Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

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This information has been made available to assist users to identify issues involved in macadamia production. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

GROWING GUIDE

Macadamia
grower's handbook

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Contents

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Chemical information was extracted from *Infopest* produced by the Department of Primary Industries & Fisheries.

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Using this guide

The handbook is constructed around two important principles. Firstly, it focuses on the core information that is most needed and regularly used by growers. Hence, it does not provide detailed information on all areas of macadamia growing. Where additional information is available and considered useful for further study, references are provided. Secondly, the information is presented in line with how it has been sought from the authors over a number of years. Hence, there are different chapters of the handbook designed to suit different needs. Here is a brief roadmap:

If you are an:	Start with:
Intending grower (thinking about growing macadamias)	**Before you start** – this is a checklist of the things you need to know before you start growing macadamias, and will give you the best introduction into other sections of the handbook. Other useful chapters are: **Common questions** – the twenty or so most commonly asked questions about growing macadamias **Contacts and references** – a list of industry organisations, product suppliers and further reading
New grower (about to establish an orchard, in the process of doing so, or taking over an existing orchard as a new grower)	**Growing the crop** – this is the authors' guide for establishing, producing and handling macadamias and will refer to other appropriate sections of the handbook where needed. Other useful chapters are: **Additional information on some key issues** – detailed information on some of the key decisions for macadamia growers **Contacts and references** – a list of industry organisations, product suppliers and further reading **Chemical handy guide** – a list of currently registered chemicals and their registered uses
Established or more experienced grower	**Additional information on some key issues** – this chapter contains detailed technical information on some of the key decisions for macadamia growers. Other useful chapters are: **Chemical handy guide** – a list of currently registered chemicals and their registered uses

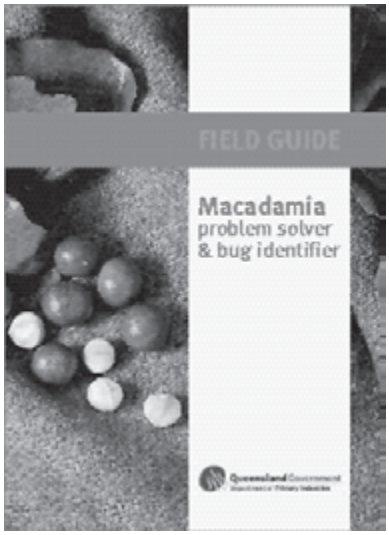
Remember that the handbook contains a detailed index at the back.
If you don't understand a term used in the handbook, refer to the *Terms and concepts* section on page viii.

WARNING!

This handbook is a general guide only and is not intended to be used as the only tool in reaching key management decisions. We always recommend that you also seek independent advice from experienced consultants in your district.
A listing of consultants is contained in the *Contacts and references* chapter.

There are some limitations in using this handbook. These include:

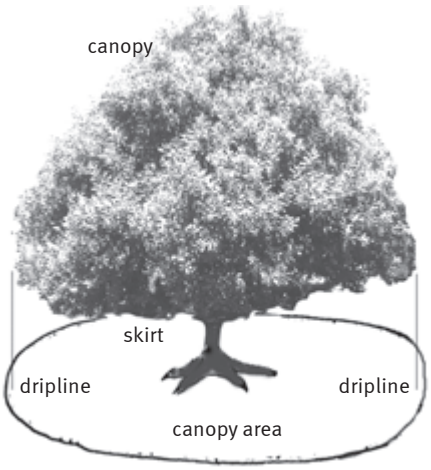
- The book does not contain colour pictures of pests, diseases or other problems that occur in macadamias. These are found in the field guide companion to the handbook – the ***Macadamia problem solver and bug identifier.*** This special pocket-sized waterproof guide is designed to be used in the field to first correctly identify a problem, before the recommendations in the handbook are consulted.

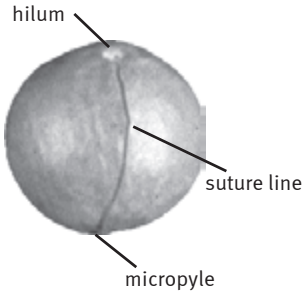


- Because chemical registrations change frequently, these should be checked at routine intervals. Sources of updated information are contained in the *Contacts and references* chapter.

Terms and concepts used

Abscission	The process by which leaves or nuts separate from the tree and fall. The abscission layer is the separation point.
Action level	The level of a pest population at which control measures should be implemented.
Adhered husk	Remains of the husk adhered to the shell; characteristic of some varieties (see diagram).
AMS	Australian Macadamia Society.
Beneficial	A commercially produced or naturally occurring insect, mite, nematode, predator or parasite that will help control a pest.
Canker	A dark discoloured area of wood or bark on the trunk or branches.
Canopy cover/canopy area	Area on the ground which is covered by the canopy of the tree. Calculated by measuring the radius of the tree (distance from trunk to edge of canopy – 'r') and using the formula πr^2 (see tree diagram). Note that this is not canopy volume.
Central leader	The main shoot of the young tree which is trained to form the trunk and main branch framework.
Dripline	An imaginary line on the ground corresponding to the outer perimeter of the canopy (see diagram).
Fertigation	Application of fertiliser through the irrigation system.
Flailing	The process by which mulch and other residue is broken down into smaller pieces (generally by flail slashers or mulchers).
Floret	An individual flower bud (see 'raceme').
G1K	Percentage first grade kernel.
Gross margin	The difference between total production income and production (or variable) costs. It does not account for fixed (or overhead) costs or capital costs.





HAES	Hawaii Agricultural Experiment Station—refers to varieties selected in Hawaii, for example HAES 344.
Hedging	Pruning of sides of the tree canopy.
Hilum	Point at which the nut was attached to the stalk (see diagram).
HVA	Hidden Valley A—refers to varieties selected in Australia by Hidden Valley Plantations, for example HVA16.
Inorganic fertiliser	A manufactured or synthetic fertiliser.
Integrated pest management (IPM)	An approach to pest and disease management that incorporates aspects of chemical, cultural, physical and biological methods to prevent pests and diseases from reaching damaging levels. It involves regular monitoring to determine if and when treatments are needed.
KR	Kernel recovery.
m.c.	Moisture content.
Micropyle	White spot at the end of the nut opposite the hilum. Water enters here to initiate germination.Very prominent in variety HAES 246.
Monitoring	A process of systematically checking the tree (and fallen nuts) for pests and diseases, and recording progress, in order to make decisions on pest and disease management strategies.
Natural enemy	A naturally occurring beneficial organism.
NIH	Nut-in-husk.
NIS	Nut-in-shell.
Nut drop period	The period of time when mature nuts fall naturally to the ground.
Petiole	Leaf stalk.
Precocious	Starts bearing at an early age.
Pre-germination	Germination on the tree before nuts fall.
Raceme	The compound macadamia flower consisting of a central stalk (called a rachis) carrying up to 400 individual flowers or flower buds (‘bud’ is the term applied to a flower before it opens; when it opens, it is referred to as a ‘flower’).
Rootstock	The lower portion of a grafted or budded tree below the graft union.
Scion	Wood that is used to graft trees. Also used to refer to the upper portion of the graft above the graft union.
Skirt	The lower part of the leaf canopy nearest the ground (see diagram).
Skirting	Pruning the bottom branches of the tree to keep a clear space under the tree for management purposes.
Sound kernel	Fully matured kernel that is free from any defects such as insect damage mould, decay, immaturity, discolouration, germination or rancidity.

Terms and concepts used...continued

Specific gravity	A term from physics denoting relative density.
Sticktight nuts (sticktights)	Dry, mature nut-in-husk (with brown husk) which stay attached to the tree and do not fall naturally.
Stomata	Small pores on the leaf surface which control the loss of water from the plant.
Straight fertiliser	A fertiliser consisting of one primary compound supplying one main nutrient.
Suture	A conspicuous small furrow extending down the side of the nut from the hilum to the micropyle (see diagram) which on germination, splits open to allow the young roots and shoot to grow out from the nut.
Systemic	A substance that is absorbed through the plant surface and translocated throughout the body of the plant.
Unsound kernel	Kernel which is unsuitable for processing and/or sale as raw kernel because of the presence of insect damage, mould, decay, immaturity, discolouration, germination or rancidity.
Whorl	The node or point on the shoot where buds (leaf or nuts) form. A whorl of leaves is the three (or four) leaves which form at the node.

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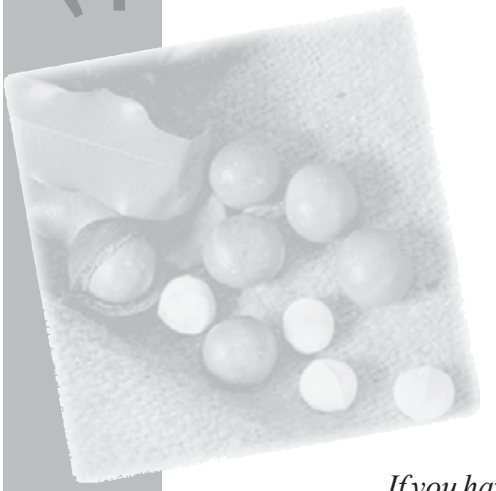
Chapter 1



Before you START

If you have never grown macadamias before, you will find this section very useful. It is a checklist of the things you need to know before you start. It will help you make the right decisions about growing macadamias. The information here is brief and to the point. We provide more detail on important areas in other sections of the handbook. Symbols on the left of the page will help you make these links.

A brief introduction to the macadamia industry

Australia grows around 16,000 hectares of macadamias with about 60% in New South Wales and 40% in Queensland. The main production areas are the Lismore and Nambucca regions of New South Wales, and the Glasshouse Mountains, Gympie, Bundaberg and Atherton Tableland regions in Queensland. A small industry also exists in southwest Western Australia. Around 800 growers are involved in the Australian industry, with orchards ranging in size up to 600 hectares. The average orchard size is about 20 hectares.

The macadamia is the only Australian native plant to be commercially grown in a major way as a food crop and so is a unique Australian industry. The industry in Australia only developed to a significant extent after Hawaii developed a commercial macadamia industry following the tree's introduction there as a windbreak for sugarcane plantations. For many years, most of the Australian industry was based on varieties developed in Hawaii, with the varieties HAES 246 (Keauhou), HAES 344 (Kau), HAES 741 (Mauka) and HAES 660 (Keaau) making up most of the orchards. However, in recent years with the development of Australian varieties such as Hidden Valley A4 and Hidden Valley A16, most new orchards are now based on a mixture of Hawaiian and Australian varieties. Trees are grown from grafted or budded nursery stock.

Nuts are harvested off the ground using mechanical harvesters, and in some situations, by hand. Harvesting begins in March-April and is normally completed by September-October.

About 25% of the crop is exported as nut-in-shell (NIS). Almost all of the rest of the crop is processed in factories in southern Queensland and northern New South Wales with about 70% of the processed product being exported. The major markets are USA, Japan, China and Europe, particularly Germany. About 1% of production is sold as nut-in-shell on the Australian fresh nut market.

Know what you are getting into

Macadamia growing is appealing to new growers because the industry is perceived to have a more secure, assured and profitable future than many other tree crops. This is underpinned to some extent by the fact that macadamias are in demand on the world nut market, yet make up only about 2% of world tree nut production. This indicates significant potential scope for expansion. Other advantages include:

- As the industry continues to mature, production and marketing risks will be better understood.
- The industry has a strong industry peak body, the Australian Macadamia Society, including growers, processors, marketers and researchers, which operates a well-organised R&D and market promotion program.
- Through the efforts of the industry, the Australian product has developed a good reputation for quality and is well respected in the world market place.
- Mechanisation is available for most orchard operations. This reduces labour management concerns, particularly when compared with most other subtropical tree crops, which require hand harvesting and pruning.
- Compared to other horticultural crops, macadamias, if handled correctly, have a longer potential storage life.
- Packaging and marketing costs are substantially lower than for other horticultural crops.

However, be aware that success in macadamias is not as easy as many are led to believe. The following points summarise the main constraints:

- Like all tree nut crops, macadamias are a long term venture with production commencing only in about the fourth or fifth year and the trees not maturing until about 12 to 16 years after planting. Individual tree yields are also lower than for most other tree crops. This means you have a long wait for your first cash flow and an even longer wait for a positive return on your investment.
- Because macadamias are predominantly an export crop, the prices received by growers can vary significantly from year to year depending on market developments and Australia's exchange rate with its trading partners. This makes it difficult to predict prices and future returns.

See The *Farm you need* on page 6 for more information on orchard selection issues.

- Macadamia trees have limited tolerance to frost, heat, wind, drought, fire and poor drainage. Therefore, selection of an orchard site has to be exacting with only a limited range of areas in Australia ideally suited to the crop. Finding farm blocks of a viable size within these limited areas can be difficult. Remember that blocks with steep and broken terrain will be substantially more expensive to bring into production and subsequently manage. Blocks in drier areas will also require irrigation.
- Macadamia trees require a high level of management for profitable yields and nut quality. They are susceptible to a wide range of pests and diseases, which require regular monitoring and application of control measures. Irrigation (where required), nutrition, harvesting and post-harvest handling also need careful management. This requires the ability to carefully plan and manage orchard operations. In addition, as prices are linked closely with nut quality, a commitment to quality and quality assurance is essential.
- As the impact of farming on the environment comes under increasing scrutiny, all orchard operations require careful management to minimise environmental risks. Particular issues include the noise from dehusking equipment in closely-settled areas, spray drift control, and soil erosion under trees from the combined effects of high rainfall, shade and mechanical harvesting.
- The establishment of a macadamia orchard requires a major capital investment. Although it may be argued that this is no greater in the initial stages than for most other tree crops, the payback period is longer and individual items of harvesting and postharvest equipment are much more expensive.

NOTE

Do a thorough marketing and business plan. This will give you a more accurate picture of what you are getting into.

It is important before embarking on growing macadamias, to take time to research the subject thoroughly. Be cautious about extravagant claims of economic performance and do a thorough business plan.

What you can expect to make

Yields

Yields vary with location, season, variety and level of management. Bearing commences in about the fourth or fifth year and reaches a peak at maturity in about the twelfth to fifteenth year. For a well-managed orchard with tree spacings of 8 m x 4 m (312 trees per ha), expected peak yields at maturity are approximately 3.5 to 4 tonnes of NIS per ha (12 to 13 kg per tree) at 10% m.c. Very well-managed orchards may do slightly better than this and conversely, poorly-managed orchards or those on poor sites may fail to reach these figures. An indication of yields for a well-managed orchard is shown in Table 1.

Table 1. Expected average yields (kg NIS at 10% m.c. based on 312 trees/ha)

Year	Yield per tree	Yield per hectare*
1	0	0
2	0	0
3	0	0
4	0	0
5	1	300
6	2	600
7	4	1,200
8	6	1,800
9	9	2,400
10	10	3,000
11	11	3,200
12–15	12–13	3,500–4,000

* Figures assume that trees are pruned to maintain machinery access and light and spray penetration. Note that in closer-spaced orchards, yields may reach the peak/ha figures earlier than indicated. However, yields may then decline without pruning and good management. With good management, yields/ha for mature trees are generally similar for all spacings.

NOTE

Price is often adjusted upwards for higher sound kernel recovery and often adjusted downwards for higher unsound kernel recovery.

Prices

Prices paid by processors vary from year to year depending on world market forces of supply and demand and Australia's exchange rate. From 1990 to 2003, prices for NIS with 33% sound kernel recovery, a maximum of 3.5% unsound kernel recovery, at 10% moisture content, varied from a low of around $1.60/kg to a high of around $3.20/kg. Approximate annual prices paid by major processors during this period are listed in Table 2.

Table 2. Approximate annual prices for NIS (33% sound kernel recovery, max of 3.5% unsound kernel recovery, at 10% moisture content)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Price ($/kg)	2.50	1.60	2.03	2.75	2.80	3.00	3.05	2.70	2.35	2.04	2.10	2.45	2.75	3.20

In developing a budget, it is suggested that a long-term average price of $2.20 to $2.60 be used.

NOTE

Production costs include only those costs actually associated with growing the crop. These do not include fixed or overhead costs (which add approximately $1,500/ha for a typical 20 ha orchard), capital costs or interest repayments.

Production costs

Before trees start to bear, it costs approximately $3,000 to $3,500 per hectare per year to operate the orchard. This is based on an orchard of 312 trees per hectare, equating to a per tree cost of approximately $10 to $12. This includes costs involved in fertilising, irrigating (if required), mulching, pest, disease and weed control, tree training, machinery operating costs and labour. When harvesting commences, the additional costs of mechanical harvesting, dehusking, drying and storage are generally about $1,000 to $1,500 per hectare (assuming a yield at 12 to 15 years of 3,500 kg NIS per hectare). This makes the total annual production costs for a mature orchard about $4,000 to $5,000.

Gross income

No significant income can be expected until the sixth year. Costs generally exceed income until about the eighth year. Accumulated costs generally exceed accumulated income until at least the eleventh year. At a NIS price of $2.50/kg, marketed yield of 3,500 kg NIS/ha and production costs of $4,500/ha, income from mature trees before fixed or overhead costs are subtracted, should be around $4,000 to $4,500/ha. This would make income from a mature orchard of 20 ha (before fixed or overhead cost are subtracted) about $80,000 to $90,000. However, remember that there can be considerable variation from these figures. Also note that taxation implications will affect the breakeven point.

The capital you need

Excluding the cost of land and a house, up to $400,000 (irrigated) and $300,000 (non-irrigated) is required to establish a 20-hectare macadamia orchard (approximately $50 to $60 per tree). This includes the cost of:

- trees, land preparation and tree establishment;
- a shed for storage, postharvest handling and drying;
- an irrigation system including a dam, piping and under-tree sprinklers (where required);
- a tractor (about 90 HP);
- a slasher;
- a trailer;
- a boom sprayer for herbicides;
- a 4WD utility.

NOTE

The approximate figure of $120,000 is a guide only. It varies according to the equipment purchased.

Once cropping commences in the fifth year, approximately a further $120,000 is required for a harvester, dehusker, sorting, drying and storage equipment, and an airblast sprayer for insecticides and fungicides. An alternative to purchasing this equipment would be to use contract harvesting services (where available), a central harvesting and dehusking facility or a processor accepting nut-in-husk (where available). If using contract services, ensure that the service will be available at critical times.

Taxation

See *Taxation* on page 74 for a brief summary of taxation provisions.

As the costs of establishing an orchard are substantial, the ability to deduct allowable expenditure through taxation is important to most growers. The issue is complex and professional advice from an experienced horticultural accountant is recommended.

The farm you need

Soil

Macadamias grow on a wide range of free-draining soils but perform best on deep, well-drained soils, rich in organic matter. For successful commercial production, a minimum depth of 0.5 m of friable, well-drained soil is essential. A depth of 1 m is preferred, as this minimises the risk from trunk canker disease and tree decline. However, be aware that extremely well-drained soils may be a problem in drought years, if not irrigated. Avoid soils with heavy clay or rock bars within 1 m of the surface. Make a soil map to check variation in soil type and depth across the site. Also avoid soils containing small stones of a similar size to macadamia nuts near the surface. These may cause excessive wear on harvesting and dehusking machinery.

WARNING
If in doubt about the quality of the soil, seek advice from an experienced soils consultant.

NOTE
It may be possible to mound the tree rows to improve soil depth or drainage.

Slope

Slopes of up to 15% are suitable provided the orchard is designed to minimise erosion. Steeper slopes present a major erosion risk and make it difficult to operate machinery safely, particularly when wet. Avoid these wherever possible.

Wind protection

Protection from strong winds is desirable, either through natural forest surrounds or planted windbreaks. Macadamia trees are brittle and breakages occur easily, particularly during storms in highly exposed sites. Wind can also slow growth in young trees and may cause premature fall of young, immature nuts. Windbreaks can also double as buffer zones to reduce the risk of spray drift. However, competition for light, water and nutrients, future orchard management problems and the reduction in planted area need to be carefully considered. Windbreaks may also be relatively ineffective in some sloping sites.

NOTE
Except in highly exposed sites, most new orchards are being established without windbreaks as the owners consider the disadvantages outweigh the advantages.

The most susceptible period for damage is during the first four years after tree establishment. Once trees within the row start to grow together and form a continuous canopy, they are less prone to significant damage, and windbreaks are generally of little benefit except in highly exposed sites. In addition, if windbreaks are to be effective, they need to be in place at least one year and preferably two years before the orchard is planted. They also need to be positioned to provide adequate protection from the direction of the main prevailing winds.

Assess each site on the basis of the above information before planting windbreaks. Choose species carefully so they will have minimal impact on later macadamia tree growth and orchard operations such as harvesting.

Climate

Leaves of mature macadamia trees have been known to withstand temperatures as low as –5°C for short periods without damage. Low frost risk areas

are preferred for all macadamia orchards because young trees as well as the lower trunks and flowers of older trees are very susceptible to damage when temperatures fall below –1ºC. The trunks of young trees can be protected from frost damage by wrapping the lower trunks with insulating materials.

Avoid sites where temperatures regularly exceed 35°C. High temperatures reduce vegetative growth, increase premature nut drop, adversely affect nut growth and oil accumulation, and may cause leaf burn. Also avoid sites where winter maximum temperatures are regularly less than 15ºC. Consult local climatic data, especially outside known major production areas.

Where possible, avoid locations prone to extended wet weather in August and September. This favours flower diseases such as blossom blight and makes pesticide application and harvesting more difficult.

Location

NOTE
Check with your local authority on noise regulations.

Because of the noise associated with dehusking equipment, and possible complaints about spraying operations, the number and proximity of neighbours' houses needs to be considered. When purchasing land, also consider the likelihood of future urban development which might impact on farming operations.

Water supply

Irrigation is recommended where annual rainfall is less than about 1200 mm or where it is unevenly distributed throughout the year. In other areas, irrigation may be useful, particularly during extended dry periods. Where it is used, calculate requirements on mature trees using up to five megalitres per hectare per year. A salt level of less than 1.2 dS/m (decisiemens per metre) is preferred. Note that all orchards require a water supply for spraying.

Fire risk

As macadamias are highly susceptible to fire damage, take the fire risk of surrounding bushland into account when purchasing land. This can be minimised by preventing the buildup of long grass in dry years.

The machinery and equipment you need

Essential equipment to set up the orchard includes:

- an irrigation system including a dam, piping and under-tree sprinklers or trickle system (where annual rainfall is less than 1200 mm or where it is unevenly distributed throughout the year);
- a tractor large enough to operate spray and harvesting equipment (for example 90HP for a 20-hectare orchard);
- two sprayers—one for weed control (boom sprayer preferred for larger orchards); one for pests and diseases (for example, a handgun);
- safety equipment to use when spraying;
- storage shed for farm chemicals;

- slasher;
- 4WD utility;
- heavy duty trailer (preferrably tipping);
- fertiliser spreader;
- workshop space and tools.

When nut production commences in the fifth year, the following equipment is also required, unless use is made of contracting services or central nut handling facilitites:

- harvesting equipment;
- dehusker and sorting equipment;
- shed for storage, postharvest handling and drying;
- a silo or similar for drying and storing nuts;
- a tree sprayer (for example, airblast sprayer) for pest and disease control.

The labour you need

One person should be able to manage up to 30 hectares (non-irrigated) and 20 hectares (irrigated) of orchard trees for the first four or five years until trees begin to bear. This includes fertilising, irrigation, tree training, weed control, pest and disease control and slashing.

From then until about the eighth year, some casual labour may be required for harvesting, dehusking and sorting.

From the eighth year on, labour needs at harvesting increase dramatically making either the purchase of harvesting machinery or the use of contract harvesting services necessary. Note that smaller orchards are generally more labour intensive due to a reduced range of machinery.

Other considerations

Macadamias are susceptible to a range of pests and diseases and failure to apply appropriate control measures can lead to major losses of yield and quality. Spraying is therefore considered essential, particularly between October and March. Pest and disease monitoring is the best way to determine the regularity and timing of spraying. This requires willingness to either employ specialised crop protection consultants or learn these monitoring systems yourself.

Knowledge of marketing will assist in the negotiation of sales with processors. A commitment to quality management throughout your entire production and marketing system is essential if you wish to maximise returns.

The orchard must be run as a business with accurate record keeping and good financial management.

Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

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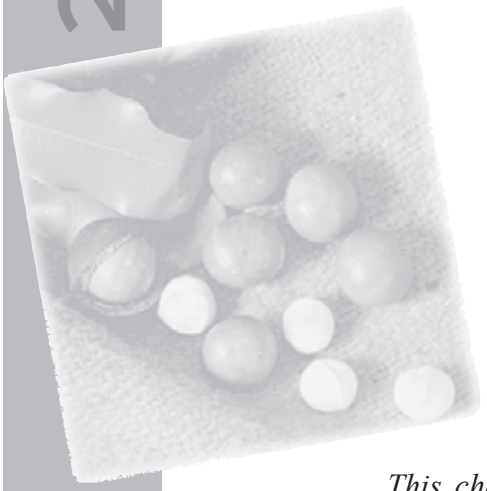
Chapter 2



Common QUESTIONS

This chapter contains the most commonly asked questions about growing macadamias. The answers are as brief as possible. Where this is difficult and more detail is required, we refer you to other sections of the handbook. Symbols on the left of the page will help you make these links.

Questions about economics and prospects

I'm thinking of planting macadamias but am aware that there are a lot of new orchards being established. What are the future prospects?

It is obviously difficult to speculate on what prices and market prospects are going to be in five to ten years time when new plantations will come into bearing. This is particularly so, given the large plantings both in Australia and in overseas countries. However, the Australian macadamia industry is facing this challenge by undertaking market research and new market development, and building a good reputation for high quality through quality management systems. This means that the Australian product has the potential to continue to expand into the future. It is also worth noting that worldwide sales of macadamia appear to have significant scope for expansion. This is based on the knowledge that it still occupies only a tiny percentage (about 2%) of world tree nut sales.

What yields and prices can I expect from my orchard?

Yields vary with location, season, variety and level of management. Bearing commences in about the fourth or fifth year and reaches a peak at maturity in about the twelfth to fifteenth year. For a well-managed orchard with tree spacings of 8 m x 4 m (312 trees/ha), expected average peak yields at maturity are approximately 3.5 to 4 tonnes of nut-in-shell (NIS) per hectare (12 to 13 kg/tree). Very well-managed orchards may do slightly better than this and

conversely, poorly managed orchards or those on poor sites may fail to reach these figures. Note that with some varieties such as HV A4, which produce higher early yields, peak yields may be reached earlier than indicated above.

See *Yields* and *Prices* on pages 3 and 4 for more information.

As far as prices are concerned, with inevitable price fluctuations, many experienced growers budget on a long-term future average price of $2.20 to $2.60/kg NIS at 33% sound kernel recovery, a maximum of 3.5% unsound kernel recovery and 10% moisture content.

What is the wait for a return on macadamias?

No significant income can be expected until the sixth year. Costs then generally exceed income until about the eighth year. Accumulated costs generally exceed accumulated income until at least the eleventh year.

NOTE
Taxation implications will influence the breakeven point. See *Taxation* on page 74 for more information.

What is the economic life of a macadamia orchard?

A well-managed orchard could be expected to be highly productive for at least 30 years, although trees may grow for a hundred years or more.

Is it possible to grow macadamias organically?

It is possible, but significantly reduced yields and nut quality would have to be expected. This is because the macadamia, being an Australian native species, has a lot of native insect pests, some of which may cause significant damage if not controlled by strategic sprays. Spotting bugs are the main problem, as there are no highly effective non-chemical alternatives yet available for this pest. Husk spot disease would also be difficult to control effectively in an organic orchard, particularly in more susceptible varieties.

Questions about establishing an orchard

What varieties are best to plant?

There is no simple answer to this question, as it depends on the location of your farm and the spacing and management system you intend to use. The process starts with analysing the data obtained from regional variety trials to identify the varieties that yield best in your general location. Then analyse these varieties for major production and quality problems and then their suitability for your management system—for example spreading varieties are not suitable in close-planted orchards. Then decide how many varieties you require to spread the risk and harvesting workload.

See *Varieties* on page 23 and the more detailed *Selecting varieties* on page 92 for more information to help you through this process.

Two issues in planning the arrangement of varieties in the orchard are cross-pollination and nut drop periods. Research has suggested that cross-pollination between varieties may be important in maintaining yields and nut quality. Current suggestions are that at least two varieties be planted in each block. Plant in alternate sub-blocks of 4 to 10 rows. Do not mix varieties within the same row. When selecting varieties for the sub-blocks, select those with

similar nut drop periods and processing requirements. This maximises efficiency of crop management and harvesting. Note that varieties with very late nut fall (after the end of September) may present problems with control of husk spot and management of the orchard floor.

Don't rely solely on the information in this handbook. Seek opinions from local growers, processors, consultants and nurseries before finalising your selection. However, be careful to distinguish between real experience and unsubstantiated perceptions or opinions.

How far apart should I plant my trees?

This is a balance between maximising yield during the life of the orchard and minimising cost and management requirements. Location, climate and variety also influence the decision. Closer row spacings, such as 7 m, provide earlier cash flow, but cost more to establish and require side trimming from early in the life of the orchard. These spacings are also only suitable for upright varieties. On the other hand, wide row spacings, such as 10 m, are suitable for most varieties and require little or no side trimming, but take much longer to provide a positive cash flow. Spacings most commonly used are generally between these two extremes—for upright varieties, 8 m between rows, and 4 m between trees, and for spreading varieties, 9 m between rows and 5 m between trees. Note that on steeper slopes, tree rows are usually wider than on flatter ground

See *Row and tree spacing* on page 25 for more information.

How do I prune young trees?

First remove any suckers coming from the rootstock. Then cut back any trees with single shoots that have grown to a height of 80 cm or more without branching. These are topped at this height to get them to branch. For trees that have too many branches coming from the one node, thin these branches to obtain a central leader and only two or three lateral branches coming from any one point. Remove any branches on the trunk below knee height.

See *Training and pruning* on pages 39 to 40 for illustrations of these pruning processes.

Questions about growing the crop

Do I need to irrigate macadamias?

Yes, where annual rainfall is less than about 1200 mm or where it is unevenly distributed throughout the year. In other situations, it may not be of any significant benefit except in the odd year with extended dry periods in the spring and early summer. This is particularly so in sites with shallow topsoils.

How much water do I need?

Mature macadamia trees can quite easily use up to 350 L of water or more a week in hot dry weather. Usage may require up to five megalitres per hectare per year. When irrigating, always use a soil moisture monitoring system such as tensiometers or capacitance probes to ensure water is being applied efficiently.

When should I do soil and leaf analysis?

See *Fertilising* on page 45 for more information.

Do a soil analysis before the trees are planted to give a guide to the pre-plant fertiliser needs. This is particularly important, as it is difficult to effectively incorporate some fertilisers into the root zone after planting. Start leaf analysis from year four, once the trees have started to crop. It is then best to do leaf analysis every year. For convenience, soil analysis is best done at the same time, but in well-managed orchards, can be deferred to every second year. Soil analysis gives a guide to the availability of nutrients in the soil, and leaf analysis a guide to the uptake of those nutrients by the tree. This means the two can be used together to give a more accurate guide to fertiliser requirements. The recommended time for leaf and soil analysis is from September to November. This is when leaf nutrient levels, particularly for the major nutrients like nitrogen, are most stable.

When should fertiliser be applied?

The timing of fertiliser application should be largely based on an interpretation of the soil and leaf analysis results. However, as a general rule, split nitrogen fertiliser requirements into as many applications as practicable throughout the year. Apply the bulk of potassium fertiliser requirements in the spring with the rest spread throughout the year. Apply fertilisers of low solubility such as phosphorus fertilisers, gypsum or zinc sulphate before the summer rains to help with incorporation. Where used, apply boron and zinc foliar fertilisers to new growth flushes (boron—spring; zinc—summer).

Is poultry manure good to use on macadamias?

See *On-farm composting* on page 169 for more information on composting nut husk.

Organic fertilisers such as poultry manure have the benefit of improving the physical and biological characteristics of the soil, as well as supplying some nutrients. However, it is important that these materials are properly composted for at least three months before use, or applied more than four months before harvesting commences. Do not apply during or near harvesting. This minimises the risk of microbial contamination of nuts on the ground. Also remember that organic fertilisers such as poultry manure are generally lower and more variable in nutrient content than inorganic fertilisers, and are slower in their response.

What pruning is necessary in bearing trees?

See *Canopy management* on page 51 for more information on pruning bearing trees.

There are two important pruning operations. First, remove the lower branches to a height of about 1 m at the trunk and 1.5 m at the dripline (skirting). This allows easy access underneath for harvesting and for weed control. Skirting

is normally done with hand-held equipment such as chainsaws or tractor-mounted hydraulic saws after harvesting is completed. Second, where trees crowd (particularly in closely-spaced orchards), side trimming (commonly known as hedging) will be necessary to maintain machinery access, increase light and spray penetration, and reduce the risk of fungus diseases developing. Regular light trimming is best, as heavy trimming (removal of 1 m or more of foliage), results in vigorous regrowth and crop loss. Side trimming is generally done with tractor-mounted hydraulic saws, and is most practicable after final harvest.

Is there a suitable ground cover for use in macadamias?

After many years of investigation by macadamia researchers, sweet smother grass has been identified as the most suitable perennial ground cover so far. Living ground covers provide benefits as mulch and in reducing soil erosion. This is very important in macadamias as trees crowd and shade out inter-row grass species, leaving the soil vulnerable to erosion and overland movement of nutrients. Finding suitable ground covers is a big ask, as they need to be shade tolerant, non-climbing, persistent, and relatively non-competitive with the macadamia trees. Ground covers must also be relatively low-growing to suit harvesting and minimise mowing.

NOTE
To use ground covers successfully, specialised under-tree offset mowers are required.

Questions about problems

My flowers are dying. What is likely to be the problem?

The most common cause is macadamia flower caterpillar, one of the major pests of macadamias. The caterpillars (larvae) festoon the raceme with webbing, insect excrement and remains of damaged buds. The insect pest has the potential to completely ruin all florets on a flower raceme. To avoid significant damage, the flowers need to be monitored for caterpillar eggs and larvae, from when flowering begins. Once the stage is reached where the pest is causing sufficient economic damage, a spray program is commenced. Note that other possible causes of dead flowers include drought, frost damage, raceme blight disease, flower thrips damage, redshouldered leaf beetle damage and felted coccid damage. If you are unsure of the cause, seek advice from pest consultants. Experienced pest and crop consultants are available in most macadamia production areas.

NOTE
Photographs of symptoms of these problems are contained in the *Macadamia problem solver & bug identifier field guide*.

What is causing small green nuts to drop?

Early nut drop can be either from natural thinning or from a pest, disease or disorder. Natural thinning results from the trees naturally setting many more nuts than they can carry through to harvest. Most natural thinning occurs when the nuts are pea-sized, when up to 90% of set nuts may fall. This is normal. No treatment is required for this natural nut thinning. Unnatural nut drop is generally caused by damage from spotting bugs, green vegetable bug, nutborer or husk spot. Less common causes are storm damage (wind or hail), and tree decline. Fruitspotting bug affects nut drop in the early stages, while

husk spot and nutborer usually affect nuts at the later stages of development. It is very important to monitor the nuts that are dropping to see if they are damaged by these insects or diseases, and if so, apply appropriate control measures.

Some of my trees are looking yellow with leaf fall and twig dieback. What is the problem?

The most likely cause is tree decline. It is believed to be brought about by a combination of factors that lead to a decline in tree health. These include nutrient deficiencies, low soil organic matter levels, soil erosion exposing surface roots to desiccation, root death in shallow marginal soils, drought, and large crop loads. Treatment involves lightly pruning affected trees to encourage vigorous new growth. When this has occurred, apply a general foliar fertiliser at regular intervals. Also apply mulch up to 5 cm thick on the soil surface under the tree to just outside the dripline—this helps encourage new root growth. Note that trees may take some time to recover.

Some of my trees show bark splitting and gumming on the trunks. What is the problem and how should I treat it?

The most likely cause is trunk canker disease brought about by a fungus. This causes cankers (dark discoloured areas of bark), from which the gum exudes. If the discoloured bark is removed, a brown discolouration of the outer wood can be seen. In young trees, suckers often shoot from the rootstock. Where cankers are small, treatment involves paring back affected bark and wood with a sharp knife, and thoroughly soaking the trunks with an appropriate fungicide. If the label recommends it, apply the fungicide in conjunction with a white, water-based paint, as this helps to maintain contact with the fungicide and seals the wound. Where cankers are more extensive, and paring back affected bark and wood is impracticable, spray affected trees with a systemic fungicide from the *Chemical handy guide*.

NOTE
Photographs of symptoms of these problems are contained in the *Macadamia problem solver & bug identifier field guide*.

Questions about harvesting and handling

How often should I harvest?

Harvest at least every four weeks wherever possible, particularly during extended wet weather or where nuts are exposed to direct sunlight. Nut quality will be improved and losses reduced the less time the nuts are on the ground.

How should nuts be handled after harvest?

Dehusk the nuts within 24 hours of harvesting. This prevents deterioration from over-heating. This is particularly important where nuts are wet or the husks are green. While the nuts are being dehusked, do an initial sort to remove nuts that have obvious defects such as rat or insect damage, cracked shells or discoloured shells. Unless nuts are being immediately consigned to a processor, they need to be dried. The extent of drying depends on whether

The Agrilink *Macadamia Sorting Guide* is a useful aid in sorting.

or not flotation grading (water sorting) of nuts is going to be used to remove immature nuts. If it is, first dry down to about 12 to 17% moisture content (exact level depends on kernel recovery), do the flotation grading and then dry down again to the desired moisture content of about 8 to 10%. If flotation grading is not used, dry down directly to the 8 to 10% moisture content.

See *Postharvest handling* on page 63 for more detailed information.

Drying needs to be completed within two weeks of harvest. If drying cannot be achieved within this time, contact your processor immediately and consign to them as soon as possible. Drying is achieved by forced-air drying (sometimes including heating), or where nut volumes are smaller, spreading out in thin layers on racks located in a cool, dry location such as a shed. Rake over the nuts on the racks regularly to ensure even drying.

Note that sorting is most important. Most nut buyers apply bonus payments for low levels of unsound nuts and penalties for high levels. This can make a significant difference to the value of a consignment.

How do I sell my crop?

Nuts are normally sold to macadamia nut buyers (processors or exporters) in bulk, one-tonne bags or bins, after dehusking and partial drying on the farm. There are about 10 major buyers operating in the Australian industry. Cartage costs may be arranged and paid for by the buyer.

Questions about chemicals

Do I need training in the safe use of chemicals?

NOTE

In other states, check State Government regulations as these may differ from those in Queensland and New South Wales.

In some states you cannot buy certain chemicals unless you have a current spray accreditation or have suitable authorisation. An authorised person is one who holds a chemical application certificate under the Australian Qualification Framework (AQF), or whose business is selling or supplying agricultural chemical products, or who is a state licensed spray contractor. Currently, by law in Queensland, you only need training in safe use of chemicals if you are a contractor spraying on other people's land or you want to buy or use restricted chemicals such as endosulfan. In New South Wales, it is a requirement under the NSW Pesticide Regulation that *all* persons applying pesticides as part of their job or business have completed accredited training. Most processors and buyers now see it as highly desirable for their growers to be able to demonstrate safe, responsible use of chemicals. One of the best ways to demonstrate this is to obtain chemical user accreditation. Remember spray accreditations must be renewed every five years.

How do I get spray accreditation?

See *Contacts* on page 193 for contact details for ChemCert in Queensland and New South Wales.

Spray accreditation can be obtained by attending a course provided by an accredited ChemCert Australia (or equivalent) trainer. In Queensland the certificate is known as ChemCert Training Queensland Certificate of Agricultural Chemical Application. In New South Wales, there are SMARTtrain and ChemCert certificates. At present, no other certification is recognised by the Australian Pesticides and Veterinary Medicines Authority (APVMA).

How should I store my chemicals?

The DPI booklet *Farm Chemical Storage Guide* (Q199064) is designed to provide growers with a user-friendly, accurate guide to what is required by law and to comply with safety standards acceptable in today's workplace. The advice given reflects closely the Australian Standards AS 2507, AS 1940 and AS/NZS 4452, as well as the Workplace Health and Safety publication *Code of practice for the storage and handling of chemicals at a rural workplace*. It covers location, construction, management of stock, planning for emergencies and waste disposal. Further information on correct use of chemicals is covered in the ChemCert and SMARTtrain chemical user courses. Employees of farm chemical resellers with ChemCert and SMARTtrain accreditations are also a useful source of information.

Do I need to keep a diary of spraying records?

Details of the information that needs to be recorded can be obtained from the NSW EPA (contact details available on page 194).

At present the only records legally required in Queensland are those kept by chemical resellers to record S7 sales and those required for the usage of endosulfan. In New South Wales, it is law that records of pesticide applications be kept, including herbicides. Properly kept records of chemical applications are a critical documentation to prove your chemical application practices. Many buyers and retailers now expect their suppliers to keep detailed spray records and will require evidence that you are doing so.

It is a requirement of the Macadamia Industry Approved Supplier Program (MIASP) to maintain detailed spray application records. You should record: what block was sprayed and the area; what was applied; how much per 100 L and how much spray volume (L/area); what pest or disease was targeted; what application method was used and by whom; when the application took place and the prevailing weather conditions at the time.

WARNING

Legal requirements are subject to regular change and are likely to become more stringent over time. Regularly check with authorities for updated requirements.

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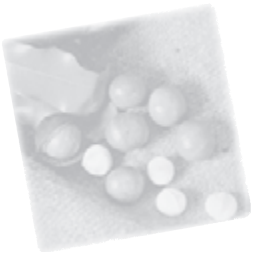
Queensland Government

Chapter 3

Growing the CROP

This chapter contains our recipe for growing and marketing a commercial crop of macadamias. To keep the section as brief as possible and easy to follow, explanation on why practices are suggested is limited. More information to help you understand these recommendations is contained in Chapter 4, Additional information on some key issues. *Symbols on the left of the page will help you make these links.*

Note that the Australian Macadamia Society has developed a macadamia industry Code of Sound Orchard Practices (COSOP), as part of an industry-wide quality assurance program. The code identifies orchard practices where nut quality can be affected, from land selection through to nut delivery to processors. This chapter has been developed in line with the Code.



Getting the orchard established

Setting up an orchard that will be profitable in the long term requires careful planning. Mistakes made with orchard layout, land preparation, variety selection and tree spacing are difficult or impossible, and costly, to rectify later on. There are 14 important steps:

- Assess the orchard site
- Plan the orchard layout
- Choose varieties and tree spacing
- Order trees
- Start to prepare the land
- Plant windbreak trees (where necessary)
- Mark out the rows
- Deep rip along the rows
- Control water flow within the orchard
- Do a soil analysis and apply required fertilisers
- Prepare the tree rows
- Mark out the tree planting sites
- Install the irrigation system (where required)
- Plant the trees

Assess the orchard site

Not all of an orchard site may be suitable for profitable macadamia production. Important elements to consider are soil depth/drainage, surface stoniness and slope.

Soil depth/drainage

As macadamias are susceptible to decline and trunk canker disease in poorly drained soils, check the depth of well-drained soil across the orchard site. A minimum depth of 0.5 m of free-draining soil without impermeable clay or rock layers is required, with 1 m preferred.

The only way to do this effectively is by digging holes down through the soil profile to the prescribed depth. Holes need to be dug on a grid pattern across the orchard site. The distance between inspection holes depends on how much the topography and soil varies, but as a rough guide a hole every 30 to 50 m is sufficient. For a small orchard, the holes can be dug by hand with a soil auger or posthole digger (Figure 1). Alternatively, a backhoe can be hired. For a larger orchard, it is best to hire a contractor with a motorised truck-mounted auger. At each inspection site, a hole is augered down to the

prescribed depth and the soil laid out on the ground in a line corresponding to its approximate depth (Figure 1).

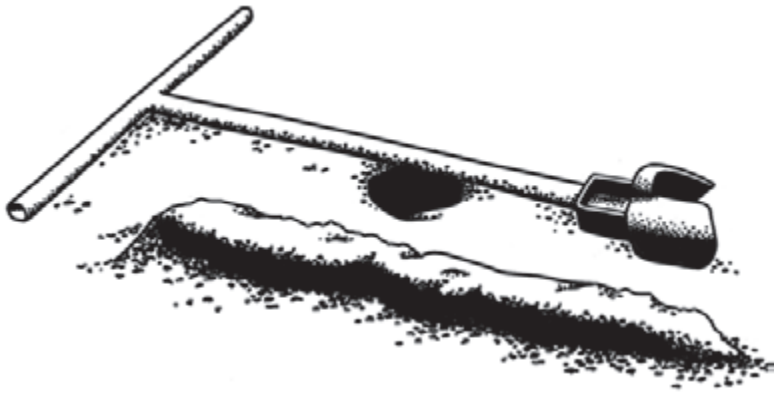


Figure 1. *A soil auger suitable for soil assessment on small properties. The diagram shows how the soil from the hole is laid out in a line corresponding to the approximate soil depth*

The soil properties, such as texture, colour and presence of rock or clay layers, are then assessed. Record the data by developing a soil map of the orchard site. It is also useful to note other features such as slope and aspect. These will be useful later in designing windbreaks and irrigation layouts. When the data has been collected, the boundaries of the major soil types can be drawn on the map, together with the location of areas of rock or heavy clay. This is then used to determine the size and boundaries of orchard areas and the need for mounding or sub-surface drainage.

Note that rock or hardpan layers are generally difficult to drill through with an auger. An assessment of their effect on drainage can be obtained by doing an infiltration test. This involves drilling an auger hole to the depth of the obstruction, pouring in about five litres of water, and recording how long it takes for the water to soak away. To be safe for macadamias, the water should drain away within at least one hour.

NOTE
Note that trees planted on soils with marginal drainage rarely achieve profitable yields.

Note that the test is only valid where the soil is moist right down the profile. This is either after good rainfall or after the hole has been previously filled with water and allowed to drain completely.

Because of the importance of soil depth/drainage, inexperienced growers are advised to employ a consultant to assess the soils and prepare a soil map.

Surface stoniness

While checking soil depth/drainage, also check the soil for small stones of a similar size to macadamia nuts. It is best to avoid such areas as the stones may cause excessive wear on harvesting machinery, and in some cases even preclude its use.

Slope

As slope determines the risk of soil erosion and the safety of machinery operation, check the angle of slopes across the orchard site. Slope can be measured in degrees using a clinometer, or as a percentage using a simple spirit level, a 1 m long straight edge and a measuring tape, as demonstrated in Figure 2.

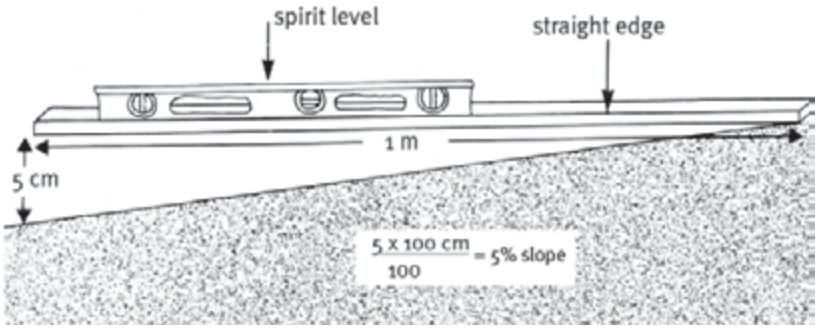


Figure 2. *Measurement of slope as a percentage*

The steeper the slope the higher is the risk of soil erosion and the more difficult it is to operate machinery safely. For macadamias, a slope of less than 8% fall (4° angle) is preferred, as the site is less susceptible to soil erosion, allows flexibility with row layout, and enables tractors and machinery to be operated safely across the slope. Slopes of 8 to 15% fall (7° angle) are acceptable, but require good surface water management and rows must be run up and down the slope for safe machinery use.

See *The farm you need* on page 6 for more information on these other factors.

Note that other factors need to be considered in initially selecting the site. These include severity of frosts, exposure to strong winds, and proximity to neighbours in relation to noise and spraying conflicts.

Plan the orchard layout

The aim of this step is to achieve maximum productivity with minimal environmental impact. Important points to consider include machinery access and use, water retention and runoff, and the impact of orchard operations on neighbours.

Planning the orchard is complex and we recommend that you seek expert assistance. This is available from some consultants and some government land conservation departments.

The process involves marking on a map of the intended orchard site the existing features such as roadways, standing timber, gullies and slope direction, and then developing an overlay plan showing proposed access roads, buildings, windbreaks, tree rows, surface drains to control runoff, and dam sites. Figure 3 is an example of an orchard design plan. Additional detail on some of the important elements of the design plan is listed below.

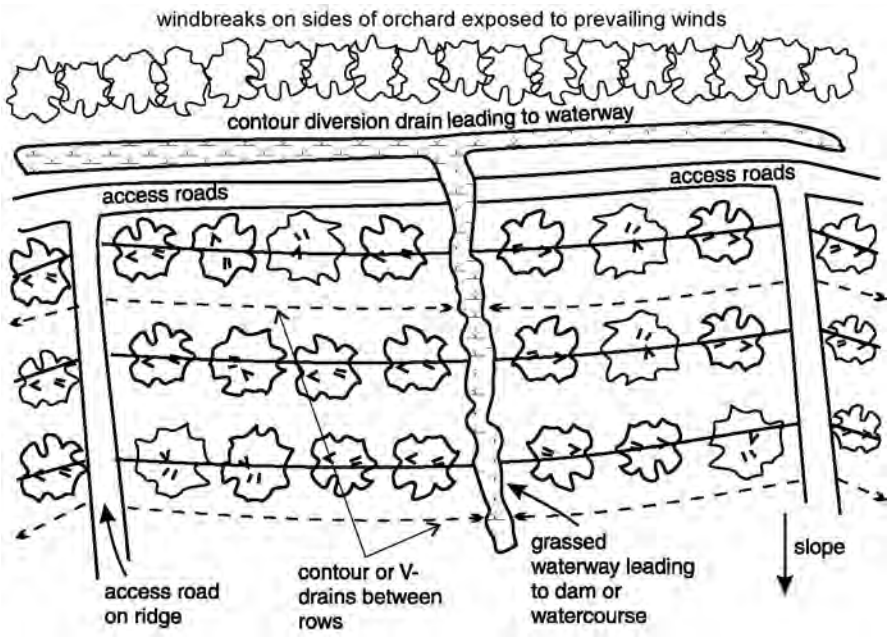


***Figure 3**. An example of an orchard design plan (slope with less than 8% fall)*

Important elements of the design plan

- **Land clearing**. If land needs to be cleared or timber burnt, first check with both your local authority and state government. Clearing of land is generally under some control, and fines can be imposed for improper clearing. Before clearing, consider preserving appropriate belts of existing forest for both wind protection and spray drift control (see next dot point).

- **Provision for windbreaks and spray drift buffer zones**. In highly exposed sites, protection from strong winds is desirable, either through natural forest surrounds or planted windbreaks.

  At the same time, consider providing enough natural forest protection or planted windbreak space to reduce the risk of spray drift onto neighbouring properties. Take into account the likely main wind directions and the proximity of neighbouring properties. Check with your local authority for any requirements on buffer zones and environmental management. Be aware that planted windbreaks have a number of problems and except in highly exposed sites, are generally of wind protection benefit only for the first four years after tree establishment.

See *Plant windbreak trees* on page 27 for more information.

- **Row direction and length**. Try to run rows in a north-south direction where possible. This maximises sunlight interception on both sides of the tree rows, particularly during winter. However, row direction needs to first suit the slope and then the design needs of the irrigation system (where irrigation is planned). Seek specialist assistance. Irrigation equipment suppliers generally provide free irrigation design advice as part of an agreement to purchase irrigation equipment. On slopes of up to 8%,

rows can be run across the slope or up and down the slope. On slopes of 8 to 15%, rows must be run up and down the slope to allow safe machinery use. Long rows are preferred for machinery efficiency. Allow a minimum of 10 m access at the end of rows for turning of machinery.

- **Internal soil drainage.** Use the soil map mentioned under *Assess the orchard site*, to identify problem drainage areas, which can be either avoided for planting, or earmarked for mounding and/or subsurface drainage. Where low profile mounds are built across the slope to improve soil depth, erosion control and drainage, it is essential to ensure that they do not act as dams. Provide a fall of 2 to 5% along the mounds to prevent water ponding within the orchard.

- **Surface drainage.** Uncontrolled water runoff removes valuable topsoil exposing roots to desiccation and machinery damage. It may also cause ponding within the orchard, exacerbating waterlogging and trunk canker problems. Surface drainage and/or permanent under-tree ground cover is essential to control water flow safely through the orchard. A drainage system normally consists of a diversion drain at the top of the orchard, shallow flat-bottomed v-drains within the orchard, and down-slope waterways to carry the water to a dam or watercourse. On slopes up to 8%, where rows and drains may run across the slope, the ideal is to locate them close to the contour with a gradient of 2 to 5% to remove water safely. On slopes above 8%, where rows run up and down the slope, major cross-slope contour drains may be necessary at regular intervals down the slope to safely dispose of runoff. Under-tree ground cover is usually provided through planting a suitable perennial grass.

NOTE
As drains interfere with harvesting and other orchard operations, their use must be carefully considered. Seek specialist advice before construction.

- **Watercourses and dams.** Gullies, creeks and depressions should be disturbed as little as possible. Leave a buffer of trees along gullies and creek banks to keep them stable. Do not plant orchard trees where runoff naturally concentrates in gullies or depressions. Seek professional advice on dam siting and construction from irrigation consultants or government water resources departments.

- **Roadways.** It is important to have all-weather access to the orchard for spraying, harvesting and other operations. Locate access roads on ridgelines wherever possible.

NOTE
The macadamia industry has a code of practice for noise management of on-farm processing. See page 197 for details.

- **Siting of storage, processing and waste disposal facilities.** It is important that chemical and fuel storage areas and waste disposal areas are sited away from watercourses and constructed and operated in accordance with legislative and duty of care requirements. Because of noise associated with dehusking equipment, site processing facilities as far as practicable from neighbours.

Choose varieties and tree spacing

Varieties

Because macadamias are a long-term crop, great care must be taken in choosing varieties. Unfortunately, there are no easy short cuts to identifying the best varieties, as the choice depends on a number of factors that different people will weight differently. However, here is a general process to follow:

See *Selecting varieties* on page 92 for the full yield data from the regional variety trials and more detailed information on tree and nut characteristics.

1. Identify the varieties that yield best in your district in terms of sound kernel. Based on regional variety trials, a list of the best yielding varieties for six broad districts, as assessed by the author panel, is shown in Table 3.
2. Analyse these varieties for any tree or nut characteristics that may affect performance. A list of one or two of the main issues for each variety is shown in Table 4.
3. Seek additional opinions from local growers, consultants and nursery tree suppliers. However, be careful to distinguish between real experience and unsubstantiated perceptions or opinions. Also check with your intended processor, who may have specific variety preferences for processing and marketing.
4. From your list, identify those varieties that suit your proposed tree spacing and management system, for example, upright varieties are necessary for close-planted orchards. This data is listed in Table 5.
5. From these, select as many varieties as is appropriate to adequately spread the risk and harvesting workload. Nut drop periods, which determine harvesting times, are listed in Table 5. As arrangement of the varieties in the orchard may influence the number of varieties finally chosen, see *Variety arrangement in the orchard* on page 26 before completing your selection.

Table 3. Best yielding varieties from regional variety trials. Assessment based on sound kernel yield (full data including ranking order is on pages 100 to 102)

Variety	Central NSW (based on Nambucca site)	Northern NSW (based on Clunes site)	South east Qld - Sunshine Coast (based on Forest Glen site)	South east Qld - Gympie (based on Wolvi site)	Central Qld (based on Rockhampton site)	Atherton Tableland (based on Walkamin site)
HV A4[1]	✔					
HV A16[1]		✔	✔	✔		✔
HV A29[1]	✔*		✔*			
HV A38[1]	✔		✔			
HV A203[1]	✔*		✔*			
HV A268[1]	✔*		✔*			
HAES 246	✔	✔		✔		
HAES 344	✔	✔	✔	✔	✔	
HAES 660						✔
HAES 705		✔*			✔*	✔*
HAES 741					✔	✔
HAES 781		✔*		✔*		
HAES 783		✔*		✔*		✔*
HAES 816		✔			✔	
HAES 835				✔*		
HAES 842		✔		✔	✔	
HAES 849		✔		✔		
Daddow		✔			✔	✔

* Limited data only. Seek additional advice.

[1] HV varieties are subject to Plant Variety rights, which restricts propagation and sale to licensed nurseries only.

Table 4. Some issues to consider in selecting varieties (full data on variety characteristics is on pages 94 to 100)

Variety	Issues
HV A4	Prone to rat attack
HV A16	Very late nut drop; moderately to highly susceptible to husk spot disease
HV A29	Not yet properly assessed
HV A38	Prone to kernel discolouration in some years
HV A203	Not yet properly assessed
HV A268	Not yet properly assessed but appears susceptible to husk spot
HAES 246	Prone to open micropyle and pre-germination on the tree; very large tree not suitable for close planting
HAES 344	More susceptible to nutborer than other varieties; appears at this stage to be more susceptible to the abnormal vertical growth (AVG) disorder
HAES 660	Large number of undersized nuts
HAES 705	Not yet properly assessed, but has very late nut drop
HAES 741	Prone to basal discolouration of kernels
HAES 781	Prone to sticktight nuts and open micropyle
HAES 783	Very late nut drop
HAES 816	As yields vary significantly between sites, investigate local yield performance in addition to regional variety trial data
HAES 835	Not yet properly assessed
HAES 842	Long and late nut drop
HAES 849	Long and late nut drop; prone to pre-germination; very susceptible to husk spot disease
Daddow	Long and late nut drop; very susceptible to husk spot disease

Table 5. Variety suitability for close planting and nut drop periods (full data on pages 94 to 100)

Variety	Suitability for close planting			Nut drop periods
	Tree size	Tree shape	Close planting?	
HV A4	Medium	Spreading	Yes	Mid-season (May to August)
HV A16	Small	Upright	Yes	Very late (May to November)
HV A29	Large	Very upright	Yes	Mid-season (May to July)
HV A38	Medium	Very upright	Yes	Mid-season (May to August)
HV A203	Medium	Slightly upright	No	Early (exact timing not determined)
HV A268	Medium	Spreading	No	Mid-season (April to July)
HAES 246	Large	Spreading	No	Mid-season (May to August)
HAES 344	Medium-large	Upright	Yes	Early (April to July) in Qld; later (May to August/September) in NSW
HAES 660	Medium-large	Upright	Yes	Early (May to June)
HAES 705	Medium-large	Spreading	No	Very late
HAES 741	Large	Upright	Yes	Early (April to June)
HAES 781	Very large	Moderately upright	No	Not yet determined
HAES 783	Medium-large	Spreading	No	Very late (June to September)
HAES 816	Medium-large	Moderately upright	Yes	Early (March to June)
HAES 835	Large	Spreading	No	Early (exact timing not determined)
HAES 842	Medium-large	Moderately upright	Yes	Extended (April to September)
HAES 849	Medium-large	Spreading	No	Extended (May to October)
Daddow	Medium-large	Spreading	No	Extended (May to September)

Rootstocks

Trees are purchased as varieties grafted or budded onto rootstocks. Nurseries most commonly use the variety Hinde (H2) as a rootstock because of its ease of progagation. It produces vigorous and uniform seedlings. Research currently in progress will help to define appropriate rootstocks for the main varieties.

Row and tree spacing

This is a balance between maximising yield during the early life of the orchard and minimising cost and management requirements. Closer spacings provide earlier cash flow, but cost more to establish and require side trimming from early in the life of the orchard. On the other hand, wide spacings are suitable for all varieties and require little or no side trimming, but take much longer to provide a positive cash flow. The main options are listed in Table 6.

Table 6. Row and tree spacing options

Distance between rows	Distance between trees in row	No of trees per ha	Variety suitability	Tree trimming required?
7 m	4 m	357	HV A16, HV A38, HAES 344, HAES 741	Yes
8 m	4 m	312	Above varieties + HV A4, HV A29, HAES 660	Yes
9 m	4 m	278	Above varieties + HAES 816, HAES 842	Yes (moderately upright varieties only)
9 m	5 m	222	All varieties	Yes (spreading varieties only)
10 m	5 m	200	All varieties	No (but may be required in mature trees)

NOTE

Wider spacings are recommended on steeper land to facilitate better inter-row grass growth. This minimises soil erosion and assists with safe machinery operation.

Spacings most commonly used are 8 m between rows and 4 m between trees (upright varieties), and 9 m between rows and 5 m between trees (spreading varieties).

Variety arrangement in the orchard

There are a number of reasons for carefully considering the way the varieties are arranged in the orchard.

1. **Cross-pollination**. Cross-pollination between varieties is believed to increase the number of nuts, the percentage of first grade kernel, kernel recovery and nut size. To obtain any benefits of cross-pollination, we recommend that at least two varieties are interplanted within each major block of trees. Arrange these varieties in alternate sub-blocks of 4 to 10 rows as shown in Figure 4. Nuts can then be harvested and supplied to the processor as separate varieties, should this be required in the future.

2. **Harvesting and orchard management.** It is important to try to match the nut drop periods of the two (or more) varieties selected above for each sub-block (see Nut drop periods in Table 5). This will help to make subsequent harvesting more efficient. There will be spin-offs for orchard management as well. For example, pest and disease infestations will generally be similar for varieties with similar nut drop patterns. This means that pest monitoring and spraying will be more efficient on a block basis. Similarly, nutrition and irrigation may be more easily tailored to the requirements of each variety.

3. **Processing**. Where possible, avoid mixing hybrid varieties (for example some of the HVA varieties) with *Macadamia integrifolia* varieties (for

6 rows of variety 1 *6 rows of variety 2*

Figure 4. *Suggested variety arrangement to maximise cross-pollination*

example HAES varieties and Daddow) in the one block. Processors may require these to be consigned separately in the future. Seek advice on this from processors.

Order trees

Once you have chosen your varieties and worked out your row and tree spacing, calculate the number of trees you need. Order your trees at least 12 months before intended planting from a specialist macadamia nursery. Give preference to nurseries using non-soil potting mixes, using a minimum pot size of 6 L, and where trees are in the pot for no more than two years.

Note that at times, some varieties may need to be ordered more than 12 months in advance. Although most macadamia nurseries train trees to a central leader, ensure that you specify this requirement when ordering trees.

See *Propagation* on page 174 for an improved understanding of the propagation process.

Nursery production of trees is a specialist job, as macadamias are difficult to bud and graft. Consequently, we do not recommend that you try to propagate your own trees.

Start to prepare the land

In sites requiring clearing, start at least 12 months before planting. The orchard design plan developed earlier in this chapter will have identified strategically placed existing stands of forest to act as windbreaks and spray drift buffer zones. Before clearing or burning, remember to first check with both your local authority and state government for necessary approvals, and seek professional advice from consultants or state government forestry departments. Then clear, cutter-bar and stick-rake the land where necessary. Failure to effectively cutter-bar and stick-rake could result in later tree losses from Armillaria root rot disease. Stack the timber into windrows for burning. Don't push it into gullies and depressions. Leave gaps in the windrows every 30 m or so to allow safe removal of runoff water.

In previously cultivated sites where clearing is unnecessary, start rehabilitating the soil at least 12 months before planting. This involves deep ripping and improving the nutrient and organic matter levels of the soil, as outlined in the following steps.

Plant windbreak trees (where necessary)

The decision to plant windbreak trees needs to be carefully considered. This is because they:

- are expensive to establish;
- tie up expensive land, which could be used for orchard trees;

Aerial photo showing good use of belts of natural forest to provide orchard wind protection

- are only generally required for the first four years until the trees start to grow together as a continuous hedgerow and become less susceptible to wind damage;
- are costly to remove later, particularly within the orchard;
- drop sticks and other debris, which interfere with harvesting operations;
- may become a habitat for rats;
- compete with the orchard trees for light, water and nutrients.

In general, permanent planted windbreaks are only recommended in sites highly exposed to strong winds, and then only where they are needed to supplement inadequate natural forest surrounds. An option in these situations may be to select the more wind resistant upright varieties such as HV A16, HV A29, HAES 344 and HAES 660 (where these are suitable for your district), or use temporary windbreaks to protect the young trees until they form a continuous hedgerow. Temporary windbreaks may be planted trees or constructed individual tree guards.

Where planted windbreak trees are used, plant them at least 15 m from the macadamia tree rows to allow space for machinery access and to reduce competition for light, water and nutrients. Seek advice on windbreak tree selection from consultants, native tree nurseries or state government forestry departments. In selecting windbreak trees, remember to consider fire susceptibility.

NOTE
Windbreaks are most effective when at right angles to the damaging winds.

Windbreak design is also important. For example, on flat ground, windbreaks are effective for a distance equal to approximately 10 times their height. That is, a 10 m high windbreak will generally protect trees growing within 100 m of the windbreak. However, on slopes facing the wind, the protected distance is reduced. Multi-row windbreaks provide more effective protection where space is available. For internal temporary windbreaks, do not use tall trees as these are difficult to remove later on and are more competitive for water

and nutrients. Shrubby small trees such as lemon-scented tea tree (*Leptospermum petersonii*) and bracelet honey myrtle (*Melaleuca armillaris*) are more appropriate. Avoid bana grass as it requires regular maintenance and harbours rats.

When planting windbreak trees in previously cultivated or grazed sites, deep rip rows to a depth of at least 60 cm before planting. If ripping downhill, lift the toolbar for a metre or so every 30 m to prevent water scouring down the rip lines. Typically, but depending on the species chosen, plant permanent windbreak trees 4 m apart, interplanted with shorter bushy species. Mulch with coarse straw. Regular applications of small quantities of a mixed tree fertiliser will promote rapid growth. Maintain a weed-free area around the trees until they are well established. Where necessary, protect windbreak trees from hares, wallabies, rabbits or livestock by fencing or deterrents.

Mark out the rows

NOTE
Remember that where rows are mounded across the slope, the surveyed key line needs to have a fall of 2% to 5%. See *Important elements of the design plan* on pages 21 to 22 for more detail.

Rows across the slope are marked parallel to a surveyed key line. Wire or rope is tightly stretched between two people at right angles to the key line and points marked approximately every 20 m along the row (Figure 5).

Rows up and down the slope are usually marked parallel to a fence line or windbreak or at right angles to the contour.

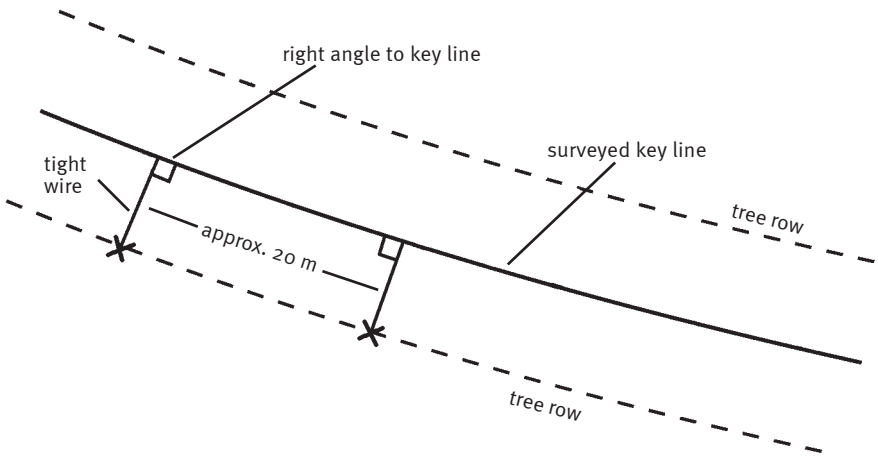


Figure 5. *Marking out parallel rows across the slope*

Deep rip along the rows

Where the land has been previously cultivated or grazed, deep rip to a depth of at least 60 cm along each row. Ripping will also help with the drainage of wet areas. If ripping downhill, lift the toolbar for a metre or so every 30 m to avoid water scouring down the rip lines.

Control water flow within the orchard

Main diversion drain above orchard

On sloping land, construct a major contour diversion drain above the orchard to divert water, where possible, into a stable waterway or dam. The drain should have a gradient of 2 to 5% and be large enough to handle water from the catchment above. Keep the steeper sections of the drain furtherest from the waterway or dam, unless you have very stable clay soils. Establish a creeping grass such as carpet grass, couch or kikuyu in the drain channel to prevent scouring.

Water flow within the orchard

There are two options to control water flow within the orchard:

- Establish a permanent ground cover such as sweet smother grass, which is tolerant of low light conditions, and will help to later protect the soil surface under the shady canopy of the trees. The ground cover reduces the risk of soil erosion by preventing raindrop splash on bare soil, and slowing and dispersing the overland water flow.

And/or

- Build shallow, wide, flat-bottomed v-drains grassed with sweet smother grass, carpet grass, couch or kikuyu in the centre of the inter-row area. This directs water flow away from the bare soil under the trees to stable grassed channels. V-drains are essential where additional drainage is required on flat ground. V-drains have a maximum excavation of 20 cm and are usually built by a small grader or tractor-mounted blade. Two shallow passes with a rotary hoe, one either side of the centre of the inter-row area, are usually required to break up the grass sward prior to grading.

Well-grassed v-drains in a young orchard. Note the slight mounding along the rows

A disadvantage of v-drains is the added difficulty for mechanical harvesters picking up nuts from the centre of the v. For this reason, the drains must not be steep-sided, and the surface on either side of the drain graded flat. V-shaped drains are more suited to wider row spacings (for example 10 m between rows) and gentle slopes.

For rows across the slope, construct v-drains in every second or third row (Figure 6). On steeper slopes and in more-erodible soils, drains may be required in every row. Soil from the drain is moved onto the proposed downhill tree line (Figure 7).

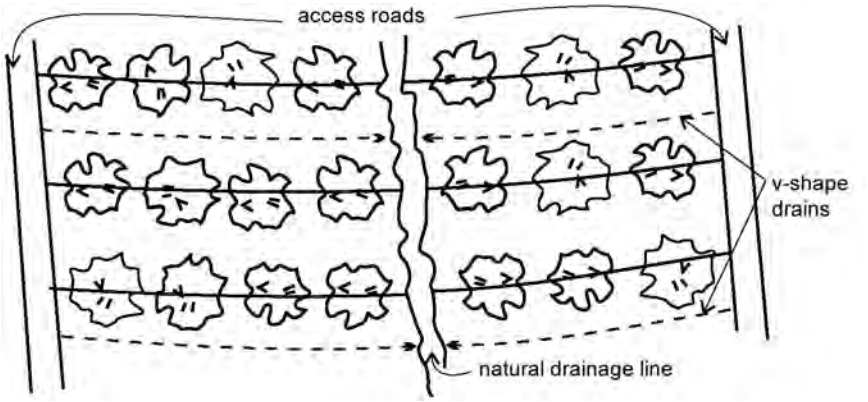


Figure 6. *V-drains for across slope rows (plan view)*

WARNING

For across-slope v-drains, it is important that the mid-point of the inter-row does not coincide with the bottom of the drain as this will make machinery access more difficult as the trees get bigger. For this and other reasons, it is difficult to get across-slope v-drains to work practicably.

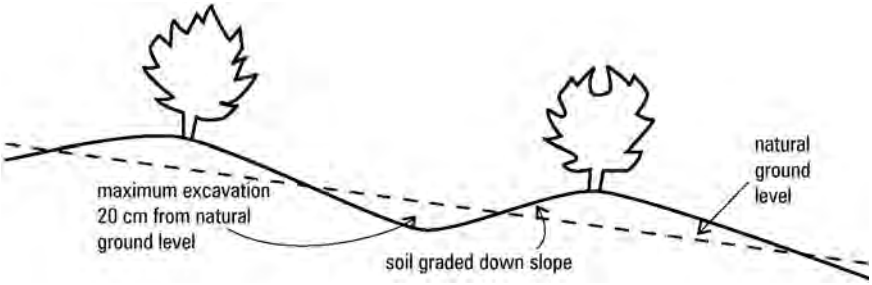


Figure 7. *V-drains for across slope rows (cross-section view)*

For rows up and down the slope, v-drains are constructed in every inter-row area to control side slope runoff and to prevent water scouring down the tree rows (Figure 8). Soil from the drain is moved both ways onto the proposed tree lines to form the mounds (Figure 9).

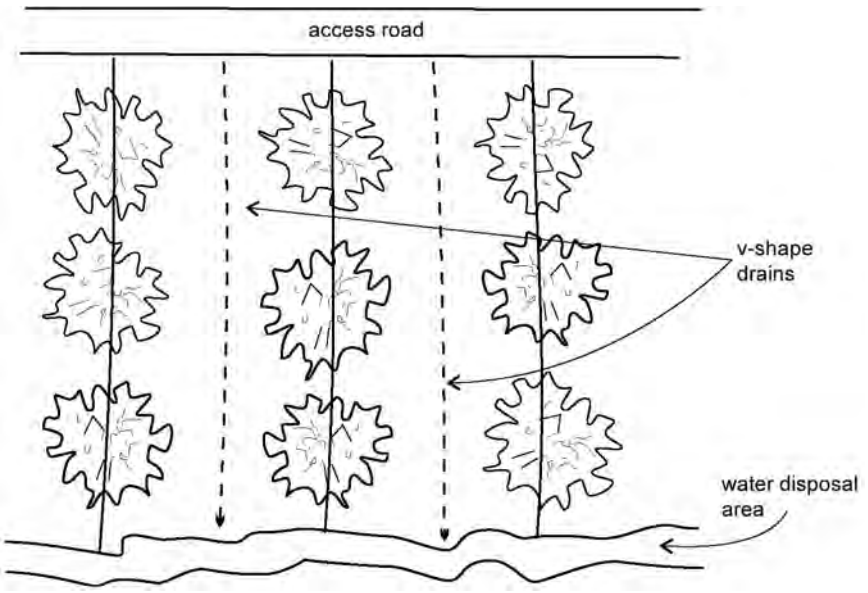


Figure 8. *V-drains for down slope rows (plan view)*

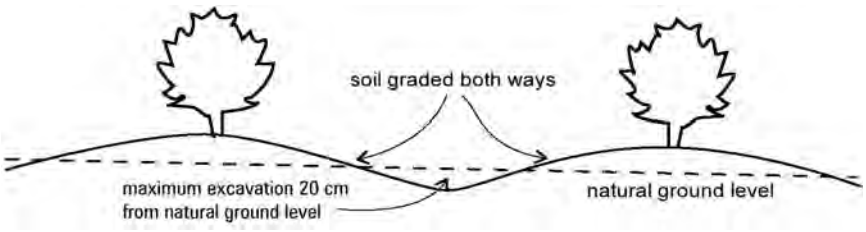


Figure 9. *V-drains for down slope rows (cross-section view)*

Immediately after building v-drains, grass all disturbed areas to minimise erosion. Carpet grass, couch and kikuyu are commonly used. These are cheapest and easiest to get established, but will persist only in the establishment phase when full sun is available to the inter-row area. Sweet smother grass is a better long-term alternative, and although more expensive to establish, has the advantage of persisting under the shady conditions that will eventually be present in the inter-row areas. An annual grass such as millet or oats may help to provide temporary protection to the drains while the selected creeping grass is getting established. A taller growing grass such as Rhodes grass can also be grown to provide a valuable source of grass mulch for under the trees. Avoid using green panic as its shade tolerance may lead to it becoming a later weed problem under the trees.

Do a soil analysis and apply required fertilisers

Do a soil analysis at least six months before planting. This allows plenty of time for required fertilisers to be applied and the soil conditioned ready for planting.

The preferred option is to hire a consultant with sound local knowledge of macadamia nutrition and the soil types in your area. This is because soil sampling, soil analysis interpretation and fertiliser selection are complex issues, requiring specialist skills. The consultant will come to the farm, collect the samples, arrange the analysis, interpret the results, and make recommendations fine-tuned to your particular farm situation. A less preferred option is to do the sampling yourself and rely on the analysing laboratory to interpret the results and make recommendations using computer models. In this case, buy a soil sampling kit from your local farm supply store, follow the sampling instructions and send the sample away for analysis. The results, an intrepretation and recommendations for fertiliser use should be returned in about two weeks.

Discuss your results with your consultant or local farm supply agent and work out what fertilisers are required. Where required, apply lime, dolomite, gypsum, phosphorus, copper and zinc fertilisers at least three months before planting. Preferably, apply fertiliser over the whole orchard site, but where cost is an issue, apply at least to the tree rows or tree sites. Any subsequent cultivation will help to thoroughly incorporate these materials into the

We do not recommend that you try to interpret the results yourself. However to help you understand what is involved, a broad guide to optimum soil nutrient levels together with some basic interpretation notes is on pages 112 to 114.

WARNING

The approaches to macadamia nutrition may vary considerably between consultants. Consequently, it is important that growers choose consultants carefully to ensure that the advice received is relevant, industry recognised and cost effective.

intended root zone. More soluble fertilisers such as nitrogen and potassium fertiliser can be applied closer to planting, to avoid leaching before planting. These may be applied to just the tree line or tree sites, but are best applied over the whole site to help with the growth of the inter-row ground cover.

Prepare the tree rows

Where the soil is loose and friable, move directly to the next step. Where it is compacted, cultivate a 1 to 2 m wide strip along the tree rows. As well as incorporating the fertiliser, cultivation along the tree rows aids tree establishment and reduces initial weed competition. Tined cultivation implements are preferred. Don't overuse a rotary hoe as it can lead to soil compaction and soil structural problems, as well as causing later settling of the tree row below ground level. This settling may cause subsequent soil erosion from water movement along the row. Minimise cultivation of other areas of the block to reduce soil erosion. Where possible, grow a green manure crop in the cultivated strips. This adds organic matter to the soil and provides protection against erosion. Use hybrid forage sorghum for spring or summer plantings, and oats in autumn or winter. A side dressing of urea two weeks after crop emergence will promote good growth. Slash when the green manure crop has reached peak growth and disc into the soil.

WARNING

Take care with marking out tree planting sites to ensure that all rows are perfectly straight. Out-of-line trees will later complicate mechanical harvesting and other orchard operations.

Mark out the tree planting sites

Mark out each tree planting site. If there is grass or weed cover, spray a metre square at each planting site or a band 1 to 2 m wide along the row with glyphosate herbicide at least one month before planting.

Install the irrigation system (where required)

As irrigation equipment is expensive and its design and operation will have long-term impact on production, we recommend that you use the services of a professional irrigation design consultant. The two most commonly used irrigation systems are:

Under-tree minisprinklers with a micro-spray or micro-jet feature. The micro-spray or micro-jet is used for the first two years and then upgraded to the minisprinkler to efficiently wet the root zone area as it expands. Use sprinklers with an output of about 70 L per hour. Use one sprinkler per tree. On wide spaced trees, a second sprinkler may be required for each tree from about the fifth year. Models that minimise ant colonisation are preferred. In the design of the irrigation system, remember to allow capacity for extra sprinklers to water the windbreak trees (where planted).

Under-tree minisprinkler

Dripper system showing the irrigation line with attached emitter running along the row

Good filtration is important for the successful operation of micro-sprays and mini-sprinklers.

Drippers or trickle tape. For drippers, suspend the irrigation line between the trees along the row, attaching two 7 to 8 L emitters per tree (one on each side of the trunk). For trickle tape, use one row of tape for young trees. When trees are about four years old, install a second row of tape on the other side of the tree row. Drip and trickle systems have some significant advantages over minisprinklers, but also one or two disadvantages. The advantages are that less water is used, it more efficiently wets the root zone depth, and is generally cheaper to install because of the use of smaller mainlines and laterals. The disadvantages are that the system needs to be well designed to operate effectively, requires more expensive high level filtration with sand filters, and must be properly maintained to prevent blockages.

Plant the trees

Nursery trees

When you take delivery of your trees, check that the trees have:

- dark green, well-formed foliage;
- no stem damage or trunk canker;
- a sound graft union (for trees that have been grafted);
- at least two growth flushes above the graft or bud;
- no pests such as felted coccid and latania scale;
- no infestations of serious weeds such as tropical chickweed;
- a well developed root system with a taproot that is not distorted;
- not become root-bound by being in the pots for too long.

NOTE
It is recommended that you visit the nursery prior to the delivery of your trees to check tree quality and pest status.

Also make sure the trees have been hardened to full sunlight.

When to plant

Unless there is a risk of frost damage, trees are best planted in the autumn. This takes advantage of the normally good soil moisture from the summer wet season. Where a site may be frost-susceptible, plant in spring. However, take care to monitor soil moisture closely through the normally hot and dry spring and early summer.

Avoid planting trees when conditions are windy or hot and dry, and during the hottest part of the day. Preferably, trees should not have active new growth (young tender leaves), as this growth is more susceptible to heat damage.

If trees have to be stored while awaiting more favourable planting conditions, hold trees in a well-protected and shaded area, preferably not in contact with soil (place on plastic sheeting or concrete). Maintain a careful watering program as trees can easily bake in the summer sun and die.

Planting procedure

One to two days before planting, water thoroughly to wet tree sites to a depth of 30 cm. Follow these planting steps.

1. Dig a hole slightly deeper and wider than the pot bag (see Figure 10). Backfill with some of the topsoil and firm down so that the surface of the potting mixture will be at the same level as the soil surface. It is best not to use posthole diggers or augers to dig the holes unless the sides of the hole are broken up to reduce any 'polishing' effects which may restrict later root growth. A small amount (100 to 150 g) of pelleted poultry manure or a teaspoon of slow release fertiliser can be added to the backfill soil in the hole. In krazozem soils, where pre-plant soil analysis endorses its use, a small amount of superphosphate (50 g per tree) may also be beneficial when added to the backfill soil. However, do not place inorganic nitrogenous fertiliser or raw manure into the hole, as these may burn the roots. Do not dig deep holes and fill with large amounts of topsoil to the required planting depth. This can cause the tree to sink as the soil settles.

NOTE
Where cuttings are being planted, plant them 7 to 10 cm deeper than grafted trees.

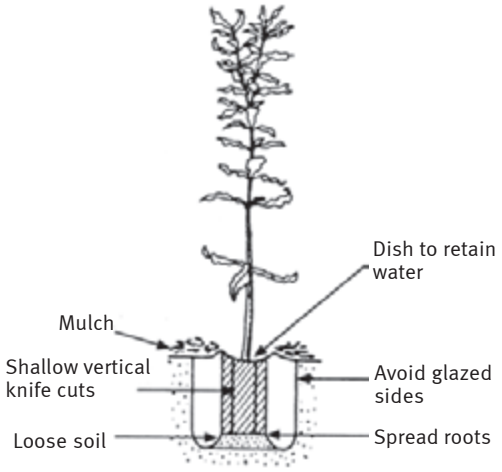


Figure 10. *A correctly planted tree*

2. Before planting, water the tree well.

3. Cut the pot bag from the tree and inspect the roots. If the roots are badly matted around the edge of the root ball, make shallow, vertical knife cuts through the matted roots at 3 or 4 points around the circumference. If the matting is less obvious, gently ruffle the edge of the root ball with the fingers to expose the potting mix. Straighten large roots at the bottom and prune off badly twisted roots.

4. Place the tree in the hole, ensuring that the roots at the bottom are spread. Face the graft or bud into the direction of the main prevailing wind. Half-fill the hole with soil, gently pressing the soil into contact with the root ball. Where practicable, fill the hole with water. This helps to bring the soil into close contact with the root ball. Allow water to drain before completing filling. Firm soil down gently with your hands (preferably do not use your feet) and leave a slight basin around trees to hold water. Water again.

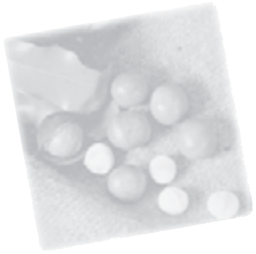
5. Mulch trees with a coarse mulch such as grass, cereal or legume stubble to a depth of 10 to 15 cm. Try to keep the mulch away from the trunk to reduce the risk of trunk canker.

6. Prune the tree to a central leader (if this has not already been done in the nursery).

7. Ensure any grafting tape is removed as soon as any constriction at the graft is noticed. This could be required several months after planting.

8. Do not allow the root ball to dry out after planting. Irrigate or hand water 2 to 3 times per week for the first few weeks, particularly where conditions are dry.

9. Paint exposed trunks immediately with white water-based paint to reduce the risk of sunburn and heat stress (if this has not already been done in the nursery). Mix copper hydroxide at 1 g/L with the paint to improve protection from trunk canker.
10. Where cuttings have been planted, stake them as per Figure 12 on page 38.



Managing young trees

During the first four years, the aim is to grow a strong, well structured tree that will produce well in future years. There are six important operations.

- Protecting trees from frost and other damage
- Fertilising
- Watering
- Training and pruning
- Weed control and mulching
- Pest and disease management

Protecting trees from frost and other damage

Where a site is susceptible to frost, loosely wrap the trunks of the young trees before winter to a point above the graft or bud union with builder's insulation foil, corrugated cardboard, newspaper or plastic sleeves. This will also protect the trunk from herbicide damage and animals such as hares. Make the wrapping a little tighter at the top to prevent cold air from entering. Strip off the leaves below the graft or bud union before wrapping (Figure 11). Remove the wrapping after the danger of frost has passed. Depending on the climate and location, wrapping may be required for up to three winters.

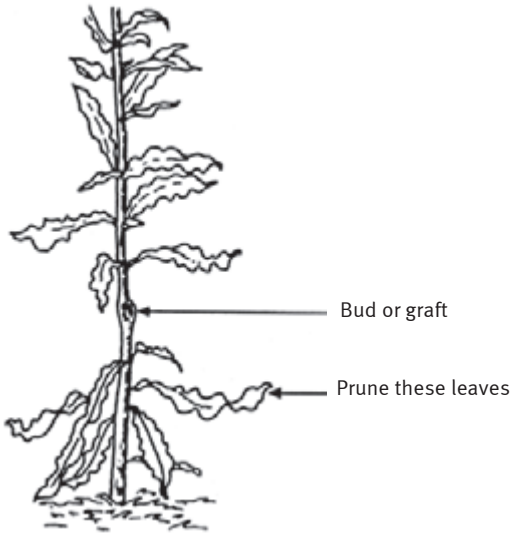


Figure 11. *Remove the leaves below the graft or bud*

Figure 12. *Staking of a blown over tree after straightening*

Individual tree guards are not recommended unless the orchard is highly exposed to wind and perimeter windbreaks are inadequate. Where used in these situations, they should be constructed of shadecloth on wooden stakes. Direct staking of the trees should only be used in emergencies, such as when trees are blown over. In these cases, straighten the trees before the soil dries out and secure to a stake driven in at an angle (Figure 12.) Staking is also recommended for trees grown from cuttings.

Fertilising

If the soil preparation recommendations from earlier in this chapter have been followed, no fertiliser will normally be needed for the first few months until trees start to put on new growth and this growth has hardened. Then, using soil analysis as a guide, apply small amounts at regular intervals (every eight weeks) during the growing season from spring to autumn. This is better than applying single large doses, which can easily kill young trees. It is also a better strategy on sandy soils, where leaching is more likely.

NOTE
Until trees are bearing, soil analysis is more useful than leaf analysis in monitoring tree nutrition.

As a general guide, apply about 50 g of a mixed fertiliser with an N:P:K of 15:4:11 per application per tree during the first two years, and about 70 g per application per tree during the third and fourth year. However, be guided by your soil analysis results. Application of lime or dolomite is not required if the soil pH is 5.0 or above (1:5 water test).

CAUTION
In young trees be cautious with fertiliser, particularly those with a high nitrogen content. It is easy to cause tree damage.

Where irrigation is available, fertigation is the best method of applying small amounts of fertiliser at regular intervals.

If applying solid fertilisers, keep them at least 20 cm away from the trunk to avoid trunk and root damage. Spread fertiliser evenly to a point 30 cm past the edge of the leaf canopy. Where irrigation is available, water in well after each application. If trees are slow to establish, apply small amounts of pelleted poultry manure in addition to the mixed fertiliser.

Watering

Do not allow the root ball to dry out after planting. Irrigate (or hand water where irrigation is not installed), for the first few weeks. Watering may be required up to two to three times per week in very hot weather.

Where irrigation is available, apply up to 40 L per tree per week during dry conditions in the first year. Use sprinklers in the microspray (or restricted) mode. After two years, convert the sprinklers to the minisprinkler mode to water as much of the root area as possible. By the fourth year, up to 150 L per tree per week may be required during hot dry spells.

See *Irrigation essentials* on page 122 for more information on tensiometers and capacitance probes.

Once trees are well established, use a soil moisture monitoring system to help calculate how often and how much to water. The main choices include tensiometers or capacitance probes.

Training and pruning

Training

Train trees to a central leader (a single dominant main trunk with smaller side branches). Keep the tip of the central leader at least 30 cm higher than the upper branches. A central leader system minimises breakage of limbs from strong winds and improves later machinery access, particularly for close plantings. Limb breakage is likely to be more of a problem in varieties with a spreading tree shape and dense foliage (for example HAES 246).

Pruning

Inspect the trees regularly during the first two years, particularly in summer and autumn when trees are actively flushing, and prune trees as follows:

1. Where a tree has produced a central leader without any branches below a height of 80 cm, prune off the top of the tree at 80 cm (Figure 13).

2. Where a tree has produced branches below about knee height, prune off these branches (Figure 14).

3. Examine the junction between branches and the main trunk or central leader, and remove any branches with a narrow crotch angle (more upright) where the bark is folded into the crotch (Figure 15). Where vigorous lateral branches are competing strongly with the central leader, pruning them back by about one-third will reduce the dominance and induce branching.

4. Where there are multiple lateral branches at any one node, remove all but the two or three strongest lateral branches, remembering to maintain the central leader as well. Where the tree terminates in a rosette of multiple shoots, none of which is a dominant central leader, follow the same principle, removing all but the two or three strongest lateral branches and the most upright branch to continue as the central leader (Figure 16). Where possible, retain branches facing the direction of the main prevailing winds (southeast in southern Queensland and northern New South Wales). However, remember that the tree needs to kept balanced with relatively symmetrical branch growth.

5. Remove any suckers at ground level and any shoots on the trunk below the graft or bud union (Figure 17).
6. To encourage the trunks of young trees to grow and thicken quickly, it is important to retain as much foliage as possible and avoid heavy, early pruning. Preferably, remove no more than 30% of the tree volume on any occasion. Too much pruning can significantly reduce the rate of tree growth.

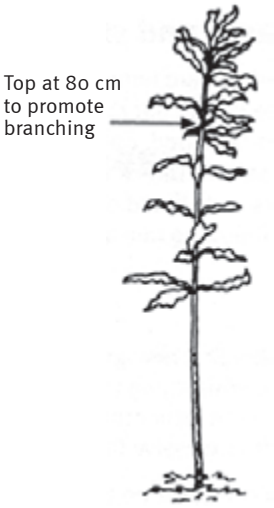


Figure 13. *Pruning action where there are no lateral branches below 80 cm*

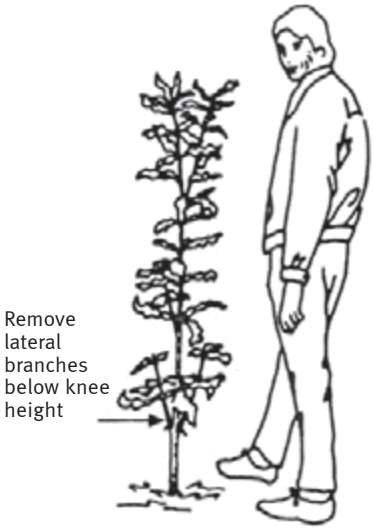


Figure 14. *Pruning action where lateral branches are too close to ground level*

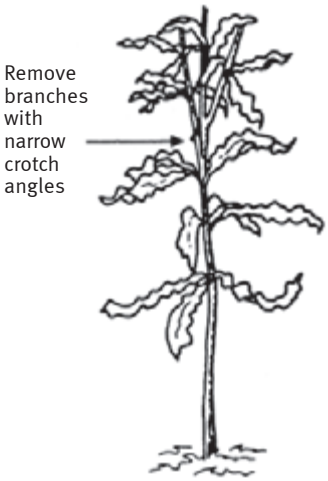


Figure 15. *Pruning action where there are branches with narrow crotch angles with the bark folded into the crotch*

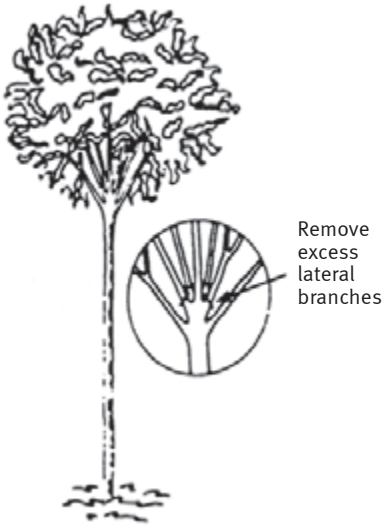


Figure 16. *Pruning action where there are multiple lateral branches at a node, none of which is a dominant leader*

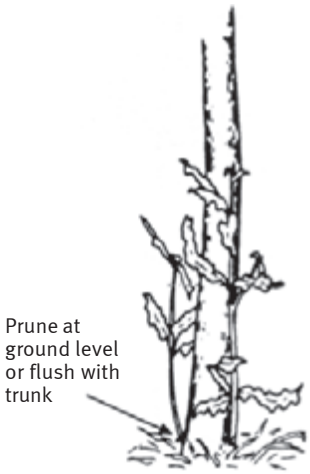
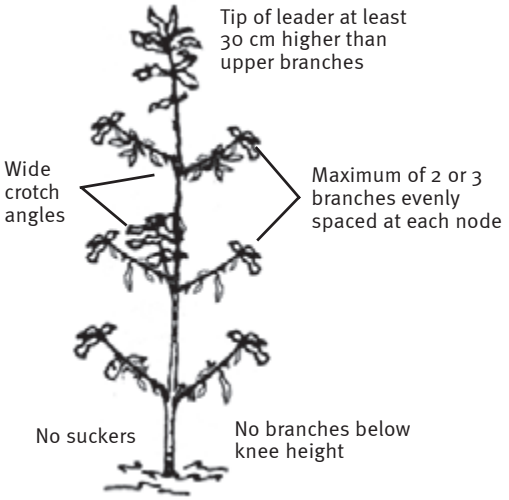


Figure 17. *Pruning action where there are suckers coming from below ground level or shoots on the rootstock*



Ideal shaped tree (composite of figures 13 to 17)

Weed control and mulching

Newly planted trees compete poorly with weeds for water and nutrients. Weed control within 50 cm of the trunk is vital.

Control weeds by maintaining a grassed inter-row area and mulching along the tree rows. Mulch not only minimises weeds – it also reduces soil moisture loss, maintains a more even soil temperature and improves the soil surface structure. Weeds that then grow through the mulch can be spot sprayed with herbicide.

The mulch can come from the grassed inter-row area by using a side delivery slasher or side delivery hay rake to divert the slashed grass along the tree rows. Fertilising the inter-row grass and letting it grow to about 15 to 20 cm high, ensures that a reasonable volume of mulch can be produced. On small orchards, mulch such as coarse straw and composted nut husk may be brought in and placed along the tree rows. The mulched area should extend to just beyond the edge of the leaf canopy.

WARNING
Before using any herbicides, carefully read the label and follow all instructions.

Herbicides suitable for spot spraying include paraquat, paraquat/diquat mixtures, glyphosate and glufosinate-ammonium (Basta®). Paraquat and paraquat/diquat mixtures are desiccant-type herbicides that kill only the green plant tissue that they contact. Consequently, these are generally suitable only for young 'soft' annual weeds such as potato weed and cobbler's pegs. Glyphosate and Basta®, on the other hand, are systemic herbicides that are absorbed by green plant tissue and translocated throughout the plant. This makes them effective against not only annual weeds but also a range of perennial weeds. It also makes them more dangerous as young trees can be killed by relatively low levels of absorption, particularly with glyphosate. For this reason, it is important that no herbicides (particularly glyphosate), are allowed to contact any part of the tree, including the green trunk.To guard against this, remove all leaves below the graft or bud union before spraying (see Figure 11), and use flat fan jet nozzles and a spray hood to reduce herbicide drift. High spray pressures will increase the potential for spray drift. Where used, the trunk wrappings for frost protection will double as protection against herbicide contact.

Do not cultivate within at least one metre of the edge of the leaf canopy. Don't use brushcutters because of the risk of damage to the trunk.

Pest and disease management

Pests

The major pests likely to cause problems in young trees are:

- macadamia felted coccid
- scale insects (mainly latania scale and long soft scale)
- macadamia twig-girdler
- macadamia leafminer
- redshouldered leaf beetle (monolepta beetle)
- hares and kangaroos/wallabies.

From planting, inspect trees regularly for these pests. Low levels of scale insects, twig-girdler and leafminer can be tolerated without spraying and will often be effectively controlled by beneficial insects. It is only if infestations become severe, that spraying is necessary. However, felted coccid and redshouldered leaf beetle are much more dangerous and if detected, spraying is generally required immediately. Pest management details are summarised in Table 7.

Table 7. Pest management for young trees

Pest	Management	Suggested chemical*	Withholding period (days)
Felted coccid	When detected, spray affected trees and trees in their immediate vicinity only. Avoid blanket or frequent use of the chemical, as natural enemies can be disrupted, causing a build-up of the pest. Oil sprays can be an effective 'soft' spraying option if targeted at the young crawler stages of the pest (registered in Queensland only).	methidathion or narrow range petroleum oil	21 1
Scale insects	Spray only when infestation becomes serious, as natural enemies will generally keep small outbreaks under control. When spraying is necessary, spray affected trees and trees in their immediate vicinity only. Avoid blanket or frequent use of the chemical, as beneficial insects can be disrupted, causing a build-up of the pest. Spraying is most effective when it is targeted at periods when the young crawler scales are moving to shoots and nuts. Oil sprays applied for felted coccid can be an effective 'soft' spraying option if targeted at the young crawler stages (registered in Queensland only).	methidathion	21
Twig-girdler	Spray only when more than 15% of terminal shoots are damaged. Natural enemies, unless disrupted by frequent spraying, are generally effective in keeping the infestation below this level. When spraying is necessary, spray affected trees only.	carbaryl or endosulfan	3 2
Leafminer	Spray only when more than 60% of terminal shoots are damaged. Natural enemies, unless disrupted by frequent spraying, are generally effective in keeping the infestation below this level. Spraying is generally unnecessary in summer as the higher temperatures keep the insect under control.	acephate or methidathion	Not specified 21
Redshouldered leaf beetle	When detected, spray trees with beetle swarms and trees in their immediate vicinity only. Be particularly vigilant after rain in spring and early summer.	carbaryl or endosulfan	3 2
Hares/kangaroos	Use the protective sleeves mentioned on page 37. Paint trunks with white plastic paint.	-	-

* For details of trade products and registration status, see the *Chemical handy guide for macadamia pests* (page 200). Note that not all of the chemicals listed are registered in all states. Check with the Australian Macadamia Society for registered chemicals and off-label permits.

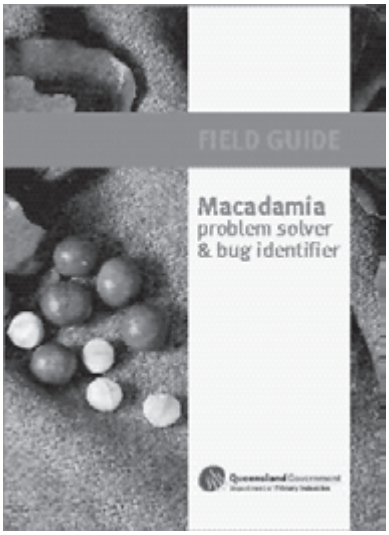
Diseases

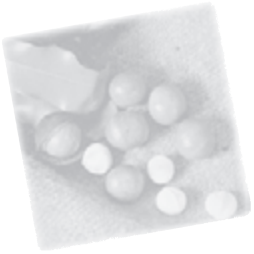
The only major disease of young trees is trunk canker.

Where cankers are small, pare back affected bark and wood with a sharp knife, and thoroughly soak trunks with a registered copper fungicide mixed with white, water-based paint. This helps to maintain contact with the fungicide and seals the wound. Where cankers are more extensive, and paring back affected bark and wood is impracticable, spray affected areas with metalaxyl and copper oxychloride. Alternatively, spray affected trees with phosphorous acid. Repeat the treatment two to three months later.

For details of trade products and registration status, see the *Chemical handy guide for macadamia diseases* (page 201). Note that not all of the chemicals listed are registered in all states.

Photographs of pests and diseases can be found in the *Macadamia problem solver and bug identifier field guide*.
Available from Department of Primary Industries & Fisheries, NSW Department of Primary Industries or the Australian Macadamia Society.





Managing bearing trees

Once trees begin to bear, the focus of management changes. Before bearing, the aim is to build a strong healthy tree. In bearing trees, the aim is to achieve maximum production of quality nuts, to keep vegetative growth in balance and to maintain a healthy root system.

There are eight important operations:

- Fertilising
- Watering
- Canopy management
- Weed control and mulching
- Management of pests, diseases, disorders and rats
- Pollination management
- Windbreak maintenance
- Fire protection

NOTE
Harvesting and post-harvest handling are covered in the next section of this chapter.

Quality management

With nut production commencing, quality management is now a vital issue. Quality management is about satisfying the needs of your customer (usually the processor), in terms of both food safety and nut quality. A quality management system needs to be in place to prevent potential hazards to food safety and quality from occurring. If a problem does occur, the system also must allow easy trace-back so measures can be taken to prevent them happening again.

See *Quality management* on page 76 for more information on quality management systems including an overview of the *Macadamia Industry Approved Supplier Program*.

Having a quality management system in place not only assists in the efficient operation of the orchard, but also maximises returns. The preferred quality management system for macadamias is the *Macadamia Industry Approved Supplier Program*. More information on the program can be obtained from the Australian Macadamia Society.

Record keeping

Maintaining records is an important part of quality management. Trends can be observed, performance fine-tuned and decisions made to prevent problems occurring. Records should include:

- a complete farm plan showing orchard layout, varieties, planting date and other important details;
- weather records, including rainfall, frost incidence etc;
- soil and leaf analysis results and recommendations and details of fertiliser applications;

- pest and disease monitoring records and recommendations and details of any pest and disease management measures including spray applications;
- equipment calibration records;
- harvesting and post-harvest handling records, including yields;
- quality test results of nuts delivered to processors;
- relevant financial transactions.

MacMan

MacMan is a special macadamia management system to monitor and improve orchard profitability and nut quality. It consists of:

- a simple, standardised recording system (both manual and computer versions are available);
- a benchmarking system that allows growers to confidentially compare their performance within their own operation and against other growers.

See *Record keeping and the MacMan software* on page 79 for more information. Also visit the MacMan website at www.dpi.qld.gov.au/macman

Fertilising

Once trees start to bear, base all fertiliser application on leaf and soil analysis, production and visual tree condition. Monitoring of leaf and soil nutrient levels is very important as it ensures that you apply the right amount of fertiliser to maintain optimum tree growth and nut quality. This maximises your profit as well as preventing potential environmental problems from excess fertiliser leaching into streams and groundwater.

Soil analysis provides a guide to the availability of nutrients in the soil and leaf analysis provides a guide to the uptake of nutrients by the tree. For bearing trees, it is best to do both leaf and soil analysis every year. A less preferred option is to do leaf analysis every year and soil analysis every second (or third) year.

As indicated in the soil preparation section earlier in this chapter, the preferred option is to hire a consultant with sound local knowledge of macadamia nutrition. The consultant will come to the farm, collect the samples, arrange the analysis, interpret the results, and make recommendations fine-tuned to your particular farm situation. A less preferred option is to do the sampling yourself and rely on the analysing laboratory to interpret the results and make recommendations using computer models. In this case, buy soil and leaf sampling kits from your local farm supply store, follow the sampling instructions and send the samples away for analysis. The results, an interpretation and recommendations for fertiliser use should be returned in about two weeks. Some brief guidelines for sampling and managing fertiliser use, based on a number of years of research by the industry, are contained on the next page.

WARNING

The approaches to macadamia nutrition may vary considerably between consultants. Consequently, it is important that growers choose consultants carefully to ensure that the advice received is relevant, industry recognised and cost effective.

NOTE

We do not recommend that you try to interpret the results yourself. However, *Understanding leaf and soil analysis* on pages 112 to 115 may help you understand what is involved.

Figure 18. *Leaves to sample for leaf analysis*

Leaf analysis

Sample leaves in the September to November period. This is when leaf nutrient levels, particularly for the major elements such as nitrogen, are most stable. Sample mature leaves from the second whorl of non-flushing terminals (Figure 18).

Sample each variety separately, preferably from trees of a similar age. Sample healthy trees only. Avoid sampling the outside rows of blocks, or trees at the end of rows. Sample leaves on the outside of the canopy exposed to the sun. Mark the trees sampled or record their position for future reference.

Note that these recommendations apply to analysis by the dried leaf tissue technique. Sap or petiole analysis techniques have not been assessed sufficiently to be recommended.

Soil analysis

Soil analysis is used primarily to monitor and adjust soil pH, organic carbon (organic matter), and the relative levels of the cation elements (calcium, magnesium, potassium, sodium and aluminium) as a proportion of the total cation exchange capacity or CEC. It is also useful in monitoring soil phosphorus and trace elements. Soil analysis can be done at any time of the year but preferably not within three months of previous fertiliser application. For convenience, it is often done at the same time as leaf analysis.

Take soil samples from under the tree canopy, within the wetted area of the sprinkler (where irrigation is installed), and at least 30 cm from the trunk (Figure 19). Sample from the 0 to 15 cm deep band, and if possible, take a separate sample from the 15 to 30 cm deep band. Follow the instructions of the sampling kit carefully, particularly those relating to the number and location of sub-samples. This is essential to ensure the sample is representative of the block. Where possible, avoid taking samples from locations where bands of fertiliser have been previously applied.

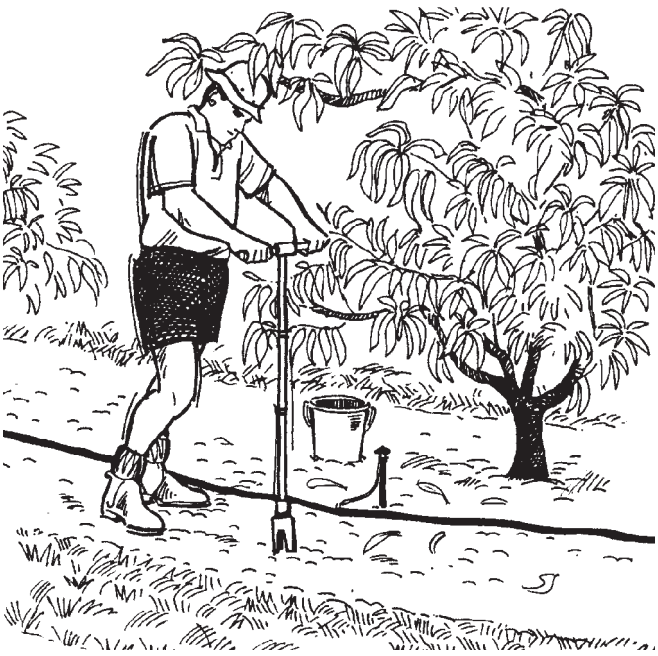


Figure 19. *Soil sampling*

Fertiliser rates

Interpretation of leaf and soil analysis results is made by comparing the sample results with optimum leaf and soil nutrient levels derived from research over a number of years. Fertiliser rates are then calculated to bring or maintain nutrient levels within these optimum ranges.

To emphasise the importance of leaf and soil analysis, and customising fertiliser use to your real

needs, 'standard' fertiliser rates are no longer provided. However, the following notes will help you to understand some of the important issues in interpreting leaf and soil analysis results.

In a typical well-managed orchard with reasonably fertile soil, nitrogen, potassium and boron are likely to be the only nutrients that need to be added each year. Phosphorus is also likely to be required in phosphorus-fixing soils such as red krasnozems and red earths, and in soils with historically low phosphorus levels, such as those in much of southwest Western Australia. Zinc may require adjustment every two years and calcium and magnesium every two to three years. Organic carbon levels need to be maintained by regular addition of organic matter. Other nutrients generally require little or no adjustment for long periods.

See *Nutrition management* on page 103 for more information on individual nutrients and fertiliser management using the nutrient replacement concept.

- **Nitrogen**. Once recommended soil and leaf levels have been achieved, maintenance rates are approximately 75 g of nitrogen per tree per year (five year old trees) and 200 g of nitrogen per tree per year (mature trees at a density of 312 trees/ha). **Note that these figures are for elemental nitrogen, not nitrogen fertiliser**, and are based on replacement of nutrients removed by the crop plus an allowance for leaching and other losses.

- **Potassium**. Once recommended soil and leaf levels have been achieved, maintenance rates are approximately 50 g of potassium per tree per year (five year old trees) and up to 150 g of potassium per tree per year (mature trees at a density of 312 trees/ha). **Note that these figures are for elemental potassium, not potassium fertiliser**, and are based on replacement of nutrients removed by the crop plus an allowance for leaching and other losses.

- **Calcium, magnesium and pH**. Where soil pH is lower than 5.0 (1:5 water test) and calcium levels are low, apply fine lime (98 to 100% fines) at a rate of up to 2.5 t/ha (light sandy soils) and a rate of up to 5 t/ha (heavier soils). Where soil pH is satisfactory and calcium levels are low, apply gypsum at a rate of 1 to 2 t/ha. Where soil pH is lower than 5.0 (1:5 water test) and magnesium levels are low, apply dolomite at a rate of up to 2.5 t/ha (light sandy soils) and a rate of up to 5 t/ha (heavier soils). Where soil pH is satisfactory and magnesium levels are low, apply magnesium oxide at a rate of up to 200 kg/ha.

- **Boron**. Where leaf and soil boron levels are low, apply up to four foliar sprays of Solubor at a rate of 1 g/L between September and March. In addition, where leaf boron levels are below 40 ppm, apply borax or Solubor to the ground under the trees. Apply at a rate of 3 g of borax or 1.5 g of Solubor per square metre of ground surface. Because boron can be toxic if not applied very evenly, it is best to either mix the required amount of borax or Solubor in water and spray onto the ground under the trees. Alternatively, where minisprinklers with an even water spread of

NOTE
Boron can also be applied incorporated into an N:P:K fertiliser mix, for example, North Coast Macadamia Mix®

5 m diameter are being used, it can be applied via fertigation. Do not apply through trickle or drip systems.

- **Zinc**. Where leaf and soil zinc levels are low, the response depends on the soil type. For red krasnozem soils, where zinc uptake is restricted, apply a foliar spray of zinc sulphate heptahydrate at a rate of 15 kg plus 1 kg of urea/1000 L/ha of water (1.5% solution) to the summer growth flush. If deficiency is severe, re-apply to the winter/spring growth flush and developing nuts. For all other soil types, apply zinc sulphate monohydrate at a rate of 3 g per square metre of canopy cover. Apply in a band 30 cm wide around the dripline (edge of leaf canopy) as shown in Figure 20.

Figure 20. Banding of zinc around the dripline of the tree

- **Organic carbon**. Where organic carbon levels are less than 2%, apply organic materials (for example composted nut husk) to the ground under the trees. However, addition of any organic material needs to be managed so that it does not interfere with mechanical harvesting. See *Orchard floor management* on page 166 for precautions.

Fertiliser timing

Timing of fertiliser application is as important as calculating the correct rate. Recommended timings for each nutrient are shown in Table 8.

NOTE
Some nitrogen fertilisers are volatile and lose nitrogen to the atmosphere. Consequently it is important that nitrogen fertilisers be applied just before or during rain, or irrigated into the soil (where irrigation is available).

Table 8. Recommended timings for fertiliser

Nutrient	Recommended timing
Nitrogen	Split into as many applications as practicable throughout the year. Avoid applying all or nearly all of the nitrogen during summer. As nitrogen is easily leached from the soil, additional small applications may be necessary after heavy rain.
Phosphorus	Apply just before the summer wet season. As phosphorus moves slowly through the soil profile, the normally heavy summer rains help with this process.
Potassium	Split into as many applications as practicable during nut growth (September to December in southeast Queensland).
Calcium	Apply just before the summer wet season. As calcium moves slowly through the soil profile, the normally heavy summer rains help with this process.
Magnesium	Often applied in conjunction with calcium, so apply just before the summer wet season.
Boron	Apply foliar sprays between September to December and soil dressings during autumn (March to May).
Zinc	Apply foliar spray to the summer leaf flush. If deficiency is severe, re-apply to spring leaf flush. If applying to the soil, apply just before the summer wet season.

Fertiliser choice

In selecting fertilisers, there are three main issues to consider:

- **Inorganic or organic fertilisers**. While organic fertilisers have certain desirable features, inorganic fertilisers are preferred as the main nutrient source for bearing trees. This is because they are of known nutrient content and produce a more predictable response. Organic fertilisers have the advantage of improving the physical and biological characteristics of the soil, but the nutrient content is low and variable, and the release of nutrients, particularly nitrogen, is generally slow and unpredictable. This means that nutrient release may occur at the wrong stage of the growth cycle. They are also generally low in potassium. The main organic materials used are poultry manure (broiler litter or pelleted) and macadamia nut husks. Pelleted poultry manure (sold in bags like inorganic fertiliser) can be applied at any time. However, other forms of poultry manure and macadamia nut husks that have been stored in heaps must either be first composted or applied ONLY after harvesting has been completed and not within four months of the next harvest. This reduces the risk of microbial contamination of the nuts.

  Composting is a process of 'cooking' the organic material to obtain partial decomposition and involves storing the material in heaps for at least three months with regular turning, addition of water and monitoring of temperature. Keep organic materials at least 20 cm from the tree trunk. The nutrient content of some inorganic and organic fertilisers is shown in Table 9.

See *On-farm composting* on page 169 for more information

- **Straight or mixed inorganic fertilisers.** Straight fertilisers (those containing one main nutrient) are preferred as they enable application rates to be adjusted individually for each nutrient. They are also generally cheaper per unit of nutrient. Mixed fertilisers (sometimes called 'complete' fertilisers), are more convenient to use, but may cause a nutrient imbalance by oversupplying or undersupplying particular nutrients. Most fertiliser companies will now specifically blend fertilisers to meet your particular requirements. The nutrient content of commonly used straight fertilisers is shown in Table 9.

- **Foliar fertilisers.** Foliar nutrient sprays are generally not recommended in macadamias, as uptake, particularly for the main nutrients, may be insufficient to meet the needs of the tree. The exception is the foliar sprays of the trace elements boron and zinc. In these cases, as only trace amounts are required, the small amount of uptake is generally sufficient to meet needs. However, as zinc and boron are not very mobile within the tree, absorption only occurs in the tissues contacted with the foliar sprays.

Table 9. Nutrient content of common fertilisers

Fertiliser	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)	Calcium (%)	Magnesium (%)
Straight inorganic fertilisers						
Urea	46					
Sulphate of ammonia	20			24		
DAP	19	20		3		
Single superphosphate		8.8		11	20	
Muriate of potash			50			
Sulphate of potash			41	16.5		
Lime					35–40	
Dolomite					12–22	8–12
Gypsum				14–18	19–22	
Organic fertilisers						
Pelleted poultry manure	3–3.6	1.6–3.6	1–1.6			
Broiler litter poultry manure	1.4–1.5	0.6–2.4	0.6–1.9			
Mixed inorganic fertilisers (only a few shown as examples)						
Crop King 77S®	13	2	13	19		
Crop King 88®	15	4	11	14		
Fertica®*	12	7	13	13	4	1
Nitrophoska Blue®*	12	5	14	4	5	1
North Coast Macadamia Mix®	14	4	11	11		

* also contain trace elements

Fertiliser placement

In mature trees, roots generally extend into the middle of the inter-row. Where using fertilisers in the solid form, spread the fertiliser evenly under the canopy and outside the edge of the leaf canopy for a distance of one metre. Apply before or during rain or water in well (where irrigation is available).

Where irrigation is installed, fertigation (application of fertiliser through the irrigation water) is recommended. Fertigation has the advantages of saving labour, more efficient nutrient uptake, and enabling fertiliser to be applied more regularly and conveniently. However, remember that the evenness of fertiliser application is only as good as the evenness of water distribution.

See *Fertigation* on page 118 for more information.

Watering

Where irrigation is installed, ensure that water stress is avoided from flowering to nut maturity. During this period, rainfall is usually low and evaporation high. Note that the most critical time is during the oil accumulation stage (December to February in southeast Queensland).

To determine exactly when to water during this period, and how much to apply, continue to use the soil moisture monitoring devices such as tensiometers and capacitance probes recommended earlier for young trees.

See *Irrigation management* on page 120 for more information on irrigation.

Where these are not used, a guide to irrigation rates for bearing trees is shown in Table 10. **Remember that the figures are a guide only, as soils vary widely and rainfall is ignored.** Also note that as sandy soils hold less water than clay soils, these require a higher frequency of irrigation with less water being applied per irrigation.

Table 10. Indicative irrigation rates (litres per tree per week) based on a spacing of 8 x 4 m or 312 trees/ha

Month	Trees with 3 m wide canopy	Trees with 4 m wide canopy
December/January	200	365
February	165	300
March	145	260
April	100	170
May/June/July	65	115
August	115	210
September	140	260
October	170	300
November	190	350

Canopy management

There are three main canopy management operations:

1. **Skirting** the trees for ease of access for harvesting, slashing, weed control and fertiliser spreading. It is usually required from about the fourth year and is done with hand-held equipment such as chainsaws or with tractor mounted hydraulic saws after harvesting is completed. Cut off limbs flush with the trunk. Use hand held equipment to remove sharp stubs left following the use of hydraulic saws. Skirt trees to leave a clearance of approximately 1 m at the trunk and 1.5 m at the edge of the leaf canopy. A suggested shape is shown in Figure 21.
2. **Trimming** the sides of the trees along the inter-row (hedging) to maintain machinery access, to increase light and spray penetration, and to reduce the risk of fungal diseases. This is particularly necessary with close-planted trees.

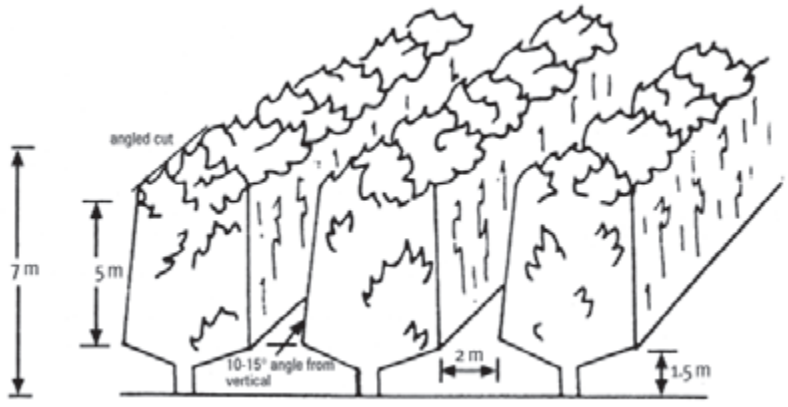
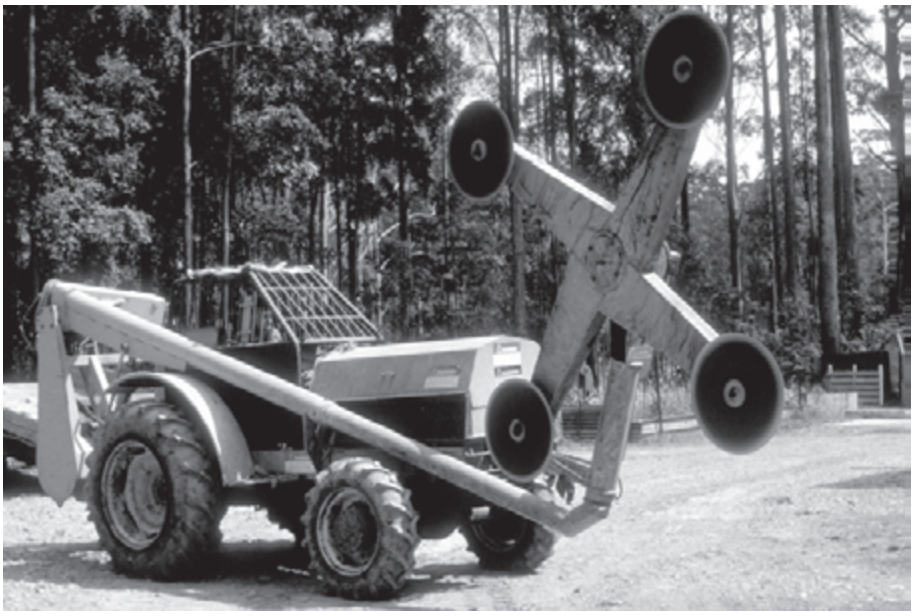


Figure 21. *Suggested tree shape*

With side trimming, the aim is to achieve a continuous hedgerow of foliage at a slight tapered angle from bottom to top and a 2 m wide machinery access corridor between the rows (Figure 21). Avoid heavy side trimming (removal of one metre or more of foliage), as this results in vigorous regrowth that limits light and spray penetration to the inside of the canopy. Best results have been



A mechanical pruning saw used for side trimming

See *Canopy management* on page 160 for more information on the principles of canopy management.

obtained when a regular light pruning program has been followed. It is important to commence this light pruning program well before machinery access is impeded. This prevents the likelihood of being forced to carry out a heavy pruning.

The most practical time to prune is after the end of harvesting and before flowering. Avoid pruning in summer as this may result in foliage scorching. Mulch or remove trimmings from the orchard as they interfere with harvesting. For best results, mulch before the trimmings dry out and become springy. Again, mechanical pruning often leaves sharp stubs that can be a hazard to orchard workers. Where possible, use hand-held equipment to remove these.

3. **Heading** (topping) the trees to a height of approximately 7 m from the ground. This is done at the same time as side trimming. Angle the cut from a point on the edge of the canopy approximately 6 m from the ground as shown in Figure 21. From time to time, removal of a major branch in the centre northern part of the tree will improve light penetration to the lower part of the canopy.

A pruned orchard

Weed control and mulching

There are two options for weed control and mulching:

1. **Maintaining a grassed inter-row area with the area under the trees being kept weed-free with mulch and herbicides**. As the trees grow out to progressively shade the inter-row area, the grassed area progressively decreases to a maximum of about 2 m wide, provided trees are side-trimmed to allow light interception. Apply mulch to the remainder of the under-tree area.

   The choice of mulch is important. Coarse mulch can interfere with mechanical harvesting and needs to be managed so that a minimum of coarse material remains on the soil surface at the time of nut drop. Also, it is essential that any mulch be well broken down before using finger wheel harvesting equipment. Flailing the mulch before harvest minimises the above problems.

   Apply new mulch after harvesting is completed. If possible, sweep back under the trees any organic matter or fine soil moved during mechanical harvesting, before the mulch is applied. A mulch layer up to 5 cm thick is ideal. Sources of mulch include grass slashings from the inter-row area, fallen leaves and composted macadamia nut husks.

   Control any weeds that grow through the mulch with the herbicides glyphosate, paraquat, paraquat/diquat or glufosinate-ammonium (Basta®). Apply when the weeds are actively growing. Take care to prevent contact with low hanging branches.

   Skirting the trees as recommended in the previous step *Canopy management* will assist with this. Avoid spraying herbicides on fallen mature nuts. If spraying is required during the harvest season, spray immediately after nut pickup.

2. **Growing a permanent, living, shade-tolerant ground cover in the inter-row and under-tree areas.** The recommended species is sweet smother grass, which has been proven effective in trials in commercial orchards in the cooler, wetter areas of southern Queensland and northern NSW. Its performance in hotter, drier areas is still unknown. Establishment is by runners or turf. To ensure a suitable orchard floor surface for harvesting, the grass needs to be mown regularly (every two to three weeks) during the harvest season. For good growth, it also requires an adequate moisture supply through rainfall or irrigation.

See *Weed control and mulching* on page 41 for more information on precautions to take when using herbicides.

See *Orchard floor management* on page 166 for more information on these options.

Pest and disease management

Insect pests

Photos of the pests can be found in the companion field guide, *Macadamia problem solver and bug identifier.*

In bearing trees, the major insect pests are flower caterpillar, spotting bugs and nutborer. In southeast Queensland, flower caterpillar is mainly a problem during the flowering period from July to September. Fruitspotting bugs are mainly a problem in the young nut stages from about October to December while nutborer is mainly a problem in developing nuts from about December to February.

See *Pest and disease management* on page 130 for more information on IPM, pest monitoring and pest management.

An integrated pest management (IPM) approach is recommended. This combines all available forms of pest management (including biological, cultural, physical and chemical) to manage pest populations safely in an economically and environmentally acceptable way. Insecticides are only used when it is shown that they are necessary to keep pests below economically damaging levels—known as action levels. The process of checking the crop to determine when pests are present and at what level is called pest monitoring. By minimising chemical use to situations where it is only absolutely necessary, minimal disruption to natural enemies of the pests is caused.

Pest monitoring

See *Consultants and contract services* on page 187.

Monitor pest populations fortnightly from flowering to nut maturity. Spray only when action levels are reached. Monitoring requires skill in observing and identifying pests and beneficial insects. For this reason, we recommend the use of professional pest monitoring consultants.

Details of action levels for the major pests and appropriate chemicals to use when these levels are reached are shown in Table 11.

Table 11. Action levels and chemicals for major macadamia pests

Pest	Suggested action level	Preferred chemicals*	Withholding period (days)	Comments
Flower caterpillar	30–90% of racemes infested (percentage depends on time of season)	endosulfan Bt (k) tebufenozide	2 0 28	
Spotting bugs	4% of nuts damaged	endosulfan beta-cyfluthrin	2 7	Do not use beta-cyfluthrin more than twice in any season
Nutborer	1–3% of nuts with live eggs (percentage depends on stage of nut development and variety)	azinphos-methyl beta-cyfluthrin tebufenozide	7 7 28	Do not use beta-cyfluthrin more than twice in any season

* Trade names for registered products are contained in the *Chemical handy guide for macadamia pests* on page 200. Note that not all of the chemicals listed are registered in all states. Check with the Australian Macadamia Society for registered chemicals and off-label permits.

Professional pest monitoring consultants will often vary these action levels depending on factors such as the history of pest activity in a particular orchard.

Note: a range of other pests may infest bearing macadamias. These include flower thrips, felted coccid, latania scale, leafminer, twig-girdler and redshouldered leaf beetle. However, these generally require only sporadic treatment.

Diseases

See *Pest and disease management* on page 130 for more information on major diseases.

In bearing trees, the major diseases are blossom blight, husk spot and trunk canker. Blossom blight is mainly a problem in New South Wales during prolonged wet weather in winter and early spring. Husk spot causes premature nut drop close to maturity. Infection of nuts may occur during moist weather conditions from nut set to maturity but early spring infections are responsible for most of the premature nut drop.

Photos of these diseases and treatments can be found in the companion field guide, *Macadamia problem solver and bug identifier.*

Trunk canker is mainly a problem in wetter areas of the orchard where water has ponded around the base of trees or where trunks have been damaged. Details of management for the major diseases are shown in Table 12.

Note: a range of other diseases may affect bearing macadamias. These include husk rot, branch dieback and Armillaria root rot. However, these generally require only sporadic treatment.

Table 12. Control measures for major macadamia diseases

Pest	When to act	Preferred chemicals*	Withholding period	Comments
Blossom blight	When monitored flowers in cooler damper areas of the orchard show symptoms.	iprodione	Nil	No benefit in spraying after flowering has peaked and nutlets have formed.
Husk spot	If disease was present in the orchard in the previous season. Monitor nuts during the early to mid season nut fall to determine disease presence and the requirement for sprays in the next crop.	copper oxychloride and/or carbendazim	1 day 14 days	If using copper oxychloride, spray every 3 to 4 weeks from nut set to December. If using carbendazim, spray at 5 weeks and at 8 weeks after main flowering. Spraying must be preventative – it is ineffective once symptoms are seen.
Trunk canker	When detected	metalaxyl + copper oxychloride or phosphorous acid	28 days Not applicable	Drench to lower trunk and soil around base of tree. Foliar spray

*Trade names for registered products are contained in the *Chemical handy guide for macadamia diseases* on page 201. Note that not all of the chemicals listed are registered in all states. Check with the Australian Macadamia Society for registered chemicals and off-label permits.

Spray application

See *Chemical handy guides* on page 199 for a complete list of registered chemicals.

Apply only chemicals registered for macadamias. Read the label carefully and use the product as directed, observing withholding periods

Always wear the recommended safety equipment and protective clothing as detailed on the label. Store all pesticides safely and securely. Ensure there is no spray drift onto neighbouring properties. Before disposing of containers, rinse them three times and add the rinsing water to the spray tank.

See *Pesticide application and safety* on page 150 for details on spray application, spray equipment and safety. Note that the macadamia industry has a code of practice for the control of spray drift and use of chemicals. See page 197 for details.

Most of the pesticides used in macadamias are applied as sprays. Airblast sprayers are the most common type of spray equipment used. Spray equipment needs to be well maintained and regularly calibrated. Sufficient spray volume also needs to be applied to ensure effective coverage.

Disorders

Tree decline

Photos of tree decline can be found in the companion field guide, *Macadamia problem solver and bug identifier.*

Tree decline is a disorder believed to be caused by a combination of factors that lead to a run-down in tree health. These include nutrient deficiencies, low soil organic matter levels, soil erosion exposing surface roots to desiccation, root death in shallow marginal soils, drought and large crop loads.

Treatment involves pruning affected trees to generate new growth. Once new leaf growth has occurred, apply a general foliar fertiliser at regular intervals. Apply a layer of mulch (5 cm thick) to the soil surface up to and just outside the edge of the canopy to help encourage new root growth. Try to keep the mulch away from the trunk to reduce the risk of trunk canker. However, even with this treatment, recovery is often slow.

Sound cultural practices that sustain soil structure and fertility and provide an environment for healthy root development are important in reducing the risk of decline. These include:

- Maintaining appropriate levels of soil nutrients by using regular soil and leaf analysis.
- Regular application of mulch to the root zone, particularly where soil erosion or mechanical harvesting has exposed surface roots. Consider the use of a perennial 'living mulch' such as sweet smother grass.
- Control of water flow within the orchard to prevent water flowing down the tree rows and causing soil erosion.
- Prompt treatment of insect and disease problems.
- Regular light pruning to encourage vigorous new growth.
- Avoiding planting macadamias in shallow marginal soils where root growth is reduced by waterlogging. Mounding may help in reducing waterlogging.

A HAES 344 tree affected by AVG (right) compared to a normal HAES 344 tree (left)

Abnormal vertical growth (AVG) disorder

The cause of this disorder is not yet known. Symptoms include unnaturally upright branch growth and a reduction in flowering, leading to yield reduction.

The disorder has been confirmed in drier production areas of Queensland (coastal districts north of Gympie and on the Atherton Tableland) and New South Wales (west of Lismore). It is frequently found on deep well-drained red soils. While a number of HAES varieties have shown symptoms, HAES 344 appears to be the most susceptible.

While research into the problem is in its infancy, current knowledge suggests the following precautions:

- Before planting in drier productions areas, obtain an assessment of soil condition from a qualified consultant to determine and correct any factors likely to limit water infiltration, water retention and root growth.
- Obtain qualified advice on design and installation of irrigation systems.
- Consider planting varieties such as HV A4 and HV A16 (where these are appropriate for your district).
- In existing orchards, maintain optimum soil conditions for healthy root growth (organic matter, mulching, moisture, nutrition).

Rats

Rats may cause significant losses, particularly in older orchards. The rats attack nuts in the tree, gnawing holes about 1 cm in diameter through the shell and eating the kernel.

Rat damage to nuts

Rat management begins well before nuts develop and involves a strategic and integrated program of measures. Note that baiting alone is ineffective. The measures include:

- Remove any harbourage for rats within or close to the orchard. These include any bana grass windbreaks, as these are a haven for rats.
- Rat numbers increase if they have access to a ready supply of suitable food. Ensure no nuts are left on the ground after harvesting is completed to reduce the food source and discourage a buildup of the rat population.
- Avoid dumping nut waste from grading and sorting in and around the orchard. Burn or hammer mill nut waste to ensure it breaks down quickly.
- Avoid long, tangled grass within the orchard and headlands. Keep the grass short and where possible, maintain a clear mown area of up to 20 m wide around the perimeter of the orchard. This deters rats from entering the orchard, as they tend to avoid open areas. It also helps predators such as owls and hawks to hunt the rats. Providing nesting boxes can encourage owls to nest in and around the orchard.
- Regularly remove rat nests from trees.
- Flooding of burrows, netting and fox terrier dogs have been successfully used by some growers to temporarily reduce rat populations.
- Bait with the registered rodenticide coumatetralyl (Racumin®). Handle baits with care and follow the label directions. Place the bait in a covered and locked station fixed to the ground to prevent all access to the baits by children. Covering and fixing also prevents accidental access by domestic animals and non-target wildlife. The cover also protects the bait from the sun and rain. Rats prefer the seclusion of covered bait stations. A typical bait station can be constructed using a car tyre with a sheet of corrugated iron covering the top, wired to the tyre on either side and fixed to the ground with a stake (Figure 22).

NOTE

Racumim® can be used within the orchard and in and around farm buildings. Other rat baits are registered for use in and around farm buildings and can be used if rats are a problem in that situation. However, these cannot be used within the orchard.

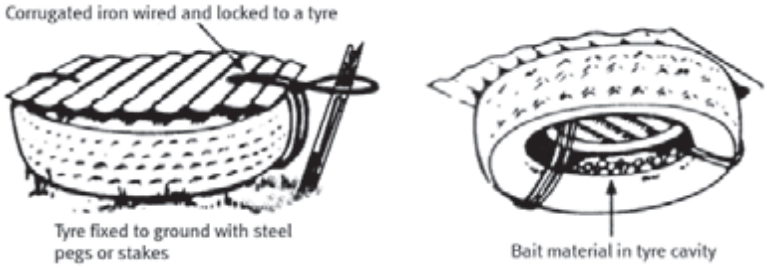


Figure 22. *Car tyre bait station for rat control in macadamia orchards*

Pollination management

The presence of honeybees and native bees in the orchard is beneficial in improving nut set. Introduce bee hives during early flowering. Contact a local apiarist for hire rates. Negotiation with an apiarist may be necessary 6 to 12 months prior to intended introduction. Advise the apiarist before any insecticide sprays are used so arrangements can be made to protect the bees.

Stock the orchard at the start of flowering with 2 to 3 strong double hives per hectare. As honey bees usually travel about 200 m in macadamia orchards, place the hives 200 m inside the perimeter in groups about 400 m apart. Use a moderately shady location. Ensure the bees do not have to fly past other flowering crops such as citrus.

Windbreak maintenance

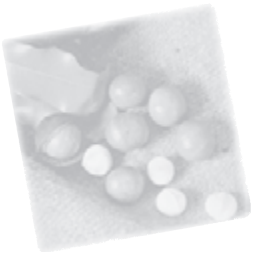
As the roots of some windbreak trees can extend for up to 50 m from the trunk, deep rip at least every second year between the perimeter windbreak trees and the macadamia trees to reduce competition for water and nutrients. Rip lines should be at least two metres from the edge of the macadamia canopy. If spreading foliage is reducing access to the macadamia trees, side trim the windbreak trees with orchard pruning equipment.

Fire protection

Maintain an effective firebreak around the orchard. During periods of high risk, keep headlands and inter-row areas mown, and keep dry mulch such as nut husk or straw away from the trunks of trees. During periods of high fire risk, have some form of fire-fighting equipment such as a mobile water tank and pump available for immediate use.

CROP PRODUCTION HANDY GUIDE

A calendar guide to all key orchard operations is provided in the ***Crop production handy guide*** on page 203.



Harvesting and marketing

Having put major effort into getting top quality nuts to maturity, the aim is to then maintain that quality through the harvesting and marketing process. Individual orchard profitability will increasingly be based on nut quality, with prices paid by processors adjusted for kernel recovery, and the level of unsound kernel.

There are four main steps:

- Preparation for harvest
- Harvesting
- Postharvest handling
- Consignment to processors

Preparation for harvest

Before nut drop, the orchard floor needs to be prepared to make harvesting efficient and to reduce the amount of material that might contaminate harvested nuts.

Mechanical harvesting requires special treatment with the need to prepare an even soil surface to maximise the pick up of nuts and minimise any nut carryover to the following harvest. During spring, level the soil surface beneath the trees, fill any holes, remove exposed stones, and clear drains. Machines are available to assist in profiling the soil surface under the trees. Remember that an alternative is a living, shade tolerant ground cover such as sweet smother grass. This has the benefits of reducing soil erosion, mulching the soil surface, and facilitating the earlier use of mechanical harvesters after wet weather. This also helps to develop a healthy root system by minimising root disturbance and the loss of soil and soil nutrients through erosion. Sweet smother grass requires regular mowing during the harvest season to minimise the number of nuts left behind during each harvesting round. Ground covers may require specialised under-tree mowing equipment to enable the surface to be appropriately prepared for efficient nut harvest.

In the month before the start of mature nut drop, ensure grass or weeds are under control and remove or use offset flail mulchers to chop up to 'corn-flake' size pieces any significant quantities of unsound, old or immature nuts, leaf or foreign matter. Old, immature and pest or disease-damaged nuts left on the ground will reduce the quality of the harvest. To minimise the amount of material on the orchard floor requiring removal or chopping up, undertake pruning operations (side trimming and skirting) as soon as possible after the previous season's harvest is complete. This ensures that prunings are well

broken down by the time of the next harvest. When herbicides are used to control weeds, avoid spraying fallen mature nuts. Where it is necessary to use herbicides during the harvest season, spray where possible immediately after nut pick-up.

The timing of the pre-harvest clean-up can have significant benefits. It is a good idea to monitor the maturity of the fallen nuts to determine the most appropriate timing. For example, early in the season, both mature and immature nuts may be falling. If you clean-up too early, you can end up with excessive numbers of immature nuts in the first harvest round. On the other hand, if you clean-up too late, you will get rid of the immature nuts but may toss out good quality nuts as well.

See *On-farm composting for mulch* on page 169 for more information.

Do not apply uncomposted organic materials such as animal manures or macadamia nut husks within at least four months of harvest. Apply after the completion of harvest. This reduces the food safety risk of microbial contamination of the nuts. Composting is a process of 'cooking' the organic material to obtain partial decomposition and involves storing the material in heaps for at least three months with regular turning, adddition of water and monitoring of temperature.

Harvesting

In southeast Queensland, mature nuts begin to drop in mid February and continue until about August. Nut drop is earlier in north and central Queensland, and later in northern NSW. Mature nut drop begins with HAES 660, followed by HAES 741, HAES 344, HAES 816, HAES 814, HAES 246, HV A38, HV A4, HAES 842, HAES 849, Daddow and HV A16.

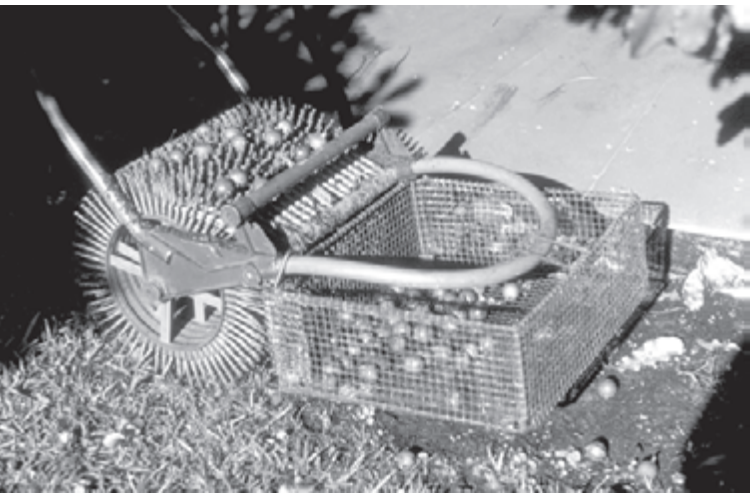
WARNING

Rat baiting needs to be carefully managed to ensure that rat baits do not contaminate nuts during harvesting. Only use rat baits in approved bait stations and monitor stations regularly to ensure that the bait has not spilt onto the ground where it may be picked up by mechanical harvesters.

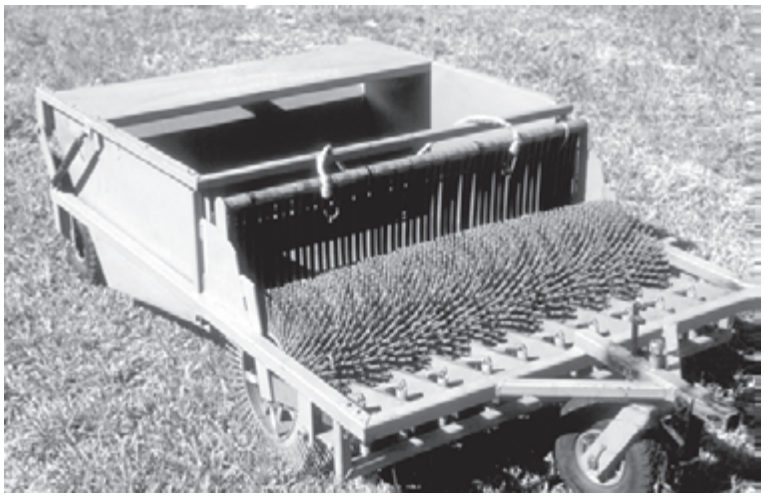
Nuts are harvested after they have fallen to the ground. Most farms use mechanical harvesters. Hand harvesting off the ground is practised on some smaller orchards and where steep slopes preclude the safe use of mechanical harvesters. It may also be necessary on occasions during extended wet weather. Most mechanical harvesters are of the finger-wheel type—a range of these is available to suit different orchard sizes and conditions (see photos).

Clean mechanical harvesters before use to reduce contamination of harvested nuts. Also clean harvesters before shifting to a different orchard to avoid spread of diseases and weed seeds.

Harvest nuts at least every four weeks, particularly during extended wet weather or where nuts are exposed to direct sunlight. The less time the nuts are on the ground, the less the deterioration from mould, rancidity and early germination, and the better the kernel quality. Ensure pick-up is efficient to avoid nuts being left on the ground until the next harvest round. These may deteriorate and reduce the quality of the next pick-up.



A hand-operated finger wheel harvester for small orchards



A small finger wheel harvester for towing alongside or behind a tractor or quad motobike

A large finger wheel harvester . Note that the larger harvesters use blowers to remove nuts from under the trees

Keep nuts from different harvest rounds separate, particularly with early season harvests that often have high levels of immature nuts.

It may be an advantage in the future to harvest, store and consign varieties separately. Where possible, harvest varieties with different processing characteristics separately. Consult your processor or buyer to check on the need for segregation of varieties.

Management of efficient mechanical harvesting requires skill and experience. In general, it is best to make a single pass per round and do more rounds than make multiple passes per round with fewer rounds. While the single passes have a lower pick-up efficiency, the cumulative effect of the extra rounds more than compensate.

Tree harvesting

Provided they are mature, nuts can be harvested directly from the tree. Tree harvesting is necessary with sticktight varieties such as Own Choice and Beaumont, unless ethephon is used to promote nut drop. For tree harvesting, the nuts are knocked, dropped or shaken from branches onto a mat spread below the tree. An indication of nut maturity is when the inside of the husk changes from white to brown. However, it is recommended that a sample of the nuts be first tested for maturity using the flotation test below.

Using ethephon to promote nut drop

Ethephon is permitted for use by the Australian Pesticides and Veterinary Medicines Authority (APVMA) for the promotion of nut fall when nuts are mature. It is applied in late March to early May. However, caution is required in its use. Note the following warnings:

- The sensitivity of some varieties to ethephon has not yet been fully evaluated. Some leaf drop and other effects may occur. For this reason, treat only a small number of trees and check their reaction before treating the whole block.
- Do not use on the variety Teddington.
- Do not apply to trees that are stressed (heat, drought, nutrients etc).
- Do not apply close to flowering as there is a risk of it causing flower drop, thereby reducing the next crop.
- Application is most effective when natural abscission has begun.
- Do not harvest for at least 7 days after application.
- Read the label carefully for other information on its use.

Maturity testing

To make a better decision on when nuts are mature and ready for tree harvesting or the use of ethephon, test a nut sample of about 500 g using a flotation test. There are two options. The simplest is to dry the nut-in-shell (NIS) to about 12 to 17% moisture content (m.c.) (exact level depends on kernel recovery) and float the nuts in tap water. Nuts are mature if 94% of them sink. Note that varieties with a higher kernel recovery need to be tested at the higher end of the 12 to 17% m.c. range. Crack samples of reject nuts to check kernel quality and maturity.

The second option is more complex but more accurate. It relies on the principle that kernels of mature nuts have a specific gravity of less than 1.0 and float in tap water (when dried to 1.5% m.c). Immature kernels sink, regardless of moisture content. Note that this is the opposite of the NIS flotation test. Dry the 500 g sample of nuts to about 1.5% m.c. by heating to 90ºC for 24 hours in a household oven. Then crack the nuts, remove the kernels and place them in water. Nuts are mature if 94% of the kernels float. Some processors will conduct this test as a service to growers.

Postharvest handling

Unless you have access to processors who accept nut-in-husk (which is very limited), you will require on-farm facilities for postharvest handling including dehusking and drying. In planning and operating these facilities, there are three important considerations:

1. The equipment must be designed and operated in accordance with legal standards under Work Place Health and Safety and other legislative provisions. For example, adequate lighting, machinery guards, ventilation and safety equipment needs to be provided to ensure worker safety.
2. As dehusking nuts is a noisy operation, care needs to be taken to site postharvest handling facilities as far away from neighbours as possible, particularly where farms adjoin residential areas.

NOTE

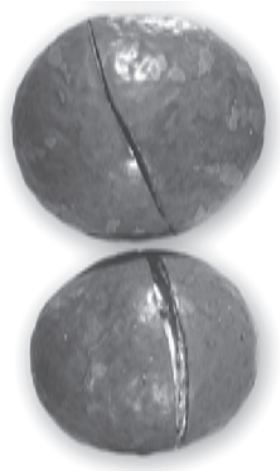
For further information, consult the *Code of practice for noise management on on-farm processing of macadamia nuts*, available from the Australian Macadamia Society.

3. Postharvest handling systems must be designed and operated to prevent physical damage to the nuts, and reduce the risk of contamination and quality deterioration of the kernels. Important issues here include:
   - **Maintaining good hygiene and food safety practices**. Keep the shed and equipment in a clean condition as dirty and poorly maintained equipment increases the risk of nut contamination from vermin and other pests. For the same reason, prevent birds, rats and other animals from entering the working areas. Provide containers for waste, including reject nuts, and frequently remove waste, disposing of it properly. Remove risks for nut contamination from either physical sources (for example bolts) or chemical sources (for example rat baits). Ensure all people handling nuts practice good hygiene.
   - **Careful design and maintenance of equipment**. Nut sorting areas that are well lit and comfortable for workers improve the efficiency of sorting. Design the shed to avoid prolonged exposure of nuts to direct sunlight, as this increases the risk of rancidity and shell cracking. Ensure dehusking equipment is properly set up to avoid cracking of shells. Regularly clean silo fans and other areas where dust builds up to maintain equipment efficiency.
   - **Monitoring systems**. Install a monitoring system to record daily movements of nut-in-husk (NIH) and nut-in-shell (NIS) through the shed, and into and out of storage. The MacMan farm recording system is ideal for this.

Dehusking

Dehusk nuts within 24 hours of harvest to prevent deterioration from sweating and overheating. This is particularly important where NIH is wet or husks are green. Remove any rocks, sticks or leaves before dehusking, either mechanically or by hand. Rocks in particular can severely damage equipment. If dehusking cannot be accomplished within 24 hours of harvest, store NIH in a container with adequate (preferably forced air) ventilation or spread out in thin layers to allow sufficient airflow over the nuts.

Optimise spring pressure on the dehusker to minimise waste from breakage and bruising of the kernel. Remove and compost husks well away from the post-harvest handling area to reduce the risk of fire.



Germination crack

Sorting nut-in-shell

Following dehusking, inspect the nuts and remove any foreign matter and any nut which is old, mouldy, germinated (cracked), excessively dark or bleached, or damaged (rat, insect or otherwise). Note that a germination crack is an open straight crack along the nut suture from the top to bottom of the nut. Smaller fine cracks do not normally affect kernel quality.

It is easier to identify and sort defective nuts when they are dry. It may be necessary to conduct an initial sort immediately following dehusking to

The Agrilink Macadamia Sorting Guide wall chart is a useful aid in the sorting process

remove easily identifiable defects, such as rat damage, followed by a second sort when the nuts are dry.

Separate and discard nuts less than 18 mm in diameter as these usually have poor kernel recovery. An exception is with the variety HAES 660 that often has small nuts with acceptable kernel recovery.

Nuts that have excessive dirt or foreign matter attached (generally when harvested following wet weather) should be spray washed before sorting or storage to reduce the risk of microbial contamination.

Regularly remove reject and unsound NIS from the shed and hammer mill (preferred) or burn. Ensure fire safety precautions are taken if burning. It is recommended that a record be kept of reject nuts and the reasons for their rejection. This will assist in identifying areas for improvement in orchard management. Crop loss protocols (available from the Australian Macadamia Society) have been produced to accurately determine measures for reject nuts. See page 83 for more detail.

Grading of nut-in-shell

As an alternative to hand sorting, there are two on-farm options for grading. The first is flotation grading, commonly used by growers in NSW.

IMPORTANT

Care with flotation grading is necessary for all varieties with a high kernel recovery as too many good quality nuts may be floated off at lower moisture contents. With these varieties, it is very important to flotation grade at higher moisture contents (at higher end of 12 to 17% m.c. range). Crack samples of reject nuts to check kernel quality and maturity.

The practice relies on the fact that NIS with sufficient air space inside the shell will float on water. Nuts that are immature, insect damaged, and with shrunken or degraded kernels, will generally have more air space inside the shell, and hence float. However, care is required as some mature nuts with a low moisture content (for example if dried below 12%), may also float due to the kernels shrinking and forming a large air space inside the shell. Optimum moisture content is 12 to 17% depending on kernel recovery (affected by variety and season).

To make better decisions on whether nuts should be accepted or rejected, it is important to test samples of the floaters and sinkers by cracking the nuts and floating the kernels. Kernels of mature nuts float in tap water especially when dried to 1.5% moisture content. The kernels of immature nuts sink at all moisture content levels. Note that this is the opposite to NIS where mature nuts sink. It is particularly important to monitor the nuts being floated off to avoid rejecting sound nuts. For further information, see the crop loss protocols (mentioned above), available from the Australian Madadamia Society.

NOTE

The Australian Macadamia Industry Code of Sound Orchard Practices (COSOP) contains useful guidelines on sorting, drying and storage (available from the Australian Macadamia Society).

One risk of flotation grading of NIS is that it potentially predisposes the nuts to microbial contamination, particularly where shells are cracked, enabling the solution to come in contact with the kernel. To offset this, change the water at least every 4 hours by emptying the water bath, hosing it out and re-filling. Empty and sanitise the water bath at the end of each day and leave empty overnight.

Discard in an appropriate way any NIS found to contain immature, insect damaged, shrunken or otherwise degraded kernels. Do not sell them. Sale of such nuts, particularly to retail outlets, will be detrimental to the reputation of Australian macadamias.

Flotation grading has more potential for use in the early season harvest where there tends to be a higher percentage of immature nuts.

The second on-farm grading option for grading NIS is air grading which uses either blowing or suction systems to remove lighter (immature or damaged) nuts. It has the advantage of not wetting the nuts and not being dependant on specific moisture contents. However, it has the disadvantage of requiring fine adjustment of the fan setting for the different weights of nuts from different varieties and different blocks.

Nut-in-shell drying and storage

NOTE

Remember that nuts should be consigned to the processor as soon as possible after sorting. Where drying to 10% m.c. cannot be achieved on-farm, two weeks is the maximum period that nuts should be kept on-farm.

Freshly harvested NIS can have a m.c. of more than 20%. Commence drying immediately following dehusking and sorting unless consigning immediately to the processor. Reduce NIS m.c. to about 10% (or kernel m.c. to 4%) within 2 weeks of harvest. At about 10% m.c., approximately half the nuts will rattle when shaken. Do not store NIS for longer than 4 weeks at a m.c. greater than 10%.

Remember from the previous section on sorting that it is easier to identify and sort defective nuts when they are dry. Consequently, it is best to do an initial sort immediately following dehusking to remove easily identifiable defects, such as rat damage, followed by a second sort when the nuts are dry (near 10% m.c.).

NOTE

Seek specialist advice from consultants or manufacturers of drying equipment or refer to the book *Drying macadamia nut-in-shell on farm* by Tim Kowitz and Richard Mason (available from the Australian Macadamia Society).

For small farms, drying small quantities of nuts is best done by spreading them on wire mesh racks to a depth of 10 to 25 cm in a shaded, well-ventilated position. Rake over the nuts at least once a week. Drying on racks may take up to six weeks depending on the drying conditions.

For larger farms where large quantities of nuts need to be handled, forced air drying in silos or bins is the only option. The forced air may be at ambient temperatures or heated. Some key points on drying, handling and storage are:

- Ensure the drying and storage facilities maintain an even and adequate air flow.

- If heating is used during drying, do not use temperatures greater than 30ºC (or more than 5ºC above ambient temperature). Excessive temperatures during drying, particularly of nuts with high moisture content, can result in internal browning and discolouration of the kernel during roasting, and reduced shelf life. With heating, care is also required to reduce the risk of fire. It is esential to have a secondary controlling system to act as a fail-safe should the primary temperature controller fail.
- Avoid prolonged exposure to direct sunlight as it can cause rancidity and shell cracking, predisposing the nuts to contamination.
- Minimise drop heights to minimise fracturing and bruising of kernels. As the moisture content of NIS decreases, the kernel is more prone to damage and the acceptable drop height decreases. The maximum acceptable drop height at 10% m.c. is 2 m. Effective letdown measures need to be in place for drop heights greater than 2 m.
- Keep the fan operating continually when moist nuts are being added to the silo. Switch the fan off at night when the nuts have been dried to about 10% m.c. and the ambient relative humidity is greater than 60%.
- Nuts will be re-wet if fans are run when the relative humidity (RH) exceeds the RH in the silo. Use simple hand-held RH meters to measure the RH of the inlet and outlet air. Alternatively, more sophicticated and expensive automatic switching systems are available. Seek professional advice from consultants or manufacturers of drying equipment.
- Ensure the ducting for the fan inlet is high enough above ground level to reduce the risk of blowing wet air onto dry nuts.
- Duct air from within the shed, preferably from higher up towards the roof. This air is generally drier and warmer.
- Adequate venting at the top of silos is required to allow sufficient air movement.
- The bed depth in silos should not exceed 3 m.
- Completely empty storage vessels when consigning nuts or transferring nuts to other storage vessels.

NOTE

As a general principle, a larger number of small silos is preferable to a few larger ones. This provides a better opportunity to separate varieties, facilitating sorting and crop estimates.

It is recommended that growers have sufficient storage capacity available to hold at least the nuts from the largest harvest round. In some instances, this may be up to 50% of the crop. At least two storage vessels are preferred as it enables wet nuts to be dried before sorting and avoids mixing of wet and partly-dry nuts. It also enables nuts to be subsequently managed as separate batches, thereby optimising storage times and preventing deterioration in quality.

Consignment to processors

Most nuts are consigned to a processor by prior arrangement. The processor then processes and markets their share of the crop. The bulk of the Australian

macadamia crop is exported as raw kernel with about 25% exported as NIS. A small market exists for domestic fresh NIS sales.

Some larger orchards arrange for their crop to be contract-processed, and then do their own marketing. Anyone contemplating doing their own processing and marketing should be aware that careful planning, organisation and meticulous attention to detail and quality management are required. Processing and marketing are specialist skills, have high capital requirements and are very competitive.

Deliver the nuts direct to the processor once drying has been completed. Minimise the time in transit of the nuts to the processor once they have been removed from storage. Delivery delays can lead to an increase in rancidity, the development of off flavours and a reduction in shelf life. This reduction in kernel quality is accelerated at moisture contents above 10%. In seasons where nuts have to be stored on-farm for a longer period, maintain them in as cool and dry a condition as possible.

Inspect the transport container before loading and ensure it is dry and clean, particularly of animal waste and chemicals. This reduces the risk of contamination. Secure and cover loads for travel. Remember to maintain appropriate records of all batches consigned so that they can be traced back if required.

Remember that once nuts are dried, the kernels are more susceptible to handling damage (bruising and fracturing). As mentioned earlier, at 10% m.c., the maximum acceptable 'drop height' (distance over which nuts can be safely dropped) is 2 m. Also avoid where possible, transporting nuts over rough roads and using vehicles with excessive vibration.

Before consigning *Macadamia tetraphylla* nuts, confirm that the processor will accept them. Then consign *M. tetraphylla* nuts separately to *M. integrifolia* nuts. *M. tetraphylla* nuts have a higher sugar content which leads to excessive browning if they are roasted at the same temperatures suitable for *M. integrifolia* nuts.

Also check with processors as to which hybrids or seedlings are acceptable before consigning. Hybrids vary in characteristics between the two species. Some processors may require nuts from hybrid varieties to be consigned separately from *M. integrifolia* nuts. Nut quality of seedlings is also variable.

Ensure there are adequate details on the consignment documents to enable appropriate handling and processing. Many Australian processors also require a delivery report detailing key food safety and quality information to accompany nut consignments.

Price

The price paid depends on the sound kernel recovery and the level of unsound or reject kernel. Standard quality NIS is considered to be 33% sound kernel recovery and less than 3.5% unsound kernel.

The price is traditionally calculated in the Australian macadamia industry on the weight of NIS at 10% moisture content or the weight of kernel at 1.5% moisture content. In recent years, there has been a move to calculate the price based on the weight of sound kernel as this more closely reflects what the processor is selling onto the market.

Sound kernel is fully matured, free from any insect or rat damage, mould, decay, immaturity, discolouration, germination or rancidity. It is suitable for roasting or sale as raw kernel. Unsound or reject kernel include those kernels that are insect or rat damaged, mouldy, decaying, immature, discoloured, germinated or rancid. High levels of unsound kernel slow processing considerably.

Most purchasers of NIS pay a bonus if the amount of unsound kernel is low and conversely, a penalty if the amount of unsound kernel is high. This can have a significant impact on price paid. Growers should adjust their level of sorting accordingly. Some purchasers accept lower grade (commercial grade) kernel that has appearance defects or is of an overall lower quality. However, prices paid will reflect this.

First grade kernel is a term often used in assessing quality. First grade are those kernels which float in tap water. At maturity, macadamias contain greater than 72% oil and have a specific gravity less than water. To test maturity and calculate first grade kernel, nuts are dried to about 1.5% m.c., cracked and the kernels removed and floated in tap water. Kernels with low oil content sink, while good quality kernels float. The percentage of floaters in the sample equates to percentage first grade kernel (often referred to as G1K). Kernels with low oil content are undesirable as they darken during roasting and have a poor shelf life. Kernels with low oil content usually, but not always, appear slightly shrivelled and are often referred to as 'immature'. Early season nuts tend to have higher levels of immature and other unsound kernel. As visual symptoms of immaturity are closely correlated with G1K, most processors now use a visual assessment of maturity/immaturity. However, the G1K test is still a useful tool for growers.

Processor quality reports

Most processors provide a quality report to the grower for each consignment of nuts delivered. The price paid to the grower is based on the results of this report. The report is also an important guide in determining nut defects so that farm operations can be managed to minimise them.

Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in macadamia production. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

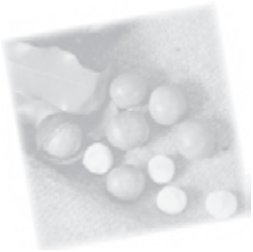
While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

Chapter 4

Additional information on some KEY ISSUES

This chapter contains some additional useful information on some of the important decision making areas and information needs for macadamias. The information supplements the information in other chapters, particularly the Growing the crop *chapter, and should be used in conjunction with it.*



Economics of macadamia growing

This section contains an economic analysis for a hypothetical orchard in southeast Queensland or northern New South Wales. The analysis provides the following details:

- Variable costs and gross margin analysis for a mature orchard.
- A gross margin sensitivity analysis for a range of yields and prices.
- Fixed costs.

Note that the information is intended to provide only an indication of potential costs and returns from the crop – it is not to be taken as confirmation of the profitability of macadamias at any particular site. It is recommended that individuals seek professional financial advice and develop a thorough business plan (including a full cash flow analysis) for their own specific circumstances.

See *The capital you need* on page 5 for brief details on capital required.

Note also that the example shows only variable and fixed annual costs – it takes no account of the significant capital expenditure required to establish a macadamia enterprise.

Assumptions

Assumptions made in the analysis include:

- Macadamia is the only crop grown.
- The orchard is 20 hectares of trees planted at 8 m x 4 m or 312 trees per hectare.
- The orchard is not irrigated.
- The orchard is 15 years old and marketed yields are 3500 kg per hectare of nut-in-shell (NIS) at 10% moisture content.
- The price received is $2.50 per kg of NIS.
- Labour is paid at a casual rate of $20 per hour, which includes award wage, super, payroll tax, and workcover. The analysis costs all labour at this rate, whether it is owner-operated, an employed manager or casual labourers.
- Machinery costs include fuel and oil only; maintenance costs are listed as a fixed cost.
- Figures used in the analysis were current as of September 2004.
- Depreciation is not included.

Annual variable costs

Item	No./yr	Units/ha	Unit	$/unit	$/ha			Total $/ha
					Labour	Machinery	Material	
Weed and erosion control								
Slashing – labour	6	1	hr	20.00	120			
Slashing – machinery	6	1	hr	15.00		90		
Weed spraying – labour	3	1	hr	20.00	60			
Weed spraying – machinery	3	1	hr	15.00		45		
Glyphosate	3	1	L	6.00			18	
TOTAL					**180**	**135**	**18**	**333**
Nutrition								
Leaf analysis	1	1/20 ha	test				10	
Soil analysis	1	1/20 ha	test				10	
Fertiliser spreading – labour	3	1	hr	20.00	60			
Fertiliser spreading – machinery	3	1	hr	15.00		45		
N:P:K fertiliser mix	3	312	kg	0.54			505	
TOTAL					**60**	**45**	**525**	**630**
Pest and disease control								
Spraying – labour	3	2.00	hr	20.00	120			
Spraying – machinery	3	2.00	hr	15.00		90		
Copper oxychloride for husk spot	1	4.00	kg	4.00			16	
Carbendazim for husk spot	2	1.25	L	29.50			74	
Beta-cyfluthrin for pests	2	1.00	L	33.50			67	
Endosulfan for pests	1	3.50	L	11.00			39	
Vermin control (labour)	1	2	hr	20	40			
Coumatetryl for rats	1	1	kg	21			21	
Pest scouting services (contract)					60			
TOTAL					**220**	**90**	**217**	**527**
Canopy management								
Tree care – labour	1	3	hr	20.00	60			
Mechanical pruning – contractor	1	1.25	hr	100.00		125		
Pruning disposal – labour	1	2	hr	20.00	40			
Pruning disposal – machinery	1	2	hr	15.00		30		
TOTAL					**100**	**155**		**255**
Harvesting and marketing								
Machine harvest – labour	5	6.0	hr	20.00	600			
Machine harvest – machinery	5	6.0	hr	25.00		750		
Hand harvest	5	1.0	hr	20.00	100			
Pre-harvest preparation (sweeping/mulch) – labour	1	6.0	hr	20.00	120			
Pre-harvest preparation (sweeping/mulch) – machinery	1	6.0	hr	15.00		90		
Dehusk, sort and handle	5	6.0	hr	20.00	600			
Freight	1	3500	per kg	0.05		175		
Levy	1	3500	per kg	0.08			280	
TOTAL					**1420**	**1015**	**280**	**2715**
TOTAL ANNUAL VARIABLE COSTS/HA					**1980**	**1440**	**1040**	**4460**
TOTAL ANNUAL VARIABLE COSTS/20 HA OF ORCHARD					**39600**	**28800**	**20800**	**89200**
TOTAL INCOME FROM NUT SALES/20 HA OF ORCHARD (3.5 T/HA @ $2.50/KG)								**175000**
GROSS MARGIN/20 HA OF ORCHARD								**85800**

Gross margin sensitivity analysis

Gross margin* for 20 ha orchard for a range of yields and nut-in-shell (NIS) prices.

Yield (t/ha)	Average price/kg NIS ($)				
	$1.50	**$2.00**	**$2.50**	**$3.00**	**$3.50**
2.5	–11,600	13,400	38,400	63,400	88,400
3.0	2,100	32,100	62,100	92,100	122,100
3.5	15,800	50,800	85,800	120,800	155,800
4.0	29,500	69,500	109,500	149,500	189,500
4.5	43,200	88,200	133,200	178,200	223,200

* Gross margin is defined as income less variable costs (that is, it does not account for fixed or capital costs)

An indication of fixed costs for a 20 ha orchard is shown below. These need to be deducted from the gross margin figures to give a more accurate indication of profitability.

Fixed costs per year for 20 ha orchard (assumes macadamia is the only crop)

Item	Total $
Repairs & maintenance – labour	4500
Repairs & maintenance – materials	6000
Repairs & maintenance – service costs	6000
Fuel & oil – non-specified	2000
Electricity and gas	2000
Accountants fees	2000
Telephone/fax/email	1000
Registrations	1300
Insurance	3000
Administration	2000
General transport	1600
TOTAL ANNUAL FIXED COSTS for the 20 ha orchard	**31400**

Taxation

This is an important issue for both new growers and those purchasing an established orchard. It is complex and specialised and professional advice from an experienced horticultural accountant is recommended.

The costs of establishing an orchard and its maintenance until a positive cash flow is achieved are substantial. Funding this appropriately is an essential requirement for successful macadamia farming. Many growers fund the orchard through other sources of income and the ability to deduct allowable expenditure is important.

Firstly you must be in the business of farming and have commenced the business. The size of an orchard and a sound business approach are some requirements for the Taxation Office to class you as a primary producer. As

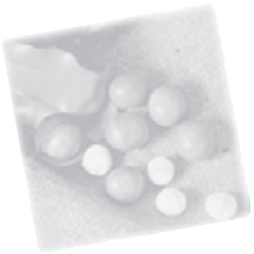
an indicator, an orchard of less than 1500 trees may be classed as a hobby farm. Determination of primary production status is by the viability of the farming, which is assessed on a property by property basis.

Macadamia farming is covered by Div. 10F of the Income Tax Assessment Act. In simple terms, this requires the costs of establishing the orchard to be recorded as capital (establishment) expenditure. This cost includes the grafted trees, preparation, planting, fertiliser, labour and other costs until the orchard is established. This total is written off over 'the effective life' of the trees and commences when the trees first start to produce (probably year 4). If 'the effective life' is taken as 13 to 30 years, the establishment costs are allowed to be written off over 8 years. Capital costs subject to usual depreciation rules such as machinery, sheds and irrigation, are treated separately. Expenditure after establishment is deductible, subject to its nature.

A purchaser of an established orchard can claim any write-offs still available.

The value of the crop harvested but unsold at 30th June each year must be accrued in that year at the cost of production.

There are many 'grey' areas and sound professional advice, development of a taxation strategy and good record keeping should be essential components of your business plan.



Quality management

The Australian macadamia industry has developed an enviable reputation over the years for producing a consistent, safe-to-eat, high quality product. This has enabled Australian macadamias to establish a competitive edge and to maintain a price advantage on world markets.

However, customers in Australia and overseas are also seeking assurance that the on-farm and processing practices meet their requirements for assured food safety and quality. To maintain and strengthen market position, the industry is responding through implementing quality management systems for assurance of product safety and quality in all sectors of the supply chain.

Macadamia Industry Approved Supplier Program

NOTE
Further information about the MIASP can be found in the publication *Approved Supplier Manual : On-farm Macadamia Quality and Food Safety Management* published by the Australian Macadamia Society and NSW Department of Primary Industries.

An Approved Supplier Program involves suppliers putting in place practices that their customers require for quality assurance. The Macadamia Industry Approved Supplier Program (MIASP) is a package of practices macadamia growers will need to implement to satisfy customer requirements. MIASP is HACCP-based.

The MIASP is not a new set of practices. It is a blending of the various recommendations and documentation from COSOP, MacMan, and processor pre-season reports and delivery reports into a single program. It is referenced to the horticulture industry *Freshcare Code of Practice*. The MIASP integrates these resources into a single structure of practices and documents for an on-farm food safety and quality management system. The MIASP is recognised by processors and endorsed by the Australian Macadamia Society. As yet, there are no auditing arrangements, but the program is designed to enable third-party auditing, if the industry chooses this path.

The MIASP requires growers to keep records on practices relating to food safety and quality. It seeks to ensure these practices are a part of routine on-farm activities. In the event of a food safety issue, the recording system needs to be auditable to enable traceback to the origin of the problem. Customers may also want to see that growers are following the program requirements.

On-farm practices addressed in the MIASP include:

- Controlling food safety hazards in chemical, fertiliser and water use;
- Controlling safety hazards from sites, employees, storage and transport;
- Product and handling specifications;
- Product identification and traceability;

- Training requirements;
- Auditing and corrective action;
- Documentation control.

The MIASP has been developed with a training course, training workbook and user manual designed to provide information about QA and assist growers to package and record the relevant information.

The MacMan farm recording system has been updated to ensure that any additional records required for the MIASP are included. MacMan is the preferred industry recording system for the MIASP.

MacMan

The MacMan recording system was first released in 1999. Available in hard copy diary and computer software program formats, it provides a convenient record keeping system for managing information required for on-farm quality management. Thus, MacMan is a tool to support other quality management systems, it is not a quality management system in itself. Growers can use MacMan to keep up-to-date records of their growing, harvesting and sorting practices, which impact on nut quality and safety. This information can also be used to assess farm performance.

See *Record keeping* and the *MacMan software* on page 79 for more detailed information on the software and how to obtain it.

MacMan is regularly updated to include any changes or resources needed for recording on-farm quality management activities, and growers are encouraged by the Australian Macadamia Society to use it. Training and support in the use of MacMan is also available.

ISO Quality management in macadamia processing

Quality management system standards were introduced to the Australian horticulture industries in the early 1990s and Australian macadamia processors were some of the first businesses to adopt the international ISO 9002 standard into their operations.

ISO 9002 is an international quality management standard. It was originally developed for manufacturing industries but increasingly is used for other product and service industries. It has many requirements that a business must satisfy to demonstrate that all aspects of the business that impact on the quality of products and services provided to customers are controlled. These systems help the processors manage their operational efficiency and assist with maintaining maximum global marketing opportunities with customers who require these standards.

Hazard Analysis Critical Control Point (HACCP)

In recent years, increasing consumer and customer concern over food safety issues has encouraged many processors to develop HACCP Plans to focus on food safety in their operations. The Hazard Analysis Critical Control Point (HACCP) method is an internationally recognised, systematic approach to identify, evaluate and control hazards to product safety and quality, before they occur.

HACCP was implemented mainly to ensure food is safe to eat, but HACCP has also been applied to ensure customer quality requirements are met. The HACCP approach is focussed on preventive practices to control food safety and product quality rather than relying on end-point detection of problems. HACCP is widely used in the food industry as the preferred system for food manufacturers and processors to manage food safety.

Processor HACCP systems can control the risks that occur at the processor facility, from receipt of nut-in-shell to dispatch to their customers. However, to be assured that the product can consistently meet the food safety and quality demands of their markets and customers, the processors need to know about on-farm practices that can potentially impact on kernel safety and quality and how growers manage them.

On-farm quality management—COSOP

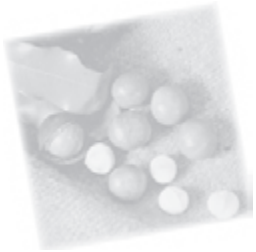
NOTE
COSOP is available from the Australian Macdamia Society. See page 186 for contact details.

In 1992, the Australian Macadamia Society released the Macadamia Industry Code of Sound Orchard Practices (COSOP). COSOP is a best practice guide for growers for managing orchards and nut quality up to the point of consignment to the processor. The introduction of COSOP was timely as a support mechanism to the many macadamia processors who were then developing their ISO9002 systems. While focussed on nut quality issues, COSOP contains many practices that are central to controlling food safety risks.

COSOP, unlike HACCP, is not normally auditable but it has provided a reference for sound orchard practices, contributed to the control of safety and quality issues, and established the foundations for the Macadamia Industry Approved Supplier Program (MIASP).

COSOP was updated in 2000 to include a greater focus on food safety, environmental management and workplace health and safety issues, as well as greater emphasis on the on-farm risk management practices required. This was necessary because of the increasing food safety concerns in key macadamia markets, which required processors to have documented assurance by growers that sound on-farm practices were in place.

Through COSOP, pre-season reports on farm activities (as part of the supply contract offer), and delivery reports with each consignment, have been increasingly adopted. Pre-season reports provide processors with important information they need for assurance about on-farm food safety practices such as pesticide application practices, fertiliser use, harvesting practices and on-farm storage of nut-in-shell.



Record keeping and the MacMan software

Record keeping is an essential part of good farm management. Records allow trends to be observed, orchard performance to be fine-tuned, and better long-term decisions to be made. They are also essential for quality management systems and to satisfy legislative requirements. MacMan is a specialised software package designed to provide a simple and powerful recording system. This section provides an overview of record keeping and the Macman software.

Record keeping

Accurate and ordered recording of information on the farm is essential for good business management. It is also a legal requirement for taxation purposes, chemical use legislation, Workplace Health and Safety audits, approved supplier accreditation and quality assurance certification systems. The Macadamia Industry Approved Supplier Program involves suppliers (that is, macadamia growers) keeping sufficient records to demonstrate that their practices are meeting customer quality and food safety requirements.

Types of information that may be recorded as part of your farm management include:

- preharvest (pest and disease monitoring records, spray program, labour inputs, leaf and soil analysis, soil moisture monitoring, fertiliser and irrigation schedules);
- postharvest (labour, harvesting records, handling and storage logs, chemical usage),
- quality management records.

This information is used to satisfy legal requirements, compare performance from year to year and to establish best farm practice. It also supports the development and updating of your business plan. It can be recorded on a computer where information can be quickly accessed and compared, or it can be recorded in books or on forms and filed in a filing cabinet.

NOTE
The MacMan farm recording computer package is the recommended way of recording and using this information (see below).

IMPORTANT NOTE

It is a legal requirement that all growers using the pesticide endosulfan, maintain a record of each application. It is the responsibility of the grower to collect (either directly or from a person on his/her behalf) and record all of the information required in a special *Endosulfan Spray Record*. The record requires the completion of information on the farm and applicator, crop and pest details, weather conditions at application, and detailed application information.

Growers may use MacMan or their own computer-generated forms or special forms available from the Australian Pesticides and Veterinary Medicines Authority or other chemical agencies.

MacMan

MacMan is a simple yet powerful recording and reporting system to monitor and improve nut quality and orchard profitability. It is designed to give macadamia growers a quick and easy way to keep important farm records and produce a wide range of useful reports. It also provides a recording system to satisfy nut processors' food safety and quality assurance information requirements.

MacMan consists of:

- A simple, standardised computer based and paper based recording system;
- A benchmarking system that enables growers to analyse performance results from their own farms and to confidentially compare these against other growers and industry standards.

MacMan development

The development of the MacMan farm recording system began in 1997. The Australian Macadamia Society recognised the need for on-farm quality management and approached the Department of Primary Industries & Fisheries to work with them to build a system to enable growers to record key food safety and quality management information. In addition, it was intended that growers would be able to use this information to identify where they could improve their efficiency and productivity.

Since then, the MacMan team of software programmers and extension staff, with the support of Horticulture Australia Limited, has worked closely with a steering group of key growers, consultants, processors, staff of NSW Department of Primary Industries and the Australian Macadamia Society to develop a farm recording system to meet the needs of the range of growers within the Australian macadamia industry. Since the first release of the software in 1999, the program has regularly been updated as the focus groups identify further needs within the industry.

What can you record in MacMan?

MacMan enables you to keep all of the important management records for your macadamia farming enterprise. These include details about the following:

- Farms, blocks and plantings. A planting is the lowest level of recording in MacMan. Plantings enable you to record jobs or harvest yields in part of a block if you wish.
- Employees.
- Contacts. This includes customers and suppliers of goods and services.
- Machinery.
- Pests and diseases. MacMan also provides you with information about the major Australian macadamia pests and diseases, including life cycles, habits and damage, host plants and distribution, monitoring methods, biological and cultural controls, and pictures of the pests and diseases and damage caused.
- Chemicals such as fertilisers and pesticides. MacMan also enables you to keep a chemical stock inventory linked to your job records.
- Storage vessels, such as silos or bins.
- Water sources, such as creeks, dams and bores.
- All the jobs performed on a macadamia farm. This also includes all labour, contract, machinery and chemical costs and products involved. You can also create your own job categories if you wish.
- Employee time sheet records.
- Variable costs. Although MacMan is an agronomic recording program, it also has a simple financial recording system that is very useful in calculating costs of production. You can also import data from farm accounting software into MacMan.
- Harvest yields.
- Post-harvest handling. This includes dehusking and sorting, resorting, transferring nuts between storage vessels and dispatching nuts to customers.
- Factory results.
- Monitoring for pests and diseases, leaf and soil analyses, and water quality.
- Weather information, such as rainfall, temperature and relative humidity.
- The timing of important growth cycle information such as flowering, leaf flushing, mature nut drop and premature nut fall.

Reports

One of the features of the MacMan farm recording software is the ability to produce a wide range of reports. There are currently more than 70 styles of reports in MacMan to suit the needs of macadamia growers. These include both tabular and graphic reports. The graphic reports include a number of highly visual trend, bar and pie charts that enable you to see and compare important information at a glance.

The reports can also be exported to a number of common file formats, including Adobe Acrobat Portable Document Format (.pdf), Microsoft Excel (.xls) and Rich Text Format (.rtf). This is particularly useful if you wish to send the reports by electronic mail.

Some of the reports in MacMan include:

- Delivery report. Many macadamia processors require a delivery report addressing key food safety and nut quality issues at the start of each session and to accompany each consignment. The data stored in MacMan is used to generate delivery reports that allow traceback to the orchard.
- Cost of production report. MacMan can calculate your costs of production for a particular farm, block or planting and for a particular time frame.
- Nut-in-shell storage estimates report. This report provides you with a current balance estimate of the nut-in-shell in each of your storage vessels and the date each of the storage vessels was last emptied.
- Weather, pests and spray overlay chart. This report provides you with a picture of what is happening in your orchard with regard to pest and disease management. It enables you to overlay your weather data (rainfall, temperature and relative humidity) with your pest monitoring results and your spray events.
- Leaf and soil analysis monitoring charts. This enables you to graph and compare results of different nutrients and locations. Further work is also planned to overlay this information with yield and quality results and fertiliser applications.
- Production trend graphs. These graphs enable you to compare harvest yields and factory results (for example, NIS, sound and unsound kernel) from different seasons and from different parts of your farm.

Best practice groups

The Australian Macadamia Society and the MacMan team are forming best practice groups with interested growers in all major macadamia-growing areas. The groups enable growers to compare their results from data recorded in MacMan. The growers can then analyse the results and identify where they can improve their productivity and efficiency.

Members of best practice groups have used data recorded in MacMan to identify where they could make improvements in their harvesting and post-harvest handling practices by comparing and analysing their yield and quality results and their costs of production in areas such as:

- Harvesting and postharvest handling practices;
- Fertiliser, pest, disease, soil surface and canopy management.

Training and support

Training and support in the use of MacMan is provided to Australian macadamia growers. Each Australian macadamia grower is entitled to attend

training sessions that are held regularly in all major Australian growing regions. A telephone and electronic mail support service is also provided free of charge to Australian growers.

MacMan-net discussion group

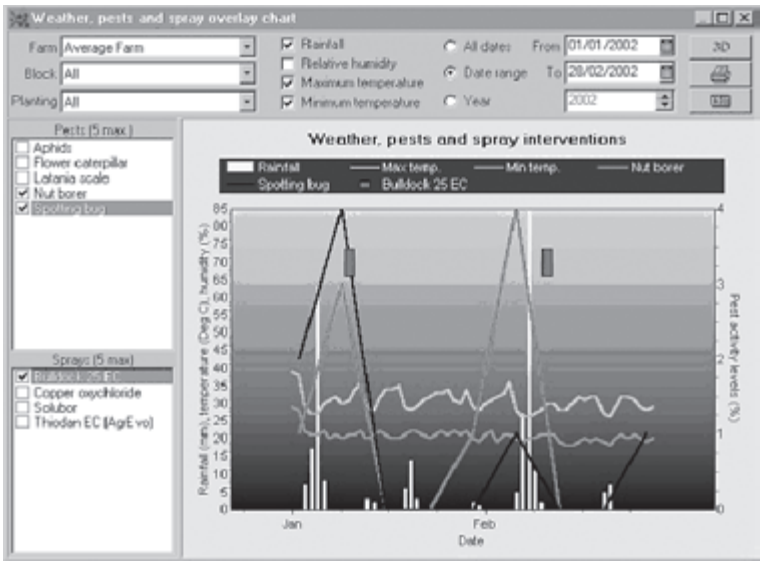
The MacMan-net discussion group is a forum where growers can share information about MacMan or macadamia farm management in general through electronic mail. Contact the MacMan team for information about subscribing to the group.

Farm diary

The MacMan diary is designed to enable users who prefer to use a paper based system rather than a computer to keep the same records as the MacMan software. The two systems are complementary to enable growers who do not use a computer for farm recording at this stage to switch easily from the diary to the software when they are ready. Many growers also prefer that their staff record information by hand and then have one person enter it into a computer on a regular basis.

Crop loss protocols

The crop loss protocols were developed to provide practical and reliable on-farm crop loss asssessment procedures in order to explore management and profitability. Three protocols have been developed. Two examine 300 NIS and 300 nut-in-husk (NIH) respectively, and provide a picture of total crop losses. The third protocol examines 100 NIS from the reject pile and identifies the major causes of crop loss. Results can be reconciled in MacMan. The protocols are available as a spreadsheet or in print form from the Australian Macadamia Society.

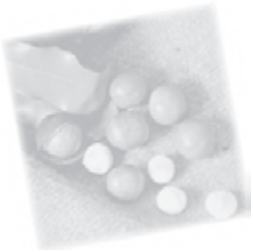


An example of the weather, pests and spray overlay chart

Further information

For further information about the MacMan farm recording system, contact the MacMan team:

E-mail: macman@dpi.qld.gov.au
Phone:(07) 5441 2211
Fax: (07) 5441 2235
MacMan website: www.dpi.qld.gov.au/macman



Understanding the macadamia tree

The aim of macadamia growing is to consistently produce a large crop of high quality kernels. To achieve this, it is essential to have a good basic knowledge of what governs nut production and quality.

Important features of the macadamia tree

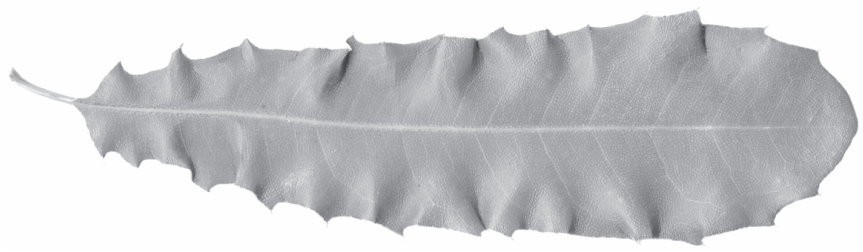
The macadamia is an evergreen, medium to large tree, growing to a height of up to 15 m. It produces a number of vegetative flushes per year (see photo) with peaks in spring and late summer. In the main commercial species *Macadamia integrifolia*, the leaves are arranged in whorls of three (see photo). A whorl is a ring of leaves originating at the same point or node on the shoot. In the species *Macadamia tetraphylla*, the leaves are arranged in whorls of four. Hybrids between the two species can have combinations of three and four leaves per whorl. Leaves often have spiny toothed margins and short petioles (5 to 15 mm long). Three buds are arranged longitudinally in the axil of each leaf. Multiple branches and/or flower racemes may therefore be produced from each leaf whorl or node.

Vegetative flush

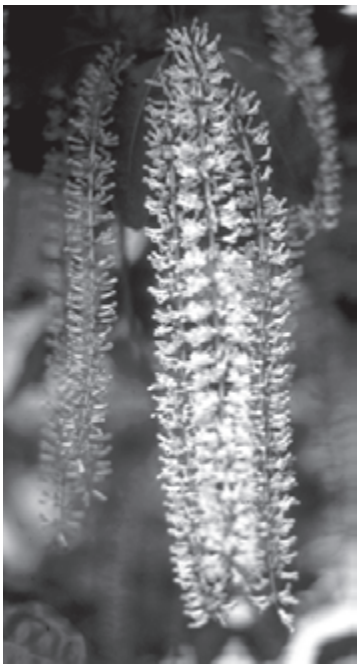
A mature tree may produce many thousands of flower racemes each year. The pendulous racemes, 10 to 15 cm long and bearing approximately 200 to 400 individual creamy to white flowers (or pink for *M. tetraphylla*), are borne on hardened wood in spring. Less than 5% of the flowers set nuts and many of these fall off in the first 5 to 6 weeks after fertilisation.

Nuts mature in 5 to 6 months, when most fall naturally. Depending on the variety, it may take several more months before all mature nuts drop. Botanically, there are two ovules or immature seeds formed in each nut, but only one generally develops to produce a typical round NIS.

Whorl



Typical leaf



Flower raceme

Nut (in husk)

See *Canopy management* on page 160 for more detail on principles of light distribution.

In some varieties however, both ovules develop in a small percentage of nuts to produce twin nuts. These are undesirable commercially as they are difficult to crack without damaging the kernel. Mature nuts usually, but not always, fall when the fibrous husk is still green. As the husk dries, it splits along a single suture line to release the nut, which consists of a hard, thick, stony, light tan shell enclosing the kernel. Darkening of the inside of the husk gives a good indication that the kernel is mature (more than 72% oil) and ready for harvesting.

Annual growth cycle

Macadamia trees have a cyclic, seasonal pattern of vegetative growth, flowering and nut production that is responsive to the environment. By monitoring this growth cycle in your orchard, and scheduling cultural operations at the appropriate stage of the cycle, the balance between vegetative growth and cropping can be maintained for optimum yield of sound kernel.

Vegetative growth

The growth and production of macadamia trees, like other tree crops, is directly proportional to interception of radiant energy from the sun. Leaves convert the radiant energy into carbohydrates that are used for growth and maintenance in the tree. Maximum light interception occurs with a completely closed canopy but operational efficiency in the orchard dictates the use of hedgerows with a 2 m wide alley for machinery access. For example, in an orchard with hedgerows and a 2 m wide alley, incident light interception is an acceptable 90% to 95%.

The carbohydrates produced by the leaves from radiant energy are either used for growth or accumulated in the tree. The seasonal pattern of carbohydrate storage consists of a general accumulation in autumn and winter and depletion in spring. This is because during nut development in spring, insufficient carbohydrate is produced by photosynthesis to meet the high demands of nut growth and oil accumulation, and the tree needs to draw on its reserves. At other times, excess carbohydrate is stored in leaves, stems and root tissue from where it can be mobilised to support other tree growth functions. Since developing nuts have the highest priority for carbohydrate, tree reserves have to be sufficient to meet this need otherwise nut yield and quality can be affected. Carbohydrate accumulation in autumn and early spring is important for the replenishment of reserves taken by the previous crop and to support the development of the new crop.

Macadamia leaves may live for many years but they are most productive (maximum photosynthesis) soon after they reach full size and harden. For trees to remain healthy, vigorous and productive, it is necessary to replenish this supply of young, actively growing leaves. Careful management of the health and vigour of the trees is therefore very important. Compare this with trees affected by the decline disorder. Here, trees have sparse foliage and when a flush

occurs, it lacks vigour and the leaves produced are often small and unhealthy. As a result, the tree's capacity to produce carbohydrate through photosynthesis is very limited, the root system is deprived of energy needed for healthy growth, and the above parts of the tree are, in turn, starved of water and nutrients. It is a slow and difficult process to reverse this downward spiral.

Research has shown that the timing of vegetative growth flushes has a profound effect on yield and quality of nuts. Maximum yields are obtained when trees flush in late winter/early spring (August/September in southeast Queensland). This maximises leaf photosynthetic capacity leading up to the period of oil accumulation, which is the period of high energy demand. This late winter/early spring flush then hardens in spring (October/November in southeast Queensland) and the trees are vegetatively dormant during oil accumulation. This timing of the flush is very important for two reasons:

- The active flush in late winter/early spring builds up a good supply of carbohydrate for the oil accumulation period to follow;
- The lack of vegetative growth during the oil accumulation period means that there is nothing to compete with oil accumulation in the nuts. This maximises nut yield and quality.

A smaller late summer/early autumn flush (March/April in southeast Queensland), when oil accumulation is largely complete, is a prerequisite for a good crop the following season.

Flushing is influenced more by temperature and rainfall (or irrigation) than by nutrition. Flushing appears to be inhibited by low temperatures in winter and by excessively high temperatures in summer. Mild water stress suppresses normal flushing. As soon as water is applied to trees under stress, flushing occurs. Consequently, in some situations, water management may be used to manipulate the timing of seasonal flushing. If this flushing can be manipulated into the desired flushing pattern above, higher yields may be possible.

Flowering

Potential yield is determined by the number of flowers produced, effective pollination and retention of pollinated nuts. Any event that interferes with these processes may limit yield. Floral buds initiate in autumn but remain dormant over winter. They recommence growth in late winter/early spring. In southeast Queensland, flowering usually commences in August, peaks in mid September and is complete by mid October. Exact timing depends on variety, location and climatic conditions. Flowering is earlier in north Queensland and later in northern New South Wales. Some varieties such as HV A4, HV A16 and HAES 741 have a short flowering cycle, while others such as HAES 246, HAES 783 and HAES 842 have a prolonged flowering cycle.

Nut production

Nuts set in early October (southeast Queensland) and reach maturity 5 to 6 months after nut set. Maximum fresh weight is achieved at about 18 weeks after nut set (fertilisation).

Premature nut drop occurs in three stages:

1. fall of unfertilised flowers;
2. rapid fall of the initial set of small immature nuts between 3 and 8 weeks after nut set;
3. fall of larger immature nuts from 10 weeks after nut set onwards. High temperatures, moisture stress and competition for resources exacerbate nut fall at this stage.

Kernels are usually mature 21 weeks after nut set (southeast Queensland) and 24 weeks after nut set (northern New South Wales). Nuts of some varieties commence dropping in mid February. The kernel is marketable (mature) when it floats in tap water (more than 72% oil). Maturity is hastened in warm climates and delayed in more temperate climates. Although the nuts of most varieties are mature at much the same time (by early March), some varieties do not drop mature nuts until late in the season. These varieties have a greater risk of pest and disease carryover.

Root growth

Little is known about root growth patterns in macadamia but a healthy, active root system is obviously essential to ensure water and nutrients do not limit healthy vegetative growth, and hence nut yield and quality. As root tips produce growth regulators, which help maintain a balance between shoot and root growth, a dense surface mat of feeder roots is desirable for healthy tree growth.

Soil removed to show the extensive mat of feeder roots under a healthy tree

Growth cycle

A typical growth cycle for trees in southeast Queensland is shown in Figure 23. Seasonal conditions, particularly temperature and rainfall, influence the cycle. The pattern is earlier and accelerated in the tropical north and later and elongated in more temperate southern areas.

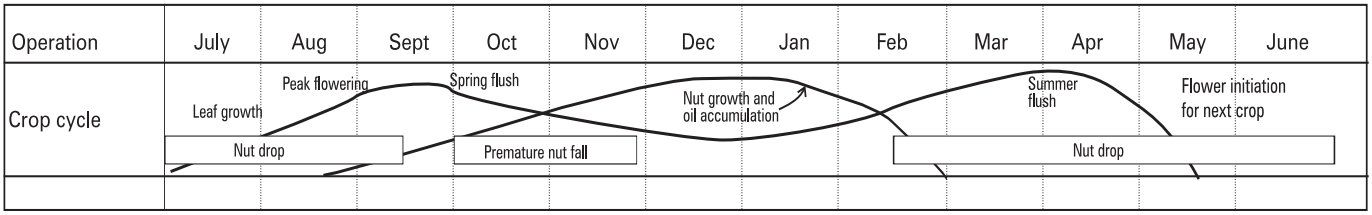


Figure 23. *Growth cycle for trees in southeast Queensland*

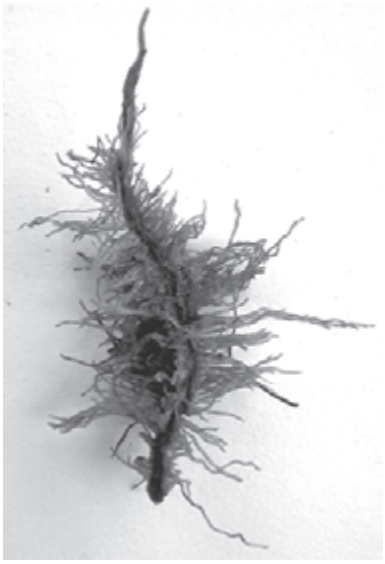
The timing of orchard operations in relation to the growth cycle is covered under *Implications for management* later in this section and in the *Crop production handy guide*.

Environmental effects on growth and flowering

Temperature

The optimum temperature range for growth and photosynthesis is 20 to 25°C. Low day temperatures suppress vegetative growth. Low night temperatures (12 to 14°C) promote flower initiation and delay raceme development, but ultimately result in more intense flowering. On the other hand, high night temperatures (above 20°C) inhibit flower initiation and raceme development. Warm nights during flowering, and warm days but mild nights during oil accumulation appear to provide the best potential for high yields.

The bark and new flush on young trees is particularly susceptible to frost damage but severe frosts can also kill mature trees. Late frosts in August/September are likely to damage flowers on older trees. Cool temperatures, combined with high humidity during flowering, provide ideal conditions for infection by blossom blight disease. Constant high temperatures (greater than 30 to 35°C) tend to inhibit vegetative growth and may induce leaf yellowing. This has the potential to reduce production, especially under conditions of low humidity and moisture stress.



Proteoid roots

The number of heat units accumulated during oil accumulation account for the higher oil content of Australian macadamia kernels, compared to other major producing countries such as Hawaii.

Soil moisture

The macadamia has several features that help it to survive drought. These include:

- hardened leaves resistant to wilting;
- special proteoid roots that increase the surface area for absorption of water and nutrients from infertile soil.

However, vegetative growth is suppressed, and nut yield and quality reduced by moisture stress at sensitive stages such as flowering, nut development and particularly oil accumulation. Rain (or irrigation where available) in February/March, coinciding with a peak of vegetative flush, is associated with high yields in the following year.

Wind damage in a poorly protected site

Soil drainage

A deep, fertile, well-drained soil provides the best conditions for tree growth. Drainage is necessary to promote healthy root growth, prevent root rot diseases, and to allow access for machinery for cultural operations and harvesting. Trees can survive inundation for several days provided the water recedes quickly and the soil is well-drained.

Wind

As the macadamia is susceptible to wind damage, wind protection is recommended. Adequate protection can generally be achieved from strategically placed natural forest surrounds, but in highly exposed sites, planted windbreaks may be necessary. Once dense hedgerows are formed, trees tend to provide mutual protection and there is less need for windbreak protection. Very high, dense windbreak trees may be counter-productive, as these tend to create turbulent wind flow and eddies that potentially cause more damage than in unprotected trees. Ideal windbreaks allow laminar wind flow over the orchard surface. Early tree training, including training to a central leader and removal of branches with narrow crotch angles, may help minimise damage later on. When major limbs are lost during strong winds, the tree responds by filling the gap with new vegetative growth. This may upset the vegetative to reproductive balance and suppress yields until the balance is re-established.

Implications for management

Establishment and management of young trees

The influence of environmental conditions on growth has important implications for orchard establishment and management. Here are the important management issues:

- Select a warm, well-protected, relatively frost-free site. Macadamias are not suited to continuous high or low temperatures. Safe limits to the mean temperature range are 31^0 C maximum to 9^0 C minimum, with a maximum diurnal fluctuation of 10^0 C. Short periods of higher temperatures can be tolerated without major effect.
- Use only deep (minimum 0.5 m), well-drained soils to avoid later problems with root growth and diseases. In small orchards where mechanical harvesting is not an issue, mounding along the row may be used to improve the drainage of marginal soils.

- Design and construct orchard drainage systems carefully to provide all-weather access to the orchard.
- Choose a well-protected slope or provide wind protection to avoid wind damage.
- Start with healthy nursery trees.
- Ensure the trees get the best start by carefully preparing the planting site, using good planting techniques, and providing optimum conditions for early tree growth.
- Planting can be carried out at any time but protection is necessary in frosty or hot, dry conditions.
- Spacing of trees within and between rows should allow for tree habit, tree vigour, soil type, climate, access for machinery, spray penetration into the canopy, and air flow to reduce humidity at flowering. With the tendency towards denser planting for quicker returns, it needs to be recognised that the trees soon become crowded, requiring pruning and possibly tree removal.

Management of bearing trees

Understanding the growth cycle and the way it is influenced by weather and other factors is important in maintaining the appropriate vegetative/reproductive balance for high nut yield and quality. Here are the important management issues.

Nutrition

- Use leaf and soil analyses, together with intepretation by an experiened consultant, to identify what fertilisers are required.
- Calculate rates of fertiliser carefully, as too much may promote excessive vigour, which may be detrimental to flowering, yield and quality. A good place to start is to calculate rates on the basis of replacing nutrients removed with the crop, adjusted for leaching and other loss factors.

See *Fertiliser rates using the nutrient replacement concept* on page 117 for more detail.

- Apply fertiliser so that it is available at appropriate times in the cycle.

  Nitrogen. Apply in frequent small doses throughout the year. If this is not convenient, apply the bulk in April to June, split into several applications, particularly where leaching is likely. Avoid applying all or nearly all of the nitrogen in summer. The aim is to have a high nitrogen level in late spring going into the major nut growth and oil accumulation period, and a high nitrogen level in autumn to promote a strong autumn flush to replenish the carbohydrate reserves for the next crop.

  Phosphorus. As it moves slowly through the soil profile, apply at any time, preferably before rain.

  Potassium. As it is needed for nut growth and kernel development, apply in late winter and spring.

  Liming materials. Apply with caution. As macadamias are tolerant of acid soils, a soil pH of 5.0 to 5.5 (1:5 water test) is optimum. As soil pH approaches 7.0, other nutrient deficiencies are induced.

Trace elements. As copper and zinc deficiencies commonly cause abnormal leaf and branch growth, apply before the major leaf flush in spring. As boron is important for pollination, flower development and early nut growth, apply during flowering and early nut growth.

Irrigation

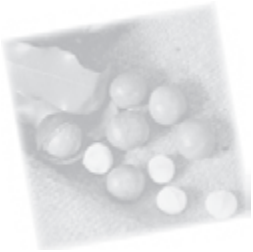
Pay particular attention to those parts of the cycle most sensitive to water stress. Critical times are nut set (fertilisation), nut development, and particularly oil accumulation. Use moisture monitoring systems such as tensiometers and capacitance probes to guide the frequency and amount of water applied.

Pruning

Once the young trees have been skirted and trained to a central leader, they require minimal pruning. Once tree growth begins to restrict access, mechanical pruning is necessary to maintain the 2 m wide alley between the rows and access under the trees for harvesting machinery. This is particularly important in high-density orchards. Commence pruning early and trim trees regularly to avoid removing a large portion of the canopy at any one time. This adversely affects production by unbalancing vegetative growth and cropping.

Other orchard operations

- **Pollination.** Research suggests that cross-pollination has beneficial effects on nut set, nut size, kernel recovery and yield. Consequently, interplant at least two varieties in alternating sub-blocks of between 4 and 10 rows. Also encourage the activity of native and commercial bees.
- **Orchard floor management.** A combination of canopy shading and the impact of mechanical harvesters often result in large areas of bare soil under the trees. This exposes the shallow root system to high temperatures, with a detrimental effect on yield. Two options for overcoming this are recommended. Either use a shade-tolerant, under-tree ground cover such as sweet smother grass or add organic matter such as composted nut husk under the trees. Note that organic matter, if not properly managed, can interfere with harvesting and increase the risk of germination and mould in fallen nuts. These problems can be reduced by adding organic matter after the last harvest with a view to it being sufficiently broken down by the time mature nut drop occurs in the following season.



Selecting varieties

Because macadamias are a long-term crop, selecting varieties is a key to long-term profitability. In addition to selecting varieties for the main characteristics of yield and quality, consideration must also be given to their ease of management and how well they satisfy processor and consumer needs. This section will help you make a sound decision on the best varieties to select for your orchard.

What makes a good variety?

A good variety has a range of desirable tree and nut/kernel characteristics. These are listed in Table 13.

Table 13. Desirable tree and nut/kernel characteristics

Desirable tree characteristics	Desirable nut and kernel characteristics
• Robust, compact and open growth habit • Resistant to wind damage • Tolerant of sub-optimal nutrition, soils and environments, but responsive to good management • No sticktight nuts • No pre-germination on the tree or ground • Tolerant of major pests and diseases • Short-harvest nut-drop season, largely complete (85 to 90%) by mid August, before flowering for the next crop begins • Begin bearing by the third or fourth year from planting out • Consistently high yields of 2 t/ha of sound kernel (equivalent to 5t/ha NIS at 40% sound kernel recovery) from 10 years onwards (This is achievable and higher than the current industry average, but will be dependent on good management)	• Sensory quality must be acceptable to processors, marketers and consumers • Uniform in colour and free from discolouration • Even colour after roasting • Regular, round kernels, weighing 2 to 3 g • Regular, round NIS • No NIS less than 18 mm in diameter • NIS remains in husk after it falls from the tree • Husk separates readily from NIS in dehusker • No husk adhering to the shell • High and stable first grade kernel (over 96%) • Sound kernel recovery in excess of 36% • High % whole kernel • Consistent kernel quality with a low percentage of appearance defects

A process for selecting varieties

See *Choose varieties and tree spacing* on page 23 for details of a process for selecting varieties. Refer to this in conjunction with the notes here.

Variety performance can vary significantly depending on environment, soils and management and thus it is difficult to accurately predict how a variety will perform in a new orchard.

The main feature used in selecting varieties is yield performance in properly-managed variety trials in a region similar to that of your own orchard. This data is shown in the tables under *Variety performance by region* at the end of this section. High performing varieties are normally identified as those with a high and consistent yield of sound kernel from mature trees (10 years old), assessed over at least three seasons.

However, don't rely on this alone. Other features which need to be considered are:

1. A substantially better kernel recovery, first grade kernel and % whole kernel than current commercial variety standards (36%, 96% and 50% respectively).
2. Freedom from major undesirable tree and nut characteristics such as sticktight nuts, pre-germination and processing problems and very late nut drop patterns that may favour pest and disease carryover.

Then combine this information with other sources of information such as local knowledge from other growers, consultants, processors and nurseries. A note of caution however, rely more on actual yield and quality data and experience rather than unsubstantiated perceptions or opinions.

Some additional considerations

- Production can be increased by planting at high density a smaller-tree variety with a high yield of sound kernel per square metre of canopy area (area projected horizontally, within the drip-zone). This strategy should be considered if you are contemplating high-density systems.
- Sound kernel yield per square metre of canopy area may be used as a rough indicator of long term yield per hectare. However, it is not appropriate to extrapolate yield per tree to yield per hectare directly, as many complex assumptions have to be made.
- Many of the new varieties have very late drop patterns that are undesirable from a pest and disease management perspective. Early drop patterns help break the pest or disease cycle and make their control easier. If you are in an area susceptible to serious pest and disease problems, it is desirable to choose varieties that drop the crop before the next season's flowering.
- In wet areas, mid-season varieties that drop after the wetter part of the year, but before next season's flowering, may be desirable.
- Think ahead to anticipate variety attributes that may be potentially valuable in the future. For example, varieties with a high percentage of whole kernels may attract an industry premium in the future. Consumer preferences will influence future preferred varieties. Because processors and purchasers have to consider issues such as roasting quality, taste, flavour and appearance defects in setting their prices, it is important to seek their opinions on what varieties they see as unacceptable or likely to incur a price penalty in the future.

NOTE

The tables in *Variety performance by region* on pages 100 to 102 show sound kernel yield per square metre of canopy area.

Characteristics of the main varieties

Legend to abbreviations in variety tables:

- KR – kernel recovery
- G1K – first grade kernel (floated in tap water)
- HV A – Hidden Valley A varieties
- HAES – Hawaii Agricultural Experiment Station varieties

IMPORTANT

The industry comments listed for each variety are a compilation of comments from a number of key growers and consultants from a range of macadamia growing districts. Some are based on limited observation and experience with that variety. As a result, some comments may be contradictory. Please accept the comments as opinions only and seek additional local expertise.

HV A4

Industry status	Widely planted in the 1990s in Queensland and NSW
Yield	Very early bearing; best kernel yields in NSW
Quality	Nuts 6.4 g, thin shell, shiny golden brown colour; kernels 2.8 to 3.3 g, larger in NSW; 42 to 47% KR; greater than 97% G1K; approximately 44% wholes
Sensory quality	Texture and flavour acceptable but below average (lowest rating of the new varieties), relatively bland flavour, attractive cream kernels
Flowering pattern	Very heavy, short, late flowering
Nut drop pattern	Mid-season (May-August)
Defects	Dehuskers may need to be adjusted to avoid damage to the large nuts
Husk spot susceptibility	Only slightly susceptible
Tree features	Medium size, spreading to rounded, open canopy; can be planted closer giving potentially higher early yields per hectare; susceptible to wind damage in exposed sites; requires careful attention to nutrition management
Industry comments	Very precocious with large nuts of high kernel recovery; often produces out-of-season flowering; young trees prone to trunk canker in NSW; can decline at 8 to 9 years; performs better in southern areas and away from the coast (better than A16); needs special nutrition and high standard of management; some concerns over flavour and roasting properties; large nut and thin shell; requires dehusker adjustment in some cases; characteristic raised crest may not be pre-germination; questions over the raw flavour but acceptable roasted and salted; some processors prefer that HV A series varieties are kept separate from HAES Hawaiian varieties

HV A16

Industry status	Widely planted in the 1990s in Queensland and NSW; still being planted
Yield	Early bearing; best kernel yield in Queensland
Quality	Nuts 6.3 g, thin shelled, oval; kernels 2.4 to 2.9 g, larger in NSW, uniform and attractive; 39 to 42% KR; greater than 97% G1K; approximately 44 to 51% wholes
Sensory quality	Texture and colour good (above average), overall acceptability and flavour 'acceptable', slightly bland
Flowering pattern	Moderately intense, condensed, late flowering
Nut drop pattern	Very late (May to November)
Defects	Late dropping (nuts hang on trees long after they are mature); prone to sticktights where trees are stressed; dehuskers may need adjustment to avoid damaging nuts
Husk spot susceptibility	Moderate to highly susceptible, exacerbated by the late nut drop pattern
Tree features	Small, moderate to dense canopy, upright, with willowy branches; can be planted closer, giving potentially higher early yields per hectare
Industry comments	Hardy; suits high-density planting; very late nut fall a major disadvantage to some growers; nut drop exacerbates susceptibility to husk spot; germination may be a problem late in season north of Gympie; consider removing branches to improve air flow and light penetration in NSW; in future, may need to be harvested separately; some discolouration after roasting; early trials indicate that ethephon can be used sucessfully to drop nuts

HV A29

Industry status	Released to industry by Hidden Valley Plantations in 1991; relatively new variety
Yield	Early bearing
Quality	Nuts 6.2 g, uniform; kernels 3.1 g; 38% KR; 98% G1K; approximately 32% wholes
Sensory quality	Not assessed
Flowering pattern	Short, mid-season flowering
Nut drop pattern	Mid-season (April to July)
Defects	Not yet properly assessed
Husk spot susceptibility	Susceptible
Tree features	Large size, very upright tree; very vigorous; susceptible to wind damage in exposed sites; very open canopy means easier spray penetration
Industry comments	Early observations suggest: looks very good in southern production areas; may be an alternate bearer; good cropper; subject to discolouration, immaturity, some germination; very large kernel

HV A38

Industry status	Released to industry by Hidden Valley Plantations in 1991; relatively new variety
Yield	Early bearing
Quality	Nuts approximately 6.7 g, uniform; kernels approximately 2.7 g, slightly flattened, cream; 37.5% KR; 98% G1K; approximately 41% wholes
Sensory quality	Not assessed
Flowering pattern	Short, mid-season flowering
Nut drop pattern	Mid-season (April to August)
Defects	Kernel discolouration, depending on season
Husk spot susceptibility	Susceptible
Tree features	Medium size, very upright tree; very vigorous; needs early tree training and pruning to size; susceptible to wind damage in exposed sites; very open canopy means easier spray penetration
Industry comments	Should be treated with some caution; very susceptible to stress and discolouration including on the suture ring; high percentage of immaturity and discolouration; variable roasting; kernel quality doubtful for various reasons; suitable variety for close planting; some years performs inconsistently; most variable variety; susceptible to husk spot; high yield could justify planting; early trials indicate ethephon can be used successfully to drop nuts

HV A203

Industry status	Not yet widely planted
Yield	Early bearing
Quality	Nuts 5.6 g, variable kernel recovery, sometimes low, oval; kernels 2.1 g, uniform and attractive; 33 to 34% KR; 89 to 97%G1K; approximately 43% wholes
Sensory quality	Not assessed
Flowering pattern	Moderately intense, condensed, late flowering
Nut drop pattern	Early
Defects	Not yet properly assessed
Husk spot susceptibility	Not yet assessed
Tree features	Small to medium, semi-compact to open, rounded tree canopy
Industry comments	None available at this stage

HV A268

Industry status	New variety, not yet widely planted
Yield	Early bearing
Quality	Large nuts 8.2 g, uniform; kernels 3.4 g; 37 to 38% KR; 89 to 96% G1K; approximately 36% wholes
Sensory quality	Not yet assessed
Flowering pattern	Short, mid-season flowering
Nut drop pattern	Mid-season (April to July)
Defects	Not yet properly assessed
Husk spot susceptibility	Not yet assessed but appears susceptible
Tree features	Rounded, spreading, semi-compact to slightly open tree canopy
Industry comments	Very large kernel; well shaped tree

HAES 246

Industry status	Widely planted in the 1960s and 1970s; still some current planting, particularly in NSW and southeast Queensland
Yield	Reliable, but not early bearing; best yields in NSW and southeast Queensland
Quality	Nuts 6.8 g, moderate flecking, with open micropyle, kernels 2.0 to 2.7 g, larger in NSW; 31% to 37% KR; less than 96% G1K; approximately 45% wholes
Sensory quality	Highly rated for flavour, texture and overall acceptability, colour slightly variable between sites
Flowering pattern	Extended, heavy flowering
Nut drop pattern	Mid-season (April to August)
Defects	Pre-germination (on the tree); basal kernel discolouration; open micropyle
Husk spot susceptibility	Highly susceptible
Tree features	Medium to large spreading/rounded tree, moderately dense canopy, suitable only for wider tree spacings; susceptible to wind damage; tree produces much leaf litter causing potential problems with harvesting
Industry comments	Heavy consistent cropper; described as a 'cash cow' for many farms; the basis of the early Australian industry; very average at Hidden Valley (Queensland) – not as good as in NSW; lower roasting quality; can leave on ground for longer periods than other varieties (less likely to germinate under wet conditions); heavy leaf fall can be a problem at harvest; susceptible to wind damage; good but variable yields; some concern about shelf life; appears to have greater than 36% KR closer to the coast.

HAES 344

Industry status	Most common variety in Australia; widely planted in 1980s/early 1990s; no longer being widely planted
Yield	Early bearing; best yield in central and southeast Queensland
Quality	Nuts 6.9 g, round, dull shell with moderate flecking; kernels 2.2 g, larger in NSW; 32 to 35% KR; approximately 97.2% G1K, variable; approximately 35 to 46% wholes
Sensory quality	Average flavour and overall acceptability; texture acceptable but less crunchy than other varieties; kernels tends to be darker (beige light brown and two-tone) than other varieties
Flowering pattern	Mid-season flowering, medium in length; light flowering some years
Nut drop pattern	Early-season nut drop (April to July); later in NSW (May to August/September)
Defects	Lowest kernel recovery of recommended varieties; prone to nutborer attack
Husk spot susceptibility	Moderately tolerant
Tree features	Medium-large, upright, dense, conical tree; dense foliage can result in poor spray penetration
Industry comments	Consistent performer in Qld; precocious; early nut fall; low kernel recovery a disadvantage; susceptible to macadamia nutborer – control difficult because of tight bunches; yield tends to be erratic in some environments; may need higher standard of management; doesn't flower under (some) stress conditions; good roaster; favourable sensory feedback; susceptible to husk spot in a hot climate; more susceptible to excessive heat and abnormal vertical growth disorder (AVG) than other varieties

HAES 660

Industry status	Widely planted in the 1970s and 1980s; current plantings rare
Yield	Early bearing; best yield in NSW and southeast Queensland
Quality	Nuts 5.4 g, pronounced flecking; kernels 2 g, larger in NSW; 35 to 39% KR, lower in north Queensland; 96 to 98% G1K, lower in north Queensland; approximately 36 to 41% wholes
Sensory quality	Good flavour, soft texture, mostly cream and beige in colour
Flowering pattern	Mid-late, variable flowering
Nut drop pattern	Very early-season nut drop (April to June)
Defects	Germinates on tree in wet conditions, large number of undersized, reject nuts
Husk spot susceptibility	Slightly susceptible
Tree features	Medium-large, upright, moderate to dense canopy, turkey's neck; more open than 344
Industry comments	Good variety in the past – under-rated; early nut fall; lot of variation in nut size particularly when stressed; small nuts; nuts dehusk on ground making finger-wheel harvesting difficult; tendency to germinate; prone to brown centering

HAES 705

Industry status	Relatively new variety; very few plantings to date
Yield	Medium to high
Quality	Nuts 7.0 to 7.7 g; round but slightly irregular; light brown with irregular, light tan blotches; kernels 2.3 to 2.8 g; good kernel characteristics; 34.8 to 35.5% KR; 96.4 to 99.0% G1K; approximately 40 to 52% wholes
Sensory quality	Acceptable flavour, texture and colour
Flowering pattern	Late to very late flowering
Nut drop pattern	Very late
Defects	Late nut drop
Husk spot susceptibility	Not yet assessed
Tree features	Small to medium, open, upright tree
Industry comments	None available at this stage

HAES 741

Industry status	Widely planted, particularly in Queensland from the late 1980's to the present
Yield	Not early bearing but in some seasons, young trees crop well; performs better as trees mature; best yield is in central and southeast Queensland
Quality	Nuts 6.2 g, variable size, some small, round and smooth; kernels 2.3 g, full, slightly dull, larger in NSW; approximately 36 to 38% KR, lower in north Qld; greater than 97% G1K; approximately 36% wholes
Sensory quality	Above average overall acceptability and flavour, slightly below average texture, attractive cream to beige kernels
Flowering pattern	Condensed, late flowering, shy flowering in some areas in some seasons (dry autumn/ winter)
Nut drop pattern	Early (April to June)
Defects	Some basal discolouration of kernels
Husk spot susceptibility	Very susceptible, impact reduced by early nut drop
Tree features	Medium-large, upright, moderate to open, turkey's neck particularly when young, becoming more dense with age, performed well at northern sites (heat tolerant)
Industry comments	Reliable; hardy; wind-resistant; the most popular of the old varieties; does not crop well under 7 to 8 years; variable cropping in NSW with low production in northern NSW; performs well in Queensland except some problems with nut setting in Bundaberg; early nut fall a major advantage with many growers; appearance is ordinary; some basal discolouration

HAES 781

Industry status	Relatively new variety; very few plantings to date
Yield	Not precocious; medium to high yields; may be variable across sites; lower in hot environments
Quality	Nuts 6.6 to 8.2 g, round, slightly flecked with distinct groove (not the suture); can be variable mainly on flat at hilum end of shell; kernels 2.6 to 3.0 g, good kernel characteristics; 35 to 39% KR, 91.5 to 98.8% G1K; approximately 41 to 51% wholes
Sensory quality	Excellent texture, good flavour and good overall quality
Flowering pattern	Light, late flowering
Nut drop pattern	Long, late nut drop; prone to sticktights
Defects	Prone to open micropyle
Husk spot	Susceptibility not yet assessed
Tree features	Large, vigorous, open, rounded, moderately upright tree; moderately dense canopy; has low heat tolerance with chlorotic leaves produced under hot conditions but this does not seem to adversly affect yield, at least in some environments
Industry comments	Quite a good yield performer but the tendency to sticktights might be a problem

HAES 783

Industry status	Relatively new variety; very few plantings to date
Yield	Not early bearing; high yields in Queensland
Quality	Nuts 6.4 g, even size, round, some white flecks; kernels 2.4 g, larger in NSW; good kernel characteristics; 40% KR, lower in north Queensland; 97 to 98% G1K, slightly lower in north Queensland; approximately 50 to 54% wholes
Sensory quality	Good texture, flavour and overall acceptability, colour variable (cream, beige, light brown and two-tone)
Flowering pattern	Extended flowering, more intense late in the season
Nut drop pattern	Extended nut drop, very late (June to September)
Defects	Late nut drop, especially in southern districts
Husk spot susceptibility	Tolerant
Tree features	Medium to large, moderately dense, spreading tree
Industry comments	Good cropper but with very long, late nut fall with some sticktights (a disadvantage); performed well in NSW

HAES 814

Industry status	Relatively new variety; minor plantings from mid-1990s following performance in regional variety trials
Yield	Early bearing; high yields in NSW and central Queensland
Quality	Nuts 4.4 g, round; small kernels 1.8 g, larger in NSW; 37 to 39% KR, lower in north Queensland; 63 to 87% G1K, variable, higher in north Queensland; approximately 34 to 37% wholes
Sensory quality	Acceptable but generally low rating, flavour similar to 344, but slightly higher incidence of off-type flavours, kernel colour good, cream to off-white
Flowering pattern	Short, late
Nut drop pattern	Mid to late (May to August)
Defects	Low first grade and whole kernel (with poor nutrition); prone to stigktights in stressed trees
Husk spot susceptibility	Slightly susceptible
Tree features	Small, upright, open canopy, large leaves
Industry comments	High to very high level of immaturity (up to 40% both in Queensland and NSW); low first grade kernel (may be acceptable in NSW); very precocious; small tree suited for high density planting; prone to leaf mottling; may require high standard of nutrition; consistent size; may dehusk in the tree; small nuts may not be picked up by harvester; stresses readily; small half kernels have reduced value in the market

HAES 816

Industry status	Relatively new variety, very few plantings to date, mainly in NSW
Yield	Not early bearing; high yields in NSW and central Queensland
Quality	Nuts 6.9 g, round, pale in colour; kernels approximately 2.9 g but 3.4 g at Clunes, round, uniform kernel; 42 to 45% KR, lower in north Queensland; 96 to 98% G1K, lower in north Queensland; approximately 53 to 58% wholes
Sensory quality	Highest rating for texture, flavour and overall acceptability, kernel colour slightly variable
Flowering pattern	Light, late
Nut drop pattern	Early to mid-season (March to June)
Defects	None apparent
Husk spot susceptibility	Slightly susceptible
Tree features	Medium to large, moderately upright, moderately dense, pale green leaves with no spines
Industry comments	Variable yield performance in different sites (caution – investigate performance locally): performs well at Childers; roasting reasonable; slightly susceptible to insect damage (twig-girdler and leafminer); may be slightly susceptible to canker (but less than A4); early to mid-season nut fall may be an advantage but up to 10% sticktights have been observed in NSW; may require careful nutrition management

HAES 835

Industry status	Relatively new variety; very few plantings to date
Yield	Medium to high
Quality	Nuts 5.7 to 6.3 g; round but slightly irregular; brown with irregular, light tan blotches, mainly on hilum half of shell; kernels 2.0 to 2.4 g; good kernel characteristics; 34.9 to 35.9% KR; 98.4 to 99.9% G1K; approximately 65 to 69% wholes
Sensory quality	Not yet assessed
Flowering pattern	Early to mid season
Nut drop pattern	Early
Defects	Variable micropyle size, but this may not be a big problem
Husk spot susceptibility	Not yet assessed
Tree features	Medium to large, moderately dense, semi-upright, spreading tree
Industry comments	An under-rated variety with good overall performance and no major problems; worthy of further assessment

HAES 842

Industry status	Relatively new variety; increased plantings from mid-1990s following good performance in regional variety trials
Yield	Early bearing; high kernel yields in Queensland and NSW; performs particularly well in central Queensland; appears to be more tolerant of high temperatures than most other commercial varieties
Quality	Nuts 5.8 g, even size, slightly flat and oval; kernels 2.1 to 2.5 g, larger in NSW; 36 to 41% KR; 94 to 98% G1K, variable; approximately 50% wholes
Sensory quality	Acceptable texture and flavour and overall acceptability, colour slightly variable but acceptable (cream, beige, light brown and two-tone)
Flowering pattern	Heavy flowering over a long period
Nut drop pattern	Extended, mid-to late-season (April to September)
Defects	Up to 10% hang late, may pre-germinate
Husk spot susceptibility	Slightly susceptible
Tree features	Medium-large, moderately upright tree; canopy open when young becoming more dense as the tree matures
Industry comments	Hardy; fairly precocious; good yields but not as good as 816 and 849 in NSW; seems suited to warmer areas; long, late nut fall a disadvantage; slight pre-germination; darker kernel colour (growers penalised); not enough planted in NSW to properly define

HAES 849

Industry status	Relatively new variety; increased plantings from mid-1990s, particularly in NSW, following good performance in regional variety trials
Yield	Not early bearing; high yields in Queensland and NSW
Quality	Even nuts 6.4 g; large; uniform kernel, 2.8 g, larger in NSW; 40 to 46% KR; approximately 95% G1K, lower in north Queensland; approximately 56 to 60% wholes
Sensory quality	Excellent texture, flavour and overall acceptability, kernels beige to light brown with a tendency to two-tone
Flowering pattern	Light, condensed, late flowering
Nut drop pattern	Extended, mid to late-season (May to October)
Defects	Up to 10% hang late, may pre-germinate
Husk spot susceptibility	Very susceptible
Tree features	Medium to large, spreading; moderately dense canopy, moderately vigorous tree
Industry comments	Good yields enhanced by high kernel recovery; late nut fall but marginally earlier than 842 and Daddow; pre-germination is a major defect; darker colour; high levels rejected due to discolouration; susceptible to twig-girdler and husk spot

Daddow

Industry status	Been around for a long time but significant plantings only since mid-1990s
Yield	Early bearing, high yields, particularly in Queensland
Quality	Nuts 6.4 g, even, tea colour, heavily striped and a very prominent suture; kernels 2.4 g, good kernel characteristics; 37 to 40% KR, lower in north Queensland; 92 to 99% G1K, variable; approximately 42% wholes
Sensory quality	Good overall acceptability, good kernel colour, acceptable but slightly below average texture and flavour
Flowering pattern	Moderately heavy, mid to late-flowering
Nut drop pattern	Long, mid to late season nut drop (May to September)
Defects	Very dense foliage; long, late nut drop; slightly prone to nutborer
Husk spot susceptibility	Very susceptible
Tree features	Medium size, slightly spreading, very dense canopy; prone to mottling of older leaves
Industry comments	No major defects; very hardy and reliable yield performance; suited to marginal conditions; late nut fall but acceptable; prone to leaf mottling; may have higher nutritional requirements; not stress-tolerant in poor soils; like most late-dropping varieties, a considerable level of germination has been observed

Variety performance by region

The data listed in Tables 14 to 19 is derived from regional variety trials, which have been conducted over more than 10 years at six locations in Queensland and northern NSW. The tables list the best yielding varieties at each of the six locations, together with standard kernel recovery and first grade kernel figures. The data tables are as follows:

- Table 14: Central NSW (Warrell Creek/Nambucca site)
- Table 15: Northern NSW (Clunes site)
- Table 16: Southeast Queensland – southern (Forest Glen site)
- Table 17: Southeast Queensland – northern (Wolvi site)
- Table 18: Central Queensland (Rockhampton site)
- Table 19: North Queensland (Walkamin site)

Further information on the identification characteristics of the varieties (which includes some useful additional information for selection) is contained in the book *Macadamia Variety Identifier* published by the Department of Primary Industries and Fisheries.

Note that growers may elect to choose varieties outside those listed where other desirable characteristics suit their farming system. For example, varieties with high yield of first grade kernel per square metre of canopy area for high-density plantings; varieties with late nut drop to spread workloads; varieties with early nut drop to assist in husk spot management by breaking the disease cycle. Similarly, growers may elect to reject some of the varieties listed because of concerns about defects and other problems listed earlier under the variety profiles.

Table 14. Best yielding varieties for central New South Wales, based on variety trial performance at Warrell Creek

Variety	A29	246	A4	A38	A268	A203	344
Yield NIS[1] (kg/tree)	25.0	22.0	15.8	19.0	17.7	18.5	17.4
Yield sound kernel[1] (kg/tree)	10.0	8.5	7.5	7.4	6.8	6.7	6.5
Cumulative yield (years 4-10) sound kernel (kg/tree)	42.7	32.1	33.0	30.3	31.7	29.1	25.9
Yield sound kernel[1] (kg/m[2] canopy)	0.45	0.42	0.47	0.41	0.43	0.44	0.38
Average canopy dia. (m) at year 10	5.3	5.1	4.5	4.6	4.5	4.4	4.7
Kernel recovery[2] (%)	38.4	36.0	46.1	37.3	38.3	34.3[3]	34.7
First grade kernel[2] (%)	92.3	88.0	98.7	98.1	88.8	89.2	93.3

[1] Yield of mature trees (average of years 8 to 10) @ 10% moisture

[2] Data from years 4 to 10

[3] A203 may be worth considering in other areas where it is reported to have much higher KR

Table 15. Best yielding varieties for northern New South Wales, based on variety trial performance at Clunes

Variety	246	842	344	849	816	814*	783	781	Daddow	705	A16[3]
Yield NIS[1] (kg/tree)	25.1	20.9	24.9	18.2[4]	17.8	20.4	19.4	20.2	22.0	21.2	10.2
Yield sound kernel[1] (kg/tree)	8.6	8.3	8.1	7.8	7.7	7.6	7.6	7.5	7.5	7.5	4.0
Cumulative yield (years 4-14) sound kernel (kg/tree)	59.9	53.3	52.6	60.9	56.5	48.1	50.2	59.0	52.3	51.0	35.0
Yield sound kernel [1] (kg/m[2] canopy)	0.29	0.40	0.34	0.27	0.40	0.58	0.34	0.26	0.34	0.42	0.29
Average canopy diameter (m) at year 14	8.1	7.0	7.5	6.7	6.2	5.8	6.9	8.2	7.7	6.7	5.7
Kernel recovery[2] (%)	37.1	41.1	34.6	46.2	45.1	38.3	40.7	39.5	37.7	37.7	41.7
First grade kernel[2] (%)	95.1	96.8	91.7	95.1	96.2	87.3	96.6	94.1	91.8	93.2	95.6

[1] Yield of mature trees (average of years 12 to 14) @ 10% moisture

[2] Data from years 9 to 14

[3] Local experience suggests A16 performs very well at Clunes. Should be considered despite results of this trial

[4] Suggestion that production may have been reduced by collection of budwood from 849 at this site

*Although good yielding, not recommended because of quality defects

Table 16. Best yielding varieties for southeast Queensland– southern, based on variety trial performance at Forest Glen

Variety	A29	A38	A268	A16	A203	344
Yield NIS[1] (kg/tree)	19.8	18.5	18.1	14.5	15.3	15.0
Yield sound kernel[1] (kg/tree)	7.3	6.9	6.7	6.1	5.0	4.9
Cumulative yield(years 4-10) sound kernel (kg/tree)	40.0	39.2	36.6	35.6	30.4	26.6
Yield sound kernel [1] (kg/m^2 canopy)	0.36	0.37	0.39	0.46	0.36	0.31
Average canopy diameter (m) at year 10	5.1	4.9	4.7	4.1	4.2	4.5
Kernel recovery[2] (%)	36.9	37.4	36.9	37.4	32.8[3]	32.5
First grade kernel[2] (%)	97.1	98.3	96.3	97.6	95.8	95.9
Whole kernels[2] (%)	30	56	36	46	43	44

[1] Yield of mature trees (average of years 8 to 10) @ 10% moisture

[2] Data from years 4 to 10

[3] A203 may be worth considering in other areas where it is reported to have much higher KR

Table 17. Best yielding varieties for southeast Queensland–northern, based on variety trial performance at Wolvi

Variety	246	344	781	835	842	783	849	A16
Yield NIS[1] (kg/tree)	24.2	24.4	21.6	20.2	18.4	17.2	15.5	15.5
Yield sound kernel[1] (kg/tree)	8.4	7.8	7.7	7.3	6.9	6.9	6.5	6.2
Cumulative yield (years 4-14) sound kernel (kg/tree)	47.1	46.6	45.5	45.0	41.7	39.5	45.3	39.0
Yield sound kernel[1] (kg/m^2 canopy)	0.33	0.28	0.17	0.12	0.31	0.38	0.33	0.31
Average canopy diameter (m) at year 14	5.7	6.1	6.9	6.0	5.7	5.0	5.3	4.9
Kernel recovery[2] (%)	35.0	32.4	37.0	37.1	36.9	39.1	43.8	40.4
First grade kernel[2] (%)	92.3	96.8	97.1	99.0	98.7	98.1	95.7	97.4
Whole kernels[2] (%)	44.4	34.9	46.5	66.7	48.3	54.4	55.9	50.3

[1] Yield of mature trees (average of years 12 to 14) @ 10% moisture

[2] Data from years 9 to 14

Table 18. Best yielding varieties for central Queensland, based on variety trial performance at Rockhampton

Variety	741	816	344	842	705	Daddow
Yield NIS[1] (kg/tree)	21.6	14.3	18.2	14.7	12.5	11.2
Yield sound kernel[1] (kg/tree)	8.0	6.6	6.1	5.3	4.8	4.6
Cumulative yield(years 4-14) sound kernel (kg/tree)	55.0	43.6	45.2	52.9	36.8	41.2
Yield sound kernel [1] (kg/m^2 canopy)	0.24	0.16	0.23	0.23	0.22	0.12
Average canopy diameter (m) at year 14	7.0	7.6	6.9	7.0	6.1	6.5
Kernel recovery[2] (%)	37.6	45.9	33.4	38.1	38.0	40.2
First grade kernel[2] (%)	98.6	97.8	97.6	94.1	97.2	99.2
Whole kernels[2] (%)	37.7	57.7	44.8	51.1	43.7	43.4

[1] Yield of mature trees (average of years 12 to 14) @ 10% moisture

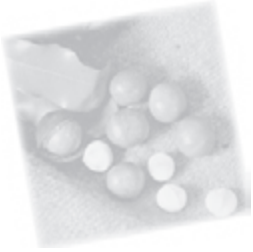
[2] Data from years 9 to 14

Table 19. Best yielding varieties for north Queensland (Atherton Tableland), based on variety trial performance at Walkamin

Variety	Daddow	705	A16	783	741	660
Yield NIS[1] (kg/tree)	24.8	25.6	19.0	21.2	19.5	19.2
Yield sound kernel[1] (kg/tree)	8.3	7.7	7.5	6.9	6.2	6.1
Cumulative yield (years 4-14) sound kernel (kg/tree)	60.7	53.6	59.0	54.9	43.4	37.9
First grade kernel [1] (kg/m^2 canopy)	0.25	0.27	0.29	0.20	0.23	0.23
Average canopy diameter (m) at year 14	7.6	7.9	6.5	7.3	7.1	7.6
Kernel recovery[2] (%)	34.7	32.1	39.1	35.4	33.4	33.0
First grade kernel[2] (%)	98.7	95.3	99.3	93.8	94.5	93.9
Whole kernels[2] (%)	42.1	37.7	51.3	50.1	35.6	38.2

[1] Yield of mature trees (average years 12 to 14) @ 10% moisture

[2] Data from years 9 to 14



Nutrition management

Applying fertiliser without knowing whether it is needed or not may lead to excessively low or high levels of some nutrients and nutrient imbalance. Blanket fertiliser applications also fail to recognise that different varieties, different blocks of trees and different soil types have different fertiliser needs. Consequently, they tend to provide too much nutrient for some and too little for others.

The modern and responsible approach to fertilising relies on regular monitoring of soil and plant nutrient levels so that nutrients are kept at optimum (or acceptable) levels. This approach also helps avoid excessive fertiliser use, which apart from deleterious effects on tree growth and production, can have serious consequences for the environment through leaching and contamination of water systems. This is particularly important as the build-up of nitrates and phosphates in watercourses arising from agricultural activities is coming under more scrutiny.

Three different monitoring tools are used:

- **Pre-plant soil analysis.** This ensures that the soil is suitable for the crop, and should consist of both a chemical analysis and a physical appraisal of the soil. Chemical analysis is used to ensure that nutrients are within the adequate range before planting. It is particularly important to allow for the adjustment of insoluble nutrients such as calcium and those with limited mobility such as phosphorus. These are difficult to adjust once the trees are in the ground. In phosphorus-fixing soils, it is desirable to concentrate phosphorus fertiliser in the planting hole to reduce the rate of fixation. Physical properties of the soil have a profound effect on root development, soil aeration and on infiltration of water. Corrective measures such as deep ripping to break up hardpans and applying gypsum to improve soil structure should be carried out before planting.
- **Annual leaf analysis.** This allows the fertiliser program to be fine-tuned each year to keep all nutrients within the optimum range. It allows variables such as the season, the crop load and the condition of the tree to be taken into account.
- **Regular (annual/biennial) soil analysis.** This monitors soil pH, major nutrients, and the important balance between pH, calcium, magnesium and potassium to ensure they are maintained within optimum ranges.

See *Consultants and contract services* on page 187 for details.

Because of the complexity of soil chemistry and nutrition, it is highly recommended that expert soil nutrition consultants be used to help guide fertiliser management in the orchard.

Understanding soil fertility

Good soil health is a balance of physical, chemical and biological activity. A good balance optimises the soil's ability to store and cycle water and nutrients, decompose organic matter, inactivate toxic compounds, suppress pathogens, enhance the efficacy of beneficial microbes (particularly at the root surface or rhizosphere) and protect water quality. Good soil health is fundamental to productive and profitable growing as well as playing an important role in the long-term sustainability of the orchard and the demonstration of good environmental stewardship.

Physical soil health

Physical properties of the soil such as soil structure, texture, bulk density, porosity, and plasticity, have a profound effect on soil health and thus on the health of the tree. These properties influence the water infiltration rate, and consequently the effective utilisation of rainfall and irrigation. They also influence susceptibility to soil erosion, soil aeration, development of hardpan layers and tendency to crusting. Well-aerated soil with low bulk density has low resistance to root growth, and encourages healthy root systems.

Chemical soil health

Soils must have adequate levels of essential nutrients, some of which should be within acceptable ratios to support optimum plant growth. More detail on the nutrients is contained later in this section in *Understanding the important nutrients*.

Soil pH

Soil pH provides one of the most valuable indicators of soil health. Soil pH is a measure of soil acidity or alkalinity and is measured on a scale from 0 to 14. A pH of 7.0 is neutral; below this the soil is acid and above it, alkaline. The pH scale is a logarithmic scale; soil with a pH of 5.0 is 10 times as acid as a soil with a pH of 6.0. The acidity or alkalinity of soil is important in influencing the availability of essential mineral nutrients for plant growth. Some are less available at strongly acid pH levels while others are less available at alkaline pH levels (Figure 24). Below pH 4.5, some mineral toxicities can occur from the soil solution becoming saturated with minerals such as aluminium and manganese. Levels of calcium and magnesium also fall. On the other hand, when soil pH rises over 6.5 (more alkaline), many mineral nutrients become fixed and plant deficiencies may develop. In general, trace elements such as boron, copper, iron and zinc are most affected by high soil pH. Nevertheless, some krasnozem soils with pH above 7.0

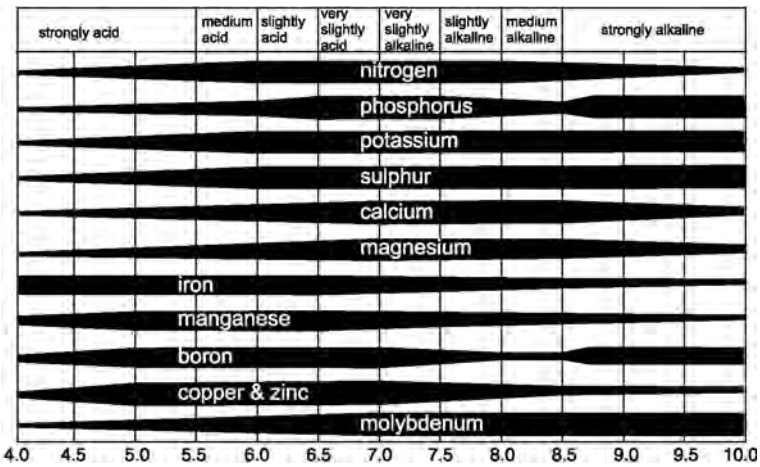


Figure 24. *Effect of soil pH on nutrient availability*

NOTE
Further information on soil pH is available in the Conservation and Land Management (CaLM) and NSW Agriculture *Soil Sense* information sheets *What is soil pH?*, *How to interpret your soil test*, *Why worry about acidity?* and *Which liming material is best?*

may support healthy, productive macadamia orchards, despite iron deficiency being common.

Soil pH can be measured either in water or in calcium chloride, the latter generally being 0.5 to 0.8 pH units lower than if tested in water. For macadamia, soil pH is best kept between 5.0 to 5.5 (1:5 water test) and 4.5 to 5.0 (calcium chloride test).

Effective Cation Exchange Capacity (ECEC)

Effective cation exchange capacity (ECEC) measures the ability of the soil to hold cations (positively charged ions) including calcium, magnesium, potassium, sodium and aluminium. It is a valuable indicator of chemical fertility of the soil and the availability of nutrients to the soil solution for plant growth. The sum of the five positively-charged ions or cations is known as the effective cation exchange capacity.

Cations are held in the soil on the surfaces of clay colloids, organic matter and humus and the quantity held is determined by pH, clay content and soil type, as well as the organic matter and humus content. Typically, sands have CEC's of 1 to 5, loams 4 to 10, clay loams 6 to 15, and clays 5 to 40. The CEC level in clay soils depends largely on soil pH.

NOTE
Further information on cation exchange capacity is detailed in the CaLM and NSW Agriculture *Soil Sense* publications *Cation Exchange Capacity* and *How to interpret your soil test*.

The balance between cations should fall between certain limits:

- Calcium (Ca) should always be present in the greatest amount and constitute 50 to 80% of the ECEC. As pH decreases, levels of Ca fall rapidly.
- Magnesium (Mg) is normally the second most plentiful cation, accounting for 10 to 50% of the ECEC. Figures greater than 20% are normally only found in heavy black and grey soils formed on basalt.
- Potassium (K) typically accounts for 2 to 10% of the ECEC, the lowest amount of the desirable cations (Ca, Mg, and K). The amount of K in sandy soils is generally quite low.
- Sodium (Na) is an undesirable cation normally present in small quantities. Larger amounts are only found in saline soils or those formed from marine sediments. Clay loams and clays with greater than 5% Na have problems with water movement through the soil.
- Aluminium (Al) is also an undesirable cation, only present in toxic forms where pH falls below 5.0 (1:5 water). Al toxicity causes root damage and reduces growth. Although sensitivity varies with different plants, macadamia appears to be reasonably tolerant.

In the past, considerable emphasis was placed on the Ca/Mg ratio being between 4 and 6, although variation between 1 and 10 is quite acceptable, especially since many Australian soils have high subsoil Mg levels. This is generally not detected in soil analysis as soil samples are usually taken no deeper than 15 cm.

Organic carbon and other indicators of soil chemical health

Organic carbon is a measure of soil organic matter, made up of any living or dead plant and animal material in the soil. Organic matter is a highly desirable constituent of the soil. Benefits of increasing the level of organic matter in the soil include improving soil structure, drainage, and water retention; providing nutrients such as nitrogen, phosphorus and sulphur; and increasing the cation exchange capacity. Organic matter can be increased by promoting growth in the inter-row area and under the canopy with under-tree ground covers like sweet smother grass or by applying bulk organic material, as long as this does not interfere with management operations such as harvesting. Organic carbon values of more than 4% are regarded as high, 2 to 4% as medium and 1 to 2% as low.

NOTE
Further information on soil organic matter can be found in the CaLM and NSW Agriculture *Soil Sense* publication *Soil Organic Matter.*

In addition to organic carbon (referred to as total carbon), other good indicators of good soil health include labile carbon content ('active' carbon), microbial biomass C, total N and pH buffering capacity.

Biological soil health

The biological balance of healthy soils helps suppress the build-up of soil-borne pathogens such as Phytophthora and maintains a stable ecological balance in the soil. There are many ways to indicate the biological health of soil, including microbial biomass, microbial activity, bacterial and fungal biodiversity, the ratio of free-living to plant parasitic nematodes and earthworm density. Enzymes produced by microorganisms play a key role in the oxidation and release of inorganic nutrients from organic matter.

Nematodes and earthworms are one or two steps higher in the food chain than fungi and bacteria and are good indicators of the physical, chemical and biological health of soil. For example, the proportion of free-living to plant parasitic nematodes is a useful ecological indicator of the functionality of the detritus food web, because it indicates the balance between the various groups feeding on plant roots, and those feeding on bacteria, fungi and other nematodes. Because of their relatively short generation times, nematodes can respond quickly to changes in food supply or other changes in the soil.

Excessive use of copper in orchards can have a major, and undesirable, effect on soil biota. Care should be taken to avoid excessive use of copper sprays.

HINT
Nutrient concentrations in the sections that follow are generally expressed in mg/kg. Note that 1 mg/kg is equal to 1ppm (part per million).

Understanding the important nutrients

NITROGEN (N)

Function

The most important nutrient for tree growth.

A key component of chlorophyll (the green pigment in leaves), which is why nitrogen deficient trees are light green or yellow.

An essential requirement for the synthesis of plant hormones, which control tree growth.

Behaviour in soil and plant

Very mobile in the soil and leaches very readily, particularly in high rainfall areas. May have to be topped up with small applications after extended periods of rain.

Very mobile within the tree. New vegetative growth has a strong demand for nitrogen and, because of its mobility, it is moved from the old leaves to young leaves during periods of rapid growth.

Too little nitrogen reduces photosynthesis and hence growth, causes early leaf fall and reduces fruit set and yield. Too much promotes excessive vigour and reduces flowering, especially if applied in large doses.

Fertiliser forms

Urea (46% N)

Sulphate of ammonia (Gran-Am®, 21% N).

Potassium nitrate (13% N and 38% K).

Calcium nitrate (15% N and 18 to 19% Ca)

Calcium ammonium nitrate (CAN, 27% N and 8% Ca)

Management

In young trees, nitrogen is applied regularly to rapidly develop the leaf canopy. When trees start bearing, its use should be related to the level of production (nutrient replacement). Nitrogen is best applied in as many applications as practicable throughout the year. During summer, small applications of nitrogen are needed to meet the high demand during nut development and oil accumulation. However, heavy applications of nitrogen to bearing trees at this time should be avoided as this can promote vegetative growth, and reduce nut yield and quality. Excessive applications of nitrogen (particularly in the ammonium form) can also increase soil acidity.

PHOSPHORUS (P)

Function

Essential for energy metabolism in maintenance and growth.

Particularly important for root growth, flower initiation and nut set.

Behaviour in soil and plant

Only a small proportion of soil phosphorus is generally available for tree uptake.

In some soils such as krasnozems and red earths, phosphorus is tightly fixed. Most macadamias in NSW are grown in these soils. The fixing of phosphorus near the surface reduces its availability to the tree and predisposes it to losses from soil erosion.

Relatively immobile in the soil and not readily leached.

Very mobile in the plant, moving readily in both an upward and downward direction.

Excessive soil levels may induce iron and zinc deficiencies. Iron deficiency is common in soils where sugar cane has previously been grown. The iron to phosphorus ratio in leaves (Fe:P) is a reliable indicator of tree health. A Fe:P ratio of less than 0.07 is often associated with phosphorus-induced iron deficiency (chlorosis).

Proteoid roots are induced to form under low soil P conditions. These roots are adapted to enhance the uptake of the sparingly available P by greatly increasing the root surface area available for absorption, and by producing specialised root exudates that make P more available to the tree.

Fertiliser forms

Superphosphate (9% P, 11% S, 20% Ca).

Triple superphosphate (19% P, 2% S, 18.5% Ca).

Diammonium phosphate (DAP, 18% N, 20% P, 2% S).

Monoammonium phosphate (MAP, 12% N, 22% P, 3% S).

Rock phosphate (phosphorus content varies according to source; check content before calculating rates).

Management

Monitor soil and leaf levels regularly, and apply phosphorus fertilisers only where required. Leaf phosphorus levels often fall rapidly as the tree commences to crop and may be hard to maintain in older bearing trees.

PHOSPHORUS (P) continued...

In phosphorus-fixing soils such as the krasnozems, extractable soil phosphorus levels above 100 mg/kg using the Colwell soil test may be required for optimum nut-in-shell production. In most other soils, the optimum level for macadamias is about 85 mg/kg, based on field trials calibrated to yield. Pot trials with a wide range of soils, however, indicated adequate soil P at 50 mg/kg calibrated to seedling growth. Many productive orchards fall between this range

Because of its slow movement through the soil profile (except in white sands), it is best applied in non-irrigated orchards before the summer rains to help with its movement into the soil.

POTASSIUM (K)

Function

Several important roles, but the most important appears to be regulation of water balance. It achieves this by influencing water movement and controlling the opening and closing of stomata (water pores on leaves).

Another important function is the synthesis and movement of starches, sugars and oils. In this role potassium has a direct effect on nut yield and quality.

Behaviour in soil and plant

Very mobile in the soil and readily leached, particularly in sandy soils.

Very mobile in the plant, readily moving in all directions. However, because it is not required to a great extent by leaves, new growth flushes do not draw large amounts of potassium away from the nuts.

Peak potassium requirements occur during nut growth and oil accumulation.

Fertiliser forms

Potassium sulphate (sulphate of potash, 41% K, 16.5% S)

Potassium chloride (muriate of potash, 50% K, 50% Cl)

Potassium nitrate (38% K, 13% N)

Management

The availability of potassium should be considered in relation to that of other nutrients, such as calcium and magnesium. An excess of one of these nutrients can reduce the availability of others. For example, excessive applications of potassium fertilisers can induce a magnesium deficiency.

CALCIUM (Ca)

Function

Plays an important role in cell division and cell development in new leaves, nuts and root tips.

Behaviour in soil and plant

Relatively immobile in the soil.

Mobile within the tree in an upward direction towards the leaf tips with little remobilisation downwards.

High soil levels may reduce uptake of manganese, zinc, boron, copper and phosphorus.

Fertiliser forms

Calcium sulphate (gypsum, 18 to 20% Ca, 14 to 18% S).

Calcium nitrate (18 to 19% Ca; 15% N).

Calcium carbonate (lime, 35 to 40% Ca).

Calcium and magnesium carbonates (dolomite, 12 to 15% Ca, 8 to 12.5% Mg).

Calcium ammonium nitrate (CAN, 8% Ca, 27% N).

Management

The availability of calcium should be considered in relation to that of other nutrients, such as potassium and magnesium. An excess of one of these nutrients can reduce the availability of others. Since lime is insoluble, and gypsum relatively insoluble in water, they should be applied before the wet season to help with incorporation. Before buying any liming material, check the neutralising value, fineness and calcium and magnesium content. Finer particles of lime react faster. Fine agricultural lime with 98 to 100 percentage fines (particles less than 0.25 mm in diameter) is recommended.

The choice of calcium product depends on the effect required. Lime is normally used when soil pH and calcium levels are both low. Dolomite is normally used when soil pH, calcium and magnesium levels are all low. Gypsum is normally used when pH is within the desired range, but the soil calcium level is low.

MAGNESIUM (Mg)

Function

An essential component of chlorophyll (the green pigment in leaves) where it helps trap light energy, converting it to chemical energy used to produce sugars (photosynthesis).

Also regulates the uptake of other plant nutrients and is essential for many biochemical cellular functions.

Behaviour in soil and plant

Relatively mobile in the soil and is absorbed by roots, mainly through passive diffusion.

High soil concentrations of ammonium, potassium and calcium may compete with magnesium for uptake, leading to magnesium deficiency.

Very mobile within the tree, moving readily from old leaves to new leaves under deficient conditions.

Fertiliser forms

Magnesium sulphate (Epsom salts, 9.5% Mg).

Calcium and magnesium carbonates (dolomite, 8 to 12.5% Mg, 12 to 15% Ca).

Granomag (magnesium oxide, 54% Mg).

Management

The availability of Mg should be considered in relation to that of other nutrients, such as Ca and K. An excess of one of these nutrients can reduce the availability of others. Because of the links between pH, ECEC, Ca, Mg and K, base the calculation of rates and timing of these nutrients on leaf and soil analysis, and on the balance of cations. Corrective application is generally only necessary once every few years. Aim to keep the pH between 5.0 and 5.5 (1:5 water test). All liming materials are best applied in autumn. The choice of magnesium product depends on the effect required. Dolomite is normally used when soil pH, calcium and magnesium levels are all low. Granomag is normally used when pH is within the desired range, but the soil magnesium level is low.

SULPHUR (S)

Function

An important component in proteins and chlorophyll.

Behaviour in soil and plant

Relatively mobile in the soil.

There is little impact from other nutrients on the uptake and movement of sulphur absorbed by roots.

Movement in the tree is mainly upwards. Once incorporated in proteins, it cannot be remobilised for use in other parts of the plant in times of deficiency.

Fertiliser forms

Sulphate of ammonia (Gran-Am®, 24% S)

Superphosphate (11% S)

Single superphosphate with sulphur (26.1% S)

Gypsum (14 to 18% S)

Elemental sulphur (98 to 100% S)

Management

There are no specific management strategies for sulphur fertilising in macadamias. Under normal circumstances, fertilisers commonly used (superphosphate, sulphate of ammonia, sulphate of potash and gypsum) generally contain enough sulphur to meet tree requirements. If leaf S levels are low, select these fertilisers to use in the fertiliser program.

Trace elements

Trace elements are extremely important although only small quantities are usually required. Trace elements most likely to be deficient are boron, copper, zinc and iron.

BORON (B)

Function

An important role in cell division and cell growth. Important in areas of the plant where cell development is significant (for example, flowers, nuts and shoot and root tips).

Important role in root health.

The range between boron deficiency and toxicity is narrow, so careful management is required.

Behaviour in soil and plant

Very mobile in the soil and is easily leached from acidic soils, and rendered unavailable in calcareous (alkaline) soils and in very wet or dry soils.

Not very mobile within the plant, with any movement occurring in an upwards direction with little remobilisation downwards. Consequently, in most Australian growing environments, trees require a constant supply of boron throughout the year from small, but frequent applications.

Fertiliser forms

Borax (11% B.

Solubor (21% B).

Boric acid (17% B).

Note: Often incorporated into N:P:K mixes (e.g. North Coast Macadamia Mix®).

Management

Use leaf and soil analysis to monitor boron levels. Take care with application rates as there is a fine line between deficient and toxic boron levels. To apply boron evenly and to avoid toxicity with soil application, it is best mixed in water and sprayed on the ground. Alternatively, use soluble forms (Solubor, boric acid) and apply by fertigation. Must be a ready supply from either the soil or foliar sprays. In situations of B deficiency, foliar boron sprays have been shown to increase yields of nut-in-shell, kernel recovery, first grade kernel and mean kernel weight. However, foliar applications provide temporary relief only. Hence, follow-up sprays and soil applications are needed.
If an application is due and the orchard has received very little rain or irrigation since the last application, postpone the application until substantial rain or irrigation is received.

ZINC (Zn)

Function

An essential role in the production of enzymes and plant hormones. Hence it is required for new growth, which is distorted when deficiency occurs.

Has a regulatory role in the uptake of water.

Necessary for normal chlorophyll formation.

Behaviour in soil and plant

Not very mobile in the soil. It has been shown that mycorrhiza assist with the root uptake of zinc in other tree species.

From research in other species, it is known to be not very mobile in the tree. Tends to accumulate in roots.

Deficiency is reasonably common, particularly on soils with high pH or where heavy applications of lime have been made. High soil phosphorus levels also inhibit the uptake of zinc. There is evidence in red krasnozem soils that macadamias take up little if any soil applied zinc.

Fertiliser forms

Zinc sulphate heptahydrate (23% Zn).

Zinc sulphate monohydrate (36% Zn).

Zinc oxide (80% Zn).

Management

In red krasnozem soils where there is evidence of inhibition of uptake from the soil, foliar sprays of zinc and urea are recommended, where leaf analysis suggests a deficiency. This is best applied to the summer leaf flush. Where deficiency is severe, re-apply to the winter/spring flush and developing nuts.

In other soils, there should be sufficient uptake from soil applied zinc to overcome a deficiency. However, concentrating the zinc in a band around the dripline of the tree is recommended to assist with uptake. Foliar sprays may be used as a supplement where necessary.

COPPER (Cu)

Function	Involved in the transfer of energy in various tree processes such as photosynthesis and nitrogen metabolism.
	Also important in the production of lignin, which provides strength to the growth of lateral branches.
Behaviour in soil and plant	One of the least mobile elements in the soil and not easily leached.
	Not readily mobile within the tree, though if present in sufficient quantities, it will be translocated from older to younger leaves.
	Copper deficiency is normally only a problem in leached, sandy soils receiving high nitrogen, or where soil phosphorus is very high.
	High levels of soil copper may induce an iron deficiency.
Fertiliser forms	Bluestone (copper sulphate pentahydrate, 25% Cu).
	Copper is also available in several fungicides including copper oxychloride and copper hydroxide. If copper fungicides are regularly used for control of diseases such as husk spot, then there is generally no need to use copper fertilisers.
Management	Routine sprays of copper-based fungicides for husk spot control generally prevent copper deficiency from developing.

IRON (Fe)

Function	Critical function in the production of chlorophyll (the green pigment in leaves).
Behaviour in soil and plant	Generally an abundant element in the soil, where it is relatively mobile.
	Not very mobile within the tree.
	Generally associated with either high soil pH (greater than 7.0 on 1:5 water test), high levels of soil phosphorus, or high levels of soil manganese.
Fertiliser forms	Iron sulphate (23% Fe). For use in all situations.
	Iron chelate or iron EDDHA (5 to 15% Fe, for example Sequestrene 138®. For use in soils with a pH greater than 7.0.
Management	Iron deficiency can be corrected by lowering the pH with sulphur or by using sulphate of ammonia instead of urea for nitrogen requirements. However, where high soil phosphorus levels cause the iron deficiency, this is ineffective. Foliar sprays of iron chelate and soluble ferrous sulfate may help in this situation.

A program for nutrition management

A detailed program for managing nutrition has been outlined throughout the *Growing the crop* chapter of this handbook. In brief, the program involves:

Before planting

Do a complete soil analysis before planting to adjust pH and the relatively immobile nutrients (phosphorus, calcium, zinc and copper) to appropriate levels. These nutrients are best worked into the entire root zone before planting.

Young, non-bearing trees

Wait until young trees have begun to put on new growth and then fertilise little and often from September to May. Young trees have a high requirement for nitrogen and phosphorus, the latter heavily dependent on soil type, but a relatively low requirement for potassium until bearing commences. Use soil analysis as a guide to fertiliser rates. Spread fertiliser in a broad ring around the tree, extending 50 cm beyond the edge of the canopy (dripline). Keep the

fertiliser 10 cm away from the trunk to avoid collar burn. Alternatively, apply through the irrigation system where available (fertigation).

Bearing trees

Base all fertiliser applications on leaf and soil analysis, together with an allowance for nutrient removal (see later in this section). In addition, factor in the tree vigour when calculating nitrogen requirements, to maintain tree health under sustained heavy cropping. Similarly, higher levels of nutrition are required for some varieties, such as the HV A series. Spread fertiliser over the whole orchard area with most directed under the tree canopy where feeder roots are concentrated. Alternatively, apply through the irrigation system where available (fertigation).

Leaf and soil analysis

Details on sampling for soil and leaf analysis are outlined in the *Growing the crop* chapter of this handbook. It was recommended there that because the processes of sampling, analysis and interpretation are complex and require specialist skills, growers engage the services of an experienced local nutrition consultant. They will manage the analysis, interpret the results and make fertiliser recommendations appropriate to each orchard. Ensure that consultants are using the services of a reputable laboratory with quality-assured accreditation for the analysis. However, to help growers understand what is involved in the interpretation, some basic information is provided here.

Understanding leaf and soil analysis results

Tables 20 and 21 show soil and leaf nutrient levels that are considered optimum for macadamia.

Table 20. Optimum soil nutrient levels for macadamia.

Element (extraction procedure shown in brackets)	Optimum soil levels
pH (1:5 water)	5.0 – 5.5
pH (1:5 $CaCl_2$)	4.5 – 5.0
Organic carbon (Walkley-Black)	more than 2.0%C
Nitrate nitrogen (1:5 aqueous extract)	more than 15 mg/kg
Sulphate sulphur (phosphate)	more than 20 mg/kg
Phosphorus (Colwell)	85 mg/kg P
Potassium (exchangeable)	more than 0.5 meq/100 g K
Calcium (exchangeable)	more than 5 meq/100 g Ca
Magnesium (exchangeable)	more than 1.6 meq/100 g Mg
Sodium (exchangeable)	less than 2% exchangeable cations
Aluminium (exchangeable)	less than 5% exchangeable cations
Chloride (1:5 aqueous extract)	less than 200 mg/kg Cl
Conductivity (1:5 aqueous extract)	less than 3 dS/m
Boron (hot calcium chloride)	1 – 2 mg/kg B
Total cation exchange capacity	preferably more than 7
Cation balance (%)	calcium 50 – 80 magnesium 10 – 50 potassium 2 – 10 sodium less than 2 aluminium less than 5

Note that soil nutrient levels in analyses vary from laboratory to laboratory depending on extraction procedures used. Hence it is important to relate the result to the extraction procedure. These are listed for each nutrient in Table 20. Note also that most soil tests do not measure total nutrient content, but rather use various solutions to extract 'available' fractions of the nutrient from the soil. To be meaningful, this amount of extracted nutrient should preferably be calibrated to yield and leaf content of the nutrient. Apart from phosphorus trials on three soils in Queensland, there is no such calibration specifically for macadamias. The optimum soil levels for other nutrients are therefore extrapolated from other research and local experience.

Table 21. Recommended leaf nutrient levels

Nutrient	Deficient	Low	Recommended	High
Nitrogen (%)	‹1.2		1.4 – 1.5	
Phosphorus (%)	‹0.05	0.05 – 0.08	0.08 – 0.10	›0.1
Potassium (%)	‹0.40		0.4 – 0.7	›0.7
Sulphur (%)		‹0.16	0.16 – 0.25	›0.25
Calcium (%)	‹0.4	‹0.4 – 0.5	0.5 – 0.9	›0.9
Magnesium (%)	‹0.06	0.06 – 0.07	0.07 – 0.10	›0.1
Sodium (%)			‹0.02	
Chloride (%)			‹0.05	
Copper (mg/kg)	‹3	3.0 – 4.5	4.5 – 10	
Zinc (mg/kg)	‹5		6 – 15	›50
Manganese (mg/kg)	‹20	20 – 100	100 – 1000	›1500
Iron (mg/kg)			40 – 200	
Boron (mg/kg)	‹20	20 – 40	40 – 75	›100

Note that the leaf nutrient ranges shown in Table 21 apply to leaves analysed by the dried tissue technique. Levels do not apply to results obtained from sap analysis techniques.

Tables 22 and 23 provide broad guidelines for interpreting leaf and soil analysis results. The tables use a concept known as 'replacement rates' which is explained after the tables.

Note that except for phosphorus on three Queensland soils, there has been little research on responses of macadamia to soil nutrient levels. Soil type should be taken into account when applying the following tentative recommendations, particularly for pH, ECEC, Ca, Mg, K, Na, Al and Colwell P. Krasnozems often have different requirements and responses to other soil types.

Table 22. Interpreting soil analysis results

Element	Optimum levels	Interpretation
pH (1:5 water)	5.0 - 5.5	5.5 about ideal. Note: pH measured in CaCl2 is usually 0.5-0.8 units lower than that measured in water. If below 5.0, toxic soluble Al levels may increase and Ca and Mg fall. In these cases, apply dolomite or a limestone/Mg blend if calcium: magnesium ratio (in this table) is close to 3–5:1 and magnesium concentration is less than 1.6meq/100g soil. Otherwise use lime. pH levels up to 7.0 appear to present no significant problems, although above pH 6.5, induced Fe deficiency may occur in white and red sands, loam soils and black earths, particularly when the soil is low in Fe and/or high in P.
Organic carbon–%C (Walkley-Black)	› 2.0	If less than 2, use green manure crops, mulches, organic manures. Values ›4% are regarded as high, 2-4% medium and 1-2% low.
Nitrate nitrogen–mg/kg (1:5 aqueous extract)	› 15	Note: nitrate nitrogen analysis of soils is notoriously unreliable because soil nitrate is very mobile in the soil. If carried out, samples should be frozen before dispatch. If ‹ 15, apply at replacement rates + 30%. If 20-30, apply at replacement rates. If › 30, apply less than replacement rates.
Phosphorus–mg/kg P (Colwell)	85	Note: a level of 85 mg/kg is suitable for loams, red sands and black earths but for white sands and loams with bleached A2 horizons, values of 50mg/kg may be adequate. Krasnozems often have levels above 85 mg/kg. Colwell extractable P, yet leaf P levels are often below 0.08. Soils in the Bundaberg area often have soil P levels of 40-70mg/kg. If ‹ 60, apply at rate of 25kg/ha P. If 60-85, apply at replacement rates. If › 100, no application is necessary (except for krasnozems–seek specialist advice).
Potassium–meq/100g K (exchangeable)	›0.5 (2-10% of ECEC)	If ‹ 0.5, apply at replacement rates + 20%. If 0.5-1, apply at replacement rates. If › 1, no application is necessary.
Calcium–meq/100g Ca (exchangeable)	›5.0 (50-80% of ECEC)	In white and red sands, and often in loams with bleached A2 horizons, soil Ca may be adequate at 2-3 as ECEC levels are only 4-5. On black earths, Ca may be as high as 20-30meq/100g. If ‹ 5 and pH ‹ 5.0, apply lime at up to 2.5t/ha on light sandy soils and up to 5 t/ha on heavier soils. If magnesium levels are also low, use dolomite or a limestone/magnesium blend instead. If soil pH ›5.0 and calcium levels are low, apply gypsum at 1 to 2 t/ha. If › 5 and pH is › 5.0 (1:5 water), no application is necessary.
Magnesium–meq/100g Mg (exchangeable)	› 1.6 (10-50% of ECEC)	Similar soil type interpretation to that for Ca (above). If ‹ 1.6, with pH less than 5.0, apply dolomite at up to 2.5 t/ha on light sandy soils, and up to 5 t/ha on heavier soils. If the pH is satisfactory and magnesium levels are low, apply magnesium oxide at 100 to 200 kg/ha.
Sodium–meq/100g Na (exchangeable)	‹ 1 (‹5% of ECEC)	If › 1, check quality of irrigation water and height of water table.
Chloride–mg/kg Cl (1:5 aqueous extract)	‹ 200	If › 200, check quality of irrigation water and height of water table, and use sulfate forms of potassium fertiliser.
Conductivity ECse*–dS/m (1:5 aqueous extract)	‹ 3	If › 3, check quality of irrigation water, fertiliser rates and height of water table.
Boron– mg/kg B (hot calcium chloride)	1 – 2	If ‹ 1.0, check leaf analysis level to see if overall deficiency is confirmed. Follow recommendations there.
Total cation exchange capacity	›2, preferably higher	Total ECEC is heavily dependent on soil type. Typically, sands have ECECs of 1-5, loams 4-10, clay loams 6-15 and clays 5-40, the latter depending on pH. See pH, calcium, magnesium and potassium above.

*Saturated extract equivalent

Table 23. Interpreting leaf analysis results

Element	Adequate levels	Interpretation
Nitrogen (% N)	1.4 - 1.5	If within desired range, use nutrient replacement to determine rates of application. If below desired levels, apply additional N. NB. Recent surveys indicate higher leaf N levels (1.6-1.8%) in high-yielding orchards, particularly in the krasnozems of northern NSW. Hence, the adequate range may be adjusted to include these levels.
Sulphur (% S)	0.16 - 0.25	Rarely out of range. HV A varieties may have lower levels.
Phosphorus (% P)	0.08 - 0.10	It is hard to increase leaf P of mature trees above 0.06% and P applications have little effect on leaf P levels. If within desired range, no action necessary. If below or above desired range, use soil analysis results and/or nutrient replacement to determine rates of application.
Potassium (% K)	0.40 – 0.70	If below desired level, either insufficient potassium or competition from high levels of calcium and/or magnesium for uptake. Use soil analysis results for potassium, calcium and magnesium to determine rates of application. Remember that potassium levels fall as the crop load increases on the tree, so timing of sampling is important when interpreting analysis results. If within or above desired range, use soil analysis results and/or nutrient replacement to determine rates of application.
Calcium (% Ca)	0.50 – 0.90	Ca continues to accumulate as leaves age so younger leaves will have lower levels. Drought may influence Ca levels. It is suggested that 0.4% Ca may be adequate for younger leaves. If below desired range, either insufficient calcium, low soil pH, or an imbalance with potassium and/or magnesium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action necessary.
Magnesium (% Mg)	0.07 - 0.1	If below desired range, either insufficient magnesium, low soil pH, or an imbalance with potassium and/or calcium. Use soil analysis results for potassium, calcium, magnesium and pH to determine type of fertiliser and rates of application. If within or above desired range, no action necessary.
Zinc (mg/kg Zn)	6 – 15	If below desired range, high soil pH, excessive phosphorus or excessive nitrogen may be indicated. Evidence suggests that soil-applied Zn is not effectively taken up by macadamias, particularly in krasnozem soils. Apply a foliar spray of zinc sulphate heptahydrate at 15kg/1000L/ha (1.5% solution) plus 1kg urea to the summer growth flush. Where deficiency is severe, re-apply to the winter/spring flush. In other soil types, band zinc sulphate monohydrate at a rate of 3 g per square metre of canopy cover in a band 30 cm wide around the dripline of the tree. If within or above desired range, no action necessary.
Copper (mg/kg Cu)	4.5 - 10	Rarely out of range if copper fungicide sprays are used. Where leaf symptoms indicate copper deficiency, use foliar sprays.
Sodium (% Na)	less than 0.02	If more than desired level, check quality of irrigation water and soil analysis results.
Chloride (% Cl)	less than 0.05	If more than desired level, check quality of irrigation water and soil analysis results.
Iron (mg/kg Fe)	40 - 200	Rarely out of range except where heavy applications of lime, dolomite or phosphorus have been made.
Boron (mg/kg B)	40 - 75	If below desired range, apply up to four foliar sprays of Solubor at 1g/L between September and March (B is immobile in the plant so repeat sprays are necessary) and spread 3 g of borax or 1.5 g of Solubor per square metre of soil surface evenly beneath the trees. Boron can become toxic so check leaf levels two months later before any further applications are made. B may be readily leached from the soil. If within or above desired range, no action necessary.
Manganese (mg/kg Mn)	100 - 1000	Only likely to be deficient on white sands. If below desired range, apply a foliar spray of manganese sulphate at 100g/100L to the spring flush.

Note that apart from some research on N at one site, most of the leaf nutrient standards are based on survey and field observation, and not on calibrated yield responses. Local monitoring of yield responses to leaf nutrient levels is recommended to refine the tentative recommendations in Table 23.

Fertiliser rates using the nutrient replacement concept

Once nutrients requiring adjustment have been identified, the next step is to calculate the rates of fertiliser that need to be applied. For the main nutrients, use the nutrient replacement concept below in conjunction with Tables 22 and 23. This bases nutrient and fertiliser application rates on the amount of nutrient removed by the crop, adjusted for expected losses of nutrient through leaching and soil fixation.

Nutrient removal by the crop has been calculated from research and is shown in Table 24.

Note that the rates of nutrient replacement in Table 24 have been adjusted using the following rules of thumb for normal (not excessive) leaching, erosion, soil fixation and other losses:

- nitrogen rates increased by 30%
- potassium rates increased by 20%;
- calcium rates increased by 10%;
- magnesium rates increased by 25%.

These allowances are appropriate in most situations but since soil type and weather conditions vary so much, loss estimates may need to be refined. For example, **in very sandy soils, nitrogen rates could be increased by up to another 20%, and in krasnozem soils, phosphorus rates should be increased by up to 100%**.

Table 24. Nutrient removal by the crop (tree nutrient removal + adjustment for leaching and other losses) with varying crop yields

Crop yield (t/ha)	Requirements for full replacement of lost nutrients (kg/ha)				
NIS at 10% m.c.	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
2	27	2.5	22	1	2
4	55	5	44	2	4
6	82	7.5	66	3	6

A simple computer program (Excel format), to help calculate the amount of fertiliser to apply based on a nutrient replacement system, is available from NSW Department of Primary Industries.

Fertiliser choice

Nutrients can be applied either as straight inorganic (synthetic), mixed inorganic, or organic fertilisers, with both the rate and timing being important. The nutrient content of a fertiliser is displayed on its label. Mixed fertilisers are usually described by their ratio of nitrogen: phosphorus: potassium (N:P:K) and there is a wide range available. Special mixtures can also be made to suit particular requirements. Some mixed fertilisers also contain trace elements, such as copper, zinc and boron.

Inorganic fertilisers are recommended as they produce a more predictable and timely response. Macadamia trees respond well to organic fertilisers, which are useful in improving soil structure, organic matter levels and microbial

activity. Their chemical composition, however, is variable and often low in some nutrients such as potassium. They are recommended as supplements to inorganic fertilisers. Organic materials such as poultry manure and nut husks are best applied as soon as harvesting is complete. Do not apply raw animal manures within four months of the start of nut drop and until after the completion of harvest to reduce the risk of microbial contamination of nuts. Husks should be composted to reduce the spread of the husk spot fungus.

Straight inorganic fertilisers are preferred to mixed inorganic fertilisers as they can supply each nutrient as required. They are also generally cheaper per unit of nutrient. Mixed fertilisers are more convenient to use but may cause a nutrient imbalance by oversupplying a particular nutrient.

Another important issue in the selection of fertilisers is how much they will contribute to soil acidity and soil salinity. If the soil is acid, choose the least acidifying fertiliser available – see Table 25. Most mixed fertilisers are based on sulphate of ammonia and therefore acidify the soil.

Table 25. Acidifying effect of common fertilisers

Fertiliser	Acidifying effect
Sulphate of ammonia	highly acidifying
MAP	highly acidifying
DAP	acidifying
Urea	acidifying (neutral if no leaching)
Superphosphate	non acidifying
Calcium ammonium nitrate	non acidifying (basic)
Sodium nitrate	non acidifying (basic)
Potassium nitrate	non acidifying (basic)
Muriate of potash	non acidifying (basic)

If salinity is a problem, choose fertilisers with the lowest salt index – see Table 26.

Table 26. Salt index of common fertilisers. (A measure of contribution to osmotic potential in the soil solution. For comparison, common salt has a salt index of 154).

Fertiliser	Salt index
Muriate of potash	114
Urea	75
Potassium nitrate	74
Sulphate of ammonia	69
Sulphate of potash	46
DAP	34
MAP	30
Gypsum	8
Superphosphate	8
Lime	5
Dolomite	1

Note that urea is readily converted to ammonia in the soil, often within a couple days of application. If the urea is not washed into the soil by rain or irrigation, large losses of N can occur through volatilisation of the ammonia.

Fertigation

Fertigation (application of fertiliser through the irrigation water) is recommended and has many advantages over the manual application of solid fertilisers. It uses less labour, gives more efficient nutrient uptake and fertilisers can be applied more regularly and conveniently. With efficient fertigation, annual rates of nitrogen and potassium can generally be reduced by up to 25%. Fertiliser can be added during every irrigation if desired, but fertigation every 2 to 4 weeks is generally most practical.

The effectiveness of fertigation is dependent on the effectiveness of the irrigation system. The full advantages of irrigation and fertigation only become evident if the irrigation system is designed correctly to meet tree requirements and to distribute water and fertiliser evenly. Irrigation output must be uniform across the block to fertigate accurately. Where fertigation is being used on sloping land, pressure compensating emitters (either mini-sprinkler or drip) are required and application should be avoided at the end of an irrigation because of uneven drainage of lines. For these reasons, seek professional advice from an experienced irrigation designer when planning the system.

Before starting, get a water-testing laboratory to analyse the irrigation water. Make sure an iron test is included to assess the potential risk of iron blockages.

Fertilisers used in fertigation must be highly soluble to avoid pump damage and pipe blockages. Mixtures of fertiliser must also be compatible to avoid precipitation which can block sprinklers and also cause root damage. For example, calcium and phosphate fertilisers mixed at high concentrations often form precipitates. The most suitable fertilisers for fertigation are urea, calcium nitrate, potassium nitrate, potassium chloride and technical grade monoammonium phosphate (MAP). Several commercial soluble fertilisers that supply a range of nutrients are also suitable.

NOTE
Because fertigation is limited to highly soluble fertilisers, and is effective in applying fertiliser to the irrigated zone only, some ground applications of fertiliser may also be necessary.

Because of the corrosive nature of many fertilisers, the components of the irrigation system that come into contact with corrosive solutions should consist of stainless steel, plastic or other non-corrosive materials. Concentrations of total nutrients in the mainline should not exceed 5 g/L. Always mix fertilisers in a sufficient volume of water. If fertilisers are not completely dissolved and mixed prior to injection into the system, varying concentrations will be applied or blockages may occur within the system.

The majority of injectors available can generally incorporate automatic operation by fitting pulse transmitters, which convert injector pulses into electric signals. These signals then control injection of preset quantities or proportions relative to the flow rate of the irrigation system. Injection rates can also be controlled by flow regulators, chemically resistant ball valves or by electronic or hydraulic control units and computers. Older systems rely on either:

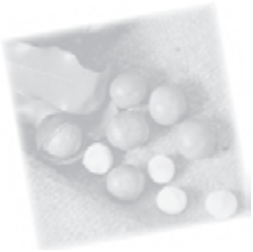
- Venturi suction from a tank with the flow rate controlled by a gate-valve;
- Direct injection into the suction line of the irrigation pump (beware of impeller corrosion);
- Pressure differential (PD) drums, where some mainline flow is bled off through a pressure drum containing a concentrated fertiliser solution, before being injected back into the main line as a dilute fertiliser solution.

Suitable anti-siphoning valves or non-return valves should be installed where necessary to prevent backflow or siphoning of water or the fertiliser solution into fertiliser tanks, the irrigation supply, household supply or stock supply.

Fertigation increases the quantity of nutrients present in an irrigation system and this can lead to a buildup of bacteria, algae and slime. These should be removed at regular intervals by injection of chlorine or acid through the system. Chlorine injection should not be used while fertiliser is being injected as the chlorine may tie up nutrients making them unavailable to the trees.

Injection can start any time after the system is fully operational (that is, it has reached operating pressures and is flowing, and all air is out of the irrigation lines). Merck nitrate test strips can be used to follow a dose of potassium nitrate through a system to give direct and visual indications of the time it takes to inject and then flush the system. Systems should always be flushed of nutrients before irrigation is completed. During the irrigation season, it is important to monitor:

- pH effects over time in the root zone,
- soil temperature effect on nutrient availability,
- corrosion and blockages of outlets, and
- reaction with salts in the soil or water.



Irrigation management

Although irrigation is only recommended where annual rainfall is less than 1200 mm or where it is unevenly distributed throughout the year, in these locations it can significantly improve nut yield, size and quality.

Research has shown that, even though mild water stress at all stages of the growth cycle reduces tree growth, its effect on yield and nut quality depends on the particular stage when the stress occurs. Stress in April (when floral initiation occurs and the trees are normally vegetatively dormant) has little or no effect on yield or quality. Stress during flowering and early nut set and development (August to November) can reduce yields. This period often has high temperatures, low humidity and low rainfall which collectively, may lead to significant moisture stress. As nuts set and develop, yield and quality become increasingly sensitive to water stress. Yield and quality are most sensitive to stress during the latter stages of maturation (December to February) when oil is accumulating in the kernel. The extent of damage to yield and/or quality depends on the severity and duration of the stress. Where water supply is limited, it should be conserved and applied at these critical stages.

Supply and demand for water in the orchard

Only a small, but essential, proportion of the tree's water requirement is used for growth of stems, leaves, roots and nuts. The majority is lost through transpiration (evaporation through the small pores or stomata on the leaf surface). This water movement through the tree is essential for carrying nutrients from the roots and for cooling sunlit leaves that would otherwise get sunburnt.

Plant water use (transpiration) depends on supply and demand – the ability of the soil to supply sufficient water to the roots, and the demand for water determined by weather conditions, the size of the canopy, and the resistance to water loss from the leaves. The stomata have the ability to close when water supplies are limiting (block off the pores), hence decreasing water loss.

The demand for water

Water evaporates from leaves that contain about 80% water into the relatively 'dry' atmosphere. The demand for water is higher in sunlight when:

- humidity is low (drier atmosphere);
- temperature is high;
- wind speed is high; and

- the leaf area (which provides the evaporative surface for water loss from the tree) is greater (up to a certain leaf area above which water use does not increase further).

When water in the leaves is less available, and at night, the stomata close to reduce further loss of water to the atmosphere. The water status of trees that are under some water stress during the day will often recover at night.

As water is lost from the leaves via transpiration, tension develops between water molecules in the leaf and this tension is transmitted through the xylem (the conduit linking leaves, through the stem, to the roots, where there is generally an abundance of water in well-managed orchards). This tension 'draws' water up from the roots to the leaves.

The supply of water

An optimum supply of water in the soil is needed for healthy and productive trees. Too much water will result in waterlogging and the tree will die from lack of oxygen for the roots. After rain or irrigation, excess water percolates down through the soil, allowing air to enter the large pores between soil particles. At this point the soil is at field capacity and a large amount of water is held loosely in the smaller soil pores and around soil particles. Much of this water is available to the tree. However, some of the water is not available because it is held too tightly around the soil particles. When all the available soil water is used by the tree, and only the unavailable, tightly held water is left, the soil is at the wilting point – the point where plants would start to wilt. Soils of different texture (different particle sizes) and structure hold different amounts of available and unavailable water (Table 27). In poorly structured soils, as soil particle size and soil pore size decrease, the amount of available soil water declines and root growth is impeded because soil particles tend to be more tightly packed together.

Table 27. The amount of water held in different soils. Note that this is an approximate guide only.

	Water held in the soil (mm water/m depth of soil)*		
Soil texture	**At field capacity**	**At wilting point**	**Available soil water**
Sand	90	20	70
Loamy sand	140	40	100
Sandy loam	230	90	140
Sandy loam + organic matter	290	100	190
Loam	340	120	220
Clay loam	300	160	140
Clay	380	240	140
Well structured clays	500	300	200

* 1 mm water = 1 L/m^2

In addition to the amount of water in the soil, the supply of water to the tree is determined by the extent and density of the root system, and the movement of water through the soil (hydraulic conductivity).

Plants with deep root systems have access to a larger reservoir of soil water and a dense mat of fibrous roots will more effectively exploit soil water reserves. However, a dense mat of roots can reduce the water holding capacity of the soil by roots filling up soil pore spaces where water is normally stored. Roots cannot grow in dry soil and tend to proliferate in moist soil.

The amount of water that is stored in the soil, as opposed to that which runs off over the soil surface, depends on the infiltration rate (the rate at which water soaks into an already moist soil). This rate is different for different soils (Table 28). Information on infiltration rate is important when planning the irrigation system. The irrigation delivery system should not exceed the infiltration rate for the soil being irrigated.

HINT
Get an experienced irrigation consultant to do an infiltration test on your soil before design and installation of the irrigation system.

Table 28. Water infiltration rates for different soils

Soil type	Infiltration rate (mm of water/hour)	
	Flat ground	**Sloping ground**
Deep sands, aggregated silts	More than 20	8
Deep loamy sands	10-20	5
Loams and sandy loams and soils low in organic matter	5-10	3
Clay loams (including krasnozem soils)	5	2
Clays	Less than 5	Less than 2

Irrigation essentials

A good irrigation system

The first essential of efficient irrigation is an adequate water supply and an irrigation system capable of delivering the required amounts of water to each tree when needed, without waste. Research has shown that mature HAES 344 macadamia trees at 8 m x 4 m spacings use up to 55 L water per day at Bundaberg in summer, hence 0.5 ML/ha is needed to provide a months storage for irrigation—equivalent to up to 5 ML/ha/year. Ask a qualified irrigation expert to prepare an irrigation design and plan.

The two preferred irrigation systems (minisprinklers with a microspray feature, and drip or trickle tape) are detailed in the *Growing the crop* chapter of this handbook. Whatever system is used, it must be able to supply water to a depth of at least 75 cm, the depth of the bulk of the root zone.

A monitoring system

The second essential of efficient irrigation is a system of monitoring how much water the trees need and when. Water use can generally be reduced without affecting yield or nut quality. It also helps ensure that sufficient water is applied at critical times without overdoing it at other times.

A range of equipment and techniques is available for monitoring soil moisture and scheduling irrigation (Table 29). The most common are the soil-based systems using tensiometers or soil capacitance probes such as the

EnviroSCAN® and C-Probe®, and these are recommended. Most of the feeder roots of macadamia trees are in the top 30 cm of soil, so soil water monitoring devices used for irrigation scheduling need to concentrate on this part of the soil profile. Nevertheless, macadamia roots extend down to 4 m or more, depending on soil type, so the tree may have access to additional soil water at depth. As soil moisture monitoring can be complex, we recommend you seek expert advice, particularly when setting up the system.

Table 29. Comparison of main soil moisture monitoring systems

System	Advantages	Disadvantages
Tensiometers	Relatively cheap Easy to install yourself Easy to read yourself	Labour intensive to collect and record data Require regular maintenance Can be inaccurate in extremely wet or dry soil Not accurate in very sandy soils Indicates when to irrigate; not necessarily how much to apply
Soil moisture sensors, e.g. gypsum blocks	Relatively cheap Easy to install yourself Easy to read yourself	Labour intensive to collect and record data. Requires a digital meter to be brought to each sensor site to take readings Can be inaccurate in extremely wet or dry soil Indicates when to irrigate; not necessarily how much to apply May only last up to 18 months because of breakdown of gypsum
Neutron probe	Portable, can be moved around sites	Not suitable for continuous monitoring As equipment is expensive and radioactive, generally need to use a consultant Less accurate in sandy soil unless sampled frequently, but accurate once calibrated for a particular soil Need special training course and license
Portable capacitance probes e.g. Gopher®, Diviner®	Relatively cheap compared to permanent capacitance probes Reasonably accurate at all depths and for all soils Lightweight and portable Easy to operate and interpret Indicates both when to water and how much to apply	Manual reading required Labour intensive to collect and record data
Non-portable capacitance probes e.g. EnviroSCAN®, C-Probe®	Automatic continuous monitoring Accurate at all depths and for all soils Enables rapid reading and recording of results Indicates both when to water and how much to apply	Expensive Needs skill in interpreting data – training and support Computer required Not portable
Evaporation pan	Inexpensive, no in-field measurement needed because the system uses weather data to predict irrigation requirements Regular schedules can be developed in advance Invaluable when planning the orchard to estimate annual requirements and peak demand needs	Less accurate as it ignores soil variability and the performance of the irrigation system Cannot accurately assess the effectiveness of rainfall received Requires evaporation and rainfall data Error can build up; actual soil moisture needs to be checked periodically

Tensiometers

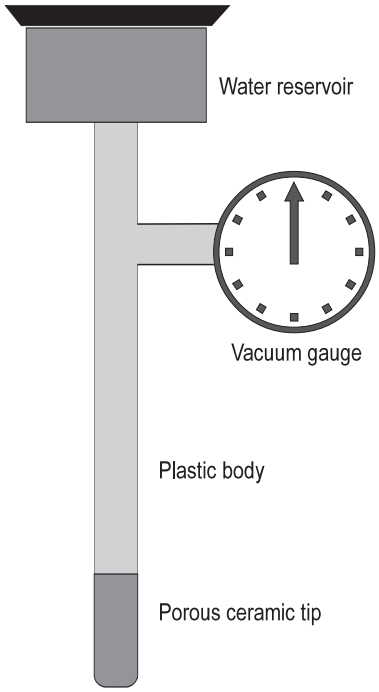


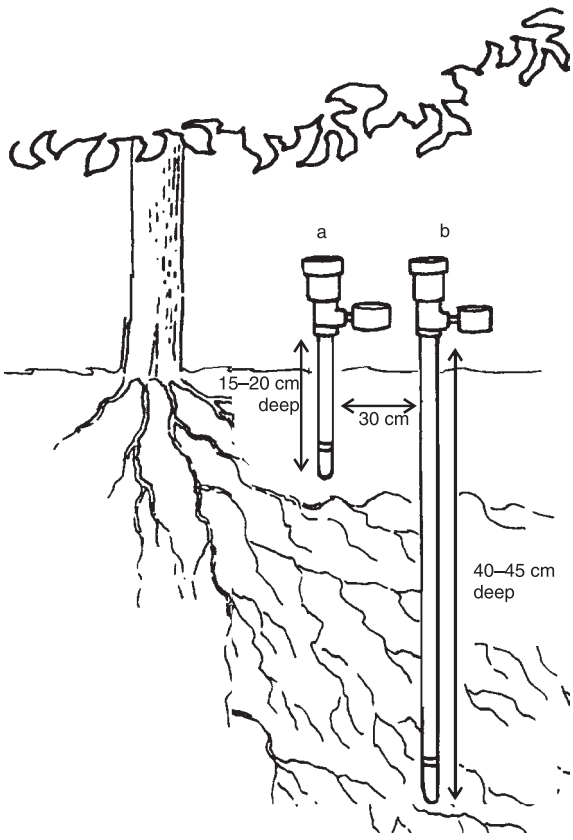
Figure 25. *Parts of a standard tensiometer*

Tensiometers, provided they are well sited and maintained, are a relatively cheap and effective way of monitoring soil moisture. Tensiometers consists of four basic parts – a hollow tube filled with water and algaecide, a ceramic tip, a water reservoir and a vacuum gauge which reads water tension on a scale of 0 to 100 centibars (cb) or kilopascals (kPa) (Figure 25). Gaugeless tensiometers, read using a special handpiece, are also available. While the tubes are cheaper, the handpiece is expensive, but these systems should be considered if you intend to purchase more than eight tensiometers. Some handpieces enable the readings to be kept and graphed on a computer.

In saturated soil, the vacuum gauge on the tensiometer displays 0 kPa. As the soil dries, water moves from inside the instrument, through the porous ceramic tip, into the soil creating a vacuum inside the tube. The gauge measures this vacuum and readings may go as high as 90 kPa. When the soil is re-wetted after rain or irrigation, water moves from the soil back into the tensiometer and the vacuum in the tube decreases and gauge readings fall.

Monitoring sites

Tensiometers are installed at monitoring sites throughout the orchard once trees are established. Use at least one monitoring site for each variety or block. At each site, install two tensiometers — one shallow, the other deep. Position the shallow tensiometer (30 cm long) in the major root zone with its tip 15 to 20cm deep, and the deep tensiometer (60cm long) with its tip 40 to 45cm deep. Place tensiometers on the north-eastern side of trees, inside the dripline and where they will receive water from the micro-jets/minisprinklers or trickle. Ensure tensiometes are installed at the same distance from the micro-jets/ minisprinklers in all blocks. Where trickle systems are used, keep the tensiometers at least 15 cm from the trickle tube. Placement of tensiometers is shown in Figure 26.



Installation

Assemble tensiometers and fill with good quality water to which algaecide has been added. Adding a dye to the water also makes it easy to observe the water level. Leave them to stand in a bucket of water at least overnight, but preferably for a day or two.

Tensiometers are more reliable if a vacuum pump is used to remove any air from the tensiometer body and gauge. Make sure the pump fits snugly over the fill point on top of the tensiometer. Top up the tensiometers with more water if neces-

Figure 26. *Tensiometers in place, (a) in major root zone and (b) below most roots*

sary and use the vacuum pump to remove air bubbles. They are now ready to install.

Carry tensiometers to the installation site with the tips either in water or wrapped in wet rags. Do not touch the porcelain tips with the fingers as grease from the fingers can block the fine pores. To ensure reliable monitoring, there must be good contact between the soil and ceramic tip. Soil should also be compacted around the tube so there are no easy pathways for water to flow directly from the soil surface to the tensiometer tip.

Tensiometers should be installed in the tree line to give consistency of readings over the years and to avoid damage due to normal orchard operations. To install the tensiometer, follow these instructions in conjunction with Figure 27. Dig a hole to the required depth. A 50 mm (2 inch) auger is ideal for this. Place the tensiometer in the hole, over to one side. The next step is critical. Good contact between the ceramic tip and the surrounding soil is most important. Take the most crumbly, moist soil from the dirt pile and pack it around the tip at the base of the hole. A piece of 10 to 15 mm diameter dowel is useful for packing. Don't over-compact the soil into plasticine, but remove large air gaps. Continue replacing and packing soil until the hole is filled. It doesn't matter which soil you use after you have packed the first 5 cm above the tip. Friable topsoil from a few metres away can be used to create a slight mound around the tensiometer. This minimises the risk of water draining down beside the tensiometer, leading to false readings. Covers made from silver/blue insulation foil can be placed over the tensiometers to minimise temperature fluctuations and algal growth. The gauge can be left exposed for easy reading.

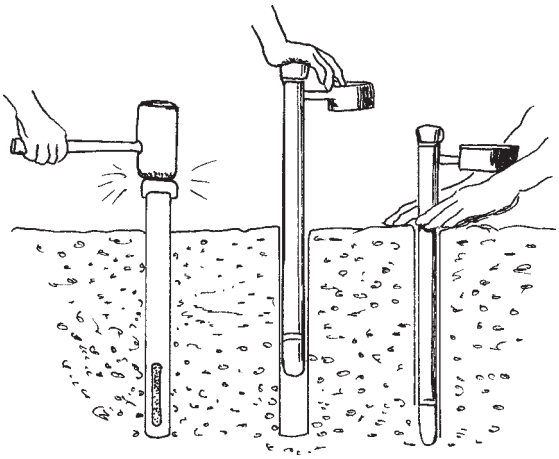


Figure 27. *Installing deep tensiometers*

The tensiometers are now ready to operate. Use the vacuum pump to remove air bubbles. Tensiometers may take a few irrigation cycles to settle down, so don't take too much notice of the readings for the first few days. During this period, air gaps may appear in the tensiometer. Simply refill with algaecide-treated water. Within a week of installation, readings should rise and fall with irrigation or rainfall. Clearly mark tensiometer locations to avoid damage by tractors and other equipment.

Reading

Lightly tap the gauge before reading. Read at the same time each day, preferably early in the morning, (before 8am) when there is little water movement in the soil or plant. It is best to read tensiometers daily for the first few weeks to get a feel for the system. Thereafter, read at least twice a week. The shallow tensiometer indicates when to water. The deep tensiometer indicates when the right amount of water has been applied.

Irrigating using tensiometers

During the high-demand nut development/kernel filling stage (December to February), start watering when the shallow tensiometer reads 20 kPa (sandy soils) and 30 to 40 kPa (loam and clay loam soils). Stop watering when the reading falls to 10 kPa (Figure 28). Monitor the trend of the deep tensiometer. If its readings continue to rise immediately after irrigation, not enough water has been added. If its readings fall to less than 10kPa soon after irrigation, too much water has been added (Figure 28). Slightly lower readings should be used for drip systems.

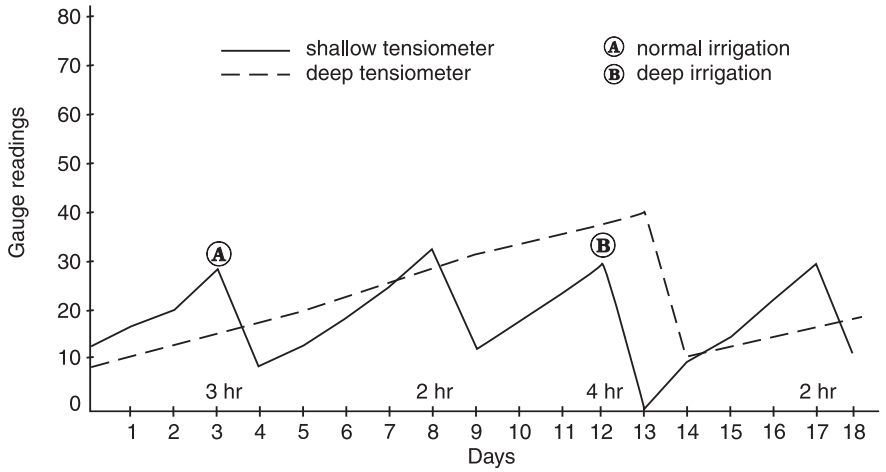


Figure 28. *A sample chart showing tensiometer readings on a daily basis*

Once a week, using the vacuum pump, remove any accumulated air and check that the gauges are working properly. Refill as required.

Capacitance probes

Capacitance probes measure the dielectric constant of the soil and consequently its water content. They are available in two forms: a portable version with brand names such as the Gopher® or Diviner® and a non-portable version with brand names such as the EnviroSCAN® or C-Probe®.

Portable versions (Gopher®; Diviner®)

These consist of a probe on the end of a rod, which is passed down 50 mm diameter PVC access tubes to determine the moisture content of the soil. A reading is taken at 100 mm intervals down the access tube and recorded by a hand-held logger. Soil moisture readings can be measured on site or downloaded into a computer and calculated later. The logger can handle up to 99 sampling sites. The machine measures soil moisture in millimetres and can be used to estimate when to water and how much to apply.

Non-portable versions (EnviroSCAN®; C-Probe®)

These are continuous moisture-monitoring devices consisting of multiple sensors mounted on probes with slots every 10 cm to accommodate the snap-in sensors. The probes are then placed within vertical PVC access tubes installed semi-permanently in the orchard. The probes are generally left in place for the season and then moved to another tube or site as required. However, a probe can be moved from tube to tube to record readings at several different sites. Sensors are positioned on the probes to provide readings at specific depths. Measurements from the sensors are relayed at set times along a cable to a data logger for recording. Data from the logger are downloaded to a computer every few days to show water use and to provide

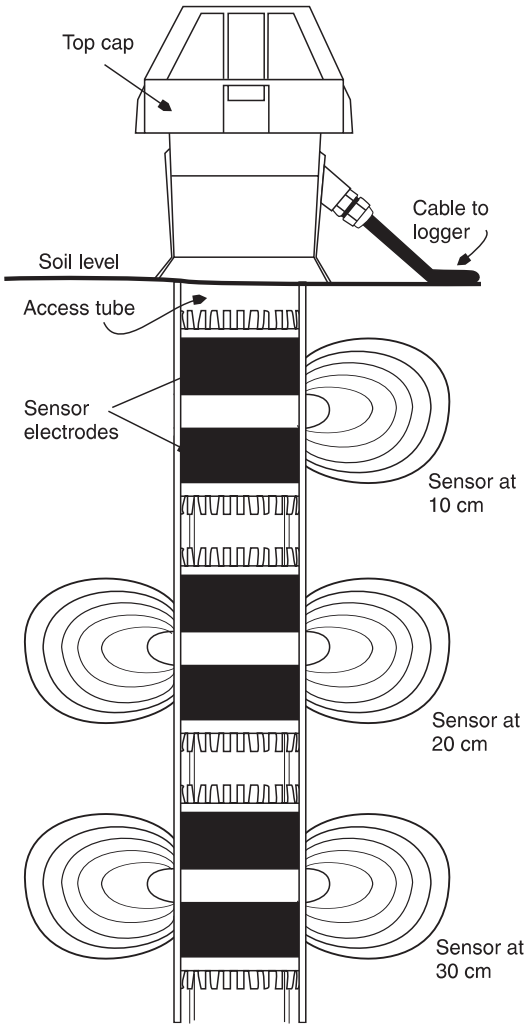


Figure 29. *Diagrammatic representation of an EnviroSCAN® probe*

recommendations for watering. Figure 29 is a diagrammatic representation of the EnviroSCAN® capacitance probe.

For macadamia, two probes are recommended for a block but the number of sites depends on variability in soil and varieties. The first probe should have sensors at 10, 30, 50 and 100 cm, and the second probe with sensors at 10, 30, 50, 100 and 150 cm to monitor losses from deep drainage. When setting up probe sites it is very important that water distribution patterns from the irrigation system are known and that the probes are positioned appropriately. The equipment can be hired from some consultants. As installation of probes and interpretation of the data requires some skill, we recommend consultants are used to set up the system and provide at least initial advice.

Irrigation scheduling based on evaporation

Because the water requirement for trees is largely determined by atmospheric demand, a common way of determining irrigation needs is to use evaporation from a Class A pan and a crop factor that estimates the relationship between pan evaporation and actual tree water use. It allows for canopy size and resistance by the canopy to transpiration. The water requirement calculated in this way estimates the irrigation required for mature crops only.

Research conducted in a lysimeter at Nambour between 1991 and 1995 provided data that enables a crop factor to be calculated for macadamia. The total water use per tree (L, watered to field capacity weekly) was divided by the canopy surface area (m^2, an index of evaporative leaf surface) to give mm of water used per square metre of canopy. This was then divided by corresponding A pan evaporation (also expressed as mm water) to give crop factors of 0.7 during spring, 0.8 in summer, 1.1 in autumn and 1.0 in winter. During the critical oil accumulation stage, a crop factor of 0.8 is therefore appropriate for macadamia.

Consequently, we can make a calculation for water need as follows:

Water Requirement (L/tree/week) = 0.56E x f_1 x R x T

Where:

- E = weekly evaporation in mm from a Class A pan (Class A pan evaporation figures for three sites are given below. For other sites, figures are available from the Bureau of Meteorology for your district);
- f_1 = crop factor (for macadamias f_1 = 0.8 in summer, 0.7 in spring for mature trees);
- the 0.56 represents factors to relate A pan evaporation to that of an open surface of water combined with a climatic factor;
- R x T = available root area (m^2), R being the distance between rows in metres and T the distance between trees in metres.

For example, for a mature hedgerow at 8 m x 4 m spacing, the water requirement in December (A pan evaporation = 42 mm/week) would be = 0.56 x 42 x 0.8 x 4 x 8 = 602 L/tree/week. It is better to base the irrigation schedule on actual soil moisture measurements. However, calculating the water requirement as above provides a check to ensure sufficient water is being applied.

Irrigation frequency

The interval between irrigations is calculated using the number of days the tree takes to use the available water in the root zone after irrigation. If the interval between irrigations is too long, trees can be stressed before the next irrigation, and hence water use declines.

$$IT = \frac{W \times T \times D \times F}{R \times T \times Cf \times A\ pan}$$

Where:

- IT = Interval between irrigations (days)
- W = wetted strip width (m)
- T = Tree spacing along the tree-line (m)
- D = Depth of root zone (m)
- F = Soil Type Factor, depending on soil type (sand = 60, clay = 80)
- R = Row spacing (m)
- Cf = Crop factor (e.g. 0.8), depending on canopy size, etc
- A pan = Average daily pan evaporation (mm/day)

For example, if we assume a wetted zone 3 m wide and a 1.2 m deep root system in a clay soil during December:

$$IT = \frac{0\ 3 \times 4 \times 1.2 \times 80}{8 \times 4 \times 0.8 \times 9.1}$$

$$= \frac{1152}{233}$$

= 4.9 days between irrigations

Hours of irrigation required

$$H = \frac{R \times T \times Cf \times E\ pan}{I}$$

Where:

- I = Rate of irrigation (L/hr/tree) = Dripper/sprinkler delivery rate x no outlets per tree

Evaporation figures

Average weekly evaporation at Bundaberg, Nambour and Alstonville

Month	Evaporation (mm/week)		
	Bundaberg [1]	Nambour [2]	Alstonville [3]
Jan	64	40	40
Feb	50	35	35
Mar	44	34	31
Apr	39	29	25
May/Jun/Jul	22-27	20-24	18-20
Aug	28	24	25
Sep	35	31	32
Oct	43	34	36
Nov	44	44	39
Dec	50	42	43

[1] Mean weekly pan evaporation from the Bureau of Sugar Experiment Station, Bundaberg for the 2001-2002 season

[2] Mean weekly pan evaporation (converted) from the Maroochy Research Station, 11 year average, 1965-1973

[3] Mean weekly pan evaporation from the Alstonville Research Station, 27 year average, 1963-2002.

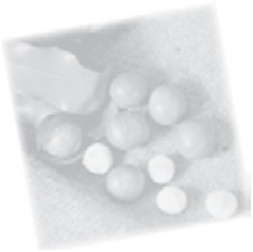
Useful conversions

Rainfall, evaporation and soil water storage are often expressed in mm but, since only a portion of the orchard (along the tree-line) is irrigated, it is often useful to express water use and storage in litres. Irrigation emitter and dripper discharge is expressed in L/hour and, since the irrigation wetted pattern is restricted to the tree-line, it is more accurate to calculate the volume of the root zone wet in cubic metres rather than in millimetres.

1000 cubic centimetres (cc) = 1 litre (L)
1 cubic metre (m^3) = 1000 L
1 m^3 = 1000 L
1 millimetre (mm) = 1 litre per square meter (L/m^2)
1 mm = 10,000 litres per hectare (L/ha)
100 mm = 1 megalitre per hectare (1ML/ha)
Water use (L/tree) = Water use (mm) x Canopy area (m^2)

Tips for managing with limited water

- Eliminate weed competition near trees. Use herbicides rather than cultivation to avoid damaging surface feeder roots and to reduce evaporation losses.
- Keep the inter-row grass sward mown close to the ground.
- If feasible, mulch trees, particularly during the drier spring months, to a depth of 5 cm, covering the area under the trees to just beyond the canopy dripline.
- Don't over-fertilise with nitrogen as the large leaf area produced increases evaporation losses from the tree.
- Irrigate at night when electricity is cheaper and evaporation is minimal.
- Apply water to the active root zone only.
- Install a drip based or trickle system.



Pest and disease management

Being an Australian native, the macadamia tree is susceptible to a wide range of insect pests, several of which are capable of causing a significant reduction in nut yield and quality. Pest management requires regular monitoring of the orchard to determine the presence and severity of pest infestations, and the timely and thorough application of pesticides. Although diseases are fewer in number and generally of less importance than pests, some such as husk spot and trunk canker are serious enough to warrant routine preventative treatments.

An overview of the major pests

Summary of pests

Pest	Where it occurs	Time of year to monitor	Tree part affected	How serious
Spotting bugs (fruitspotting bug; bananaspotting bug)	Fruitspotting bug: coastal Qld and NSW Bananaspotting bug: coastal Qld	September to March	Nuts	Major pest, causes premature nut drop and kernel damage (considered the most important pest)
Macadamia nutborer	Qld and NSW	September to March	Nuts	Major pest, causes premature nut drop and kernel damage
Rats	Qld and NSW	All year in trees, orchard floor and surrounds	Nuts: in trees and fallen	Major pest; can cause severe losses if not controlled
Macadamia flower caterpillar	Qld and NSW Less severe in more elevated locations	July to September	Flower buds and flowers	Major sporadic pest
Macadamia leafminer	Coastal Qld & NSW	Throughout year	Lush new growth	Can be major pest in young trees
Macadamia felted coccid	Qld and NSW	Mainly July to October	Leaves, twigs and stem	Minor to insignificant if clean trees/propagation material used
Macadamia twig-girdler	Qld and NSW	September, December, March	New growth on young trees	Minor pest in older trees. Can be major pest in young trees
Latania scale	Qld and NSW	Young trees: throughout year Bearing trees: September to March	Branches and nuts	Generally minor unless sprays disruptive to beneficials are over-used
Green vegetable bug	Coastal Qld & NSW	September to March	Nuts	Occasionally a major pest in some orchards

Fruitspotting bug *(Amblypelta nitida)* and bananaspotting bug *(A. lutescens lutescens)*

Host plants

In addition to macadamia, both insects attack a variety of horticultural crops including avocado, custard apple, guava, lychee, passionfruit, pecan and citrus. Spotting bugs are usually more severe in orchards surrounded by natural scrub or rainforest.

Pictures of all pests and their damage are contained in the *Macadamia problem solver and bug identifier field guide*.

Further information on diseases and disorders is available in the book *Diseases and disorders of macadamias* by R.D. Fitzell and further information on insect pests is available in the book *Insect pests of macadamia in Queensland* by D.A. Ironside.

Life cycle

Both insects pass through seven stages, the egg, five immature stages (nymphal instars) and the adult. Females lay eggs that are placed singly on nuts, leaves or terminal branches. The eggs are often placed on the edges of leaves, and in crevices on nut stalks. The eggs are oval, about 1.7 mm in length, and pale green in colour. After hatching, the nymphs go through five stages, before becoming adults. The adults are capable of mating within 5 days of emergence and can live for up to 6 months, but summer life expectancy is only 2 months. During summer, the eggs hatch in 6 to 7 days and the period required for complete development of the fruitspotting bug (laying of eggs to emergence of adults) is about 40 days. Lower temperatures reduce development rates. The insects pass through three to four generations each year, one in spring, one to two in summer and one in autumn. The adults of the autumn generation live through the winter and commence egg laying in spring. Nymphs may also be found on alternative hosts, especially mock orange (*Murraya paniculata*) during winter.

Nymphs and adults do not move far from the fruit or nuts on which they feed. Both adults and nymphs are very alert and tend to escape observation by hiding behind fruit or leaves when they are approached. It is common to find trees with fruit heavily damaged while adjacent trees are untouched. Intense areas of activity (known as 'hot spots') are well documented. These hot spots can be used to advantage when monitoring for bug activity and may also be useful for targeted spraying.

Other important issues

Most damage occurs in the September to December period. Often, the first indication of spotting bug activity is a patchy, heavy fall of green nuts under the tree. This may be especially noticeable if it occurs before natural nut fall. The fallen nuts need to be dissected and examined to determine whether the fall has been caused by natural thinning or by spotting bug.

Macadamia nutborer *(Cryptophlebia ombrodelta)*

Host plants

In addition to macadamia, the insect also attacks lychee, longan and a range of ornamental plants including bauhinia, bird of paradise tree, cupania, easter cassia, golden rain tree, mimosa bush and poinciana.

Life cycle

Females lay eggs singly on the surface of the green husk, on the nut stalk, on the stem of the flower raceme, and sometimes on parts of the tree canopy. The scale-like eggs are oval, approximately 1.0 x 0.8 mm in size, and vary in colour from ivory-white when first laid, to red prior to hatching. Fully- grown larvae are up to 20 mm long, pinkish with discrete, dark green spots. They pupate in the damaged nuts or husks and also in sheltered sites in other parts of the tree. The eggs hatch in 4 to 6 days, larval development takes 3 to 4 weeks and moths emerge after a pupal period of 8 to 10 days. In summer, egg laying to moth emergence takes about 5 weeks.

Other important issues

Attacks on immature nuts cause premature nut fall during the December-February period. Early maturing varieties often avoid much of this loss. Husk damage to the mature nuts may cause some reduction in kernel quality. Populations usually begin to increase noticeably in November and December. The most susceptible varieties are those with a soft and thin husk and shell, such as HV A16.

Rats

Rats cause significant losses to the Australian macadamia industry, particularly in older orchards. In individual orchards, losses greater than 30% have been recorded. Most of the damage is caused by the black rat (*Rattus rattus),* which is an introduced species. Several species of native rats also attack macadamias. The black rat is actually a grey-brown colour with a grey-white underbelly that may be tinged with yellow. It can be easily distinguished from native rats, as its tail is longer than its body. Black rats will also voluntarily enter buildings whereas native rats will not.

Management

Rat management begins well before the expected peak damage period from December to February. Baiting as a control measure by itself is not effective. It needs to be implemented strategically and closely integrated with other management procedures.

Control measures include the following:

- Remove any harbourage for rats within or close to the orchard.
- Rats increase in numbers if they have access to a ready supply of suitable food. Ensure no nuts are left on the ground after harvest is completed in order to reduce the food source and discourage a build-up of the rat population.
- Avoid dumping nut waste from grading and sorting in and around the orchard. Compost nut waste (best if done after hammer milling) to ensure it breaks down quickly, or burn it. Ensure safety precautions are taken if burning.
- Avoid long, tangled grass within the orchard and headlands. Short grass in the orchard before and during harvest assists predators such as owls

See page 58 for an illustration of a typical rat bait station and information on the use of other baits in and around farm buildings.

and hawks. Ensure that orchard verges are kept short and free of undergrowth.

- Regularly remove any rat nests from the trees.
- Bait with the registered rodenticide, coumatetralyl (Racumin®). Handle baits with care and follow the label directions. Prevent all access to the baits by children, domestic animals and non-target wildlife. Place the bait in a locked covered station. Rats prefer the seclusion of covered stations and these also protect the bait from rain.

Macadamia flower caterpillar (*Cryptoblabes hemigypsa)*

Host plants

In addition to macadamia, all known host plants of this insect are Australian native trees belonging to the family Proteaceae. They include non-cultivated macadamias such as *Macadamia ternifolia*, red bottlebrush (*Grevillea banksii*), silky oak (*G. robusta*), *G. pinnatifida*, *G. glauca*, and woody pear (*Xylomelum pyriforme*).

Pictures of all pests and their damage are contained in the *Macadamia problem solver and bug identifier field guide*.

Further information on diseases and disorders is available in the book *Diseases and disorders of macadamias* by R.D. Fitzell and further information on insect pests is available in the book *Insect pests of macadamia in Queensland* by D.A. Ironside.

Life cycle

Eggs are white, oval shaped and with an average size of 0.5 mm x 0.3 mm. They are laid singly or in groups of two or three anywhere on the buds or the raceme stem. They are often hidden beneath the small bracts between adjacent bud stalks. Over 400 eggs may be laid on one raceme. Generally, moths prefer to lay eggs on racemes when the buds are about 3 to 7 mm long but may continue to lay when the flowers are at the full bloom stage. The larva goes through five instars during its development. The first instar larva is yellow and about 0.75 mm long. It bores into a floret bud, and during its first two stages, feeds within the bud, mainly on the stamens and pistil. Longitudinal stripes appear on the body of the third instar and become progressively darker during the later stages. The larva is about 12 mm long and reddish brown when mature, though it can vary in colour from light green to a slaty grey.

Mature larvae usually leave the tree and pupate in a silken cocoon in debris on the ground, but some seek out sheltered sites on the tree. The adult is a small, grey moth 6 to 7 mm long, with a wing span of 14 to 18 mm. When at rest, the wings are folded back so that three transverse, darker grey stripes at the tip of each forewing match and appear as inverted V-shaped marks. The moth is nocturnal and most mating and egg laying occurs during the first 4 hours after dusk.

Other important issues

The timing and intensity of infestations in relation to the time of flowering determines the degree of severity of the damage caused to macadamia flowers. Infestation of the main flowering begins with the migration of adult moths from other hosts. The time of migration can vary greatly, but is most common during August. In most seasons, varieties flowering early or over a short period during winter avoid attack, while those flowering later or over a

prolonged period into spring, become heavily infested. Thus the earlier the flowering, the more likely it is that attack by this insect will be avoided.

Macadamia leafminer (*Acrocercops chionosema)*

Host plants

In addition to cultivated macadamia, hosts include the non-cultivated species of macadamia, *Polyosma cunninghamii* and *Stenocarpus salignus*.

Life cycle

Eggs are laid singly, mainly on the upper surfaces of young leaves. As many as 96 eggs have been recorded on one leaf. Eggs are about 0.5 x 0.4 mm in size and oval in shape with a low, rounded profile and a flattened margin. They resemble tiny, glistening water droplets on the leaf. The larva goes through five stages during its development. The first three stages have flattened, blade-like mouthparts that are used to tear apart the leaf cells and suck the sap. The last two stages have biting and chewing mouthparts with which they cut deeper into the leaf. Larvae at first are a pale green colour but become white to bright yellow, sometimes with an underlying dark hue. During the last stage, the larva develops bright red bands. Fully-grown larvae leave the damaged leaves and seek out pupation sites in debris on the ground. Pupation occurs within an oval, flattened, silken cocoon. After moth emergence, the pupal case is left protruding from the cocoon. The adult is brown with prominent silver bands on the forewings and has a wingspan of about 8 mm. It is active mainly at night but is occasionally seen on foliage during the day.

Development from egg to adult takes 19 to 23 days in summer and 50 to 53 days in winter. In summer, the eggs hatch within 3 to 4 days.

Other important issues

Heavy pruning should be avoided, particularly during the first few years of tree life, as such pruning may weaken the tree and intensify the effects of leafminer damage.

Damage is most severe in young trees grown in elevated rainforest areas. Damage is often worst in plantings with internal windbreaks of bana grass.

Macadamia felted coccid (*Eriococcus ironsidei)*

Host plants

Restricted to macadamia.

Life cycle

The female passes through an egg and two crawler stages before becoming an immobile adult. The male, before becoming a winged adult, also has a pupal stage.

The oval-shaped eggs are laid in large numbers within the felted sac of the female. They are 0.2 x 0.1 mm in size, translucent in appearance with a pale

pink or purplish tinge. When hatching, the lemon-coloured crawlers leave the parent. After the first moult, the insects, which are then about 0 .4 x 0.2 mm in size, locate new feeding sites. Prior to the second moult the male crawlers become enclosed in their felted coverings. This covering is elongate, about 0.8 x 0.4 mm in size, white with three longitudinal ridges. The male crawlers moult to form the pupae within their coverings and the winged orange-coloured adults emerge.

The second stage female crawler moults to become an immobile adult. Mating is then necessary before it can develop its felted sac covering. This is white to yellow-brown and averages 0.7 x 1.0 mm in size with a tiny opening at the anal end.

Development is hastened by increasing temperature. The minimum duration for the complete life cycle is 42 days at 20°C. Females began to lay eggs about 4 to 5 days after forming the felted covering. Eggs are laid over an extended period, resulting in considerable overlapping of the generations, with about six generations possible in a year.

Pictures of all pests and their damage are contained in the *Macadamia problem solver and bug identifier field guide*.

Further information on diseases and disorders is available in the book *Diseases and disorders of macadamias* by R.D. Fitzell and further information on insect pests is available in the book *Insect pests of macadamia in Queensland* by D.A. Ironside.

Other important issues

Dispersal over long distances is mainly passively via transport of infestations on propagative material such as budwood, cuttings, and potted nursery trees. It is worthwhile to disinfest propagative material to prevent the spread of the insect.

Natural enemies can maintain adequate control. However, when the pest is introduced into new areas, its numbers often increase and it may cause severe damage before its natural enemies can catch up and maintain effective control. In these circumstances, insecticide sprays may be required.

Macadamia twig-girdler (*Neodrepta luteotactella)*

Host plants

In addition to macadamia, the insect attacks many other native proteaceous trees such as *Banksia*, *Grevillea*, *Hakea*, *Persoonia*, *Buckinghamia*, *Stenocarpus*, and *Xylomelum.*

Life cycle

Adult females lay eggs singly in leaf axils, on terminal shoots and in the vicinity of old twig-girdler damage. Eggs are approximately 0.7 x 0.4 mm, yellow when laid and changing to reddish-orange as the embryos develop. The proportion and pattern resemble corn on the cob.

The larvae go through six to seven stages and first instar larvae are about 1.5 mm long, and yellow-orange with a black head. When fully grown, the larvae may be up to 23 mm long. They have a dark brown to black head capsule and a mottled brown body, with longitudinal rows of dark brown dots. At the pre-pupal stage, the larvae contract and become lighter in colour. Larvae

construct dull brown, silken cocoons (about 12 mm in length) in which the pupae develop.

The life cycle takes from 62 to 84 days. This comprises 7 days for the egg, 39 to 69 days for the larva, and 12 to 17 days for the pupa. During spring and summer, egg laying to adult emergence on trees in the field can take from 3 to 5 months.

Other important issues

The insect is active throughout the year and most damage to macadamia occurs during summer and autumn. The moths are least active during winter. Tunnelling in the husks and kernels causes damage similar to that caused by macadamia nutborer.

Latania scale (*Hemiberlesia lataniae)*

Host plants

In addition to macadamia, known hosts include avocado, bangalow palm and brush box.

Life cycle

The stages of the insect are egg, crawler, two nymphal instars, and adult. The life cycle takes about two months in summer and there are several generations each year.

Other important issues

Continuous use of broad-spectrum insecticides disrupts natural enemies of the scale and encourages scale build-up. Use of these needs to be minimised in well-managed orchards. Also avoid bringing scale into the orchard by using scale-free nursery stock.

Green vegetable bug (*Nezara viridula*)

Host plants

In addition to macadamia, the insect also attacks legumes (such as beans and soybeans), pecan, citrus, tomato, maize, passionfruit and cucurbits.

Life cycle

Female bugs lay clusters of 40 to 80 eggs arranged in parallel rows on host plants. The eggs are pale-yellow, becoming pink with age, about 1.25 mm long, and hatch after about a week. After hatching, the nymphs develop through five stages before becoming adults. The complete life cycle takes about 5 to 8 weeks. There are at least 3 to 4 generations per year. The bug over-winters as an adult and starts laying eggs in spring. It does not normally develop on macadamia, most infestations being the result of the adults migrating into the orchard from adjacent host plants such as soybeans and weeds.

Other important issues

Bug feeding produces no external symptoms of damage. Damage is not usually recognised until the nuts have been shelled, when damage on the surface of the kernels is obvious. Most damage occurs from early shell hardening onwards (December onwards in southeast Queensland and northern New South Wales). The lack of external symptoms requires sampled fallen nuts to be cracked to observe the presence or absence of bug damage on the surface of the kernel.

The bug appears to be a more serious problem in northern New South Wales, and may continue to cause damage to nuts beyond the end of the period of spotting bug damage.

Pictures of all pests and their damage are contained in the *Macadamia problem solver and bug identifier field guide*.

Further information on diseases and disorders is available in the book *Diseases and disorders of macadamias* by R.D. Fitzell and further information on insect pests is available in the book *Insect pests of macadamia in Queensland* by D.A. Ironside.

Diseases

Trunk canker (*Phytophthora cinnamomi)*

This is an important disease that attacks trees of varying ages. It is an especially important disease of nursery stock and young plantings under 10 years old. The fungus that causes the disease is soil-borne and can be spread in mud, muddy water, soil based potting mix, rain splash, muddy hands, machinery and even dust. It attacks a wide range of plants including pineapples, avocados and native plants such as *Acacia, Casuarina* and several *Eucalyptus* species.

The fungus gains entry to the trunk through wounds or natural openings such as growth cracks in immature bark. Diseased trees are commonly found in low-lying areas where water ponds, or in natural drainage lines.

Management

- Since the major infection occurs in young trees, it is best not to buy plants with black, poorly developed root systems. Only obtain plants that have been grown in a sterilised or disease-free medium. Trees should be planted into a low mound.
- Avoid wounding trunks during all cultural practices.
- In the spring, pare back affected bark and thoroughly paint butts with a registered systemic fungicide mixed in white, water-based, flat paint. Repeat in autumn, but not within one month of picking up nuts. Fungicides that can be sprayed onto the foliage to aid in control are also available.
- Trees more than two years old that have been blown over should be replaced – don't attempt to rejuvenate them. Older trees damaged in this way are very susceptible to canker. Consideration should also be given to replanting badly infected young trees.

Blossom blight (*Botrytis cinerea)*

This disease is most prevalent after intense showery periods in spring or when prolonged high humidity persists as a result of fog. It is sporadic but potentially devastating in NSW where yield losses of up to 40% have been reported. It is less significant in Queensland and is rarely seen in trees younger than 10 years of age. The fungus has a wide host range and its powder-like spores can travel on air currents. Light rain or heavy dew can also disperse spores. Outbreaks can occur when showery weather prevails for three or more days and temperatures range from 10 to 22°C. The fungus infects racemes and produces huge crops of grey spores (hence the name grey mould). *Botrytis* spores are dry spores and they can remain viable for several weeks on decaying racemes. This is important when early July flowers become blighted, as this can create an inoculum bank that might infect the main flowering in late August. New infections occur when these spores are washed or blown onto flowers that are at a susceptible stage of development and that have been wet for more than 6 to 8 hours.

The disease commonly occurs when out-of-season or early flowering coincides with cool, showery weather. However, major epidemics occur when similar conditions prevail during the main flowering (late August/September). Blossom blight is more severe in crowded orchards or in high density plantings where trees are shaded.

The susceptibility of flowers depends upon their stage of development, with flowers at the light green to white stage through to when the sepals turn brown being most susceptible.

Management

Monitor the flower racemes and determine when approximately 60% of the main flowering is in the green bud to white flower stages. During this period, monitor weather conditions and consider spraying where temperatures of around 14°C coincide with 10 hours of continual wetness. Warmer and prolonged wet conditions could lead to a severe disease risk. In dry conditions, spraying will generally not be required.

Keep in mind that a large amount of flower loss can be tolerated without significant yield reduction. If blight occurs in the July flowers, be prepared to spray the subsequent flowering. This is because inoculum can carry over into the main flowering period. The aim is to apply fungicide so that it penetrates flowers before the sepals of the flowers start to turn brown.

Thinning out or hedging is encouraged as it reduces the conditions favourable for the disease by letting in more sunlight and improving air circulation. It also promotes nut set on maturing racemes.

Pictures of all pests and their damage are contained in the *Macadamia problem solver and bug identifier field guide*.

Further information on diseases and disorders is available in the book *Diseases and disorders of macadamias* by R.D. Fitzell and further information on insect pests is available in the book *Insect pests of macadamia in Queensland* by D.A. Ironside.

Husk spot (*Psuedocercospora macadamiae)*

Husk spot can cause heavy premature shedding of nuts. The fungus has a long incubation period, making its detection difficult until after the disease has caused premature nut drop. Husk spot has been found in macadamia plantations in all major growing areas of Queensland and New South Wales. There are no reported cases of husk spot in other countries that produce macadamias. It is also unique to macadamias.

Symptoms are evident 12 to 18 weeks after the initial infection, depending upon temperature and variety. Spots are confined to the husk tissue of full sized to mature nuts. There have been no reports of infections on young nuts, twigs, leaves or flowers.

Varieties that are sensitive to husk spot may drop nuts 4 to 6 weeks earlier than non-infected trees. Fallen nuts infected with husk spot may be observed in January to March. These nuts are usually immature, having low oil content, and are unsuitable for processing.

Management

Husk spot can be spread on infected husks carried from farm to farm on machinery. Husks used for mulch pose no disease threat provided they have been composted or dried using hot air. The fungus is killed by temperatures of more than 35°C persisting for more than 10 to 14 days.

Spores are produced on infected husks during damp or humid weather. They are spread by wind and by rain splash during prolonged wet periods. Blowers and sweepers used on mechanical harvesters can also disperse spores through the tree canopy. Varieties differ in their level of susceptibility, with no variety having complete resistance.

Control of husk spot involves the application of protectant and eradicant (systemic) fungicides. Since infection begins 1 to 2 months after flowering, early season applications (when nuts are 'match head' to 'pea size') are essential for effective control. Applications should be made once a month for three months, beginning in September or early October. Once tan lesions are seen on husks, it is too late for sprays to be effective.

Spot spraying is recommended in areas known to be prone to infection, such as older, denser trees in lower areas where there is less air circulation. Harvest the entire crop as early as possible so that spores on the mature crop are dispersed before next season's nut set.

Ensure that contract machinery coming onto the farm is clean of all traces of husk. Do not import husk from other farms for mulching purposes unless it is extremely well composted.

Growers who dehusk infected nuts from other plantings should be aware of the possibility of introducing husk spot.

NOTE

There are many other pests and diseases that affect macadamias, but these are generally of minor importance. In some locations and under certain seasonal conditions, treatment may be required. For pictures of these other pests and diseases and their treatment, refer to the *Macadamia problem solver and bug identifier field guide*.

Pest management approaches

Approaches to pest management have changed significantly over recent years. These changes are a response to the need for more cost-effective control methods, as well as the need to reduce chemical reliance.

The traditional approach

The traditional approach to pest management involved routine calendar spraying. This approach had several problems:

- It was a waste of money if pests were absent.
- There was no regard for trees being able to tolerate a small number of pests without significantly impacting upon quality or yield. Often the cost of spraying in these cases was greater than the benefit gained.
- It increased the risk of chemical damage to the crop.
- It relied upon the development of new chemicals to control pests that had developed resistance to chemicals being used. This contradicts the modern reality where fewer new chemicals are being discovered and developed.
- Workers were commonly exposed to a range of chemicals.
- There was increased chemical residue in both the crop and the environment.

The modern approach – Integrated Pest Management (IPM)

The new approach to pest management involves less reliance on chemicals by using complementary techniques in a program, hence the name integrated pest management. There are several key elements:

- Using cultural control measures such as growing less susceptible varieties.
- Using naturally occurring biological control measures such as parasites or predators (often termed beneficials).
- Using a monitoring system to determine pest and beneficial levels and using chemicals only where pest numbers exceed pre-set limits (thresholds).
- Use of sprays that have minimal impact on beneficials ('soft sprays'), and only using these sprays when necessary.

Monitoring pests

Monitoring works by first determining pest action levels – the pest population at which damage is considered of economic importance. The action level is the point at which the cost of damage is approximately equivalent to the cost of control. Pest populations are regularly monitored and control measures are applied only when pest populations approach or reach this level. Monitoring continues throughout the season to allow populations of pests to be managed at or below the action level. Not only are pests monitored, but beneficial

insects that attack the pests are also monitored. They may be present at levels that will control the pest, negating the need for spraying.

See *Consultants and contract services* on page 187 for details of pest consultants in your district.

Monitoring requires skill in observing and identifying pests and beneficials. A good knowledge of the life cycles of the pests is also important, as many treatments require correct timing to give good control. This requires considerable training and experience. **For this reason, we recommend using professional pest monitoring consultants.** These consultants visit the orchard regularly during the season to monitor pest and beneficial populations. After each visit they provide a report on pest status and action required.

Note: Diseases are difficult to monitor in the same way that insect pests are monitored. A disease is microscopic and in most cases, by the time you see symptoms, it is well established and difficult to control. We therefore rely on preventative sprays, or monitoring of environmental conditions to indicate when a disease outbreak might occur. Monitoring of diseases is nevertheless important. For example, grey mould or Botrytis disease, which infects flower racemes, is monitored in the first flowering, and if found at sufficient levels, control in the next flowering may be warranted. Monitoring is useful in detecting obvious problem areas and for evaluating how well your disease prevention program is working.

Do-it-yourself monitoring

If you wish to do monitoring yourself, we suggest you first get some training from a pest consultant or attend formal training. TAFE NSW at Wollongbar runs a course in IPM, which is very useful for those who are starting out in IPM. The main requirements for monitoring are:

Materials

- x10 hand lens;
- Notebook, prepared monitoring charts and pens;
- Paper bags or small bottles and marking pen for samples;
- Sharp pocket knife;
- Roll of coloured plastic tape.

Other

- Commitment and time to monitor at least fortnightly;
- Good eyesight;
- Good knowledge of the pests and beneficial insects.

Monitoring is not difficult. It is just a process of systematic observation and recording.

NOTE
These monitoring guidelines are a general guide only. Some consultants may vary in their approach.

How many trees to monitor

Define your orchard as blocks. A block consists of trees that are managed the same way and are about the same age. Each block should be monitored separately. If you manage your whole farm the same way, then treat it as a block. A block should be no more than 5000 trees in size. When you start out monitoring, you need to monitor enough trees closely so that you feel confident you have identified pest and disease outbreaks and any 'hot spots'. A good start is to monitor 10 nuts per tree, visiting about 5% of trees within a block, while scanning the rest of the block as you move through. These trees need to be chosen randomly. As you gain experience, the size of the sample can be reduced significantly. Many pest consultants work on a sample of 320 nuts per block taking 10 nuts per tree from 32 trees. This has been found to be statistically valid.

How often to monitor

Although monitoring usually occurs throughout the year, the critical period is from August to March. During this period, monitor fortnightly. During the remainder of the year, monitor monthly.

Monitoring procedure

Prepare some monitoring charts to record the results of your monitoring. An example of a monitoring chart is shown in Figure 30.

Each time you monitor, select trees randomly, but from different parts of the block. You need to do this until you are confident you have located 'hot spots' and understand pest movement within the orchard. Once you are confident in monitoring, you can visit 'hot spots' while scanning the rest of the orchard for damage. While moving between selected trees, keep alert and visually scan intervening trees. Inspect nuts on the trees and from the ground, of the selected trees in the block. Cut open nuts and examine the husk, shell and kernel for damage, using your hand lens. If you collect samples for later examination or identification, place them in a paper bag. These are best stored in a cooler, particularly if you are going to be in the field for some time. Mark the bags with the block name and date.

It is best to do monitoring on foot rather than drive, as trees can be inspected more thoroughly. Pay particular attention to the edges of the orchard adjacent to rainforest, windbreaks and watercourses as these are often the areas where pests first enter the orchard.

It is a good idea to transfer your monitoring results to a recording system, such as MacMan, to review the season's results. This will be very useful once you have several seasons' data, as it allows the identification of patterns and 'hot spots' of pest incidence. This will help develop and improve monitoring strategies.

Tree no	Pest or disease							Beneficials			
	FSB	MNB	FC								
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
TOTAL											
%											

Figure 30. *Sample pest monitoring chart*

Pest monitoring and management guidelines

Spotting bugs

How to monitor

Monitor trees from all areas of the orchard, but pay particular attention to trees adjacent to bushland and known 'hot spots' (research has shown bugs will infest the same areas consistently each year). Note any 'hot spots' for future monitoring and possible targeted spraying (often termed 'spot spraying').

Monitor green fallen nuts for fresh damage. Sample at least 10 freshly fallen nuts from each tree, ensuring that adequate numbers are sampled to determine the presence or absence of bugs. A good method of sampling is to monitor 10 trees in known 'hot spots' and then examine trees randomly throughout the rest of the block, ensuring a minimum of 32 trees are monitored. Cut open the nut and separate the husk, shell and kernel. Examine each part for damage, with spotting bug damage appearing as a brown lesion on the inside of the husk. The developing shell may have crinkled areas.

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

When to monitor

Fortnightly from nut set to shell hardening (usually September until March).

Continue to monitor after a spray application to check spray efficacy and determine when and if another spray application is necessary.

Observe re-entry periods before monitoring again after spraying. Ignore old damage, and base spray decisions on fresh damage only.

Comments

Monitoring of the bugs themselves is difficult, as they are elusive and well camouflaged. Instead, monitor nuts for early signs of damage.

Although small nuts damaged early in the season fall during natural shedding, it is recommended to monitor from nut set because it provides a very good indication of the increasing number of nymphs, and so control can be targeted when needed.

Management

Spray when 4% of nuts monitored have spotting bug damage. Do not spray within 2 weeks of a previous spray (unless that spray for some reason was ineffective).

Parasitism and predation is considered relatively unimportant in regulating spotting bugs in the orchard, because of their continuous movement into the orchard. The assassin bug, spiders and coastal brown ants (*Pheidole megacephala*), have been observed preying on fruitspotting bugs, but generally do not give adequate control.

Macadamia nutborer

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

How to monitor

Monitor trees throughout the orchard, but pay particular attention to trees adjacent to bushland and known 'hot spots'. Note 'hot spots' for future monitoring.

Monitor at least 10 nuts per tree from 32 trees per block (320 nuts) for **live eggs** especially nuts in bunches, ensuring that an adequate number of trees are monitored to determine the presence or absence of nutborer. Nuts examined will usually be from marble size up (20 mm or greater in diameter), as this is the peak period for nutborer activity. As eggs are easily confused with latania scale, training in egg identification is critical. Cut open nuts, and examine the husk for larae.

When to monitor

Fortnightly from nut set (September) to March.

Continue to monitor after a spray application to check spray efficacy and determine when and if another spray application is necessary.

Comments

The South African egg parasitoid, *Trichogrammatoidea cryptophlebiae*, may be an effective natural enemy of the macadamia nutborer. Strategies for its conservation and manipulation in macadamia plantations are still being devised, but the monitoring of natural parasitism levels in the eggs of

macadamia nutborer is important. The level of parasitism must be taken into account when determining whether or not to spray.

Management

Spraying is necessary if 1%, 2% or 3% of nuts in a sample have **live eggs** present (action level depends on nut development and variety). The 1%, 2% and 3% action levels correspond to 3, 6 and 9 live eggs in the 320 nut sample. The lower thresholds are generally used earlier in the season when the aim is to prevent subsequent generations of the pest.

Macadamia flower caterpillar

How to monitor

Examine flower racemes for eggs and larvae. Damage is often seen as webbing of the flowers, similar in appearance to grey mould (Botrytis). Examine randomly selected racemes in each block for eggs or larvae, ensuring that an adequate number of racemes are examined to determine the presence or absence of the pest. Monitor a minimum of 20 racemes with at least one raceme per tree. It is best to pick racemes off the tree to examine closely. As flower caterpillar eggs and larvae are easily confused with those of beneficial insects such as hover flies and lacewings, training in correct identification is critical.

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

When to monitor

Monitor during flowering (July to September).

Comments

Macadamias flower profusely, with only a small percentage of flowers setting nuts. Therefore a reasonable degree of damage can be tolerated.

Activity of the macadamia flower caterpillar is variable and may be sporadic, and regular monitoring needs to be conducted to determine if control is required. The macadamia flower caterpillar is generally a problem in warm and dry spring conditions. It is rarely a problem in northern New South Wales.

Management

Over 20 different insect species are either predatory or parasitic on the macadamia flower caterpillar. These natural enemies are important in regulating numbers of the pest and may provide sufficient control in seasons of low infestation. Their activity should be encouraged through the minimal use of insecticides or use of softer insecticides.

Spraying is required when:

- 90% of racemes have flower caterpillar eggs or larvae present during raceme emergence (generally up to about mid August in southeast Queensland).
- 60% of racemes have flower caterpillar eggs or larvae present during raceme extension (generally from about mid August to early September in southeast Queensland).

- 30% of racemes have flower caterpillar eggs or larvae present during flower opening or anthesis (generally early to late September in southeast Queensland).

Macadamia leafminer

How to monitor

Examine 5 terminals per tree, examining trees widely spaced throughout the orchard. It is best to monitor young trees more closely for this pest as this is where it can be a greater problem. Cut open mines to detect the larvae.

When to monitor

Monitor throughout the year. The most crucial time for monitoring is during the spring, summer and autumn periods when new vegetative leaf flushes are present. Damage is generally more severe in spring and autumn when temperatures are a little cooler.

Comments

The most severe damage occurs in elevated rainforest areas and in plantings protected from the wind. Infestation of young trees can cause severe damage, reducing growth of the trees. Vigilance is required in macadamia nurseries, where low populations can cause serious damage.

Management

Parasitism by a tiny wasp, *Elachertus* sp. (Family Eulophidae), is at times important in regulating macadamia leafminer populations. Control in the field is rarely necessary and is only needed where severe infestations occur.

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

Macadamia felted coccid

How to monitor

Examine 5 racemes and flushes per tree, ensuring that an adequate number of trees are monitored to determine the presence or absence of the pest. For young trees, the flush is the most important part to monitor. Examine new flush, particularly on the undersides of leaves, and if felted coccid is found, spraying may be necessary. Examine surrounding trees and only spray the trees that have an infestation.

In bearing trees, felted coccid is mainly a problem on the flower racemes, causing distortion of the racemes. Look at 20 trees widely spaced throughout the block and see if you can see any obviously distorted racemes. If 5% of racemes are distorted, then spraying will need to be considered. Note if natural enemy activity is evident.

When to monitor

Monitor for the whole year but pay particular attention to the winter pre-flowering period to stop the pest getting into the flower panicles and the spring flush of leaves. It is generally monitored while inspecting racemes and nuts for other pests.

Comments

Macadamia felted coccid is not generally a problem if planting material is pest-free. Inspect trees when they are purchased, and reject infested trees.

If you are propagating plants, disinfest propagative material by dipping it in a suitable insecticide to ensure the pest does not survive.

Management

Natural enemies generally maintain adequate control. However, when the pest is introduced into new areas, its numbers generally increase and cause severe damage before natural enemies get established and exert effective control. In these circumstances, insecticide sprays may be needed.

Macadamia twig-girdler

How to monitor

Examine 5 terminals per tree, ensuring that an adequate number of trees are monitored to determine the presence or absence of the pest. Record the number of terminals infested on these trees. New flushes are the most susceptible to damage from twig-girdler, so pay particular attention to these.

There are many other caterpillars that can be found on new flushes of macadamias and these are generally not of concern. Most are grazers, causing the loss of a few leaves. It is important to distinguish between twig-girdler and these other caterpillars.

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

When to monitor

Most damage is observed in the summer and autumn periods. It is therefore best to monitor during September, December and March. Monitor young trees more frequently.

Comments

Twig-girdler is not usually a problem in bearing trees, with some damage being acceptable. It has most impact on young trees, reducing growth by killing the growing tips.

Management

On young trees with a basal trunk diameter of less than 30 mm, apply control measures if more than 15% of the terminals are damaged.

Latania scale

How to monitor

Monitor scale levels on nuts fortnightly while monitoring macadamia nutborer and fruitspotting bug. Also visually assess scale populations on twigs and branches as you pass through the orchard. Examine new growth for distortion and discolouration of foliage. Record the presence or absence of scale, and apply control measures on trees where a heavy infestation is found. Note any evidence of parasitoid or predator activity. The most crucial issue in scale management is to avoid excessive use of broad spectrum insecticides.

When to monitor

September to March.

Comments

Avoid excessive use of broad spectrum insecticides which cause disruption of natural enemies. Monitor susceptible varieties. Plant scale-free nursery stock.

Management

Avoiding the use of broad spectrum insecticides will reduce the risk of scale problems developing. Control will only be necessary when very high levels of scale are present.

To help with monitoring, pictures of the main pests, their eggs, and beneficial insects are contained in the *Macadamia problem solver & bug identifier field guide*.

Hairy caterpillar

How to monitor

Monitor small nuts while monitoring for fruitspotting bug and macadamia nutborer.

Examine 10 racemes containing small nutlets for caterpillar grazing, ensuring that an adequate number of trees are monitored to determine the presence or absence of the pest.

When to monitor

Monitor when nutlets start to form, usually while monitoring for fruitspotting bug and macadamia nutborer.

Comments

Activity of the hairy caterpillar is quite variable, and therefore regular monitoring needs to be conducted to determine if control is needed.

Management

There are natural enemies that are important in regulating numbers of the pest in seasons of low infestation. Minimise the use of insecticides to reduce the impact on these natural enemies.

Control is required when there is obvious damage evident on small nutlets.

Green vegetable bug

How to monitor

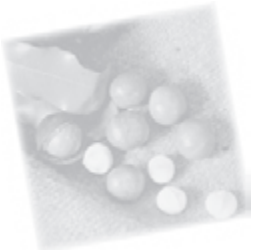
Monitor trees from all areas of the orchard in conjunction with the monitoring for spotting bugs. Monitor green fallen nuts for damage and trees for the presence of adult bugs. Crack the nut; damage appears as circular, whitish lesions on the surface of the kernel.

When to monitor

Fortnightly from nut set (September) to March (the most critical period is from early shell hardening (December) to March.

Management

Spray when 4% of nuts monitored have green vegetable bug damage or when adult bugs are observed. Sprays applied for spotting bugs are effective against green vegetable bug. Where green vegetable bug is active beyond the end of the period of spotting bug damage, additional sprays targeted specifically at this pest may be necessary.



Pesticide application and safety

Although there have been significant advances in the use of integrated pest and disease management systems in macadamias, current technology still depends substantially on the use of chemical pesticides. There are two important aspects of responsible use of chemicals. The first is efficient application so that the effect of each spray on the target is maximised, thereby reducing the number of sprays that may be necessary. The second is safety in use and application so that any impact of chemicals on operators, farm workers and the community in general is minimised.

Basic understanding of spray application

Spray application is a very complex area, but it essentially revolves around two important issues, (1) knowing and understanding the target, and (2) having the necessary equipment and skills to deposit the correct dose of chemical on the target.

Knowing and understanding the target

The first step is to clearly identify what you are targeting and understand what makes it easy or difficult to contact. For example, scales, mites and husk spot disease are essentially stationary organisms, and require very good coverage of the chemical to give effective control. On the other hand, flower caterpillars, fruitspotting bug and, to a lesser extent, macadamia nutborer and thrips move about on the plant surface and have a greater chance of coming into contact with the chemical.

Getting the right dose of chemical to the target

Once you have identified and understood the target, the next step is to ensure the correct dose of pesticide reaches it and makes maximum contact. There are four key steps in this process:

- Starting with the right concentration of pesticide in the tank mix;
- Turning the spray from your tank into droplets;
- Moving them to the target area;
- Depositing them on the target surface.

1. Starting with the right concentration of pesticide in the tank mix

By the end of 2004, every tree crop product label in Australia, including those for endosulfan, should conform to the Australian Pesticides and Veterinary Medicines Authority (APVMA) Tree Crops/Vines Model Label. The model recognises that growers use a wide range of spray volumes and that the chemical concentrations need to be adjusted accordingly. It also recognises

that different sized canopies need different doses of chemical. The label uses the high volume *dilute* (per 100 L) rate, defined as "1X", as the base point for calculating the rates for lower volume *concentrate* spraying.

Dilute spraying

Use a sprayer designed to apply high volumes of water up to the point of run-off and matched to the crop being sprayed. Set up and operate the sprayer to achieve even coverage throughout the crop canopy. Apply sufficient water to cover the crop to the point of run-off. Avoid excessive run-off. **The required water volume may be determined by applying different test volumes, using different settings on the sprayer, from industry guidelines or expert advice.** Add the amount of product specified in the products *Directions for Use* table for each 100 L of water.

Concentrate spraying

Use a sprayer designed and set up for *concentrate* spraying (that is a sprayer which applies water volumes less than those required to reach the point of run-off) and matched to the crop being sprayed. Determine an appropriate *dilute* spray volume (See *Dilute spraying* above) for the crop canopy. This is needed to calculate the concentrate mixing rate. The chosen spray volume, amount of product per 100 L of water, and the sprayer set up and operation may need to be changed as the crop grows. Do not use a concentrate rate higher than that specified in *the Critical Comments* on the product label.

The 'required volume' for dilute spraying

What you will NOT find on the pesticide label is any clear indication as to what VOLUME of spray to use for a *dilute* spray and hence how to calculate the *concentrate* rate.

The appropriate spray volume for *dilute* spraying can be estimated from some measure of the tree or orchard and the nature of the pest. Research into several tree crops has determined that the appropriate *dilute* volume is in the range of 6 to 12 L/100 m^3 of canopy.

See page 156 for a process to calculate dilute spray volumes.

The current recommendation in macadamias is to consider 6 L/100 m^3 of canopy as the *dilute* volume on which to base your *concentrate* rates for both insect pests and husk spot. The recommendation to consider 6 L/100 m^3 as the basis for calculating *concentrate* sprays does not mean you must use 6 L/100 m^3 of actual spray for effective control. You may, for example, be able to use 3 L/100 m^3 and mix at 2X concentration, or 1.5 L/100 m^3 and mix at 4X. In general do not use less than 1.2 L/100 m^3 or the concentration required will be over 5X. Several pesticides used in macadamias, including Bulldock 25EC® have maximum permitted concentrations of 5X.

NOTE
As mentioned above, 1x = the concentration of a chemical at the high volume dilute rate.

2. Turning the spray from your tank into droplets

Spray liquid is turned into droplets at the sprayer nozzle. There are 3 main types of nozzles being used in the macadamia industry today:

- Hydraulic nozzles are the most common and rely on forcing liquid through a small jet at a relatively high pressure of 10 to 30 bar (145 to 435 psi). Higher pressures result in smaller droplets and the smaller the droplet the greater the risk of drift. Experience has shown that the best coverage and penetration is achieved with droplets ranging from 70 to 250 microns (μm) in diameter. Most nozzles will produce a high proportion of this size droplet at 15 to 20 bar (220 to 290 psi). However even at optimum pressure, 15 to 25% of droplets will still be in the 1 to 70 μm range, and prone to evaporation and drift.
- Airshear nozzles rely on spray moving at a low 1 to 2 bar (14 to 29 psi) pressure into a very high speed airstream (250 to 350 km/hr), which rips the liquid apart into small droplets. Faster air and lower flow rate results in smaller droplets. It is difficult to obtain data on droplet size for airshear nozzles but the range of droplet sizes from an airshear nozzle is less than for a hydraulic nozzle. In general, airshear nozzles produce fewer very fine droplets prone to evaporation and drift.
- Spinning disk or cage nozzles were originally designed for aerial application. As the disc or cage spins, liquid fed at low pressure of 1 to 2 bar is thrown outwards and broken into droplets by centrifugal energy. Spinning discs produce a very narrow range of droplet sizes. Droplet size increases with flow rate and reduction in speed of rotation of the discs.

3. Moving them to the target area

Droplets can move from the nozzle to the target in two ways:

- **Under their own momentum.** Droplets leaving fan jets, solid cone jets and cone jets without swirl plates have their own forward momentum. The droplets are basically fired from the nozzle and can travel a short distance on their own – this is how a hosepipe works. An airstream can ASSIST the process.
- **In an airstream.** Droplets leaving hollow cone and CDA spinning disc jets have angular momentum nearly at right angles to the target but very little forward momentum. Droplets from airshear sprayers have no momentum until air hits them.

An airstream is ESSENTIAL for droplets to travel any distance at all.

As orchard sprays consist of water-based droplets, evaporation plays an important role in determining their fate. Where small droplets are used (as is the case with most airblast and misting machines), sprays are best applied in the early morning, late evening or night, when evaporation rates are lowest.

4. Depositing them on the target surface

Droplets reach their final destination in three ways:

- They can travel straight from the nozzle in the airstream and impact the target. Turbulence improves coverage of the underside of leaves as they move in the air.

- They can travel up to the target in the airstream and then settle under gravity. This could be termed 'drift spraying'. This is what happens once the sprayer has passed the tree.
- They can reach the target and then run off or drip to another position. This may be important in achieving coverage of nut clusters for nutborer and husk spot control.

A good result for both fungicides and insecticides is about 50 to 70 droplets/ cm^2 on both sides of the leaves and nuts. This can be checked using water-sensitive papers.

Spray equipment

Steep slopes on many macadamia orchards means that most growers use low-profile ground-based air-assisted sprayers. On flatter ground, different types of tower conveyors can be added. Use of helicopters or fixed wing aircraft to spray pesticides may be efficient but is now rarely feasible in most macadamia growing areas.

To operate an air-assisted sprayer efficiently:

- If trees are very tall, use the machine in single-sided air-delivery mode for greater spray penetration. Single–sided conveyors are often height adjustable.
- The airstream outlet should be a minimum of about 1 m from the edge of the canopy to allow for unobstructed airflow and droplet dispersal (spraying distance in Figure 31).

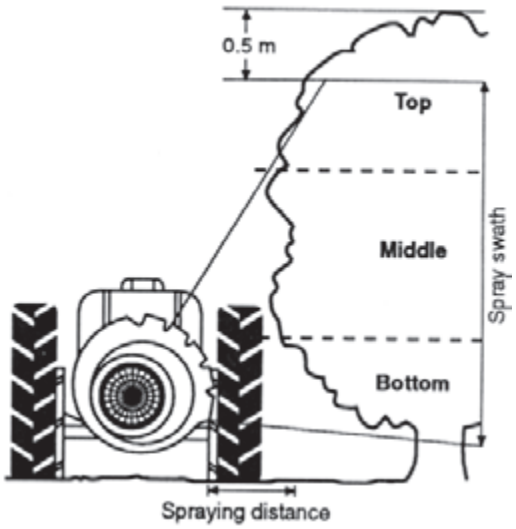


Figure 31. *Positioning of spray machine to achieve effective spray swath*

- Keep trees to about 6 to 7 m high, to facilitate coverage in the top part of the tree. Coverage at 6 m is rarely more than 30% of coverage at 2 m. More even canopies give more even coverage.
- Trees must be pruned to maintain a suitable alley width to avoid damage to nozzles and fans.
- Set up the machine to spray the largest trees in the orchard. The spray swath (from lowest to highest nozzle) should cover the full height of the tree, but not waste spray in the air space above the tree. Adjust the spray swath so that the top of the airstream is about 0.5 m from the top of the tree (see Figure 31).
- Select and arrange nozzles so that the largest proportion of spray volume is directed towards the top half of the tree. In a variable height canopy, apply 30:50:20% of the spray volume to the Top:Middle:Bottom of the canopy (Figure 32a).

  If canopy is even in height, apply 50:30:20% (Figure 32b). It is better to use more nozzles rather than larger nozzles to achieve these differences.

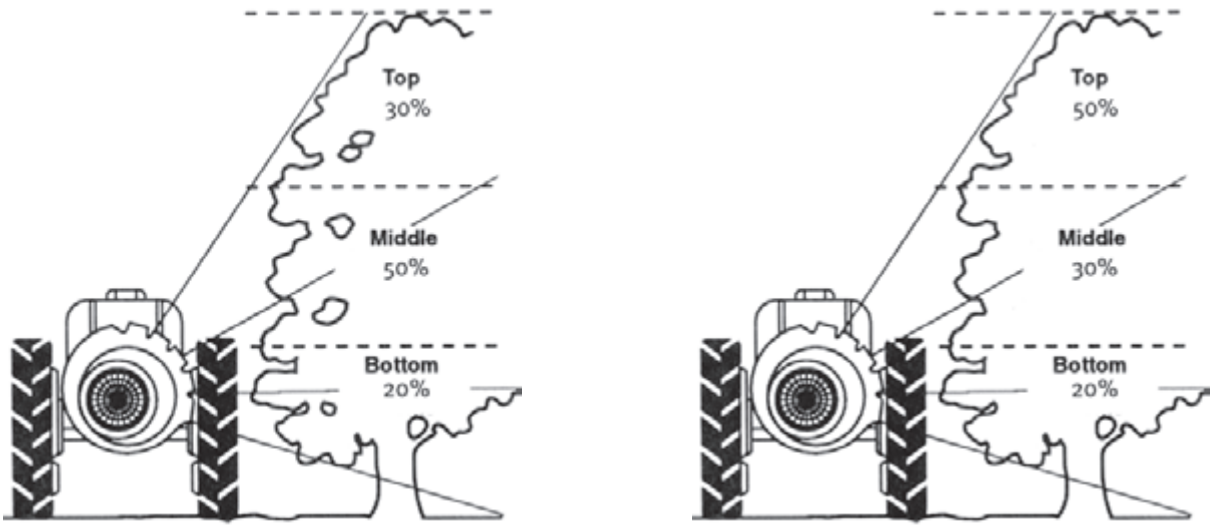


Figure 32. *Nozzle selection and arrangement to achieve appropriate spray volume proportions. (a) left: variable height canopy; (b) right: even height canopy)*

- Operate the machine first at a ground speed of 2 to 3 km/hr. To ensure coverage is adequate, fill the sprayer with water and check spray penetration using strips of water-sensitive paper at several positions within the tree canopy. If spray coverage is good, it may be possible to spray at a faster speed.

Types of air-assisted sprayers

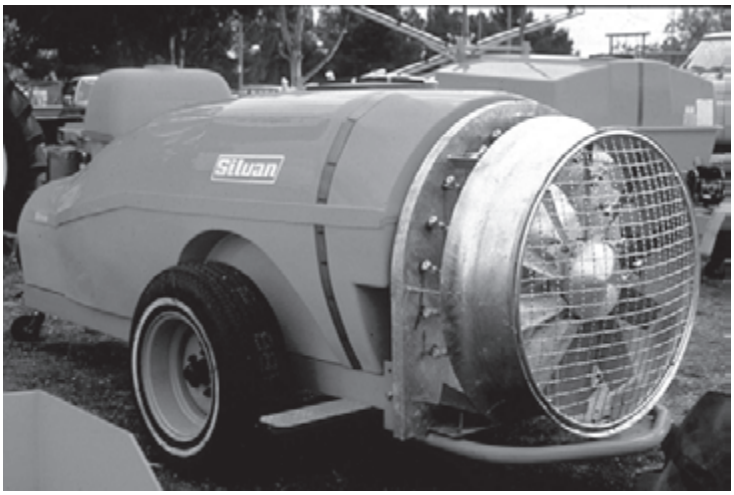
There are three main types of air-assisted sprayers used in the macadamia industry.

Airblast machines

Approximately 70% of macadamia growers use airblast sprayers. Airblast machines are designed to transport droplets produced by hydraulic nozzles in an airstream, produced by a large axial flow fan 800 to 900 mm in diameter. These machines produce high volumes (50,000 to 100,000 m^3/hr) of low speed air. They are very versatile and can be operated at low spray volumes (250 to 1000 L/hectare), and also in higher volume mode (2000 to 4000 L/hectare).

Misting machines

Misting machines are designed to transport droplets produced by airshear nozzles in an airstream, generally produced by a smaller centrifugal flow fan. Droplets are produced by airshear nozzles placed in the path of a lower volume (10,000 to 25,000 m^3/hour), high speed airstream (250 to 350 km/hr). These sprayers are more suitable for low volume spray applications of 300 to 600 L/hectare or less. Some airshear machines also use electrostatic charges to improve coverage and reduce drift.



A typical airblast sprayer

A typical misting machine

Controlled Droplet Application (CDA) machines

CDA machines use spinning discs or spinning cages driven by hydraulic motors to produce droplets. The discs, with individual fans behind them, can be separately positioned under or alongside the canopy. CDA machines are dedicated very low volume machines and produce the narrowest range of droplet sizes and least risk of drift. However in some CDA machines, droplets may escape from the airstream resulting in poor penetration of the canopy.

New developments – hybrid machines

Some CDA machines have been modified by switching from spinning disc nozzles to hydraulic nozzles. This retains the advantage of separate highly efficient fans and increases the flexibility of using medium or higher spray volumes. Separate hydraulic fans with hydraulic nozzles are now available as complete purpose-built machines or as add-ons to low-profile airblast sprayers.

Calibration

Sprayer calibration is an essential, and often misunderstood concept which covers both spray volume and pesticide calculations. Calibration should be carried out every year, just like a service of the sprayer. The process of calibration is as follows:

- Check that your pressure gauge is working and that the pressure can be adjusted.
- Check your spray jets for cracks and visible wear and replace as necessary. Clean filters and jets with a toothbrush and detergent, not with wire. Ceramic jets need changing every 3 to 4 years.
- Fill the tank with clean water, set the pressure at 10, 15 or 20 bar and operate the sprayer for a minute or so in a level stationary position to get all spray lines full.
- Check all valves hoses and nozzles for leaks.
- Then EITHER measure each nozzle output for one minute using a hose kit, OR fill the tank to a predetermined mark, operate the sprayer in a stationary position for one minute and measure the amount of water required to top up the tank again to the predetermined mark. For a single-sided sprayer, double the figure. This is the total sprayer output in L/min.

NOTE

Hose kits are available from:

- Australian Macadamia Society, Lismore
- Northern Rivers Rural Buying Service, Lismore
- Maroochy Research Station, Nambour
- Bunbaberg Research Station, Bundaberg

- Compare output with the manufacturer's specifications for the jets at your chosen pressure. This will indicate if your gauge is working. If there is a discrepancy, first check your gauge, then check for any blockages in the valves, hoses or jets.
- Check your ground speed. Don't rely on the tractor speedometer. Mark out a distance of 50 to 100 m and, with the sprayer operating, time the speed both up and down hill. Select a gear to produce an operating speed of about 2 to 3 km/hr. From this, calculate the actual speed in km/hr from the following formula:

  $$\text{Speed (km/hr)} = \frac{\text{(distance (m) x 3.6)}}{\text{time taken (sec)}}$$

- Check your coverage using water-sensitive paper or a UV dye.
- Regularly check nozzles, pressure gauge and spray volume to ensure that the desired spray volume continues to be applied. If it increases or decreases, find out why, and act accordingly. You now have the basic information to calculate your spray volumes (per unit canopy, per tree or per hectare) and to calculate the pesticide concentration to use.

For example, assuming:

- The DILUTE spray volume in macadamias is 6.0 L/100 m^3
- Trees have 9 m row spacing and 4 m tree spacing, ie. 278 trees/ hectare (10,000 ÷ 9 ÷ 4)
- Tree canopy is 4 m long, 5 m wide and 6 m high, ie. 120 m^3 of canopy/tree (4 x 5 x 6)
- Your speed is 2.5 km/hr
- Your output is 15.7 L/min per side or 31.4 L/min total output (both sides)

To calculate the DILUTE spray volumes:

- (L/tree) = 6.0 L x 120 ÷ 100 = 7.2 L/tree
- (L/ha) = 278 x 7.2 L = 2002 L/hectare
- To calculate the ACTUAL spray volumes:
- $\text{(L/ha)} = \frac{\text{600 x sprayer output (L/min)}}{\text{row spacing (m) x speed (km/hr)}}$
- = (600 x 31.4) ÷ (9 x 2.5) = 837 L/hectare
- (L/tree) = 837 ÷ 278 = 3.0 L/tree
- If the ACTUAL spray volume is less than the desired amount, travel at a slower ground speed or increase jet size or number, and re-calibrate.
- To calculate the RECOMMENDED pesticide concentration:
- If your sprayer is set up for general insect spraying to spray 3 L/tree, ie. 834 L/hectare (3 x 278) you would mix your chemical at 2.4X, ie. 2.4 times the Dilute rate (7.2 ÷ 3).

Records

All users of agricultural chemicals should keep comprehensive records. Calibration and individual spray records provide good evidence of each operation should a dispute arise. Records should include such details as:

- date and time of application;
- chemical used and rate;
- block, pest and area sprayed;
- weather conditions;
- equipment and operating conditions.

In NSW under the NSW Pesticides Act 1999, there is an obligation on users of pesticides to keep written records of every application. There are additional requirements for endosulfan usage in all states.

Pesticide safety

The environment

Always think of your local environment when you are applying pesticides.

There are four main areas where pesticides can pose a threat to the environment.

- Spray drift is generally the result of incorrect sprayer set-up or spraying during inappropriate weather conditions. In areas or conditions where drift is a high risk, use larger jets and lower pressures. Do not spray in high winds or inversion conditions.
- Excessive spray run-off is caused by excessive spray volume or poor direction of nozzles.
- Inappropriate disposal of excess pesticide (both concentrate and dilute) and empty pesticide containers can pollute your land and local waterways. It is essential to ensure that there is no potential risk of pesticides entering watercourses. When using pesticides, never leave pesticide drums or containers at water fill up points, particularly when these are near watercourses or there is a risk of flooding. There are documented methods for the safe disposal but all containers should be triple-rinsed and crushed or punctured. All growers should be aware of their state and local disposal regulations.
- Poor location of your pesticide storage shed, fill up and wash down areas can pollute your land and local waterways. If chemicals need to be stored close to a water source, ensure precautions are in place to handle any accidental spillage or flooding event.

NOTE

drumMUSTER is a scheme designed to safely dispose of empty chemical containers. It is funded by a levy on farm chemical purchases. See page 194 for contact details.

Occupational health & safety

Occupational health and safety is your responsibility. Pesticides can enter the body in three ways.

- **Absorbed through the skin**. Liquids are particularly hazardous and skin exposure, particularly during handling and mixing the pesticide concentrate, may lead to acute poisoning (short-term and severe). Long-term exposure to drift from sprays or by contact with recently sprayed plants may also lead to chronic poisoning (continues over a long time). Dermal absorption occurs when inadequate protective clothing is worn. Try not to re-enter sprayed areas for 12 to 24 hours.
- **Inhaled**. This is an extreme problem with powders, dusts and fumigants. Inhalation of spray droplets may also lead to both acute and chronic poisoning. Inhalation poisoning occurs when a suitable and properly maintained respirator is not worn or where tractor filtration is not effective. If you can smell the spray, then something is not working.
- **Swallowed (ingestion).** Children under the age of five are most at risk from swallowing pesticides. The danger results mainly from inadequate storage security or improper disposal of empty containers. Never put pesticide into any type of drinking bottle.

NOTE
Some chemicals require longer periods before re-entry of people into the orchard is deemed safe. Check chemical labels for details.

Chemical accreditation

Growers must be able to demonstrate that they are meeting their duty-of-care and using pesticides safely and responsibly. One way is to obtain user accreditation under the ChemCert Training scheme. ChemCert accreditation is required for all persons wishing to purchase or use the pesticide endosulfan. In some states, some other pesticides (for example S7's) cannot be bought without current accreditation. Your nut processor or buyer, as part of an on-farm quality assurance program, may require ChemCert accreditation.

See page 193 for Chemcert contact details.

ChemCert is a special farm chemical user training course available throughout Australia. Participants undergo the training at a group workshop, complete an assessment at the end of the course and, if they pass, are issued with a statement of accreditation by their state ChemCert organisation (SMARTtrain in NSW). The accreditation is valid for five years.

Safety requirements

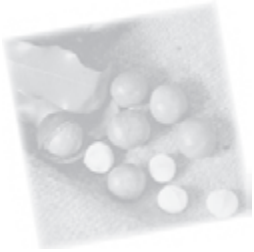
All pesticides should be considered potentially hazardous. However, if simple safety precautions are taken, these hazards can be minimised or even eliminated. Correct use, storage and disposal of chemicals will ensure your health and safety and that of others. Here are the main precautions:

- **Always read the label before handling.** It provides advice on safe handling, storage and use.
- Obtain and study the Material Safety Data Sheet (MSDS) for each chemical used (chemical suppliers should be able to supply copies). File these in a safe place so they can be quickly referred to in emergencies.
- Use pesticides only as directed. Follow all safety directions, including on the use of safety equipment.
- Keep all chemicals in a secure location, that is in a locked, well-ventilated, well-lit room or in a separate storage area that has an impervious floor and impervious shelving. Store away from foodstuffs and eating and packing facilities.
- Store chemicals in original containers, with labels intact. Never store chemicals in food or drink containers. Re-label if a label comes off the original container.
- Ensure a suitable fire extinguisher and fresh water supply are available close to where chemicals are stored.
- Mix and measure in a level, well-ventilated area. Keep a spill kit, eg. a bucket with a bag of lime and/or sawdust, where chemicals are stored or mixed. Chemical spills should not be diluted with water.
- Place a sign 'Danger Agrochemicals' on the chemical store.
- Keep a first aid kit available on-farm and make sure it is in an easily accessible location.
- Do not store personal protective clothing and equipment in a chemical store.
- Do not burn containers. Dispose of empty containers immediately in the correct way.

Key points

Before any spraying make sure that:

- All equipment is in good working order.
- All equipment has been properly calibrated.
- The operator is properly trained and skilled.
- The weather conditions are suitable for spraying.
- The correct personal protective equipment is used.



Canopy management

Productivity of macadamia orchards is fundamentally dependent on maximum interception of light energy. Light interception is directly related to the amount of canopy (effective canopy volume or leaf biomass). The greater the effective canopy volume and the greater the light interception, the greater will be the photosynthetic production of carbohydrates to support the development of vegetative growth and nuts. This is provided that there are no other limiting factors such as high or low temperatures or water stress.

The ideal canopy

The ideal canopy should:

- maximise interception of radiant energy from the sun;
- maximise light penetration through the canopy to maintain optimum fruiting wood for sustainable heavy nut production;
- maximise early returns per hectare to offset the high cost of land;
- minimise energy lost in non-productive respiration such as that associated with excessive vegetative growth (that is, be no larger than necessary to achieve optimum productivity);
- minimise the amount of 'plumbing' needed to display canopy foliage for maximum light interception and to supply that canopy with water and nutrients from the roots;
- allow appropriate access for spray application and harvesting equipment, and management of the orchard floor.

Canopy management

The aim of canopy management is to achieve the above 'ideal' canopy conditions as rapidly as possible and then to maintain them during the life of the orchard with minimal pruning. Sound canopy management practices depend on an understanding of how the crop develops and the relationship between vegetative growth, flowering and nut production. By planning canopy management to start as early as possible (before orchard crowding occurs), less drastic intervention is needed and, hence, adverse effects on tree growth and production are minimised.

Light energy

Effective canopy management depends on an understanding of the role of leaves in capturing radiant energy from the sun (via chlorophyll) and converting this energy into chemical energy (sugars and more complex

carbohydrates) that is needed for growth and maintenance of the tree organs. During nut development, a large part of the sugars produced by photosynthesis are used directly to support the developing nuts, which have a high energy requirement due to their oil content. At other times of the year, excess carbohydrate is stored in tree tissues such as the wood and bark. These stored carbohydrates are then drawn upon during nut development to supplement those provided directly by current photosynthesis.

Productive macadamia orchards, therefore, depend on having a leaf canopy that captures as much of the radiant solar (sunlight) energy as possible. It is not sufficient, however, for all the sunlight to be captured by the outer leaves. Inner leaves are closer to developing nuts and contribute more carbohydrate to nut development. Thus, these inner leaves should have sufficient light for photosynthesis to support adjacent developing nuts.

In full sunlight, leaves on the outside of the canopy receive more light than they need. Some of it is a captured by the chlorophyll in the leaf, some of it is reflected off the leaf surface (contributing to diffuse light) and the rest of the light is transmitted through the leaf. This light, in turn, is reflected, captured, or transmitted through the next leaf layer, and so on. As outer leaves absorb more of the total light available, there is progressively less light available for leaves in the middle of the canopy. The further light penetrates into the canopy, the more productive the tree is likely to be. Thus, canopy management for maximum productivity depends on having sufficient leaf cover to intercept the maximum amount of available sunlight as well as arranging leaves in the canopy so that as much of the available light penetrates through to illuminate inner leaves.

Canopy growth

As the canopy grows and spreads laterally, particularly in high-density plantings, branches overlap and light penetration through the canopy is reduced, although light interception remains high (mainly at the outer surface of the canopy). Because of the lower light environment in the crowded canopy, overlapping branches become spindly with fewer leaves, and trees grow taller.

Flowers are borne in the axils of leaves on mature wood. Flowering may be suppressed inside dense canopies where few leaves, and fewer active buds are present to support flowers. As canopy density increases, the crop tends to be concentrated towards the top of the tree, leaving a 'hollow centre' towards the bottom. This is important for several reasons. It becomes more difficult to get good spray coverage for pest and disease control at the top of the canopy. Air circulation is more restricted in dense canopies, thus predisposing to diseases such as Botrytis. The intense shading from the dense canopy also suppresses inter-row ground cover growth, thereby creating the potential for more soil erosion. It also slows the drying of the orchard floor after rain, and this can delay harvest and result in a deterioration of nut quality.

Young trees grow vigorously but vegetative growth progressively slows as crop load increases. Management that promotes cropping tends to inhibit vegetative growth, which is desirable in mature, bearing orchards. The lateral flowering on mature wood of macadamias is an advantage as light side pruning of the canopy is less likely to remove potential flowering sites. By commencing pruning early, there should be no need for heavy pruning and hence less disruption to the vegetative:reproductive balance and yield.

Canopy light interception

If an orchard had a continuous cover of leaves, with no alleyways between rows, light interception (the amount of radiant energy captured by the tree canopy) would be maximised and no light would be wasted (no light reaching the ground). Such an orchard would be impractical so good orchard management requires a compromise between practical orchard management and achieving optimum light interception. Light interception increases as the ratio between tree height (excluding skirt height) and alley width increases. It approaches a maximum the closer an orchard gets to a continuous cover of leaves. When light interception is near the maximum, the size, arrangement and shape (angle of hedge sidewall) of trees has less influence on the light intercepted. Light interception is greater in north-south rows than in east-west rows.

In denser (hedgerow) plantings, light penetration within the canopy is reduced because of increased light interception by denser foliage cover. As row spacings become narrower, the shape of the hedgerow (angle of cuts) has less influence on light interception. For the same total leaf cover, light interception increases as hedgerow height increases because larger gaps between leaves allow more light to penetrate into the canopy where it is captured (intercepted) by leaves inside the canopy.

Optimum tree size

The optimum tree size is a trade off between maximising light interception and maintaining a manageable orchard that has sustainable yield and quality. There are some guiding principles that growers should take into account when working out the optimum tree size for various orchard layouts:

- Yield of nuts per hectare in macadamia increases up to a high level of orchard crowding, equivalent to 90 to 95% light interception. This corresponds to a hedge height **(tree height less skirt height)** of 6 m and alley widths between 1 and 1.5 m. This is in general agreement with computer models of light interception, which predict that there is only a small increase in light interception beyond 95% when hedge height is greater than 6 m and alley width is 2 m.
- Because yield increases up to a high level of light interception, the main reason for intervening with hedging and topping is to enable access for orchard operations, to achieve good spray coverage and to achieve effective growth of ground cover.

- A 2 m alley width is generally considered the minimum for machinery access.
- Ground cover growth and orchard floor drying, both of which assist orchard access after rain, require adequate light penetration to the orchard floor. Light penetration to the floor decreases as the ratio between hedge height and alley width increases. In a ground cover trial near Alstonville in New South Wales, shade tolerant sweet smother grass (*Dactyloctenium australe*) provided good ground cover in an orchard with a 5.2 m hedge height and a 2 m alley width.
- Effective spray coverage of trees is limited at tree heights greater than 6 m. Allowing for a skirt height of 1.5 m, this corresponds to a hedge height of 4.5 m.
- While hedging and topping trees to meet these management requirements will reduce yield at least in the short term, the economic risk of not controlling tree size is significant.
- Only moderate amounts of nitrogen fertiliser should be applied once trees commence bearing to reduce vegetative vigour. Use the nutrient replacement principles outlined in the *Nutrition* section of this chapter.

Variety selection

High-density orchards of closely planted trees rapidly achieve maximum light interception but require more intensive canopy management practices to maintain the canopy. This can be alleviated by selecting appropriate varieties to suit the orchard environment. For example, where possible, select compact, upright varieties with open canopies for high-density plantings. Large, spreading varieties should only be used for low-density plantings. Macadamia orchards may be planted more densely and require less frequent pruning where tree vigour is lower, for example in cooler or drier areas, on less fertile soils or where moderate amounts of fertiliser are applied.

NOTE
Exercise caution in selecting upright varieties such as HAES 344, that appear more susceptible to Abnormal Vertical Growth (AVG) disorder in some areas.

The search for dwarfing rootstocks is important, as it would allow higher density plantings that maximise light interception early in the life of the orchard. Furthermore, dwarf, compact trees are more easily managed to maintain an ideal canopy that maximises light interception and penetration through the canopy as the orchard matures. However, to date, no dwarfing rootstock has been found.

Tips for developing strong healthy canopies

See *Plant the trees* on page 34 for full details of the things you need to check with nursery trees.

1. Start with healthy, well-trained nursery trees

2. Train trees carefully during the first four years

See *Training and pruning* on page 39 for full details on tree training for young trees.

The main reason why this is important is that macadamias have a tendency to produce side branches with weak, narrow crotch angles that are prone to breakage in strong winds. As the trunk and side branches increase in diameter, bark growing between the two weakens the union. However, if the angle of the side branch to the trunk is wider, a strong woody attachment forms at the top of the junction. The branch angle depends on the variety and the type of bud from which the branch grows. In the axil of each leaf, there is a series of buds, one on top of the other. The top 'primary' bud usually grows out at a narrow angle whereas lower 'secondary' or bottom, 'tertiary' buds grow out at progressively wider angles. Thus, by selectively pruning, one is able to get side branches growing at wider angles, which are consequently more strongly attached.

3. Start to hedge (side prune), head (top) and skirt trees as soon as required (do not defer)

See *Canopy management* on page 51 for full details on canopy management practices for bearing trees.

Hedging (side pruning)

As pruning reduces yield in proportion to the amount of wood removed, commence hedging as soon as growth encroaches on the desired alley width. This allows small amounts of wood to be removed without significant yield loss. From then on, regular, light pruning is recommended. If hedging is left until the inter-row is crowded, severe pruning is required to restore access. This is undesirable for several reasons. It removes many potential flowering sites and produces strong vegetative growth, which inhibits flowering. Also, the efficiency of the canopy is low because the leaves remaining were previously heavily shaded and they do not recover their photosynthetic efficiency quickly. This is only achieved after several growth flushes when new, efficient leaves develop in full sunlight.

Heading (topping)

Start heading or topping as soon as the desired height is reached, since drastically reducing the height of very tall trees is almost certain to result in dense regrowth, reduced light penetration into the canopy, and reduced yields, at least in the short term. Although there is little information on whether the heading cut should be horizontal or at an angle, this is unlikely to have a major influence on light interception. It is more likely to affect light distribution down the side of the hedge as the top of the tree grows more vigorously and tends to shade the lower portion. Cutting the top back at an angle will minimise this effect. Heading also allows better spray coverage for pest and disease control by maintaining the canopy (and target flowers and nuts) within the effective range of spray equipment.

Skirting

Remove branches that are close to the ground that will interfere with cultural operations such as harvesting, weed and pest control. If suspended sprinkler irrigation systems are used, remove any branches that may interfere with water throw.

More drastic measures in canopy management

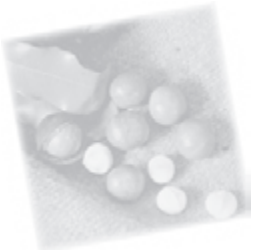
Tree removal

Tree removal is sometimes advocated in high density plantings. Despite claims of yield increases from tree removal in Hawaii and South Africa, trials in Australia have clearly demonstrated that tree removal does not increase yield. It merely results in lost production until the canopy closes again. Hence, there does not appear to be any compelling evidence to support this practice.

Limb removal

Limb removal has been advocated for opening up the canopy to improve light penetration. This is less drastic and less expensive than tree removal, with costs around half of the cost of tree removal when 20 and 30% of the canopy is removed. More than half of the cost is due to disposal of limbs by chipping. However, it does not appear to result in a sustained yield improvement in old mature trees, because the gap is soon reoccupied by a proliferation of regrowth. The gain in better light distribution is offset in the short term by the loss of fruiting wood. The one instance where limb removal is useful is in removing weak branches, particularly those with weak crotch angles that are prone to splitting.

Note that if the removed limbs are chipped, it is preferable to compost them before use around trees. If used fresh, extra nitrogen fertiliser may need to be applied to compensate for the nitrogen used up in decomposition.



Orchard floor management

Orchard floor management is a vital issue in macadamias for the following reasons:

- Maintaining a surface that maximises the pick-up of nuts and minimises the carry-over of old nuts to the following harvest;
- Providing a soil environment to foster the development of a healthy root system and the uptake of nutrients; and
- Controlling runoff water and minimising the potential for soil erosion and the loss of nutrients such as nitrogen and phosphorus from the orchard.

Consequently, it needs to be considered from orchard establishment right through to managing bearing trees.

Orchard establishment

Important issues in orchard establishment include:

- **Controlling overland water flow and runoff**. Uncontrolled runoff causes soil erosion and exposes the surface roots to desiccation. Poor drainage can lead to tree death. A surface drainage system is required to control and direct water flow. It is much easier and cheaper to construct this drainage system before planting the orchard. Remember that drain channels need to be protected by grass or plant cover to prevent scouring. This is normally achieved by the planting of creeping grasses such as carpet grass, kikuyu, couch or sweet smother grass. An annual grass such as millet or oats may also be necessary to provide temporary protection to the channel while the creeping grass is being established.
- **Planting density**. The importance of orchard floor management increases with the density of planting. This is because in denser plantings, less sunlight reaches the orchard floor and it becomes harder to maintain plant cover there. This increases the potential for soil erosion and nutrient loss. An alternative is to use shade tolerant species such as sweet smother grass.
- **Land preparation**. During land preparation, ensure that issues related to orchard floor condition are attended to. For example, remove or bury any surface stones where possible, as these cause excessive wear on finger-wheel harvesters as well as damage dehuskers. Where a subsoil compaction layer from previous cultivation or grazing exists, deep rip along the rows. Ripping may also assist with the drainage of wet areas and springs. Before planting, adjust soil pH and levels of those nutrients such as phosphorus, calcium, copper and zinc, which are more difficult to adjust once the trees are in the ground. Establish a permanent grass cover using carpet grass, kikuyu, couch or sweet smother grass on any

See *Plan the orchard layout* on pages 20 to 22 and *Control water flow within the orchard* on pages 30 to 32 for more detail on the planning and construction of drainage systems.

NOTE

Further information is available in the NSW Agriculture AgNote *Reducing soil degradation and erosion in macadamia orchards.*

See pages 27 to 33 for more detail on land preparation.

disturbed or bare areas to prevent further soil erosion. An interim fast-growing cover crop such as oats in autumn or winter or millet in spring or summer may be necessary to stabilise the soil while the permanent grass cover is being established.

Young trees

The first three to four years of the orchard provide an excellent opportunity to establish a vegetative ground cover and to build up soil organic matter levels.

Maintain the grassed inter-row area and divert slashed grass from it to the tree rows, using a side delivery slasher. The inter-row area is a valuable source of mulch. Do not slash until the grass is 15 to 20 cm high to ensure a sufficient volume is available.

See page 169 for more information on composting.

Alternative mulches include coarse straw and composted nut husk. The mulched area should extend to just beyond the canopy dripline. Where herbicides are used, keep the sprayed area along the tree line to a minimum to reduce the potential for soil erosion.

Bearing trees

When orchards begin to bear, the need to maintain a healthy soil environment and minimise soil erosion and nutrient loss is balanced against the need to efficiently harvest nuts from the orchard floor. As trees crowd in orchards, non-shade tolerant inter-row grasses die out and leave the soil vulnerable to erosion and overland movement of nutrients. There are two main options at this stage:

- A vegetative ground cover grown under the trees as living mulch, or
- The area under the canopy is kept weed free with a combination of imported mulch and herbicide spraying.

Mulching, whether by living mulch or imported mulch, has many advantages:

- Adds organic matter and increases organic carbon (C) levels. Organic matter provides food for soil life and increases stability of the soil so it becomes more resistant to erosion and compaction and holds more moisture;
- Improves soil structural stability, moisture holding capacity and water infiltration;
- Reduces soil moisture loss;
- Helps to control weeds;
- Reduces soil temperature variation, thus reducing soil water loss;
- Protects the soil against erosion;
- Adds some nutrients (slow release);

- Encourages a wide range of beneficial soil organisms (microbes and earthworms), which improve soil health.

Under-tree ground covers

This option has the advantage of enabling mechanical harvesters to enter the orchard more easily following wet weather. Living mulch ground covers need to have the following characteristics:

- Low growing, so that they are less competitive, require less mowing and minimise the number of nuts left behind on each harvest round (height of preferably less than 3 cm during the harvest season);
- Shade tolerant;
- Non-climbing;
- Persistent under regular mowing.

NOTE
Further information is contained in the NSW Agriculture publication *Shade tolerant ground cover in macadamia orchards* and the NSW Agriculture Agnote *Sweet smothergrass – a perennial groundcover for subtropical orchards*.

To date, sweet smother grass has been identified as the most suitable perennial ground cover for Australian macadamia orchards. It is established by runners or turf. Rolls of sweet smother grass can be obtained from some specialist turf suppliers. It is best established before total canopy closure. It can be planted in spring, summer or autumn. It needs to be watered in if there is no follow-up rain. Where irrigation is unavailable, autumn is usually the best time to plant.

Mulching and herbicide use

Sources of mulch include grass slashings from the inter-row area, leaf drop, tree prunings and composted nut husks. Whatever the source of mulch, it needs to be managed so that, at the time of harvesting, a minimum of coarse material remains on the soil surface. This is because coarse mulch can interfere with mechanical harvesting. Even with hand harvesting, mulch needs to be well settled or chopped up finely prior to nut drop. The best time to apply mulch is after harvesting is completed. A layer up to 5 cm deep is ideal.

Slashings from the grassed inter-row area can provide a valuable source of mulch until shading reduces the volume available. Fallen leaves and tree prunings need to be finely chopped up with implements such as offset flail mulchers otherwise they interfere with finger wheel harvesting equipment. This material is best placed on the soil surface under the trees rather than in inter-row areas. If husk is to be applied as mulch, it is recommended that it is composted properly before use.

See page 41 for more detail on herbicide management.

Herbicides are used to control any weeds that grow through the mulch. Management of herbicides is important, particularly when nuts are on the ground.

Tree decline

A condition known as tree decline can occur, particularly in orchards on marginal or eroded soils, or on steeper slopes, or following environmental stress. It can significantly reduce yields and the life of the orchard. Older trees are most affected. Some varieties such as H2, HAES 508 and HV A4 appear more susceptible to the problem. In the case of HVA4, this may be due to its need for additional fertiliser to compensate for its precocious habit.

See page 56 for more detail on treatment of tree decline.

Trees affected usually have a reduced fine feeder root system. Sound cultural practices that sustain soil structure and fertility and provide an environment for healthy root development are important in reducing the incidence of decline. This increases the importance of the effective use of surface drains and vegetative ground cover to limit water flow, thus reducing soil erosion and exposure of surface roots.

Overcoming decline is a slow process. Treat affected trees as soon as symptoms are visible.

On-farm composting for mulch

(Adapted from Jenkins, Abigail and Van Zweiten, Lukas (2003) *How to compost on farm*. NSW Agriculture Agnote DPI-448)

Composting is the breakdown of any organic material into a crumbly, dark, soil-like product in which none of the original material can be easily identified. Various organic waste materials produced by farming such as nut husk, effluent, vegetable waste, stubble and so on can be used to produce compost. Nut husk makes an ideal compost to use as mulch for macadamia trees.

Types of composting include:

- **Vermicomposting** – where worms are used;
- **Passive composting** – where plant waste degrades slowly, for example when mulch is added to soil;
- **Thermophilic composting** – where organic material breaks down rapidly. Here, the compost pile gets hot and sterilises weed seeds and disease organisms.

The information contained below relates to thermophilic composting.

What you need to make good compost

The key elements needed when making good thermophilic compost are:

1. Aeration

To ensure air can move in the compost heap, it is important to turn the pile regularly and include a range of different sized and shaped materials. BUT,

remember that large pieces of woody material will take much longer to break down than smaller 'chips'.

2. Moisture

Ideally, water content should be 50 to 60% (it feels like a moist sponge but no water comes out when you squeeze it with your fingers). To make sure the pile stays wet enough during the composting process, you may need a water supply to keep moisture up to the pile.

3. Organic ingredients

Good compost must have a balance of carbon-rich (woody material) and nitrogen rich (green leafy matter or manure) materials. The ideal is a carbon: nitrogen (C:N) ratio of about 30:1. Materials can be selected and mixed to achieve this desired ratio. Materials with a C:N ratio significantly lower than this (for example lucerne hay), tend to decompose too rapidly and raise nitrogen levels too high. Materials with a C:N ratio that is significantly higher can cause a nitrogen draw-down effect unless extra nitrogen fertiliser is applied (the material takes nitrogen from the soil in order to decompose, thus starving the tree). A list of materials and their approximate C:N ratios is shown in Table 30.

Table 30. Approximate carbon:nitrogen (C:N) ratios in a range of dried materials (after Handreck, K.A. and Black, N.D. (1994). *Growing media for ornamental plants and turf* (revised edition). University of New South Wales Press; and Jenkins, Abigail and Van Zweiten, Lukas (2003) *How to compost on farm.* NSW Agriculture Agnote DPI-448)

Material	Carbon : Nitrogen (C:N) ratio
Pinus radiata sawdust	500
Cardboard/newspaper	500-600
Eucalyptus sawdust	500-800
Sugar cane bagasse	120
Woody tree prunings	100
Wheat or oats straw	80-100
Sugar cane tops	80-100
Mature leaves/soft tree prunings	50-60
Macadamia nut husk	40
Non-legume hay/corn stalks	35
Horse manure	30
Mill mud (filter press)*	25
Grasses/grass clippings/mixed weeds	15-20
Cow manure	15-20
Lucerne hay	10-15
Poultry litter	10-15
Pig and poultry manure	5-8
Blood and bone	3-5

* Note that this figure is for mill mud only. Some sugar mills blend fly ash with mill mud and this mixture will have a different C:N ratio

4. A suitable area

You will need to dedicate an area to composting for at least three months. The area you identify should be relatively flat and free of stones, tree stumps, drainage lines and weeds (especially bulbous weeds). A good base for the compost pile can be created using crusher dust. There should be enough room for machinery use to turn the compost. The pile should be located so it will not contaminate adjacent land or waterways via wind drift and water runoff.

5. Machinery

If making a large amount of compost, you will need machinery to turn the pile. A front-end loader or excavator is ideal. Alternatively, you may consider hiring a machinery contractor.

6. Cover

You may need to cover the pile if there is excessive rainfall.

Making the compost

1. Constructing the pile

Mix all materials and construct a pile that is between 1.5 and 2 m high and 2 to 3 m wide. It can be as long as required. Using these dimensions, every 1 m in length will make about 3 cubic metres of compost.

Add water so that the pile is wet through but not soaked. Check a sample. It is wet enough if it glistens with water but doesn't drip excess water.

2. Turning the compost pile

After about one week, check the temperature in the pile. It should be between 50 and 65ºC (this is now considered a thermophilic compost). Use a shovel to dig a hole in the middle of the pile. You will probably notice steam rising and the compost should feel uncomfortably hot. You can check the temperature accurately with a thermometer or a data logger, which transfers temperature information to your computer.

Preparing nut husk compost on a farm in New South Wales

If the temperature is right, turn your pile about seven days after measurement, or when the temperature starts to decline. If the temperature is above 70ºC, turn the pile immediately and reduce pile height to a maximum of 1.5 m.

When turning the pile, ensure the materials from the outside of the pile are placed on the inside. This can be achieved by rolling the pile over using a front-end loader or lifting the pile and dropping in its original place using an excavator.

NOTE

It is important for the compost pile to reach about 60°C to kill any unwanted pathogens and weed seeds and break down all the material properly. It must not get hotter than 70°C as this will reduce the nutrient and carbon value of the compost and kill beneficial decomposer organisms.

3. Monitor the temperature

Keep monitoring the temperature on a weekly basis and turn the pile after the correct temperature has been reached each time. The pile will probably need to be turned at least three times before the compost is ready for use but may need up to six turns, depending on the materials used. Once the pile has stopped producing heat, let it 'cure' for at least two weeks before use.

4. Trouble shooting problems

Some common composting problems and their remedies are shown in Table 31.

Table 31. Trouble shooting problems

Problem	Cause	Remedy
Excess water running off	Compost too wet	Add dry materials or let pile dry out a little
Bad smell	Anaerobic conditions	Add larger materials and turn more often
Ammonia smell	C:N ratio too low	Add extra high-C materials
Clumping	Compost is too wet	Add dry materials and turn
Pile won't get hot after set-up; the compost process does not appear complete	C:N ratio too high Moisture is incorrect Too little oxygen	Add high nitrogen materials, but avoid fertilisers such as urea Adjust accordingly Turn pile

When is the compost ready?

Good quality compost should take about 8 weeks to complete; macadamia nut husks can take up to 12 weeks. It is very important not to use the compost before it is ready as beneficial organisms will not have established, and nitrogen will have been temporarily taken by the decay organisms and be unavailable to the trees. When the compost is ready it has the following distinct characteristics:

- **Smell**: nice earthy smell, with no sour or rotten odours;
- **Feel**: moist and earthy; not wet and sloppy or dry and powdery;
- **Appearance**: original organic materials are not distinguishable. Pile contains dark soil sized particles;
- **Temperature**: pile stops getting hot;
- **C:N ratio**: between 15:1 and 20:1 (a laboratory test for this costs about $25).

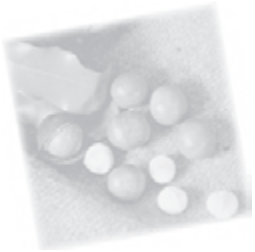
The composting process takes longer if there is insufficient water or too much carbon rich material.

Applying compost

For small farms, compost can be raked out by hand or applied using a manure dropper of about 1 cubic metre capacity, attached to the three-point linkage of a small tractor. The bin can double as a scoop for filling, making this an effective one-person operation. Do not apply compost more than 50 mm deep and do not allow it to build up around the trunk, particularly in young trees.

For larger farms, a mechanical spreader with 3 to 4 cubic metre capacity is required. In some areas, contractors are available for hire. A separate front-end loader is desirable. There are two types of spreader:

- **Disk or twin disk spreader.** This throws compost out behind the hopper and is effective at getting an even coverage to a depth of 30mm. Compost is either thrown out to one side by a single disk or spread both sides using a twin disk. However there is little control over where the compost ends up so it is difficult to limit the compost to a particular area such as the dripline.
- **Belt spreader.** This consists of a large bin with a moving belt for the floor. An opening at the end of the bin allows the compost to exit. The quantity of compost delivered depends on the speed of the belt and the size of the opening. A belt spreader will place the compost in the row in a pile 30 mm or more thick. It may then have to be spread further using a rake or other machinery. The advantage of using the belt spreader is the more accurate placement. The disadvantage is the need for further spreading.



Propagation

Most macadamia trees are propagated by grafting or budding selected varieties onto seedling rootstocks. When establishing an orchard, there is a choice of buying or propagating your own trees. Propagating macadamias, however, is a difficult and specialised operation. For this reason, it is best left to specialist macadamia nurseries. However, a basic knowledge of the process is valuable to assist in understanding nursery tree quality. In addition, topworking existing trees to new varieties may be an option for some growers instead of replanting with new trees.

Terminology

Grafting The art of joining parts of different plants together so they unite and form a single new plant: one forming the root system (the rootstock), the other forming the tree canopy (the scion).

Rootstock The rootstock (or stock) is the lower portion of the graft below the graft union, from which the root system of the grafted tree develops. A seedling rootstock is a rootstock produced from a seed and a clonal rootstock is a rootstock produced from a cutting.

Scion The scion is the upper portion of the graft above the graft union. Initially, it consists of a short section of a branch from a mother tree of the desired variety, containing about three nodes or whorls of well-developed buds that, when grafted onto the rootstock, forms the tree canopy of the grafted tree

Callus When plant tissues are damaged, the cambium layer is stimulated to produce callus tissue of unspecialised (parenchyma) cells, designed to heal the wound (like a scab). In grafting, the cambium of both stock and scion are placed close together and the callus produced by both 'knits' and interlocks. Eventually the unspecialised parenchyma cells develop into specialised wood and bark tissue to form a permanent and strong union.

Cambium The cambium is a thin layer of very specialised (meristematic) cells between the bark and wood, capable of dividing and forming new cells. The cambium is responsible for the growth in trunk diameter of woody plants. Matching the cambium of the rootstock and scion is essential for successful grafting.

Cincture Cincturing (or girdling) is the process of interrupting the downward flow of sap in the bark (usually by removing a strip of bark right around the base of the stem). This allows carbohydrates, auxins and other growth chemicals to accumulate above the cincture. In macadamia, this buildup of materials enhances the successful 'take' of grafts.

Cuttings A section of one plant that under the right conditions forms a complete new plant. Stem and leaf cuttings initiate new root systems while root cuttings initiate new shoot systems. When cuttings are taken, specialised meristematic cells that have the ability to divide are stimulated to produce a mass of callus tissue that forms the new roots (for stem and leaf cuttings) or shoots (for root cuttings).

Clone A vegetatively produced plant that has the same genetic make up as the parent plant from which it was produced. Note that a cutting is a clone of the parent plant.

Topworking Topworking is used to change a tree from one variety to another by grafting wood from a desirable variety onto the stump (or major branch) of a superseded variety, or preferably onto the original rootstock of the tree.

Budding Budding or bud grafting uses a small piece of bark with a single bud to form the scion.

Budwood Scion wood or bud sticks taken from the mother tree of the desired variety to form the scion of the graft.

Why use rootstocks?

The main reason macadamia trees are grafted or budded onto rootstocks is to obtain varieties that are less variable and more precocious than seedlings. However, it is also possible to get true-to-type, precocious trees directly from cuttings, without the need for rootstocks. Clonal macadamia trees (produced from cuttings) are widely and successfully used in South Africa. There, trees are produced in two ways, either from rooted cuttings (without rootstocks), or by grafting a scion variety onto a rooted cutting. Rooted cuttings give a more uniform orchard because they are genetically identical. Seedlings, on the other hand, are genetically diverse.

See page 181 for more information on cuttings and their production.

In other tree crops, rootstocks are also often important in contributing desirable characteristics such as disease resistance and dwarfing. However, there is little information yet available to indicate such benefits with grafted macadamia trees. This may emerge as current and future research is completed.

Understanding the basics of propagation

While there is some interest in growing trees from cuttings, the majority are grafted to seedling rootstocks. A bud or bud stick from the required variety is grafted onto an established rootstock or, in the case of topworking, an established tree. The most commonly used variety for rootstock production is H2 (Hinde). H2 seedlings are used because they are uniform (most seedlings look and perform like the mother tree), vigorous, and easy to graft. However, it must be emphasised they are not true-to-type. Renown (D4), which was used in the past, was highly variable, producing a very diverse progeny of seedling rootstock trees. Very little is known about rootstocks and their effect on production except that grafted trees are more uniform and come into production much earlier than variable seedling trees.

The scion wood is generally cinctured 5 to 6 weeks before grafting, depending on variety and season, by removing a strip of bark about 15 to 20 mm wide from the base of suitable branches 15 to 20 mm thick. A pair of pliers can be clamped around the branch to squeeze and tear the bark in a twisting motion around the branch. Branches should be mature but not old. They should also be healthy, leafy, long, evenly thick with long internodes, and preferably with no side shoots. Cinctured scion wood is ready for grafting when the cincture forms a good callus, indicating buildup of carbohydrates in the budwood above the cincture. Do not allow the callus to heal over as this will allow the buildup of stored carbohydrates to bypass the cincture. If necessary, trim the cut to remove callous overgrowth.

Cinctured wood ready for grafting

Bud grafting (budding) is a specialised operation, requiring skill and experience. It is less wasteful of scion wood and scion wood branches do not have to be cinctured. Budding is usually done in spring when sap flow is expected. The bark must lift readily from the cambium layer on both budwood and scion wood.

Raising seedlings for rootstocks

Potting mixes

The choice of potting mix will depend on availability and cost of ingredients, and the method of watering. It should be well drained, particularly if automatically-timed, overhead sprinkling is used. If watering on demand, heavier mixes can be used. Potting mixes containing soil and madacamia husk tend to settle in the pot, thus reducing air-filled porosity, a requirement for

good seedling root growth. Soil also presents a disease risk unless sterilised. Some examples of potting mixes (by volume) that are used include:

- one part coarse river sand; one part composted macadamia husk;
- one part coarse river sand; one part peat; one part soil;
- One part coarse river sand; one part composted sawdust; one part composted pinebark.

Potting mixes, especially those containing soil, should be sterilised before use, although sterilisation of potting mixes is not universally carried out in macadamia nurseries. Steam pasteurisation at 65°C for 40 minutes is ideal. Methyl bromide is sometimes used for sterilisation but is less popular. After treatment, add fertiliser and mix thoroughly. Two commonly used fertiliser combinations are shown in Table 32.

Table 32. Common fertiliser combinations for macadamia potting mixes

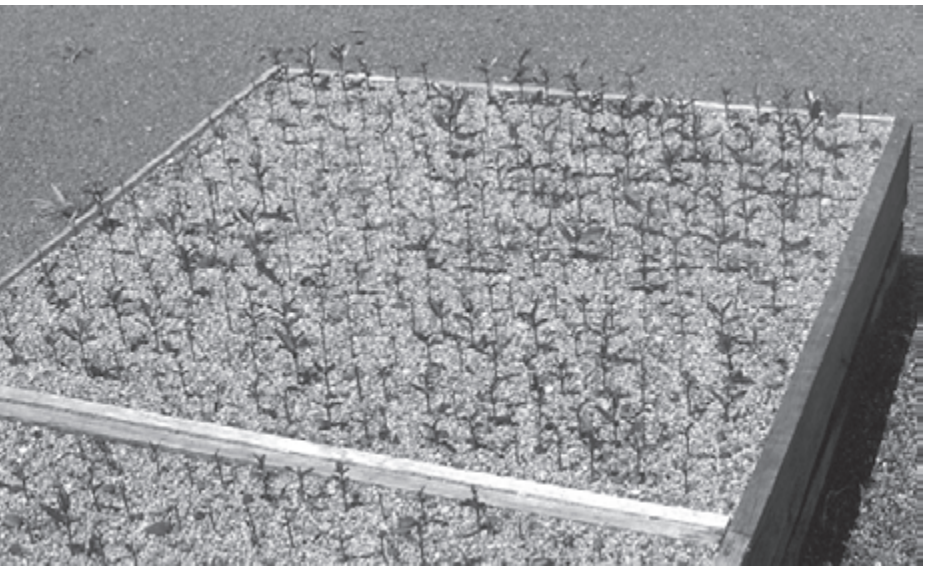
Combination 1 (per cubic metre of mix)	Combination 2 (per cubic metre of mix)
325 g sulphate of ammonia	1 kg fine superphosphate
1 kg fine superphosphate	1 kg fine lime
200 g potassium nitrate	1 kg fine dolomite
3 kg dolomite	3 kg 9-month slow release NPK (18:2.6:10 or similar)
1 kg trace element mixture	1 kg 3-month slow release NPK (16.3:3.5:10 or similar)
	1 kg slow release micronutrients
	0.5 kg coated iron
Note: with this combination, seedlings need additional fertiliser after they have started to grow.	**Note:** with this combination, the slow-release fertilisers should last for several months.

Many brands of trace element mixtures are commercially available. However, 1 kg of the trace element mixture referred to is approximately equivalent to 50 g iron sulphate, 12 g copper sulphate and 6 g zinc sulphate.

Raising seedlings

Seeds are easy to germinate. They can be planted at any time as long as they are protected from extremes of temperature. To reduce contamination, harvest the green-mature nut-in-husk from the tree and dehusk straight away. Plant the nut-in-shell immediately or store in a perforated plastic bag for up to 12 months in the warmest part of a refrigerator or cold room. Do not store or plant nuts that are damaged or pre-germinated as the resultant seedlings may be distorted and have multiple shoots.

Seeds can also be planted directly into pots or planter bags, but this is wasteful. The most common method is to plant into seedbeds, usually of coarse river sand, and then replant the seedlings into planter bags. To ensure an even batch of seedlings, place the nuts in an unshaded, raised bed lined with black plastic, and water three times a day. When the shells split, plant them out into a seedbed, ensuring that the suture is on the side, parallel to the soil surface to allow unhindered root and shoot growth. When the seedlings are



A macadamia seedbed

A nursery with seedlings. Note that the planter bags are on pallets on gravel to provide good drainage and to prevent contact with the soil

big enough (approximately 10 to 15 cm or when 6 to 8 leaves have formed) and the first flush has hardened, plant them into 9 L planter bags to avoid distortion and twisting of roots. To maintain good drainage and minimise disease, keep the seedbed and planter bags off the ground on pallets or on a bed of gravel.

Growing-on

Seedlings are ready for grafting in 12 to 18 months. They should be well grown with long internodes for ease of grafting. Segregate the young trees for size, and discard unthrifty trees.

Container-grown plants

The main advantages of growing plants in polythene planter bags are the ease of handling, lack of disruption to the root system at planting, and relative freedom from root diseases. Ideally, the planter bags should be at least 300 mm deep (9 L preferred—6 L minimum) to encourage a framework of straight, well-developed roots. Trees may be kept in these bags for up to 24 months.

Be careful not to over-fertilise young trees. It is easy to upset the phosphorus:iron balance, the consequence being yellow, unthrifty leaves. The best approach is little and often. A safe fertilising regime is monthly applications of liquid fertiliser. A common mixture is 2 teaspoons of Aquasol® or Thrive®, one teaspoon of urea and one teaspoon of iron chelate in 10 L water. This supplements the fertiliser incorporated into the potting mix, especially if slow-release mixtures have not been used in the mix. Commercial preparations of foliar fertiliser are equally suitable.

Figure 33. *Whip grafting showing the scion wood and rootstock about to be brought together*

Water plants regularly. Daily watering may be required, depending on size, time of the year, and density of the potting mix. Check at regular intervals to make sure plants are not under-watered or over-watered. Remove all side shoots to encourage a strong, upright stem for grafting. Insect pests, such as twig-girdler, broad mite, thrips, scales and caterpillars, are a major problem in nurseries and can quickly devastate trees.

Grafting and budding

Macadamia rootstocks are ready for budding or grafting when they are up to 1m high and 10 to 15 mm in diameter. Both rootstock and scion wood need to be in good condition (healthy and free of pests and disease). Grafting in the spring is preferred but it can be done at any time, provided trees are protected from hot, frosty or windy conditions. Remember that for grafting, scion wood needs to be cinctured 6 to 12 weeks beforehand, as outlined earlier in this section. Budding is more difficult but is quicker and less wasteful of (uncinctured) budwood. For budding, rootstock stems, approximately 7 mm in diameter at a point 25 cm from the soil, are ideal. Plant out grafted plants after the second flush from the scion wood has hardened. In the meantime, remove grafting tape and all side shoots and suckers. Contract grafters will graft or bud trees for a unit price per tree. This is often a viable option when propagating a large number of trees.

Whip graft

The whip graft, the most commonly used grafting technique for macadamias, is simple and effective. To whip graft, make matching, sloping cuts about 30 mm long at the base of the scion and on the stock with a sharp grafting knife (Figure 33). A small wood-plane can also be used to ensure perfectly flat surfaces for good contact. The cut needs to be longer if the diameter of the wood is more than 10 mm. Matching the thickness of the rootstock and scion wood, before cutting off the top of the rootstock, will help to get a good match between the cambium layers of the rootstock and scion wood. If the stock and scion are not the same size, match the cambium layers on one side only. The cambium is the slightly darker layer just under the bark. It lifts with the bark. Secure the scion to the stock with budding tape. Clothes pegs can be used to help hold the scion in place. Always apply tape from the bottom upwards to produce an overlapping pattern that sheds water away from the graft. Paint the scion and tape with grafting mastic to prevent it drying out. The graft is successful when the scion wood produces a new shoot. The whip graft is commonly used by nurseries but is difficult for the beginner. Once mastered, it is a relatively quick method of grafting.

A small wood-plane is useful for getting flat surfaces for grafting

Matching the thickness of the scion wood and rootstock before cutting the top of the rootstock

Applying grafting mastic to seal the graft

A completed graft union before taping

A successful whip graft after removal of shoots below the graft

Punch budding

Punch budding allows a perfect match between the scion and stock by using the same tool to remove the bark from the rootstock and the bark with a bud from the scion wood. Punch budding is best carried out in the spring but can be done at any time provided there is sap flow in both rootstock and budwood. Sap flow is detected by seeing how easily the bark is removed from the wood and bending the bark backwards between the thumb and forefinger to detect the presence of sap.

A successful bud take showing the new bud growth

Select an internode position on the rootstock, approximately 25 cm from soil level. From the bud stick, select a bud to suit. Remove a patch of bark from the rootstock with an oval punch. Remove the bud from the bud stick with the same punch and place the bud in position on the stock. Wrap the bud completely with grafting tape. Remove the tape after 6 weeks. At this time, if the bud is green and healthy, cut the rootstock at the node above the bud. Paint the bud and the cut on the rootstock with grafting mastic to seal the wound. Remove any shoot growth from the rootstock as it appears. Cut the remaining stub above the bud after the bud has established.

Note that this is a simplistic description of the operation. In reality, it is very difficult to perform successfully, and expert advice and practice is necessary to achieve good results. For further reading, refer to *Punch budding macadamia in New South Wales, what is the problem?* in the AMS News Bulletin, July 1998 edition.

Cuttings

Growing macadamias from cuttings (clones) is a specialised operation requiring skill. As mentioned earlier in this section, cuttings have been used in South Africa for some time, the variety Beaumont being particularly popular. There are big differences between varieties in successful striking of cuttings. Beaumont cuttings root readily and grow vigorously. Cuttings from other tetraphylla varieties and hybrid varieties (for example the HV A series and H2) also strike readily, but those from Hawaiian varieties (HAES 246, HAES 344) are more difficult.

Although clonal rootstocks such as cuttings have the advantage of being uniform, since there is no genetic variability compared with seedling rootstocks, any defects, weaknesses or desirable characteristics may be magnified in the orchard. When cuttings were first used, resultant trees had a reputation of being prone to wind damage. However, as long as cuttings are planted deeply enough, and root systems are well developed, tree stability is not a serious problem.

Misting house requirements

To produce good, healthy, vigorous trees successfully from cuttings, it is essential to propagate them in a misting house. It is not essential to provide bottom heat, although it may result in a better and more rapid strike in cooler areas. Ideally, root temperature should be maintained between 24 and 26°C. In summer, cuttings take about 3 to 4 months to strike and produce a good root system, after which they can be transferred to a shade house. The misting house should be well ventilated, allowing hot air to escape at the top. Leaf temperatures should not exceed 30°C and some provision should be made for cooling when these temperatures are reached, for example evaporative cooling by sprinklers on the outside of the structure. It is desirable for the misting house to be covered with shade cloth to prevent excessively high temperatures developing inside.

To prevent leaves drying out at high temperatures, electronic leaf sensors can be used to control misting to ensure the leaves remain wet. As the leaf dries, the sensors activate misting jets via a solenoid. The sensor electrodes require regular maintenance every 2 to 3 weeks and should be cleaned with 00 emery paper. Misting jets operate at not less than 90 p.s.i.

Chlorination of misting water is necessary to minimise the risk of disease. Use liquid chlorine injected on the delivery side of the pump. Pass the chlorinated water through a sand filter to remove iron precipitate. Monitor the chlorine level to ensure it does not exceed 10 ppm free chlorine. The chlorinated water is then stored and regulated by the electronic leaf sensors. As an additional precaution against root disease, a phosphorous acid drench may be applied every few weeks. Set misting jets about 2 m above the cutting trays on either raised benches or on well-drained screenings on the ground. Arrange the jets in a triangular grid, 1 m apart.

Cutting material

Healthy, leafy, semi-hardwood tip cuttings with 4 to 5 nodes taken from the last hardened flush in spring/summer give the best results. Collect cutting material early in the day, before it gets too hot. Prepare and plant cuttings the same day. Store cuttings in a plastic bag, wrapped in moist paper to prevent drying out, under shade, in an esky or in a refrigerator. Cut off basal leaves, leaving about two sets of leaves, and trim the bottom cut just below the last node. Hold secateurs or a knife at right angles to the cutting and use the blade to scrape down to the cambium layer on each side of the cutting for a short distance from the base. Dip the base of the cutting in purple Clonex® gel or similar rooting hormone formulation.

Rooting media

Use a sterile, well aerated and well drained potting mix to raise cuttings. A successful mix is 2 parts 2-mm washed sand, 1 part coir and 1 part 4-mm polystyrene prill. Plant the cuttings so that the bottom two nodes are covered. Keep cuttings in the misting house until the roots are well established (generally in 6 to 12 weeks).

Shade house

Once the roots are well established, transplant the cuttings into planter bags of at least 6 L capacity (9 L preferred). These allow the cuttings to be planted more deeply. Use a free draining potting mix. A suitable mix is 35% composted hardwood sawdust, 35% pinebark, and 30% coarse river sand, to which is added 100 g urea, 400 g dolomite, 1 kg gypsum, 2 kg blood and bone, and 700 g single superphosphate per cubic metre. The shade house should provide 60% shade. Sprinkle the cuttings with water frequently, particularly during summer. An automatic irrigation system is ideal. Small amounts of foliar or slow release fertiliser can be applied to struck cuttings in the shade house. When the plants are approximately 45 cm high, move them to a hardening-off area and progressively expose to full sunlight.

Once hardened off, cuttings can be planted in the field. Alternatively, if the cuttings are being used as rootstocks, they can be grafted to the desired variety in the same way as seedling rootstocks.

Topworking

Topworking in the field involves grafting established trees to a new variety. This provides an alternative to completely removing trees of unsuitable varieties and replanting with new nursery stock. Topworking gets the orchard back into production more quickly than replanting. However, the cost effectiveness of topworking has not been thoroughly documented yet for macadamia. Studies indicate that the cost of topworking is similar to the cost of tree removal and replanting. The cost effectiveness will therefore depend on the rate of return of topworked trees to production. This is currently being determined in trial work.

Various methods can be used for topworking. Preparation of the original tree ranges from:

- Stumping (cutting back to the main trunk at about the level of the first whorl of branches);
- Staghorning (cutting back to three to five main branches about 50 cm long); or
- Partial canopy removal (temporary retention of whole limbs left to maintain assimilate production, nutrient translocation and protection from sunburn and wind damage).

Stumping is thought to be risky, as trees may die or lose vigour. Studies have shown that partial canopy removal results in greater tree growth, less sun damage and earlier return to production than complete canopy removal.

Grafting methods include grafting or budding of regrowth or bark grafting which involves inserting scion wood under the lifted bark of a newly cut limb.

Topworking using the partial canopy removal method

For the partial canopy removal method, lop off one to three major limbs about 0.75 to 1.5 m above the ground, leaving a 15 cm stub to encourage suckering. For better protection from the sun, it is best to remove branches on the southern side of the tree, preferably in October/November and no later than April, so that vigorous suckers, 8 to 12 mm thick at the base, are ready for grafting next spring. About one third, but no more than half, of the canopy is removed at this time. The remaining branches help to protect the new growth from wind and sunburn, and maintain assimilate supply and translocation of nutrients. For autumn grafting, reverse the process so that vigorous suckers are ready for grafting on the northern side of the tree in autumn. Because of the risk of sunburn, it is best to paint the exposed trunk with white plastic paint. Also avoid, where possible, topworking on very hot, sunny days.

Cincture scion wood at least 6 to 12 weeks before grafting and allow plenty of material of varying sizes. Identify the cinctured branches with flagging tape marked with the variety name and date. Graft when favourable cool weather is forecast. In the case of grafting regrowth, select at least two, well-placed suckers per limb and remove the remainder. If the area has become shaded, remove overhanging branches. The suckers to be grafted should be near the top of the stub on opposite sides so that they callus across the top of the stub, join up and add strength to the graft union. Paint all exposed limbs and grafts with white plastic paint to protect from sunburn.

Remove all suckers on grafted branches regularly to force the buds to grow. Also remove suckers or small limbs likely to cause physical damage to soft new shoots. De-suckering should be carried out every 2 to 3 weeks. When the scion has grown approximately one metre long, remove another half of the old limbs remaining on the tree. Remove all old limbs within two years of topworking. The cuts must be clean and close to, but not flush with, the main trunk (just outside the branch collar), with no stubs, so that the callus can heal over the surface. If reworking an entire block, it is advisable to do alternate rows or trees. This provides wind protection and minimises crop losses in the change over period.

Field grafting

This involves grafting specified varieties to a seedling rootstock already established in the field. It is generally done 12 to 18 months after planting out, depending on the size of the seedlings and growing conditions. The whip graft is most popular. It is important to protect the graft with Steriprune® or a similar protectant. The main disadvantages are that grafting is slow, maintenance is high, and the trees are subject to the elements of heat, cold, wind, animals and birds. The rootstock may also be stunted or completely fail.

Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in macadamia production. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

Chapter 5

Contacts & REFERENCES

Want more information? This chapter helps to direct you to the other important providers and sources of macadamia information. Names are provided solely for assisting readers to make contact. Inclusion of a person or organisation does not constitute an endorsement by the Department of Primary Industries and Fisheries or the authors, nor does it endorse a particular person or organisation over others not mentioned. Lists of names are based on the best knowledge available to the authors at the time of printing and does not necessarily include all suppliers of services. The authors regret any omissions.

Contacts

- Grower organisations
- Nursery tree suppliers
- Consultants and contract services
- Processors
- Equipment manufacturers/suppliers
- Chemical and spraying information
- Organics organisations
- Government technical services

References

This is not an exhaustive list of references for macadamias. It consists of references that the authors recommend as important sources of information and reading for the macadamia grower. If you require more detailed information on a subject, use the literature search facilities available from libraries (see Library services).

- Specialist macadamia information
- Other available products of potential relevance
- Newsletters
- Library and information search services

Grower organisations

The major organisation catering for macadamia growers, processors and others involved in the industry is the Australian Macadamia Society Ltd. The Society provides a range of services including conferences, meetings, field days, seminars, information, and a regular AMS News Bulletin. As the peak macadamia industry body, it also administers funds collected from growers for research and promotion.

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Ph: (07) 4151 5576; (07) 4151 9150
(07) 4152 3432

Heat and Control Pty Ltd (food processing/packaging equipment)
407 Creek Road
MT GRAVATT QLD 4122
Ph: (07) 3877 6333; Fax: (07) 3343 8371
Email: info@heatandcontrol.com.au
Web: www.heatandcontrol.com

R J and J M Hooper (general farm equipment)
PO Box 100
1 Balmoral Road
MONTVILLE Q 4560
Ph: (07) 5442 9202; Fax: (07) 5442 9233
Email: info@hooperengineering.com
Web: www.hooperengineering.com

Metcraft Industries trading as **John's Engineering** (harvesting, dehusking, storage equipment, full range of processing equipment)
Blackbutt Road (PO Box 258)
PALMWOODS QLD 4555
Ph: (07) 5445 0844; Fax: (07) 5478 9690
Mobile: 0403 381 506
Email: johnseng@aceconnect.com.au
Web: www.johnsengineering.com.au

PB Machinery Sales (tractors, harvesting/spraying machinery)
13 Pioneer Road
YANDINA QLD 4561
Ph: (07) 5472 8111; Fax: (07) 5446 8846
Mobile: 0438 467 476

Silvan Australia Pty Ltd (spraying equipment)
44 Lysaght Street
ACACIA RIDGE QLD 4110
Ph: (07) 3345 9500; Fax: (07) 3345 9511
Email: info@silvanaust.com
Web: www.silvanagcess.com.au

New South Wales

Alstonville Steel (dehusking, handling and storage equipment, repair and maintenance of plant, delivery transport)
3 Owens Crescent
ALSTONVILLE NSW 2477
Ph: (02) 6628 0026; Fax: (02) 6628 1926
Email: tburnett@nor.com.au
Web: www.alstonvillesteel.com.au

Ballina Hydraulics and Engineering (harvesting equipment)
Mark Burgmann
110 Teven Road
BALLINA NSW 2478
Ph: (02) 6686 7400; Fax: (02) 6686 7922
Email: rmburgmann@hotmail.com

David Barnsley Industrial Spares (belt services for harvesting/handling equipment)
26 Tweed Street
LISMORE NSW 2480
Ph: (02) 6622 2747; Fax: (02) 6622 5131

Doc Dorahy Tractors & Machinery (orchard floor preparation machinery/harvesting equipment)
26 Tweed Street
LISMORE NSW 2480
Ph: (02) 6622 2842; Fax: (02) 6621 4777

Bill Farrell Fabrication Pty Ltd (dehusking/ harvesting equipment)
4 Wilson Street South
SOUTH LISMORE NSW 2480
Ph: (02) 6621 8154; Fax: (02) 6622 7199

Orchard Systems (dehusking/handling equipment)
Richard Hurley
Arthur Road
CORNDALE NSW 2480
Ph/Fax: (02) 6688 2052
Email: orchsys@bigpond.com

Ongmac Trading Pty Ltd (specialised macadamia tractors/spraying equipment)
86 Conway Street
LISMORE NSW 2480
Ph: (02) 6621 5981; Fax: (02) 6621 8480
Email: ongmacsales@nor.com.au
Web: www.ongmac.com.au

Rural Buying Machinery Centre (harvesting/ spraying equipment; general machinery)
145 Casino Street
LISMORE NSW 2480
Ph: (02) 6621 8837; Fax: (02) 6622 7108
Email: rbmcadmin@spot.com.au
Web: www.rbmc.com.au

Victoria

IDS Consulting Services Pty Ltd (pruning, mulching, herbicide application equipment. Operating in Queensland and NSW)
PO Box 245
BERWICK VIC 3806
Ph: (03) 9796 2968; Fax: (03) 9707 5358
Email: ian@idsconsulting.com.au
Web: www.idsconsulting.com.au
Queensland contact:
PO Box 568
BEERWAH QLD 4519
Mobile: 0428 171 479

Chemical and spraying information

AVCARE LIMITED
National Association for Crop Protection and Animal Health
Level 2, AMP Building 1 Hobart Place
CANBERRA ACT 2601
Locked Bag 916 Canberra ACT 2601
Ph: (02) 6230-6399; Fax: (02) 6230-6355
Email: info@avcare.org.au; Web: www.avcare.org.au

Chemcert Australia
PO Box E10
KINGSTON ACT 2604
Ph: 02 6273 2308
Web: www.chemcert.org.au

ChemCert Training Queensland Inc
University of Queensland, Gatton Campus
GATTON QLD 4343
Ph: (07) 5460 1295; Fax: (07) 5460 1283
Mobile: 0427 732 886
Email: chemcertqld@bigpond.com

Chemcert (NSW) Ltd
249 Bronte Road
WAVERLY NSW 2024
Ph: (02) 9387 4714; Fax (02) 9387 4716
Mobile: 0407 938 704 (Julie Mc Alpin, Executive Manager)
Email: chemcertnsw@bigpond.com
Web: www.chemcert.com.au

Victoria: Ph: (03) 5622 2055
Fax: (03) 5622 2199
Email: chemcertvic@sympac.com.au
South Australia: Ph: (08) 8226 0514
Email: Johnson.Meredie@saugov.sa.gov.au
Tasmania: Ph: (03) 6331 2131
Email: tritb@bigpond.com.au
Western Australia: Ph/Fax: (08) 9341 5325
Email: farmcarewa@bigpond.com.au
Northern Territory: Ph: (08) 8973 8346
Email: chemcertnt@kthntrc.ntrc.nt.gov.au

SMARTtrain
NSW Agriculture and TAFE
Contact your local TAFE institute or NSW Agriculture office
Web: www.lg.tafensw.edu.au/smarttrain

Infopest – pest management system on CDROM
Department of Primary Industries & Fisheries
Animal & Plant Health Services
GPO Box 46
BRISBANE QLD 4001
Ph: (07) 3239 3967; Fax: (07) 3211 3293
Email: infopest@dpi.qld.gov.au
Web: www.dpi.qld.gov.au/infopest/

Australian Pesticides and Veterinary Medicines Authority
PO Box E240
KINGSTON ACT 2604
Ph: (02) 6272 5852; Fax: (02) 6272 4753
Email: contact@apvma.gov.au
Web: www.apvma.gov.au

NSW Environmental Protection Authority (EPA)
Web: www.epa.nsw.gov.au
General Enquiries 131 555

drumMUSTER
National office: GPO Box 816
CANBERRA CITY ACT 2601
Ph: (02) 6230 6712
Fax: (02) 6230 6713
Email: drummuster@drummuster.com.au
Web: www.drummuster.com.au

Organic organisations

These organisations do not have the resources to provide a general advisory service about organic production. Their main function is to provide information about certification standards and processes. Special services are also provided to members after joining. Kits containing information on membership and certification standards and processes are available for purchase.

Biological Farmers of Australia
PO Box 3404
TOOWOOMBA VILLAGE FAIR QLD 4350
Ph: (07) 4639 3299; Fax: (07) 4639 3755
E-mail: bfa@icr.com.au

National Association for Sustainable Agriculture Australia Ltd
PO Box 768
STIRLING SA 5152
Ph: (08) 8370 8455; Fax: (08) 8370 8381
Email: nasaa@dove.mpt.net.au

Bio-Dynamic Agricultural Association of Australia
c/- Post Office
POWELLTOWN VIC 3797
Ph: (03) 5966 7333; Fax: (03) 5966 4333

Organic Retailers and Growers Association of Australia
c/- The Secretary
PO Box 12852
A'Beckett Street Post Office
MELBOURNE VIC 3000
Ph: (03) 9737 9799
Email: organic@alphalink.com.au

Government technical services

Macadamia technical enquiries (commercial growers only)

Queensland

Paul O'Hare
Department of Primary Industries & Fisheries
PO Box 5083 SCMC
NAMBOUR QLD 4560
Ph: (07) 5444 9673; Fax: (07) 5441 2235
Email: paul.o'hare@dpi.qld.gov.au

Pat O'Farrell
Department of Primary Industries & Fisheries
PO Box 1054
MAREEBA QLD 4880
Ph: (07) 4048 4653; Fax: (07) 4092 3593
Email: pat.o'farrell@dpi.qld.gov.au

New South Wales

Kevin Quinlan
NSW Department of Primary Industries
Tropical Fruit Research Station
PO Box 72
ALSTONVILLE NSW 2477
Ph: (02) 6626 2400; Fax: (02) 6628 5209
Email: kevin.quinlan@agric.nsw.gov.au

Peter Newley
NSW Department of Primary Industries
PO Box 530
COFFS HARBOUR NSW 2450
Ph: (02) 6650 3111; Fax: (02) 6651 2780
Email: peter.newley@agric.nsw.gov.au

Other information sources

The Department of Primary Industries and Fisheries Call Centre provides help in accessing the range of DPI&F information products and services. The Call Centre operates from Monday to Friday, 8 a.m. to 6 p.m. on 13 25 23 for the cost of a local call (Queensland only). Callers outside Queensland can phone the Call Centre on (07) 3404 6999.

FarmBis provides training grants to primary producers for individual or group training. Contact:
Queensland Rural Adjustment Authority (QRAA)
GPO Box 211
BRISBANE QLD 4001
Free call: 1800 623 946; Ph: (07) 3032 0100
Fax: (07) 3032 0180
Email: contact_us@qraa.qld.gov.au
Web: www.qraa.qld.gov.au

OR

NSW Rural Assistance Authority (RAA)
Locked Bag 23
ORANGE NSW 2800
Freecall: 1800 678 593; Ph: (02) 6391 3000
Fax: (02) 6391 3098
Email: farmbis@raa.nsw.gov.au
Web: www.raa.nsw.gov.au

TAFE NSW, through its Wollongbar Campus, offers specialised training in macadamia production and IPM. For information on courses and availability, contact
Alan Coates
Ph: (02) 6620 4287
Phil Harvey
Ph: (02) 6620 4291

Specialist macadamia information

The Department of Primary Industries and Fisheries (DPI&F), NSW Department of Primary Industries and the Australian Macadamia Society (AMS) have collaborated over many years to produce a wide range of specialist macadamia information products. Those currently available for individual purchase are listed below. Some are available from all three organisations; others are available only from the publishing organisation (as indicated in the list).

DPI&F Publications
Primary Industries Building
Ann Street (GPO Box 46)
BRISBANE QLD 4001
Ph: 1800 816 541 (within Australia)
or (07) 3239 3804
Fax: (07) 3239 6509
Email: books@dpi.qld.gov.au
Shop on-line at:
www.dpi.qld.gov.au/shop/

NSW Department of Primary Industries
Publication Sales Unit
Locked Bag 1
ORANGE NSW 2800
Ph: 02 6391 3433
Orders: Freecall 1800 028 374
Freefax: 1800 642 065

Australian Macadamia Society Ltd
Suite 1,113 Dawson Street
LISMORE NSW 2480
Ph: 02 6622 4933
Fax: 02 6622 4932
Email: admin@macadamias.org
Web: www.macadamias.org

Note that there is a vast range of other published macadamia reference material, which is now out of print. This includes books, pamphlets, articles in the AMS News Bulletin, and research papers. This material can be accessed through the AMS and specialist libraries listed below under Library and search services.

Macadamia problem solver & bug identifier (book), Gallagher, E., O'Hare, P., Stephenson, R., Waite, G., and Vock, N. (2003), Department of Primary Industries.

Growing macadamias in Australia (book), O'Hare, P., Loebel, R., and Skinner, R. (2003), Department of Primary Industries.

MacMan (farm recording software package), Mulo, S., O'Hare, P., Bartel, L., and Quinlan, K. (2003), Department of Primary Industries. (Enquiries in first instance to DPI&F)

Macadamia variety identifier (book), Bell, D., Bryen, L., Firth, D., Jones, K., Gallagher, E., McConachie, I., O'Hare, P., Stephenson, R., and Vock, N. (2000), Department of Primary Industries.

Macadamia sorting guide (laminated wall chart), Vock, N., Bell, D., Wilson, K., Jones, K., Gallagher, E. and Bryen, L. (2000), Department of Primary Industries.

Diseases & disorders of macadamias (book), Fitzell, R.D. (1994), NSW Agriculture.

Insect pests of macadamias in Queensland (book), Ironside, D.A. (1981), Department of Primary Industries.

Australian Macadamia Society information products (available only from AMS):

- *Australian macadamia industry code of sound orchard practices* (booklet), O'Hare, P. et al (2000), Australian Macadamia Society.
- *Approved supplier manual* (book), Ekman, J. et al (2002), Australian Macadamia Society.
- *Drying macadamia nut-in-shell on farm*, (2001), Australian Macadamia Society.
- *Macadamia promotional video/CD,* Australian Macadamia Society.
- *Macadamia crop loss protocols* (booklet), Treverrow, N. (2002), Australian Macadamia Society.

Other macadamia information products

- *Code of practice for noise management of on-farm processing of macadamia nuts* (2003), Australian Strategic Planning Pty Ltd.
- *Code of practice for the control of spray drift and use of chemicals in macadamia orchards* (2003), Australian Strategic Planning Pty Ltd.

Both codes are available from the Australian Macadamia Society.

NSW DPI Agfacts, Agnotes and information sheets (available from NSW DPI only)

- *Shade tolerant ground cover in macadamia orchards*, Reid, G. (2002)
- *Reducing erosion and other soil degradation in macadamia orchards*, Firth, D.J. (2000)
- *Sweet smothergrass—a perennial groundcover for subtropical orchards*, Firth, D.J. (2001)
- *Soil management in orchards*, Jenkins, A. (1999)
- *Profitability of macadamia growing*, Reilly, T. (1995)
- *Buying a macadamia harvester—some things to consider*, Reilly, T., Bevan, P., and Loebel, M.R. (1994)

Horticulture Australia Limited macadamia research reports

Available only from Horticulture Australia Limited, Level 1, 50 Carrington Street, SYDNEY NSW 2000; Ph: (02) 8295 2300; Fax: (02) 8295 2399; Website: www.horticulture.com.au

Other available products of potential relevance

Diseases of fruit crops (book), Persley, D.M.(ed) (1993), Department of Primary Industries.

Managing insects and mites in horticultural crops (book), Brough, E.J., Elder, R.J. and Beavis, C.H.S. (eds) (1994), Department of Primary Industries.

Pesticide application manual (2nd edn) (book), Banks, A., Broadley, R.H., Collinge, M., and Middleton, K. (1990), Department of Primary Industries.

Soil sense—soil management for NSW North Coast farmers (book), Lines Kelly, R. (1994), NSW Agriculture.

Trees for the North Coast (book), Lines Kelly, R. and Currey, A. (eds) (1994), NSW Agriculture.

Infopest—pest management information system (CD-ROM package) (2003), Department of Primary Industries.

Australian Rainman 2.2 (decision support computer package), Department of Primary Industries.

Plant nutrient disorders 2—tropical fruit and nut crops (book), Weir, R.G. & Cresswell, G.C. (1993), Inkata Press, Melbourne.

The good bug book — second edition (book), Richard Llewellyn et al, M.J. (2002), Australian Biological Control Inc.

Organic agriculture—getting started (book), Madge, D. (1995), Agmedia.

Profitable organic farming (book), Newton, J. (1995), Blackwell Science.

Organic farming (book), Burlace, M. (1995), NSW Agriculture.

Newsletters

The Australian Macadamia Society Ltd produces a bi-monthly publication *Australian Macadamia Society News Bulletin*. It is available to members only as part of the annual subscription to the Society.

Direct enquiries to:
The Australian Macadamia Society Ltd (AMS)
Suite 1,113 Dawson Street
LISMORE NSW 2480
Ph: 02 6622 4933; Fax: 02 6622 4932
Email: admin@macadamias.org
Web: www.macadamias.org

Library and information search services

The Australian Macadamia Society Ltd maintains a large collection of macadamia-related information on its website at www.macadamias.org

AMS members have access to more detailed information via the password protected members-only web pages.

DPI&F's Central library in Brisbane and **NSW DPI's library** at Wollongbar (including information at Alstonville Research Station) provide a range of special information services of interest to growers. These include:

- access to the library's extensive book and journal collection;
- on-line public access catalogue (OPAC) terminals that provide access to the DPI&F library catalogue and to material held in the State Library of Queensland (Brisbane only);
- literature searches from CD-ROM and the Internet (fee charged).

General enquiries can be directed to:
Brisbane: Ph: (07) 3239 3126
Fax: (07) 3239 3128
Wollongbar: Ph: (02) 6626 1321

Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

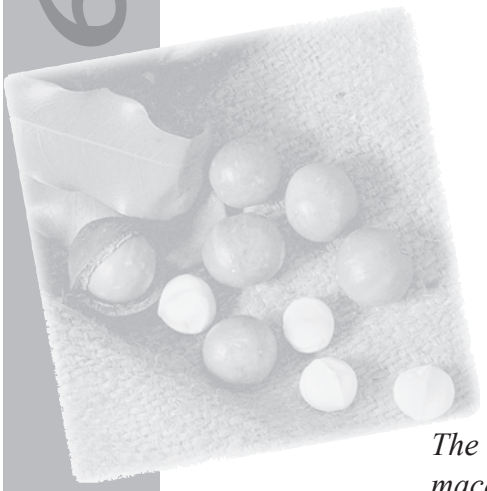
This publication was last revised in 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in macadamia production. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

Chapter 6



Handy GUIDES

*The **Chemical handy guide** lists common pests and diseases of macadamia and the chemicals registered for their control. Withholding periods are indicated for individual chemicals. The handy guides are followed by a listing of trade names and registration status in the different states of Australia.*

These registrations are current as at June 2004, but are subject to continuous change. Always check the label before use. Updated information on registrations can be obtained from your chemical supplier, Infopest, the Australian Pesticide and Veterinary Medicines Authority (APVMA) or the Australian Macadamia Society.

*The **Crop production handy guide** is a calendar of the major crop management operations timed to match the desired crop cycle for an orchard in southeast Queensland. It provides an easy to view monthly guide to the things that need to be done in the orchard.*

Disclaimer

This is a guide only. The product label is the official authority—use it to confirm all data relating to use of a chemical. In no event shall the authors or their respective organisations be liable for any damages whatsoever resulting from use of the data in this handy guide.

Chemical handy guide for macadamia pests

Canegrubs include: negatoria, southern one year

Mealybugs include: citrus, hibiscus, longtailed

Scales include: black (brown olive), latania, long soft, macadamia mussel, macadamia white, pink wax, soft brown, white wax

✔ indicates that a trade product containing the active ingredient is registered in at least one Australian state.

Note that different trade names may have different withholding periods. Check the label before use.

NB = Non-bearing

NA = Not applicable

NS = None supplied on label

Active ingredient	Withholdng period (days)	o (NB)	Bt	sulphur	petroleum oil	endosulfan	trichlorfon	carbaryl	azinphos-methyl	beta-cyfluthrin	diazinon	methidathion	tebufenozide	acephate	coumatetralyl	chlorpyrifos
	Aphids					↘										
	Bananaspotting bug					↘	↘					↘		↘		
	Black citrus aphid					↘						↘				
	Canegrubs: see sidebar	↘														
	Caterpillars - leafeating		↘													
	Cornelian butterfly							↘								
	Flower thrips													↘		
	Fruitspotting bug					↘	↘		↘	↘		↘		↘		
	Green vegetable bug					↘										
	Hairyline blue butterfly					↘										
	Macadamia cup moth							↘								
	Macadamia felted coccid				↘						↘	↘				
	Macadamia flower caterpillar		↘			↘	↘						↘	↘		
	Macadamia lace bug					↘										
	Macadamia leafminer										↘	↘		↘		
	Macadamia nutborer							↘	↘	↘			↘	↘		
	Macadamia twig-girdler					↘		↘				↘				
	Mealybugs: see sidebar											↘				
	Nut stemborer															↘
	Rats														↘	
	Red flat mite			↘												
	Redshouldered leaf beetle					↘		↘						↘		
	Scales: see sidebar											↘				
	Yellow peach moth							↘								

Chemical handy guide for macadamia diseases

✔ indicates that a trade product containing the active ingredient is registered in at least one Australian state.

Note that different trade names have different withholding periods—check the label before use.

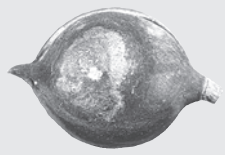
NA = Not applicable

SAFETY FIRST

Read the label

Follow the directions
Wear protective clothing

Active ingredient	Withholdng period (days)	Alternaria blight	Anthracnose	Blossom blight	Botrytis blight	Macadamia husk spot	Phytophthora root rot	Phytophthora trunk/collar rot	Pink disease	Raceme (blossom) blight	Trunk and stem canker
thiram	NA									✔	
phosphorous acid	NA							✔			✔
prochloraz as $MnCl_2$ complex	NA	✔									
copper hydroxide plus metalaxyl-M	28						✔				✔
copper oxychloride plus metalaxyl	28						✔				✔
metalaxyl-M	28						✔				✔
metalaxyl	28						✔				✔
benomyl	14									✔	
carbendazim	14					✔					
benomyl plus carbendazim	14			✔		✔				✔	
copper ammonium acetate	1										✔
copper sulfate (tribasic)	1										✔
copper oxychloride	1		✔			✔			✔		✔
cuprous oxide	1		✔			✔			✔		✔
copper hydroxide	1										✔
iprodione	NA/0				✔						

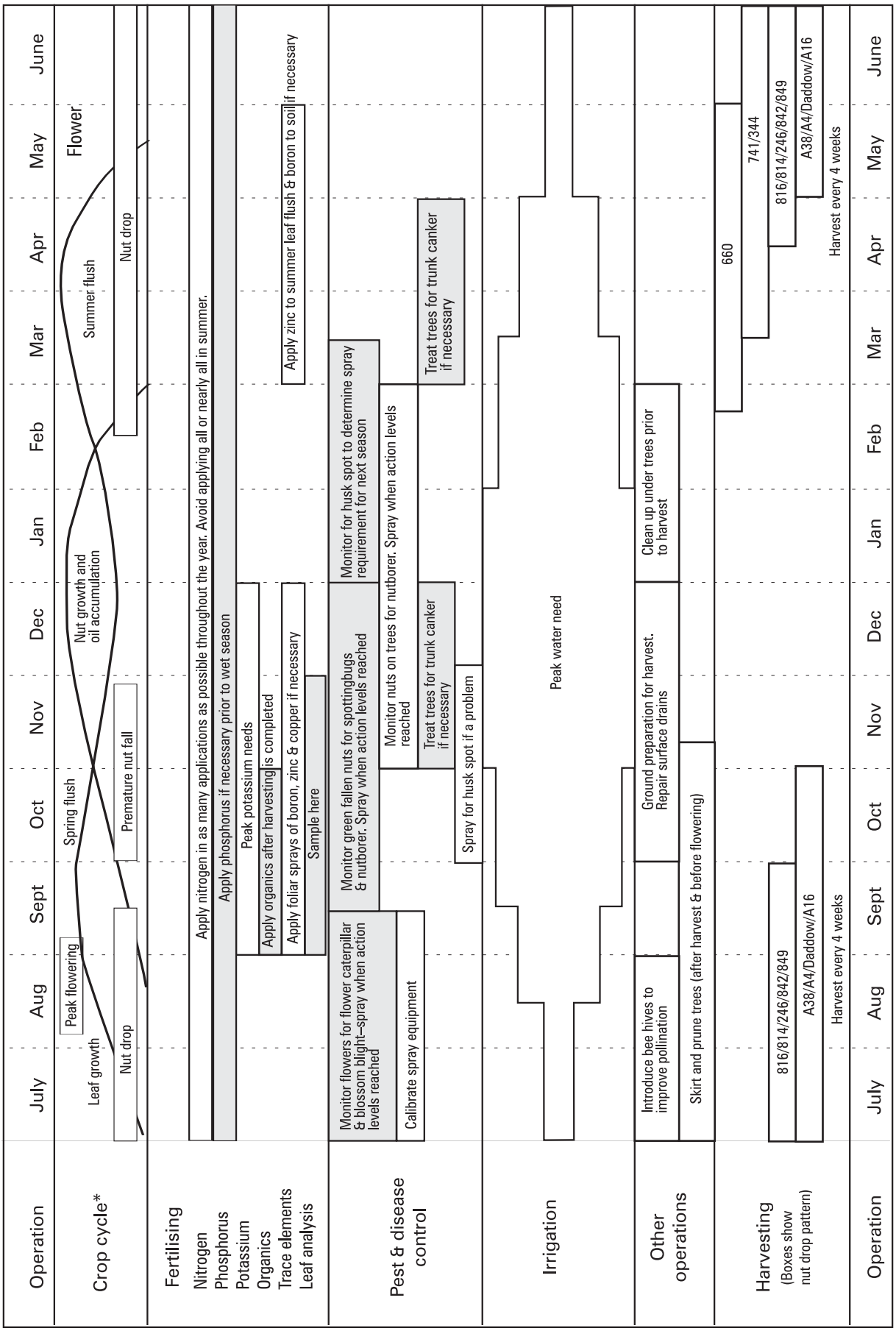


Chemical trade names and state registrations

Chemical	Chemical type	Trade name	Qld	NSW	Vic	SA	WA	NT	Tas	ACT
acephate	Group 1B Insecticide	Lancer 750 DF, Orthene Xtra	Yes	Yes	No	No	Yes	Yes	No	No
azinphos-methyl	Group 1B Insecticide	Benthion 200 Flowable, Gusathion 200 SC	Yes	Yes	No	No	Yes	No	No	No
benomyl	Group A Fungicide	APVMA permit	Yes	Yes	No	No	No	No	No	No
benomyl plus carbendazim	Group A fungicide	APVMA permit	Yes	Yes	No	No	No	No	No	No
beta-cyfluthrin	Group 3A Insecticide	Bulldock Prime, Bulldock 25 EC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Btk	Group 11C Insecticide	Delfin	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Btaz	Group 11C Insecticide	Agree, Bacchus	No	Yes	No	No	No	No	No	Yes
carbaryl	Group 1A Insecticide	Bugmaster Flowable, Carbaryl 500, Carbaryl 500 Flowable, Carbaryl WP	Yes	Yes	No	No	Yes	No	No	No
carbendazim	Group A Fungicide	APVMA permit	Yes	Yes	No	No	No	No	No	No
chlorpyrifos	Group 1B Insecticide	APVMA permit	No	Yes	No	No	No	No	No	No
coumatetralyl	coumarin	Racumin, Racumin 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
copper as ammonium acetate	Group Y fungicide	Liquicop	Yes	No	No	No	No	No	No	No
cuprous oxide	Group Y Fungicide	Flocop, Norshield, Nordox 500, Norshield 750 WP, Norshield WG	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
copper hydroxide	Group Y Fungicide	Kocide Blue, Kocide Blue Xtra, Kocide Liquid Blue, Champ Dry Prill, Copper Hydroxide 500 WP, Kocide, Flo-bordo	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
copper hydroxide plus metalaxyl-M	Group DY Fungicide	Ridomil Gold Plus	Yes	Yes	No	No	No	No	No	No
copper oxychloride	Group Y Fungicide	APVMA permit	Yes	No	No	No	No	No	No	No
copper oxychloride plus metalaxyl	Group DY Fungicide	Axiom Plus, Zee-Mil Plus	Yes	Yes	No	No	No	No	No	No
copper oxychloride	Group Y Fungicide	Brycop, Copper Oxychloride, Copper Oxychloride 50% WP, Copper Oxychloride WP, Copperoxy 500 WP, Coppox, Copper Oxychloride 500 WP, Oxydul DF	Yes	Yes	No	No	Yes	Yes	No	Yes
copper sulfate (tribasic)	Group Y Fungicide	Tri-Base Blue	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
diazinon	Group 1B Insecticide	Diazinon, Diazinon 800	Yes	Yes	No	No	Yes	No	No	No
endosulfan	Group 2A Insecticide	APVMA permit	Yes	Yes	No	No	Yes	No	No	No
ethoprophos	Group 1B Insecticide	APVMA permit	Yes	No	No	No	No	No	No	No
iprodione	Group B Fungicide	Rovral Liquid, Civet Aquaflo, Ippon 500 Aquaflo, Rovral Aquaflo Rovral 750 WG	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
metalaxyl	Group D Fungicide	Axiom 50G, Zee-Mil 50G, Ridomil 50G	Yes	Yes	No	No	No	No	No	No
metalaxyl-M	Group D Fungicide	Ridomil Gold 25G	Yes	Yes	No	No	No	No	No	No
methidathion	Group 1B Insecticide	APVMA permit	Yes	No	No	No	No	No	No	No
methidathion	Group 1B Insecticide	Supracide 400, Suprathion 400 EC	Yes	Yes	No	No	Yes	No	No	No
petroleum oil	Insecticide, Spreader	APVMA permit	Yes	No	No	No	No	No	No	No
phosphorous acid	Group Y Fungicide	APVMA permit	Yes	Yes	No	No	Yes	No	No	No
prochloraz as $MnCl_2$ complex	Group C Fungicide	APVMA permit	No	Yes	No	No	No	No	No	No
sulphur	Scabicide, macro element	APVMA permit	Yes	No	No	No	No	No	No	No
tebufenozide	Group 16A Insecticide	Mimic 700 WP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
thiram	Group Y Fungicide	APVMA permit	Yes	Yes	No	No	No	No	No	No
trichlorfon	Group 1B Insecticide	Dipterex 500 SL, Lepidex 500	Yes	Yes	No	No	No	Yes	No	No

Crop production handy guide

* Timing shown applies to southeast Queensland—some adjustment will be necessary for other production areas.



Macadamia grower's handbook

Reprint – information current in 2004

REPRINT INFORMATION – PLEASE READ!

For updated information please call 13 25 23 or visit the website www.deedi.qld.gov.au

This publication has been reprinted as a digital book without any changes to the content published in 2004. We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research:

- Chemical recommendations—check with an agronomist or Infopest www.infopest.qld.gov.au
- Financial information—costs and returns listed in this publication are out of date. Please contact an adviser or industry body to assist with identifying more current figures.
- Varieties—new varieties are likely to be available and some older varieties may no longer be recommended. Check with an agronomist, call the Business Information Centre on 13 25 23, visit our website www.deedi.qld.gov.au or contact the industry body.
- Contacts—many of the contact details may have changed and there could be several new contacts available. The industry organisation may be able to assist you to find the information or services you require.
- Organisation names—most government agencies referred to in this publication have had name changes. Contact the Business Information Centre on 13 25 23 or the industry organisation to find out the current name and contact details for these agencies.
- Additional information—many other sources of information are now available for each crop. Contact an agronomist, Business Information Centre on 13 25 23 or the industry organisation for other suggested reading.

Even with these limitations we believe this information kit provides important and valuable information for intending and existing growers.

This publication was last revised in 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

This information has been made available to assist users to identify issues involved in macadamia production. This information is not to be used or relied upon by users for any purpose which may expose the user or any other person to loss or damage. Users should conduct their own inquiries and rely on their own independent professional advice.

While every care has been taken in preparing this publication, the State of Queensland accepts no responsibility for decisions or actions taken as a result of any data, information, statement or advice, expressed or implied, contained in this publication.

Queensland Government

Chapter 7

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