detect differences of as little as 10 or 20 per cent.

With computers, sound statistical research is within the grasp of anyone engaged in instinctive research. Following the simple statistical rules at the beginning of chapter 7, even the most inexperienced researchers can be confident in the output of their analyses. This manual explains the processes of effective statistical analysis as well as how to carry out careful research.

Statistical research provides results that can be used to formulate recommendations and make objective decisions. This manual was developed to help operators carry out such research.

1.5 THE DOOR MANUAL

1.5.1 THE DOOR CYCLE

The DOOR implementation cycle provides the structure on which the manual is based. It leads the reader through the chronological process of research, commencing at the opportunity or problem, and concluding with its recommendation for action. The intermediate steps are outlined in the implementation cycle that is illustrated at the beginning of each chapter.

Do-Our-Own-Research: How It Works

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2.1 INTRODUCTION

DOOR promotes a major move away from the old way of providing research information, away from its dependency on externally generated research, to a new way of self-reliance with industry generating its own research information.

This new way of research empowers nursery operators to conduct research that is relevant and self-generated. Operators will own the research that they use and so are more likely to adopt any solutions that are generated.

Slow adoption rates of some government-generated research will no longer pervade the industry as other operators will quickly see the value of information that has welled up out of their own environment.

2.2 CONSULTANCY INVOLVEMENT

Each DOOR experiment requires about 10 to 15 hours of consultancy support on a one-to-one basis. The preferred relationship between the operator and the consultant is that of equal partners with a common goal of resolving an issue.

This relationship is a stark contrast to the way horticultural research was conducted in the past. Research was previously conducted through a teacher–learner relationship in which knowledge was passed in one direction only. The consultant often controlled the amount of information passed on to the operator.

DOOR emphasises skill development in the operator without detracting from the supportive role of the consultant, through partnership and co-development of both participants.

The operator and the consultant are interdependent. Consequently, operators need to be familiar with the consultants' role within the DOOR cycle so that they can be more involved in the process. Although the consultant and the operator may work separately at some stages, they still communicate fully on the process.

2.3 THE DOOR IMPLEMENTATION CYCLE

The DOOR implementation cycle (see figure opposite on page 8) starts with the recognition of a problem or opportunity. To find a solution or exploit that opportunity, the operator needs to undertake a number of activities as progressive steps.

Some of these activities can be the operator's responsibility: identifying the problem or opportunity, gathering information, providing resources, implementing the trial, collecting data, validating recommendations. Other activities may be carried out by the DOOR consultant: designing experiments, analysing and interpreting data. Together, the operator and the consultant can carry out the remaining tasks: clarifying the issue and selecting keywords, evaluating and making decisions, calculating cost-benefits, and formulating recommendations.

PROBLEMS, OPPORTUNITIES AND GATHERING INFORMATION

C. J. CARSON AND S. CHAMALA

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3.1 PROBLEM/OPPORTUNITY

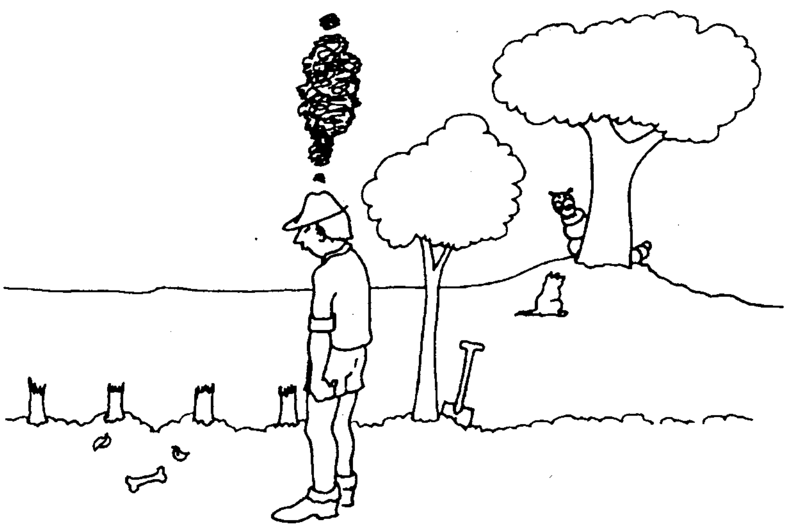
Problems and opportunities are the forerunners to research. They provide the catalysts that advance our knowledge on both small research projects and global breakthroughs. This chapter looks at the problems or opportunities and how to gather the information needed to develop a project.

First you must be aware of the problem's existence. This is the first step of the problem-solving cycle. If there is no perception of a problem, or only a faint "She'll be right mate" awareness of one, this can mean one of three things: there is no issue, or (more dangerously) an opportunity for increased efficiency is being missed, or there is a real problem going unrecognised. If the last, the situation may reduce net revenue and cause serious losses to your business.

Your perception of a problem or opportunity is shaped by what you see and hear, what you read, people that you come into contact with, your level of education, your motivations and your values.

Factors that shape awareness are important because a problem or opportunity is a discrepancy between what is and what should or could be. Compare the existing situation against another: for example, healthy plants versus diseased ones, or the best available practices versus your own. The "closed-shop" culture of the nursery industry can stop you being aware of possibilities for improvement or change.

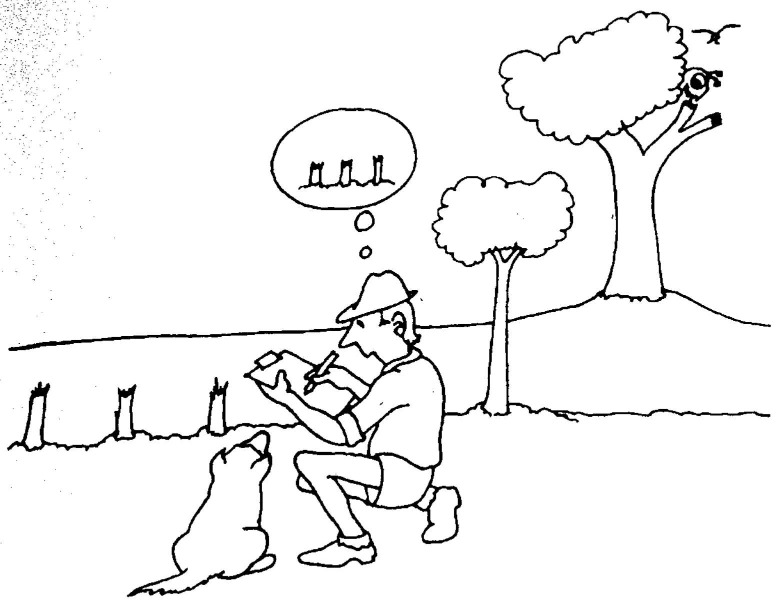
Personal knowledge, the involvement and feedback of staff and access to a good range of external information reduce the possibility of the missed opportunity or escalating problem because you "didn't know". Once you are aware of a need and you feel motivated, you can move to the next step in the problem-solving cycle.



3.1 PROBLEM/OPPORTUNITY

The first step in the problem-solving cycle is awareness.

- Perceptions of a problem or opportunity are shaped by experience and environment.
- Comparing situations or products helps you recognise problems.
- Stay informed and seek the involvement and feedback of staff.



dispatch shed" might be rewritten as "How to increase output in the dispatch shed in spring from 100 to 130 trays of plants per hour". Representing some problems as maps, photographs, floor plans, process flow charts or conceptual diagrams can be valuable. List the key terms that may be used later in the literature search.

Having committed your problem or opportunity clearly to paper, you are now ready to gather together all the available information on the issue.

3.2 INFORMATION GATHERING

3.2.1 USE THE EXPERIENCE OF OTHERS

The value of gathering information is that the experience of others can often shorten the problem-solving process. Do not reinvent the wheel. Try to answer these questions: Have others had this problem? What have they done about it? What is the history of the problem in my nursery, my district, my state and overseas?

Enlist the assistance of experts. Make use of information databases through generalist and specialist libraries, use your contacts and save yourself both time and money.

3.2.2 NETWORKING

It is very difficult to succeed in isolation from others. Cooperative research often encourages the sharing of information. Strong industries are based on unity and trust. Technical secrets rarely make or break a business. Appropriate management of finances, staff and the marketplace are what make the real difference between success and failure. Rarely will any of your secrets mean as much to others as they do to you.

A strong network of informed contacts whose knowledge, experience and advice you can rely on (and in turn supplement) is a great business asset. Information sharing and networking benefits individuals and the industry as a whole.

3.2
INFORMATION GATHERING

3.2.1
USE THE EXPERIENCE OF OTHERS

- Information gathering can shorten the problem-solving process.
- Enlist the help of experts, databases, specialist libraries and fellow growers.

3.2.2
NETWORKING

- Networking is very important for business success.
- Enhance your relationships with colleagues by sharing technical information.

Professional information brokers

Brokers will facilitate a search and the delivery of documents on a subject(s) of your choosing. This service is personalised but can be very expensive.

3.2.4

REVIEWING THE LITERATURE

Do not neglect this important part of the research cycle. Reading is a simple means of bringing the world beyond your gates home to your business. Local and state association newsletters, Australian and international journals, books and workshop proceedings are all useful.

When reading, ask "How relevant are the findings to my situation?". Check the source of the information and the date of publication. Look for clues as to the credibility of the author. How close are the growing conditions to your own?

If the locality or age of the information reduces its relevance, use it cautiously. Take similar action if you doubt the reputation of an author or journal. Further DOOR experience will sharpen your own judgement in reviewing the literature. Your consultant will be able to help you.

Keywords

Unassisted searches will only be as good as the keywords you select. Select problem-defining words that will open the door, but not the flood gates, on your issue. For example a search on the word "nursery" will turn up records on the care of human infants, fish hatcheries and piggeries! Some libraries provide fact sheets on running a successful search. They may also have a thesaurus of broader and narrower search terms that enhance or confine the search. The use of exclusion terms, for example by searching for "nurseries" but specifically excluding "fish", "primates" and "pigs", can help to exclude irrelevant information from your result.

3.2.4

REVIEWING THE LITERATURE

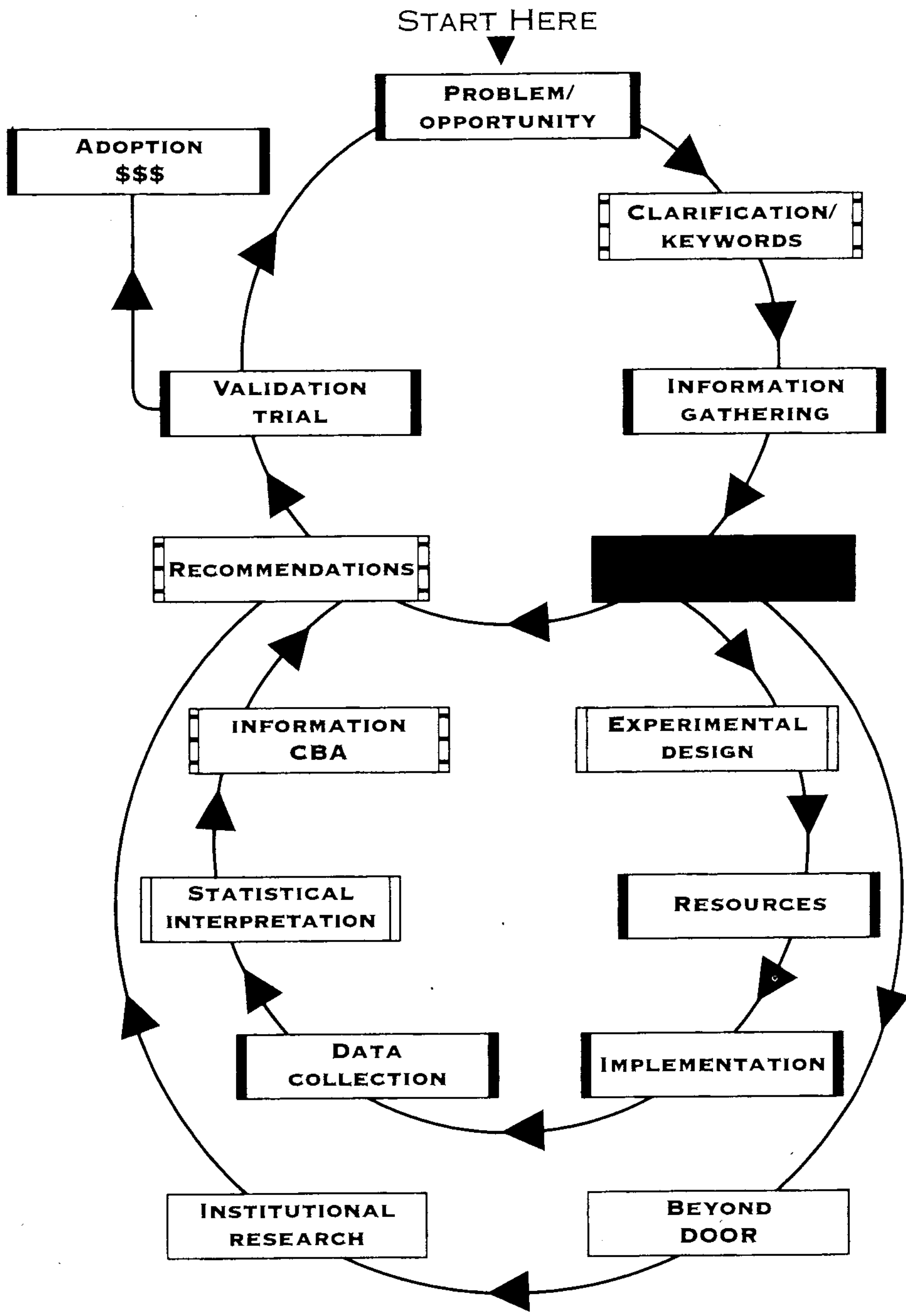
- Revisit past knowledge and critically evaluate current thinking.
- Consider how relevant the information is to your conditions.
- Keywords should be relevant to your subject and designed to exclude other material.
- Scientific papers have a well-defined structure.
- Once understood, scientific papers are a valuable tool.
- The abstract, introduction, and discussion provide the most important and easily understood information for growers.

Fertiliser components

Nitrogen (N), phosphorus (P) and potassium (K) ratios for fertilisers in the USA need to be converted to Australian equivalents. A clue to the need for conversion is a P level greater than 10. The P and K are reported as percentages of phosphoric acid and potash (potassium oxide) respectively. The N level remains unchanged, as elemental nitrogen.

To convert, use the following equation: $\% P = 0.44 \times \% P_2O_5$; $\% K = 0.83 \times \% K_2O$. For example a 10:14:10 fertiliser in the US system is equivalent to 10:6.2:8.3 in Australia.

DOOR
Implementation Cycle



LEGEND

[redacted]

ACTION KEY

CONSULTANT ONLY

JOINT

OPERATOR ONLY

CBA = COST-BENEFIT ANALYSIS

Card sorting

A large number of alternatives can be sorted into categories to be evaluated on a group basis before individual options are selected. Cards or adhesive labels can be written on. Write each activity or aim on a card or label, then place them in sequences or groups (or other patterns) depending on the problem. This activity can help clarify the situation.

Word associations

Words can trigger memory associations that help to identify problems. A list of words and phrases that can be used as a starter in word association exercises is included in appendix 8.

4.2.3

EVALUATING POTENTIAL SOLUTIONS

- Decide the criteria on which to base decisions.
- There are lots of ways of making group decisions.

4.2.3

EVALUATING POTENTIAL SOLUTIONS

Having identified various potential solutions, consider which of these alternatives is most suitable.

What are the advantages and disadvantages of different solutions? On what criteria will you base your decision? Cost-effectiveness? Time to implement? Legality? Space needed? How would you rank the alternatives?

Group decision making

What do the other stakeholders think? Canvassing the views of staff who may be called upon to implement the new practices can be valuable. Group decisions can be reached using various techniques, including:

- consensus (everyone agrees)
- testing more than one idea
- building a more suitable solution from a number of suggestions
- eliminating least-favoured alternatives (according to your criteria) or those with the highest risk of a poor result
- ranking or voting (the majority wins, the minority loses).

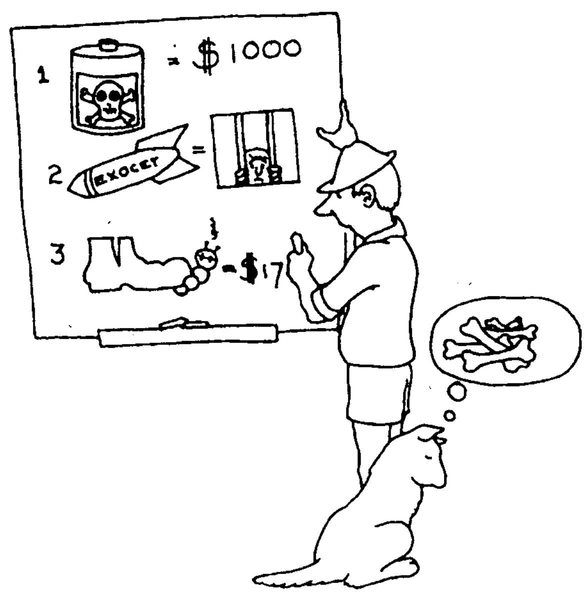


Table 4.1 A comparison of profit and cash flow

Profit	Cash flow
Important	Urgent
Strategic, visionary	Tactical
Long term	Short term
Proactive	Reactive
About the creation of wealth	About the use of wealth
Thriving	Surviving
Conservative — considers changes in asset values when they are incurred	Exploitative — ignores changes in asset values except when they are "cashed in"
Challenging, non-limiting, positive	Limiting, passive

Businesses that are struggling tend to focus on cash flow — the need to have cash to cover accounts due, interest and repayments is urgent. Resources are shuffled around in a tactical way in response to new emergencies and the planning horizon is short term.

This raises the question: "Are struggling businesses struggling because of their short term tactical focus or are they forced to adopt this focus because they are struggling?" .Table 4.1 aids the decison about whether the project is of short- or long-term benefit.This information could persuade a lender to supply the necessary funds to proceed with the project.

4.3.3

Partial budgeting

- Partial budgets are a simple way of looking at the profit and cash-flow implications of research projects.
- Use the formats provided to explore partial budget implications.

4.3.3

Partial budgeting

Partial budgeting is a simplified way to generate answers to the "Does it pay?" and "Can I afford it?" questions. A partial budget, as the name implies, looks at part of the business.The parts examined are the components that change as a consequence of the decision being evaluated.

Two partial budget formats are offered in tables 4.2 and 4.3. Table 4.2 is used to calculate the change in net profit associated with an investment in a research project and table 4.3 is used to examine the impacts on cash flow. An example of some of the items considered in a partial profit budget is shown in table 4.2.

If you are not familiar with the format of partial budgets, the best way to gain skills, knowledge and insight is to have a go at preparing them using the formats provided and then discuss your conclusions. Photocopy the formats in appendix 9 and use them to examine the profit and cash-flow implications of research projects recently completed or being considered. The formats can be copied onto a computer as a spreadsheet so that the computer can do the calculations.

Partial budgets may not provide an adequate answer. Sometimes it is necessary to look at whole farm impacts. Sometimes other budgetary procedures, such as discounted cash-flow budget, or even a risk analysis model, may be required to give the confidence required to pursue a project. This is increasingly the case with the type of projects pursued by the DPI Queensland.

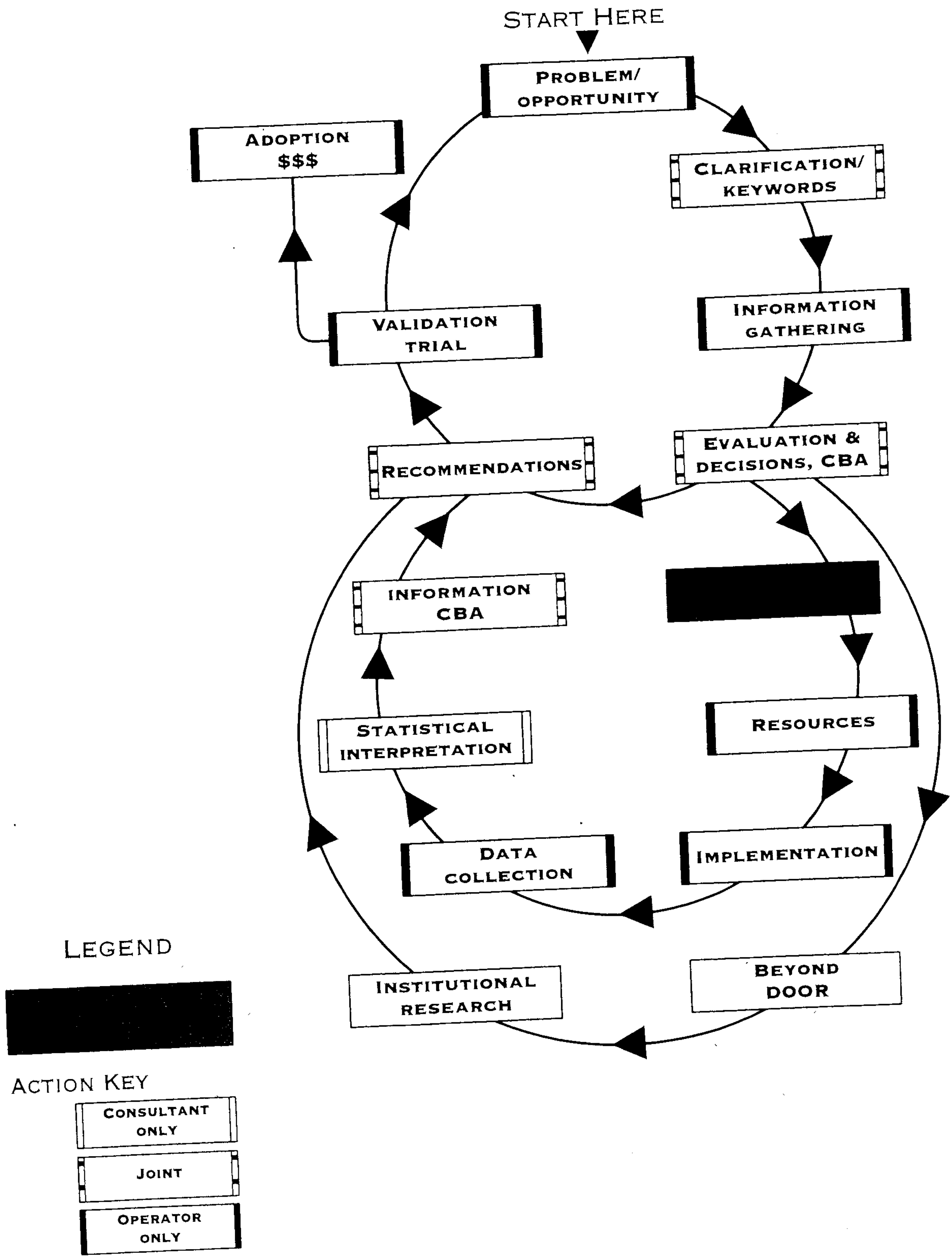
The recent release of *Greenhouse Cost Accounting* by Dr Robin Brumfield of Rutgers University may help with the evaluation of some of the more complex issues facing nurseries.

Now that the problem or opportunity has been defined, researched, and evaluated, it is time to plan the experiment.

Table 4.3 Partial cash flow budget of format (see proforma in appendix 9)

PERIOD	1	2	3	4	5	6	7	8	9	10	11	12
ADVANTAGES ASSOCIATED WITH THE RESEARCH												
a] Cash inflow increase due to research												
b] Cash outflow decrease due to research												
c] Total increase (a + b)												
DISADVANTAGES ASSOCIATED WITH THE RESEARCH												
d] Increase in cash outflows												
e] Decrease in cash inflows												
f] Total decrease (d+e)												
NET GAIN DUE TO RESEARCH (C-F)												

DOOR
IMPLEMENTATION CYCLE



CBA = COST-BENEFIT ANALYSIS

In testing water retention agents, control treatments could be both the wetting agent usually used by the nursery (if any) and also no wetting agent. Including this latter treatment allows you to discover the benefit obtained by using a water retention agent. Of course, if this was already well established, it may not need to be included.

In a weed-control experiment, treatments could be a number of herbicides and three control treatments. The first control could be the standard herbicide (if there is one), the next control would be left untreated (to assess growth of the plant in the presence of weeds) and the third control would be the ideal state brought about by hand weeding (to measure growth of the plant unimpeded by weeds or reduced by the negative effects of herbicides).

Generally, inclusion of control treatments helps you interpret treatment effects.

Factorial treatments

Sometimes two types of treatments are tested at the same time, e.g. the effect of different levels of nitrogen (N) and the effect of different levels of phosphorus (P). If there are three levels of nitrogen (low, medium and high) and two levels of phosphorus (low and high) the experiment would include six treatments in total (listed below).

1. low N, low P
2. low N, high P
3. medium N, low P
4. medium N, high P
5. high N, low P
6. high N, high P

Including all six treatments allows you to estimate the average effect of adding three different amounts of nitrogen, the average effect of adding two levels of phosphorus and also whether the effect of adding additional phosphorus varies depending on the level of nitrogen applied. This last effect is called the interaction between nitrogen and phosphorus levels.

Other examples of factorial experiments include the 12 combinations of four media and three fertiliser treatments, or the 18 treatments formed from three potting mixes, three levels of application of fertiliser and the addition, or not, of ferrous sulphate.

Conditions for testing

Experiment results will be affected by the conditions under which the treatments are to be tested. Define the type of plant (seedlings, size classification, cultivar, source of supply, etc.), and management factors such as water and fertiliser applications, environmental conditions (if controlled), etc. The best combination of treatments for growth may well depend on the conditions under which the plants are grown.

Consider a comparison of different amounts of fertiliser on the growth of a bedding plant where water is supplied by overhead irrigation. Plants that show big responses to high levels of fertiliser will consume more water than the smaller, less-fertilised plants. Increasing the irrigation to meet the requirements of the larger plants probably means that the smaller plants will be over-irrigated, with the excess water leaching out fertiliser and thereby exacerbating the difference between the two treatments. Conversely, applying water to suit the smaller plants will prevent the larger ones from reaching

If the experiment involves 60 plants and six treatments, divide the plants into 10 groups, with the six biggest plants in block 1, the next biggest six in block 2, etc., with the six smallest plants in block 10. Each treatment would be allocated to one plant from each size group (block). When the statistical analysis is done, as well as comparing the effects of the six treatments on plant growth, you can compare the performance of the 10 size groups.

You can block according to the condition of the plants before the experiment, for example vigour or source of supply.

You can block according to differences which might develop during the experiment. Some glasshouse benches may receive more sun or shade than others so put block 1 plants in the sunniest position, block 2 plants in the next sunniest position, etc. Similarly, positions closer together will probably be more alike so blocking might be on geographical position.

Make use of blocking during the experiment. Complete procedures like fertilising and measuring by blocks so that despite interruptions, at least all of a block can be completed at one time. If two operators are assessing the experiment, then one might assess the first five blocks and the second the last five.

Thus, in an experiment, block 1 might consist of the plants which were most vigorous before treatments were applied, are positioned on the northern edge of the experiment, are fertilised first and are assessed first by Fred (Tom assesses some of the other blocks).

The analysis might tell us that block 1 was the best performing block. It cannot tell us whether this was because it started with the most vigorous plants, or because it had the sunniest position or because Fred's technique gives larger measurements than Tom's. This is another example of confounding but, because it is blocking factors that are confounded, it does not affect our comparison of treatments.

5.3.3

RANDOMISATION

- Randomisation gives each plant an equal chance of being allocated to any treatment.
- Randomisation prevents bias. This is necessary for statistically sound analysis.
- Randomise treatments by using a random number generator or picking numbers out of a hat.

5.3.3 RANDOMISATION

Randomisation means that each plant has an equal chance of being allocated to each treatment. Randomisation prevents bias — vital if the results are to be analysed statistically.

Randomisation avoids any conscious or unconscious bias when selecting plants. It works this way: the experiment calls for eight treatments on 12 pots. Number the pots from 1 to 96 and then randomly choose 12 pot numbers which then become treatment 1. One way of doing this is to place all the numbers in a hat. Allocate the first 12 numbers drawn to treatment 1, the next 12 to treatment 2, etc. You can also use random number tables or a computer randomisation.

Randomisation protects experiments from problems that may or may not arise.

The experiment described above (eight treatments, each with 12 pots) did not include blocking but experiments would usually include that technique as well.

Randomisation and blocking together work as follows. Suppose you had an experiment with six treatments and 10 replicates, where the replicates corresponded to 10 blocks. The blocks might be based on plant vigour, for example. The pots would be numbered from 1 to 6 within each block. Within each block you could randomly decide which treatment was applied to which pot so that, for example, pot 1 becomes treatment 4, pot 2 treatment 6, etc. Repeat the procedure for

5.5.1

OBJECTIVE VARIABLES

- Objective variables are more reproducible and scientific than subjective measurements.

5.5.2

SUBJECTIVE VARIABLES

- Subjective variables are scored intuitively by individuals.
- Subjective scoring is less helpful in detecting changes over time.

5.5.1

OBJECTIVE VARIABLES

Objective variables are measured as numbers of units (e.g. counts of flowers, shoots, etc.) or with some measuring device (a ruler, a measuring cylinder or scales or other specialised equipment). Useful variables may include plant height, plant width, leaf number, the number of dead leaves, the number of shoots, the number of flower buds, the number of open flowers, the length of the flower stem, the width of the flower and the width of the topmost fully expanded leaf.

If plants can be sacrificed at the end of the experiment, cut them off at ground level (include bulbs and rhizomatous material, free of roots) and weigh then immediately before they lose water. Alternatively, place all material from each pot in individual, pre-weighed plastic bags, seal, and weigh them when convenient (within 6 hours unless stored in a cool room). Material can also be dried at about 70°C in paper bags for two days or so (hotter temperatures may cause dry matter losses). The difference between fresh weight and dry weight (amount of water) is also a useful variable. Percentage moisture content can also be derived from these data.

Only a limited amount of data can be collected on root growth during the course of the experiment without plant damage. One variable could be the number of roots that cross an imaginary line marked down the pot wall, measured after carefully removing the intact root ball from the pot. This may prove difficult until the pot volume is occupied by enough roots to keep the whole root system intact. Roots may be recovered for weighing at harvest by washing out the medium, but some nursery media such as peat may not separate satisfactorily. Partial drying of the media may help.

5.5.2

SUBJECTIVE VARIABLES

Subjective variables are scored intuitively rather than by objective measure. These variables are often rated on a scale 1-10, with 1 being equivalent to nil, and 10 being the maximum. Alternatively, an average plant is scored as 5 and other scores increase or reduce depending on growth relative to the average. Subjective variables may include plant colour, overall growth or vigour and a plant's water stress. However, because scores are rarely well related to time, it is difficult to establish time-based changes in responses.

Rating levels must be equally spaced, for example, if the difference between 3 and 4 is equivalent to 30 per cent then this should also apply to the difference between 7 and 8.

5.5.3

OBJECTIVE VERSUS SUBJECTIVE ASSESSMENTS

Objective measurements are better than subjective ones simply because the ability to detect subjective differences varies between people, with time and according to personal bias. However, aesthetic appeal may be a very important variable. Try to establish whether there are any objective variables involved. Measuring these could greatly enhance the value of the aesthetic appeal variable. Ask a number of people to conduct their own aesthetic-appeal rating in order to minimise individual bias.

Resources and Trial Implementation

M. N. Hunter

6

6.1
PLANT HUSBANDRY

To be relevant, DOOR experiments must not differ too much from normal nursery operations. However, ensure that variability is minimised within an experiment.

Plants in experiments should not be exposed to uncontrolled variation, such as disease or mite infestation.

6.2
CHECK LIST OF REQUIREMENTS

The DOOR experimental pre-schedule check list appears in appendix 10.This pre-schedule must be completed prior to the start of the experiment. While some of the items cannot be completed until the experiment is concluded, most need to be addressed in one way or another before starting. This becomes a very useful document for anyone else involved in the experiment, as well an informative permanent record of the experiment itself.

6.2.1
STOCK

Minimise variation in early growth by selecting seed that falls within 10 per cent of mean size or weight. Calculate the mean by weighing 100 seed selected at random from the seed lot. Use only seed from the same batch since variations in origin can affect subsequent performance. Pre-germinate seeds and select undamaged uniform seedlings for planting. Plant two to three times more seedlings than are finally required, thinning back to the most even after about 7 days.

Cut off unwanted seedlings at ground level. Do not remove by pulling out because this may disturb the root system of the remaining plants.

Cuttings for testing must be as uniform as possible. If using a number of source plants, allocate cuttings that are from the same plant to individual blocks (or replicates). Slight variations in the vigour of the source plants will then not interfere with treatment effects.

6.2.2
POT SIZE AND COLOUR

All pots used in an experiment must be the same shape, volume and colour and have a similar pattern of drainage holes. Variation in any of these may influence the outcome of the experiment.

6.2.3
MEDIA

Fill pots with the same amount of uniform medium by weighing out media into pots rather than filling pots on a volume basis (although this is an option).Tamp the medium down to the same degree in all pots so that porosity levels are similar. Whatever technique is used, aim to provide uniform growing conditions other than differences associated with the treatments.

Pot media must be thoroughly mixed. Mix media for small pots by rolling the components vigorously in a large, sealed plastic bag with air inside. Media components for larger pots (>10L) should be mixed in a heap.

6.1
PLANT HUSBANDRY

- Manage experimental plants as they are managed in the nursery.
- Minimise the exposure of experimental plants to environmental variation.

6.2
CHECK LIST OF REQUIREMENTS

- Fill out the check lists in appendix 10 before starting the experiment. Make copies for future reference.

6.2.1
STOCK

- Reduce variation by selecting the stock carefully.
- Pre-germinate seeds before using, over-plant and thin back.
- Ensure cuttings are uniform. If not, allocate variation in cuttings to blocks.

6.2.2
POT SIZE AND COLOUR

- Pots need to be the same size, colour and volume and have similar drainage patterns.

6.2.3
MEDIA

- Put the same amount of media in each pot by filling the pots by weight.
- Mix the total amount of media thoroughly before filling the pots.

temperature and irrigation. Statistical analysis can accommodate substantial variation in the effect of environmental factors from block to block but not within a block.

6.4 ENVIRONMENTAL CONTROL

To be as relevant as possible, the whole experiment must be conducted in an environment similar to normal commercial practice. If for some reason the experiment, or part of it, is treated differently from surrounding plants, record this difference and the pots involved. In most cases, such variation may have had little effect on the experimental results, but when unexpected results occur, such information could be vital in providing explanations.

6.4.1 LIGHT

Expose all experimental units to a similar light environment. Be aware of shadow lines and their movement during the day and locate the trial site appropriately. If possible, minimise the competition between plants for light by maintaining adequate space between plants.

If you expect that inter-plant competition for light is going to occur at the optimum pot density then you must include guard plants. They are placed around the data plants to minimise the competitive effects of adjacent treatments, but are not measured as a source of data because their growth is a reflection of both the treatment and the competitive effect.

6.4.2 DRAUGHTS

Plants exposed to draughts are likely to perform differently to others, particularly in nutrient and irrigation experiments. Minimise draught effects by locating the trial within a larger area of the same species and away from doorways, etc.

6.4.3 IRRIGATION

Of all the uncontrolled factors, water supply variation to an experiment may account for much of the trial variability. Assess sprinkler performance before laying out an experiment and ensure uniform water distribution by replacing worn nozzles or by adjusting water pressure. Reassess and map distribution patterns. In setting the experiment up, avoid those spots that are excessively over-, or underwatered and lay out replicates accordingly. Water distribution problems may also be minimised by using properly adjusted individual pot drippers or sprays or the use of sub-irrigation (capillary flow, ebb and flow). (See *Waterwork* (Atkinson & Rolfe, 1995), available from NSW Agriculture, and similar publications.)

6.4 ENVIRONMENTAL CONTROL

- The environment of the experiment must be similar to the commercial environment.

6.4.1 LIGHT

- Light intensity can influence plant growth.
- Use guard plants to minimise light competition between adjacent plants.

6.4.2 DRAUGHTS

- Minimise draughts if likely to affect nutrition and irrigation experiments.

6.4.3 IRRIGATION

- Minimise water supply variation by checking sprinkler systems.

6.8
COSTS

Experimental work costs money and this is first addressed in the cost-benefit analysis carried out before the selection of the project. Once the project is initiated, keep records of costs of resources, as well as the amount of labour expended, to help cost future research.

6.9
STAFF AND OTHERS

It may be trite, but it's true. Your staff are your most valuable resource and should be treated accordingly. They can prove invaluable in the conduct of DOOR. With their daily activity "at the coal face" they are confronted with problems and opportunities all the time. Create an environment in which staff are encouraged to identify problems and potential solutions. Give staff incentives and involve them in brainstorming sessions.

While staff will be skilled enough to collect data, they should not be given this responsibility until they are familiar with the experiment itself and have some sense of ownership of the aims and outcomes. Only then will you get the level of commitment necessary for this job. Insist on complete honesty and rigour in data collection; emphasise the need for a record to be made of any mistakes. Point out that some of the greatest breakthroughs in science have come about as a result of mistakes.

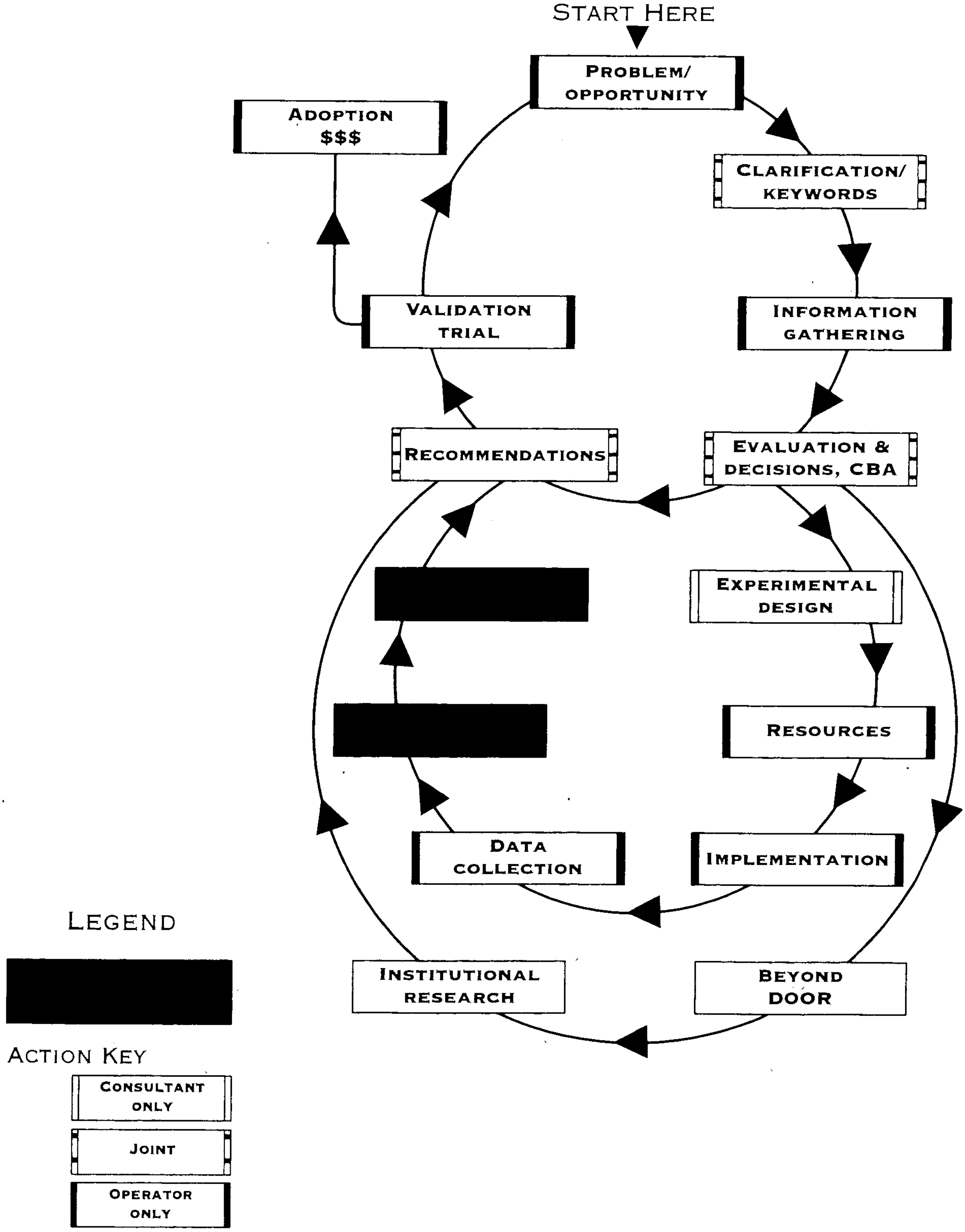
6.8
COSTS

- Do a cost–benefit analysis before starting the experiment.
- Keep records of costs and labour to use for future reference.

6.9
STAFF AND OTHERS

- Create an environment which encourages and involves staff.
- Involve staff in designing experiments and train them in record keeping and data collection.

DOOR
IMPLEMENTATION CYCLE



CBA = COST-BENEFIT ANALYSIS

Then consider another two situations. In the first we have two treatments with average heights of 20 cm (range of 10 values between 17 and 23 cm) and 30 cm (range of 10 values between 27 and 33 cm). In the second we have two treatments with average heights of 20 cm(range of 10 values between 10 cm and 30 cm) and 30 cm (range of 10 values between 20 cm and 40 cm). We are more convinced that one treatment produces taller plants than the other treatment in the first case. The difference between means is 10 cm in both cases. However, in the first case, the two treatments are separated into two distinct groups (treatment A ranges from 17 to 23 cm and treatment B varies between 27 and 33 cm) whereas in the second case there is a lot of crossover, with both treatments having plants in the range 20 to 30 cm. The variability in the second case is much higher.

Thus the test of significance considers both the differences between treatment means found in the experiment, and the variability of the plants with the same treatment. Instead of using range as a measure of variability we use something that is less influenced by extreme values. But the principle remains the same.

Using this test, you can calculate the probability of experimental differences occurring just by chance if the treatments do not, on average, have different heights. This sort of thing happens when one treatment, by chance, was allocated to all the plants with the most potential and was positioned in the most favourable locations, etc.

Thus, a test of significance can help you be at least 95 per cent sure that treatment A produces taller plants than treatment B. This is usually stated as, "treatment A produces taller plants than treatment B ($P<0.05$)" in scientific papers. The bracketed probability just tells us that the probability of the statement being incorrect is less than five times in 100 experiments or 0.05. It is conventional to select this probability or 0.01 (once in 100 experiments).

7.2.2

COMPARISON OF TWO TREATMENT MEANS

- The simplest type of experiment compares two treatment means with no blocking.
- Consider practical significance as well as statistical significance.

7.2.2

COMPARISON OF TWO TREATMENT MEANS

The simplest type of experiment comparing means (average values) is the experiment that tests two treatments with no blocking.

For example, an experiment is set up to test whether increasing the air-filled porosity of the growing medium by adding 20 per cent coco peat gives better or worse growth of calatheas. The two treatments are standard medium and standard medium with 20 per cent coco peat added; 48 pots are allocated to each treatment. For this example, the measurement is the number of shoots per pot after 2 months. For each treatment the number of pots with zero to five shoots is given in the table below.

Table 7.1 Number of shoots of *Calatheas* produced in standard potting medium and in standard medium to which coco peat had been added (20 per cent)

Shoot number	Standard media	Plus 20% coco peat
0	2	3
1	14	7
2	13	9
3	8	18
4	11	8
5	0	3
Mean	2.25	2.63

7.3.1

COMPLETELY RANDOMISED DESIGN

- ANOVA in a completely randomised design separates the variability between treatments from natural variability or error.
- Error is the base value against which treatment effects are compared.
- If the variability between the treatments is significantly larger than the error term, there are differences between the treatment means.
- To determine which treatments are significantly different from one another, use the least significant difference test (LSD).

7.3.2

RANDOMISED BLOCK DESIGN

- ANOVA for randomised block design is similar to that for the completely randomised design except that the variability in the experiment is split into three sources instead of two: treatments, blocks and error.
- After doing an ANOVA, do an LSD test.
- LSD is calculated using the error mean square and the number of values used to calculate each mean.
- The LSD is the smallest difference between treatment means which will give a significant difference at the probability level chosen.
- Any two means that differ by more than the LSD value are significantly different.
- Assess the block means to look at the effectiveness of blocking.

7.3.1 COMPLETELY RANDOMISED DESIGN

The analysis of variance partitions the variability in the experiment into its various causes. In the case where there are different treatments but no blocking (known as a completely randomised design), the variability is divided into that caused by treatment differences and what is left over. The part left over, or unexplained variability, also known as error, gives us a base value against which treatment effects are compared. It is a measure of the natural variability between plants and, though commonly called the error term, has nothing to do with mistakes.

If the variability between treatments is much larger than the error term (variability within treatments in this instance) then we conclude that there are differences between treatments. We can attach a probability of error in making this statement, just as we did for the 't' test.

Having established that there are significant differences between treatments, the next step is to define where the differences are. We do this using multiple comparison procedures. There are a number of these to choose from. We will only consider the least significant difference (LSD) procedure.

7.3.2 RANDOMISED BLOCK DESIGN

The analysis of variance for a randomised block design is similar to that for a completely randomised design except that the experiment has three sources of variation instead of two: treatment differences, block (or replicate) differences, and the residual, (again known as error).

For example, an experiment compares five different pot insulation treatments on the growth of murrayas:

1. insulate continuously
2. insulate from February to April, then remove
3. insulate from May only
4. no insulation at all
5. improved insulation

The 40 pots were allocated to eight blocks, with block 1 on the western edge of the experiment through to block 8 on the eastern edge. Table 7.3 shows the collected growth data (as estimated by height multiplied by width).

The analysis of variance table for size is as follows:

Table 7.3 ANOVA table for data shown in table 7.2

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Probability
Treatments	4	4 453 560	1 113 390	4.33	0.0075**
Blocks	7	2 898 165	414 024	1.61	0.1736
Error	28	7 199 402	257 122		
Total	39	14 551 127			

If you are not familiar with this method, don't worry too much about all the figures in the table. Concentrate on the column labelled probability.

Table 7.3 shows significant differences between treatments.The probability 0.0075 (0.75 per cent) gives us the likelihood of this statement being incorrect.Two asterisks (**) in the probability column shows significance when testing at P = 0.01.

Although there is no significant difference between blocks when testing at P = 0.05, they would differ if tested at any level above 0.1736 (17.4 per cent). Accept this as an indication that blocking might be effective in this case.

The next step in the analysis is to establish which pairs of treatment means are significantly different. First, calculate the treatment means and then use the LSD test.

These are the treatment means (in descending order):

3. insulate from May only	3 600	a
4. no insulation at all	3 488	a
2. insulate from February to April, then remove	3 199	ab
1. insulate continuously	2 851	b
5. improved insulation	2 760	b

From the means, we can see that the biggest plants were produced by the two treatments that had no insulation between February and May and the smallest plants came from the treatments with improved insulation.

Calculate the LSD by using the experiment's variability (the error mean square, in this example 257 122) and the number of values used to calculate each mean (the number of blocks). It is the smallest difference between treatment means which will give a significant difference at the probability level chosen.

If we choose to test at a probability level of 0.05, then the LSD for this example is 519. The actual calculation, in which the t value at 0.05 is 2.047, is given below:

$$2.047 \times \sqrt{\frac{2 \times 257122}{8}} = 519$$

Table 7.4 Fresh weight of marigolds grown in different media compositions

		Fresh weight of shoot (g)					
Blocks		1		2		3	
Nitrogen		No	Yes	No	Yes	No	Yes
Treatments (% composition)							
Peat 0	Sand 10	51.0	58.2	40.1	33.1	50.8	89.9
Peat 0	Sand 30	38.9	36.6	46.6	45.2	46.1	60.4
Peat 10	Sand 10	58.9	55.6	49.4	58.0	55.3	69.1
Peat 10	Sand 30	37.1	33.0	52.5	45.4	72.3	61.6
Peat 20	Sand 10	62.5	69.9	58.5	62.4	76.7	81.6
Peat 20	Sand 30	50.6	40.5	47.1	59.0	67.6	59.4
Peat 30	Sand 10	64.8	59.2	57.0	79.4	77.4	97.2
Peat 30	Sand 30	55.9	53.4	66.0	59.8	75.2	60.6

The analysis of variance partitions the variability in the experiment into that caused by treatments, that caused by blocks and the residual (known as error). The treatment variability is further split into the effect of peat composition, the effect of sand composition, the effect of nitrogen addition and the various interactions between these factors. Remember the interaction between two factors is a measure of the extent of difference in response to one factor at varying values of the other factor. For example, the difference between how fresh weight of marigolds changes as the proportion of peat in the mix varies in the presence or absence of nitrogen. This is the peat by nitrogen interaction. The analysis of variance table is given below.

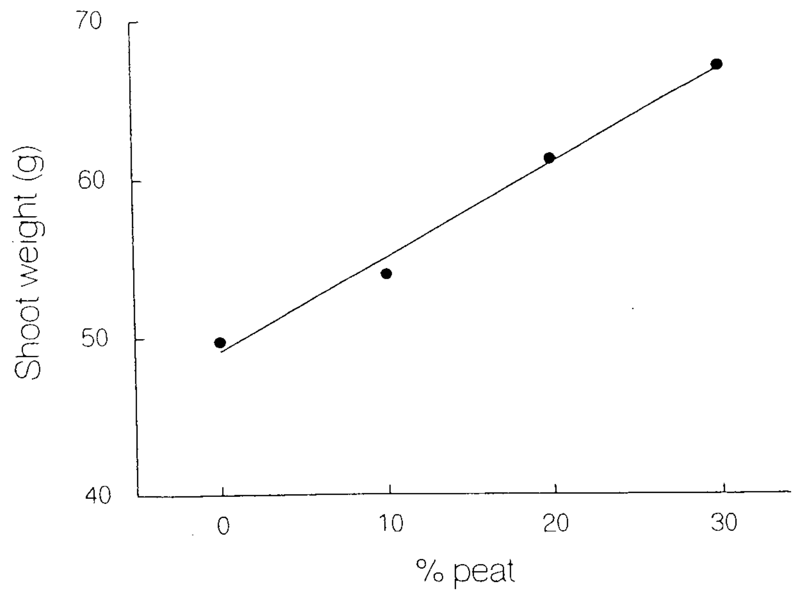
Table 7.5 ANOVA for data shown in table 7.4

Source of variation	[1] Degrees of freedom	Sums of squares	Mean square	F
Blocks	2	2 816.97	1 408.48	17.69**
Peat	3	2 147.15	715.72	8.99**
Sand	1	1 252.56	1 252.56	15.73**
Peat*Sand	3	93.22	31.07	0.39
Nitrogen	1	102.67	102.67	1.29
Peat*Nitrogen	3	138.23	42.74	0.54
Sand*Nitrogen	1	482.60	482.60	6.06*
Peat*Sand*Nitrogen	3	67.69	22.56	0.28
Error	30	2 389.01	79.63	
Total	47	9 480.10		

[1] Degrees of freedom (df) is the number of possible comparisons that can be made between a treatment (or blocks) and all others. For example, one level of peat can be compared with the other three levels (four levels in total) and thus has a df of 3.

The LSD for comparing the means when using a probability level of P = 0.05 is 7.17.This shows that shoot weight for 20 per cent and 30 per cent peat is significantly higher than for 0 per cent or 10 per cent peat. However, this is not a logical way to look at the response to peat.

The appropriate approach is to plot the response and fit a curve to it so that fresh weight can be predicted for any level of peat between 0-30 per cent. In this case a straight line provides a very good fit, as illustrated below.



The final table of means is for blocks.

Table 7.8

Block 1	51.63
Block 2	53.72
Block 3	68.83

The LSD for comparing blocks (P=0.05) is 6.21. Block 3 produced larger shoot weights than the other two blocks.This may have been due to the effects of enviromental factors such as shade.

7.4
RESPONSE CURVES

In some experiments the main aim is to examine the response of one variable to differing levels of another variable, for example, the response of yield to increasing levels of fertiliser. In this case, design the experiment with many levels of fertiliser (usually equally spaced). If the response is expected to increase with higher levels of fertiliser up to a certain point and then decrease with larger applications, try to plan the fertiliser levels in the experiment so that the amount required to produce this optimum is exceeded. A curve could then be fitted which will estimate this optimum. It would also be useful to estimate the fertiliser level which results in maximum profits.

RECOMMENDATIONS

M. N. HUNTER

8

8.1 INTRODUCTION

The experimental phase ends with the development of practical recommendations for preferred nursery practice.

8.2 AVAILABILITY OF INFORMATION

8.2.1 SUFFICIENCY

Recommending changes in practice must be based on sound and relevant information from experiments that can be repeated. Where necessary, qualify recommendations by such things as climate, species, season and general pot environment. Extending recommendations beyond the conditions of the experiment is not a good idea, but such extrapolations could form the basis for another experiment.

8.2.2 QUALITY

The outcome of the experiment depends on the timeliness of data collection and the precision and accuracy of the data itself. You must be sure that data are sufficiently accurate before basing recommendations on them.

8.2.3 RISK

Significance tests and probability statements may impede easy communication but they do take care of the level of doubt associated with biological information. Repeating an experiment and getting the same results will increase your confidence in making statements about the results. Remember that your results may have occurred just by chance.

8.3 INTEGRATION WITH CURRENT INFORMATION

Most experimental results will not contradict existing information, though they may vary somewhat in reflecting your experiment's unique environment As a result of the initial gathering of information, it should be possible to place the new finding into an existing context. Such confirmation gives the result credibility.

When the results conflict with the current dogma, research becomes very exciting, especially if the results actually confirm a personal feeling, or hypothesis. Confirming these results can often move the whole technology ahead. Current practices can be done differently, hopefully with gains in areas such as productivity, quality and sustainability.

Such different results should be backed by some plausible explanation that perhaps has been overlooked previously. Of course this is not a prerequisite—some processes work better than others but we don't really know why. An explanation may lead to fresh views on doing things and this can be very enlightening. Half the battle in doing good research is getting out of the old rut.

8.1 INTRODUCTION

- Develop practical recommendations after obtaining analysed results from the DOOR experiment.

8.2 AVAILABILITY OF INFORMATION

- Check that there is enough relevant information to back up your recommendations.
- Avoid recommendations based on extrapolations.

8.2.2 QUALITY

- Data collection needs to be as accurate as is practical.
- Leave room for error. There is always a risk of being wrong in converting information into fact.

8.3 INTEGRATION WITH CURRENT INFORMATION

- Confirmation from outside sources increases the credibility of results.
- Results that vary from available information are not always wrong, especially if the statistics show the significance of the results.
- New results lead to improved practices and insights.

8.6.2

PUBLICATION AND SHARING INFORMATION

Assuming others in the industry would find the information useful, it becomes the responsibility of the author to publish the information. In Australia, *Ornamentals Update* is an appropriate forum.

Much of the information generated via the DOOR approach would be quite suitable for presentation at conferences such as those held by the International Plant Propagators' Society (IPPS). Presentations that collate experiences of a number of operators all carrying out similar research could be very valuable.

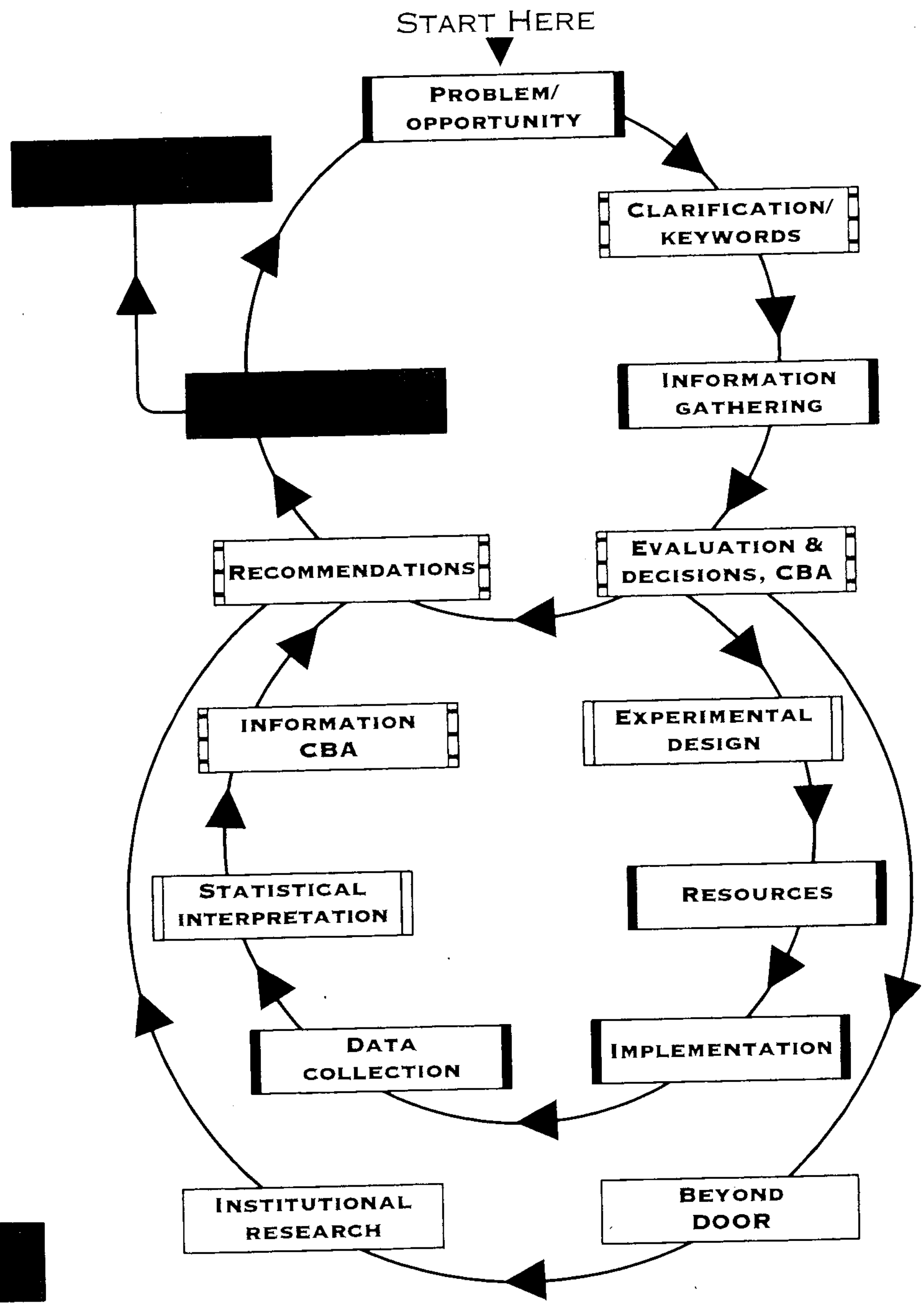
Those who are willing to share information unconditionally can expect a return of the favour many times over. A shift in the nursery industry to embrace a sharing culture would have undreamt-of consequences in the rate of adoption of new technology.

8.6.2

PUBLICATION AND SHARING INFORMATION

- Authors should publish their results. Journals and conferences are suitable avenues.
- Those who share their information are more likely to recive information in return.

DOOR
Implementation Cycle



Legend

[redacted]

Action Key

- Consultant only
- Joint
- Operator only

CBA = cost–benefit analysis

APPENDIX 1

DOOR-ACCREDITED CONSULTANTS

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Janet Giles (Statistics) Animal Research Institute, Locked Mail Bag 4, Moorooka Q 4105

Jim Page (Economics) Nambour and Maroochy Office and Laboratory Complex
Department of Primary Industries, Queensland
Sunshine Coast Mail Centre,
PO Box 5083
Nambour Q 4560

Add new consultants as they become qualified.

APPENDIX 3

PHILOSOPHY OF R&D MANAGEMENT AND LEARNING: DIFFERENT WAYS OF SOLVING PROBLEMS TOGETHER

PROFESSOR SHANKARIAH CHAMALA

INTRODUCTION

The philosophy of Research and Development (R&D) and technology transfer is being transformed in response to the complex problems of industry in the market-driven and highly competitive new world. Similarly, research, extension, and educational agencies are changing their educational methods and their ways of providing research and extension services to industry.An understanding of the philosophical background to the development of the DOOR (Do-Our-Own-Research) project, will aid the appreciation of this different way of solving problems.

The strengths and weaknesses of the traditional research, development and transfer model will be described. The Participative Action Management (PAM) model (Chamala, 1995), which formed the basis of DOOR project, is briefly explained. The PAM model is a major paradigm, or mind set, shift in the way technology is developed and adopted by stakeholders. Adults learn collaboratively in a win-win mode using adult-learning principles and action-learning processes. The role of consultants and other service agencies in collaborative learning is briefly outlined.

TRADITIONAL MODEL OF TECHNOLOGY DEVELOPMENT AND ITS TRANSFER

The traditional research, development and transfer of technology model is presented in figure 1 below.

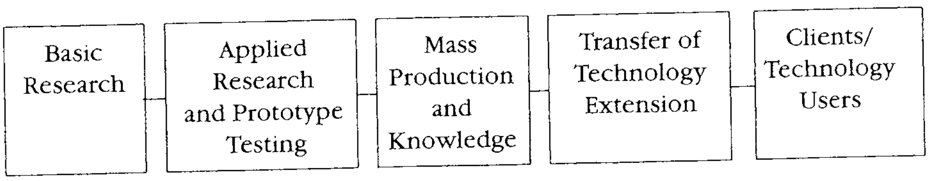


Figure 1 Traditional research, development and transfer of technology model.

In this traditional linear model, the development of scientific research and technology is seen as a top-down, centralised, mostly government run and technocratic approach to solving the agricultural production needs of clients. Technology transfer or extension is simply to tell or sell the technology. Either incentives, penalties (such as legislation) or diplomacy (through education) are used. The client is viewed as very passive and willing to accept anything that is promoted. It is hoped that by working through the most innovative people, the good news will eventually reach everyone. Extension agents used this "trickle down" approach to promote the spread of technology.

This model has its advantages. It helped to bring about the "green revolution" and to increase production. However its limitations, among others, are that government R & D has to concentrate its efforts on the issues of most value to the greatest number of people. Many technologies promoted under this model have not been readily adopted and the reasons for lack of adoption were unclear.

This approach suits research of a general nature, but may be of little use in specific practical situations. For example, a hypothetical new insecticide may have been proven to be very effective in controlling mites in cyclamen. However, this chemical is known to cause serious

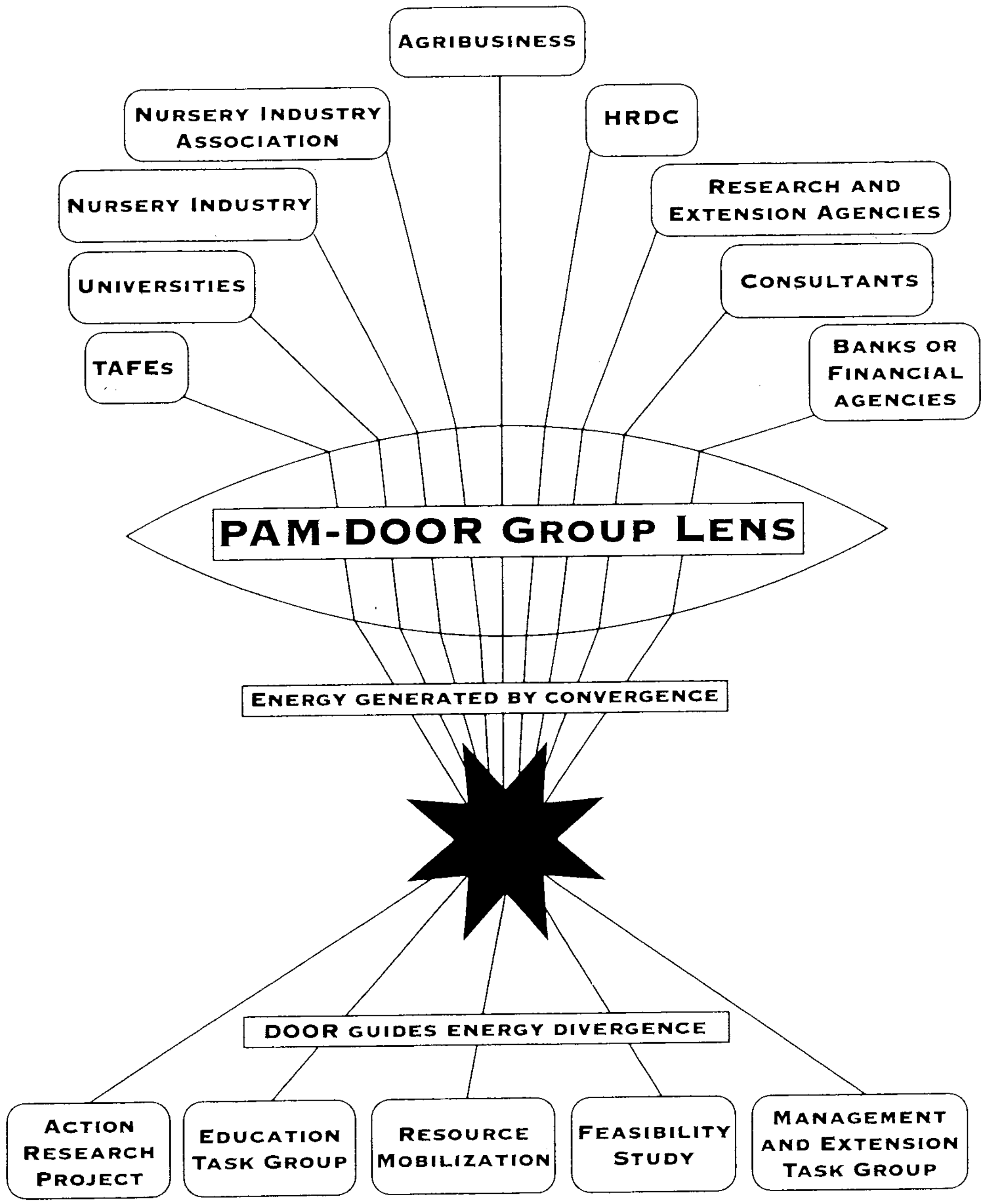


Figure 2 Modified PAM model for DOOR project. PAM DOOR group (lens) focuses energies to yield synergistic, empowering effects.

- from industry **dependency** on service agencies to **inter-dependency.**
- from **passive** learning to **active** learning.
- from **competition** amongst members to **collective action** and competition for the common good.
- from complete **secrecy** to **sharing information** for mutual benefit.
- from a **one-to-one** mode of action to **collective/collaborative** action.
- from **win-lose** approach to **win-win** approach.
- from **individual** problem solving to **collaborative** problem solving.
- from a **personal efficiency** perspective to industry **bench marking.**
- from **competing** with each other in Australia to **complementing each other** in overseas market development.
- from a **limited** market to an **unlimited international** market **outlook**.
- from **closing the door** on inhouse research to **active participation** in **DOOR projects**.
- from **just taking actions** to **action learning** mode.

ACTION LEARNING FOR INDIVIDUAL AND COMMON GOALS

Most individuals learn by trial and error, intuition and the school of hard knocks — experience. However, to achieve major mind set changes in problem solving, all the stakeholders (see PAM model) need to collaborate in learning together.

It is important to understand the principles of adult learning, action learning processes and collaborative problem solving. Only then can we alter our paradigms and accelerate the process of change.

People continually seek to acquire the knowledge and skills that will empower (enable) them to understand more, do more, and make more choices in their lives. Understanding the process of adult learning is very important. It has five basic principles.

SELF-DIRECTION

Adults have a deep psychological need to be perceived by others as self-directing. They want to feel, and they want others to know, that they are in charge of their own lives, actions and learning.

BUILDING ON EXPERIENCE

Adults recognise that people learn and change through experience, then see their own experience as part of their identity. If their experience is devalued or ignored, they perceive this as a rejection of themselves as people. Learning must be facilitated and built on their experience.

READINESS TO LEARN

Adults learn things so that they can perform their responsibilities within their occupation, family, or community. They are most ready to learn when they can see that they can immediately use a new skill or new knowledge.

PROBLEM-CENTRED LEARNING

Adults usually learn for immediate application, rather than for some future use.

ENJOYMENT AND IMPROVED SELF IMAGE

Adults choose learning experiences which are enjoyable for them and which enhance their self image as it helps them feel good.

APPENDIX 4

FACILITATORS NOTES AND RESOURCE MATERIAL

NOTE 1

Participants may be introduced to the potential ambiguities that can exist in what seems to be a straightforward situation through the young lady/old lady diagram provided below. This image is not copyright and may be copied onto an overhead transparency.

Old lady Young lady Composite

Figure 1 How our perceptions influence our perceptions

NOTE 2

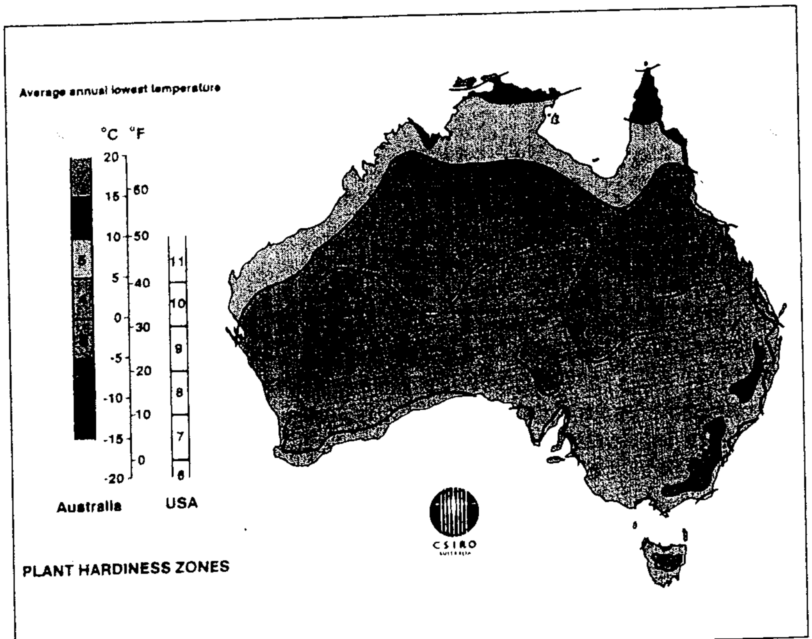
Pamphlets and further details on the GrowSearch service are available on request. Special bulk purchasing details can be arranged for groups of DOOR participants.At time of going to press, normal annual subscriptions cost $95, with up to 30 pages of information available for $30 to casual users. CD-ROM and online searches of international databases are available at commercial rates.

In the pilot workshop for this series, a quick search of world literature through the GrowSearch specialist library revealed the answers to many of the participants' recurring problems.

NOTE 3

Choose a relatively straightforward example of a scientific paper for workshop participants to work through.The aim should be to build grower confidence in dealing with this material.

I prefer to call the USDA term the average annual lowest temperature. This figure tends to make places look very cold! For example, Florida, which we think of as a warm place, is in the US Zone 10 which has minimum temperatures from 30°F to 40°F (−1°C to +4°C). Zone one (eg central Alaska) is below −50°F (−45°C) which is very cold!



Australian plant hardiness zone map prepared by Iain Dawson, CSIRO, Canberra.

Australian conversion

I have used the same statistic for Australia, but rather than use US zones directly I have modified the limits for each zone. This is because Australia, in winter, is much warmer than most of North America in winter, so the lowest US zones aren't relevant. All of Australia (excluding Macquarie Island) is covered by just over four US zones (7b-11). to make the map more useful to Australians I have created seven zones to fit our climatic range, and used metric units.

The limits to each zone, and a comparison of US and Australian zones, are shown alongside the map.

The main factors determining average lowest temperature are altitude, latitude and proximity to the coast. Zone 1 covers the alpine areas of south eastern Australia.

Zone 2 the tablelands of south east Queensland, New South Wales and Victoria, and the uplands of central Tasmania.

Much of the southern half of the continent is in Zone 3, except for localities on or near the coast.

Many of our weather stations are on the coast on off-shore islands (some of them are lighthouses) and these are often a zone or two higher than adjacent mainland stations because of the warming effect of the ocean in winter.

As a result of this warming effect Zone 4, which covers a broad area of coastal Queensland in the east across the continent to Shark Bay and Geraldton in the west, also includes Sydney and the north coast of NSW, the Mornington Peninsula, areas adjacent to Spencer Gulf and Adelaide, the south western coastal zone, along with a number of localities dotted all around the southern coast of the continent.

Zone 5 covers some of the Queensland coast, Western Australia north of Shark Bay and across the Top End. Zone 6 includes the Queensland coast north of Cairns, Cape York Peninsula and the coast of the Northern Territory. Zone 7 is mainly restricted to islands off the north coast.

There are many problems with maps of this type. For example, the spread of weather stations is insufficient to give good resolution of the zones and too many places with different climates are lumped together. In Australia we have only 738 stations with a record of more than 10 years. This is one station per 98,491ha.

Admittedly, the more populated areas have relatively fewer hectares per station but the basic difficulty remains. Even worse are the problem of local factors such as aspect, altitude, proximity to the sea and so forth. For example, Mt Isa has three climatic stations with more than a 10 year record.

One is a Zone 4a, one a Zone 4b and the other is in Zone 5a.

Sydney residents can choose between Zones 3a to 4b depending which station is used. Most other cities have similar problems. Everyone is aware that different locations in the same city or suburb are suitable for different plants but it is hard to quantify these differences and even harder to draw a meaningful map.

There may even be a case for publishing a list of weather stations and their zone classification so that people can decide for themselves which is the most appropriate location to use for their local conditions.

Map variables

Plant hardiness refers to their ability to survive the conditions of a particular location, including tolerance of heat, soil moisture, humidity and so on. Other environmental factors may be important but this map is based only on how well they survive low temperatures in winter.

Even that is a gross oversimplification. For example, are plants affected more by a single extremely low temperature night, or is the number of days of frost (the duration of winter) more important? In fact both are important, but the statistic for the map only relates directly to the former.

Another limitation is plants will often survive in an area for some time, but every now and then there will be a catastrophic cold snap that will kill them.

APPENDIX 6

ORIGIN OF RELEVANT JOURNALS

Southern Hemisphere	Northern Hemisphere
Australia • *Australian Horticulture* • *Flower Link* • *Ornamentals Update* • *Australian Plants* • *Floriculture Industry Newsletter* • *Australian Protea Grower*	**United Kingdom** • *Grower* **United States of America** • *American Nurserymen* • *Connecticut Greenhouse Newsletter* • *Foliage digest* • *Florida Foliage* • *Greenhouse Grower* • *Greenhouse Manager* • *Grower Talks* • *Nursery Manager* • *Ornàmental Uplook*
Articles from both Northern & Southern Hemisphere	
World perspective • *Acta Horticulturae* • *Hortscience* • *International Plant Propagator's Society International Combined Proceedings* • *Journal, American Society for Horticultural Science*	• *Scientia Horticulturae* • *World Flower Trade Magazine* • *FloraCulture*

In creative thinking

- Stretch the imagination
- Use the right brain

In career planning/business

- Overcome tendencies to set up unrealistic limits, restraints, barriers

In dealing with prejudices

- Overcome tendencies to stereotype, limit, or narrowly define others

In developing assertiveness

- Look for new options as opposed to staying "frozen" in a given non-productive position.

APPENDIX 9

PARTIAL PROFIT BUDGET FORMAT

Use the following formats with the partial budgeting section discussed in 4.3.2.

Description of issue		
ADVANTAGES ASSOCIATED WITH THE RESEARCH		
a] Income increase due to research	CAPITAL	ANNUAL INCOME & EXPENSE
b] Expense decrease due to research		
c] Total benefits (a + b)		
DISADVANTAGES ASSOCIATED WITH THE RESEARCH		
d] Increase in expense		
e] Decrease in income		
f] Total disadvantage (d+e)		
NET PROFIT GAIN DUE TO RESEARCH (C-F)		

APPENDIX 10

EXPERIMENTAL PRE-SCHEDULE CHECK LIST

(TO BE COMPLETED FOR EACH EXPERIMENT)

TITLE	

AIM/OBJECTIVES
•
•
•
•
•

TIMING			
Project start		Experiment start	
Experiment finish		Report complete	

RELEVANT INFORMATION *

* Attach additional items

MATERIALS (QUANTITY, TYPES, RATES)

Species, variety		Temperature	
Media		Humidity	
Fertilisers		Monitoring equipment	
Amendments		Labels	
Fungicides		Bags	
Insecticides		Measuring tape	
Herbicides		Scales (range)	
Nematicides		Record sheets	
Irrigation: type frequency		Random numbers	
Pots: colour, size		Specialist equipment	
Light			

MEASUREMENTS

DEPENDENT VARIABLES TO BE MEASURED	HOW	WHEN (TIMES, FREQUENCY)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

LABOUR

(ADDITIONAL TO WHAT WOULD BE NORMALLY EXPENDED)*

MONTH

PERIOD	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Number of hours*												

* Indicate your valuation of the hourly rate, e.g. a superscript of ^{1} = standard rate, ^{2} =x 2 standard rate, ^{3} = x 3 standard rate. Qualify hours by type of work, e.g. $3M^1$ = 3 hours, at the standard rate on measurements; L = laying out experiment; O = overall observations; M = measurements; W = weeding; S= spraying; I = irrigating by hand; E = organising pots, media, labelling and planting.

APPENDIX 12

CASE STUDY: EXPERIMENTAL PRE-SCHEDULE CHECK LIST

THIS IS AN EXAMPLE OF AN EXPERIMENTAL PRE-SCHEDULE CHECK LIST WHICH IS TO BE COMPLETED FOR EACH EXPERIMENT.

TITLE	Response of *Murraya* sp. to container insulation.

AIM/OBJECTIVES

- To establish whether insulation around pots of *Murraya* affects width or height of plant
- To assess the effect of insulation on soil temperature
- To assess how root distribution on the wall of the pot is influenced by insulation
- To see whether the effect of keeping insulation on for 4 months and then removing (and vice versa) had a different effect on shoot or root growth than continuous insulation or its continuous omission

TIMING

Project start	Nov 1994	Experiment start	10/2/95 Start
Experiment finish	25/8/95	Report complete	Oct 1995

RELEVANT INFORMATION *

- Root death can occur at temperatures greater than 48°C depending on time exposed
- Species vary in their response to temperature effects
- With wide spacing, media in white bags are cooler than in black bags
- Temperatures are highest on east and west walls, half down container profile (Arizona)
- Excess temperature of media can affect susceptibility to root rot in hibiscus (California)
- Temperature significantly affects the release rate of Osmocote^R (Florida)

Other reports

Ingram, D.L., Martin, C., and Ruter, J. (1989). Effect of heat stress on container grown plants. *International Plant Propagators' Society Combined Proceedings* 39 (pp. 348-353).

Tilt, K., West, D., Goff, W., and Olive, J. (1993). Summary of new containers for nursery production. *International Plant Propagators' Society*, 43 (pp. 363-371).

Whitcombe, C.E. (1988). Effects of temperature in containers on plant growth. In *Plant production in containers* (pp. 165-167). Stillwater, OK: Lacebark Publications.

MATERIALS (QUANTITY, TYPES, RATES)

Species, variety	*Murraya* spp.	Temperature	natural
Media	15% sand	Humidity	natural
	42% sawdust		
	42% pinebark		
Fertilisers	Nutricote® 6 g/L	Monitoring equipment	Digital thermometer
Amendments		Labels	plastic stick
Fungicides		Bags	
Insecticides		Measuring tape	Retractable builders tape
Herbicides	Rout®, rec. rate	Scales (range)	
Nematicides		Record sheets	done
Irrigation: type frequency	Pot spray, daily, 1 L in 5 mins	Random numbers	done
Pots: colour, size	300 mm, black	Specialist equipment	none
Light	natural		

MEASUREMENTS

DEPENDENT VARIABLES TO BE MEASURED	HOW	WHEN (TIMES, FREQUENCY)
1. Height (mm)	From plastic rim to top most growing point	3 times
2. Width (mm)	Maximum width across plant (leaf tip to leaf tip (mm))	3 times
3. Soil temperature (T°C)	5 cm in and 5 cm deep from west wall	End of experiment
4. No. of roots N,S,E,W	Number intersected by on surface of root ball	Vertical line
5. No. of root balls retained following removal	Present or absent	End of experiment
6.		
7.		
8.		

LABOUR

(ADDITIONAL TO WHAT WOULD BE NORMALLY EXPENDED)

	MONTH											
PERIOD	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**TOTAL**
Number of hours*	$P4^3$ $L3^3$ $L6^1$ $M6^1$		M6				M16 $M6^1$	$J4^3$				
TOTAL (SHE)	33		6				22	12				73

* Indicate your valuation of the hourly rate e.g. a superscript of ^{1} = standard rate, ^{2} =x 2 standard rate, ^{3} = x 3 standard rate. Qualify hours by type of work e.g. $3M^1$ = 3 hours, at the standard rate on measurements; L = laying out experiment; O = overall observations; M = measurements; W = weeding; S= Spraying; I = irrigating by hand; E = organising pots, media, labelling and planting; J = interpretation; P = preparation. Total Standard Hours Equivalent (SHE) ($10/hr)= 73 hours.

which insulation had been removed at some stage. As a result, these plants were saleable in September, whereas sale of those with full insulation had to be deferred. This observation probably reflected more rapid root growth as well as shoot growth due to warmer media temperatures. It should be acknowledged that root numbers at the root wall are not necessarily a good indicator of overall root growth. Root tip pruning at the pot wall because of high temperatures may in fact stimulate secondary root development in much the same way as does root-pruning paint.

RECOMMENDED ACTION

Discontinue the use of foil insulation during the cooler months. Investigate the value of bi-coloured pots (dark on one side, silver on the other) and turning pots through 180^0 depending on whether heat reflection or absorption is required on the exposed surface.

FURTHER EXPERIMENTAL WORK

Carry out further experimental work to establish whether the use of foil is beneficial during the hot summer months. It would be reasonable to expect that the optimum system would be one that absorbs heat during the winter and reflects it during the summer.

APPENDICES

Table 1 Effect of pot insulation on temperature of medium and growth variables in *Murraya paniculata* (28/4/95). Cedar Glen Nursery, Samford.

Period of insulation	Temp. in pots (°C)[1]	Height (cm)	Width (cm)	Increment (cm^2)[2]	Vigour rating[3]
Nil	29.7	66.1	52.4	2094	2.14
May-Sept	29.3	65.1	55.1	2061	2.71
Feb-April	26.9	66.0	48.5	1616	2.86
Feb-Sept	27.0	62.0	45.9	1323	3.43
Feb-Sept[4]	25.6	59.3	46.3	1444	3.86
LSD[5] (P=0.05	1.5	5.3	5.2	534	1.7
Coeff. of varn (%)	5.3	8.2	10.2	30.6	52.7

[1] 5 cm deep, 5 cm from western wall commencing at 2 pm on 28/4/95; [2] Change in height x width over period 10/2-28/4/1995; [3] Rating where 1 = rapid growth and 5 = slow growth; [4] Upgraded version of treatment immediately above; [5] Required difference between values for statistical significance at P = 0.05.

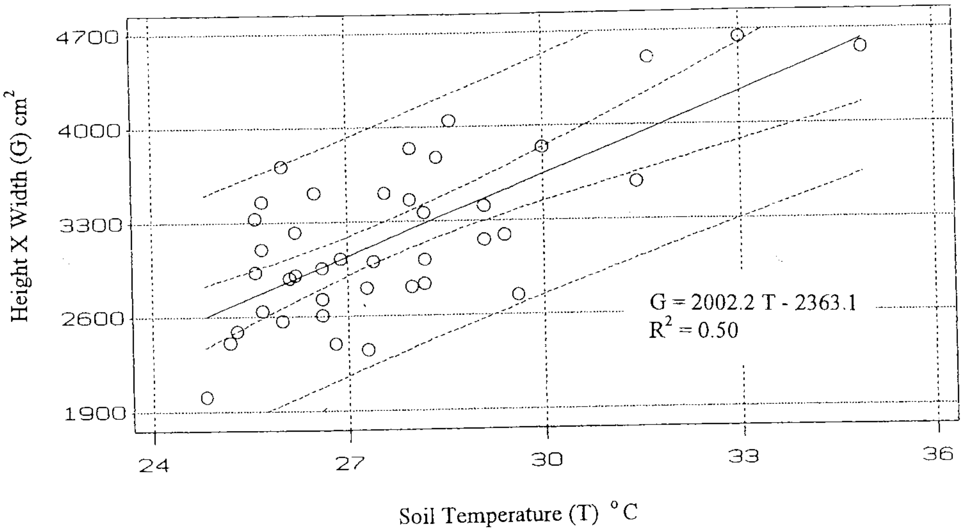


Figure 1 Relationship between soil temperature (5 cm inward and 5 cm deep) on western pot wall and growth of *Murrayas* as estimated by height and width measurements on 28/4/95

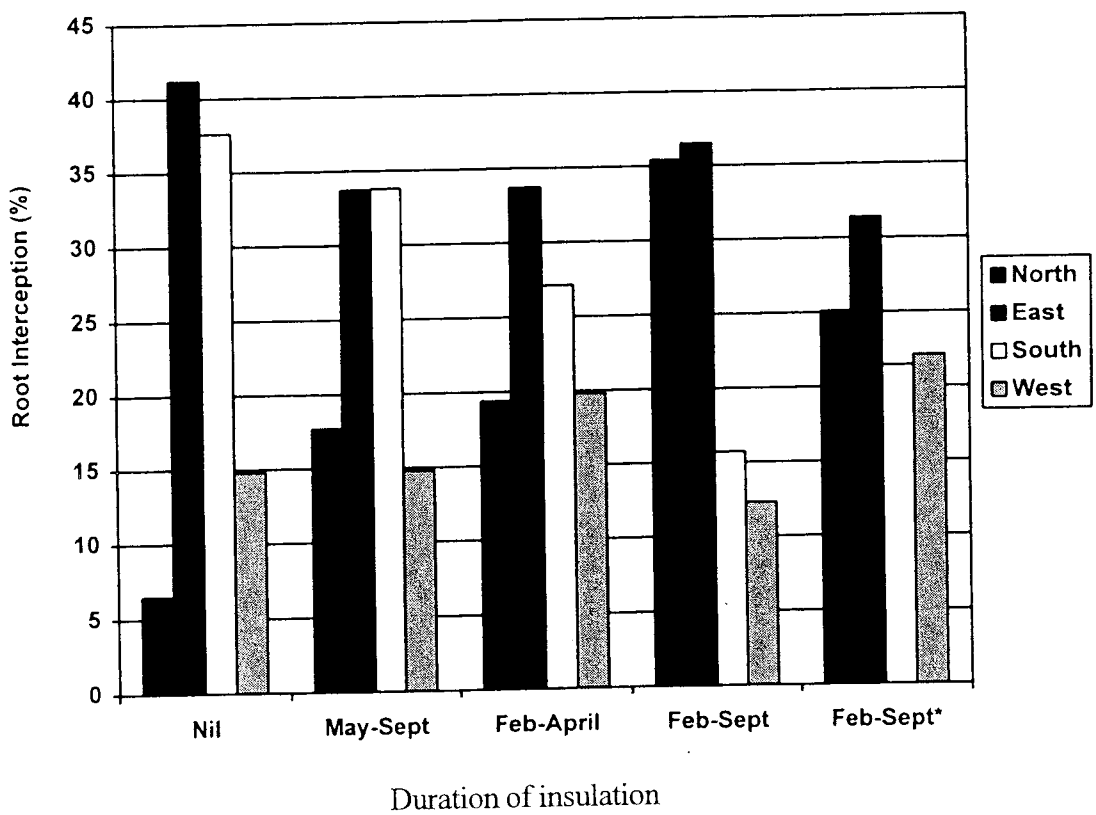


Figure 2 Effect of insulating pots on the proportional (%) distribution of root interceptions in the four quadrants of each pot. Note that Feb-Sept* treatment is similar to Feb-Sept, but with more insulation cover

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