

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 We advise readers to take particular note of the areas most likely to be out-of-date and so requiring further research: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- Financial information—costs and returns listed in this publication are out of date.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.

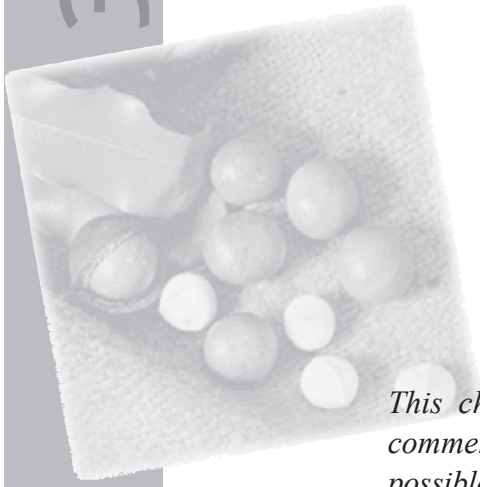
This publication was last revised in 2004. The information is not current and the accuracy of the information cannot be guaranteed by the State of Queensland.

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



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.

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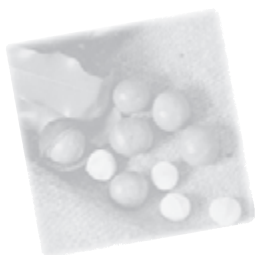
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Getting the orchard established

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).

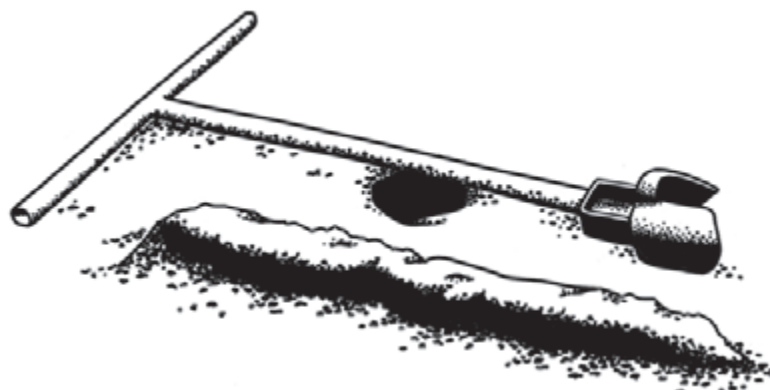


Figure 1. A soil auger suitable for soil assessment on small properties. The diagram shows how the soil from the hole is laid out in a line corresponding to the approximate soil depth

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.

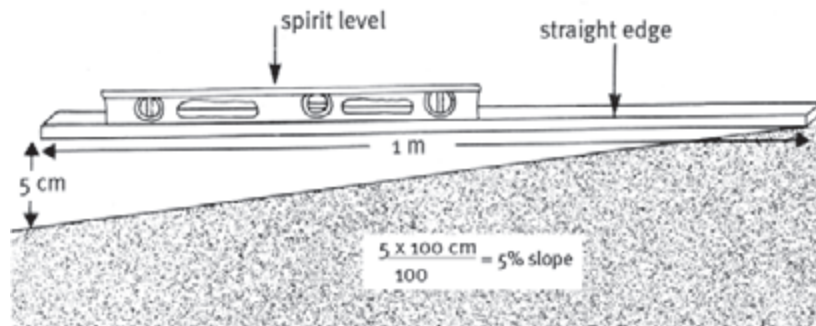


Figure 2. Measurement of slope as a percentage

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.

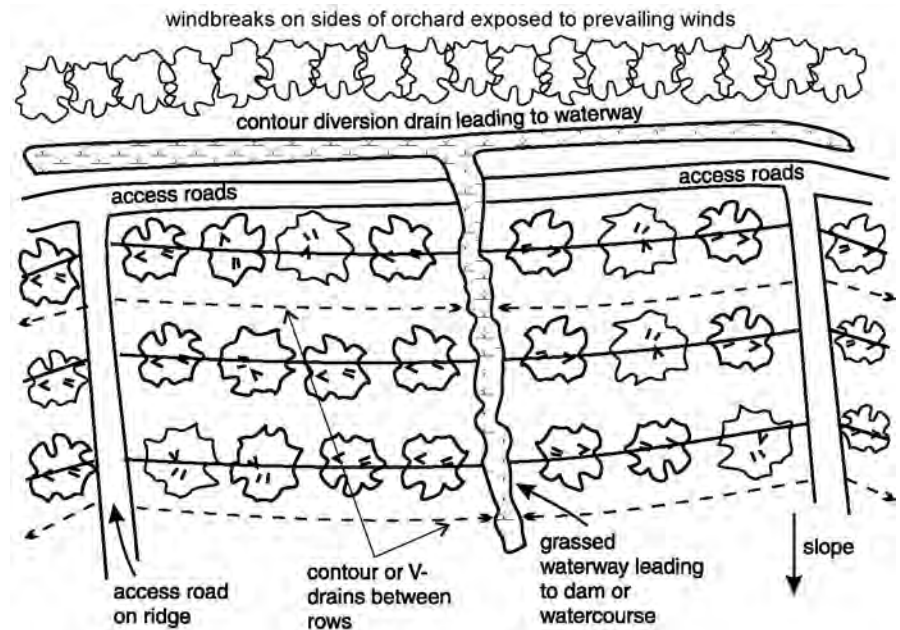
Plan the orchard layout

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.
- **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.
- **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.

NOTE

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

NOTE

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

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 propagation. 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

**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.

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

NOTE

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

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.

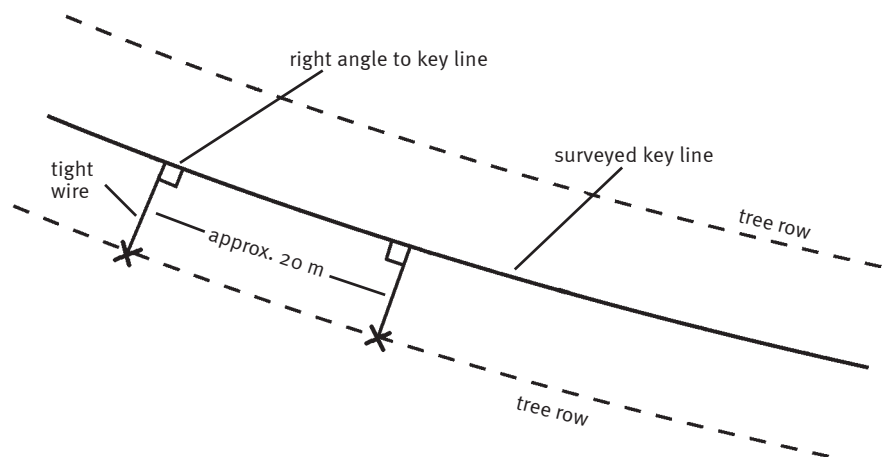


Figure 5. Marking out parallel rows across the slope

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 furthest 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).

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.

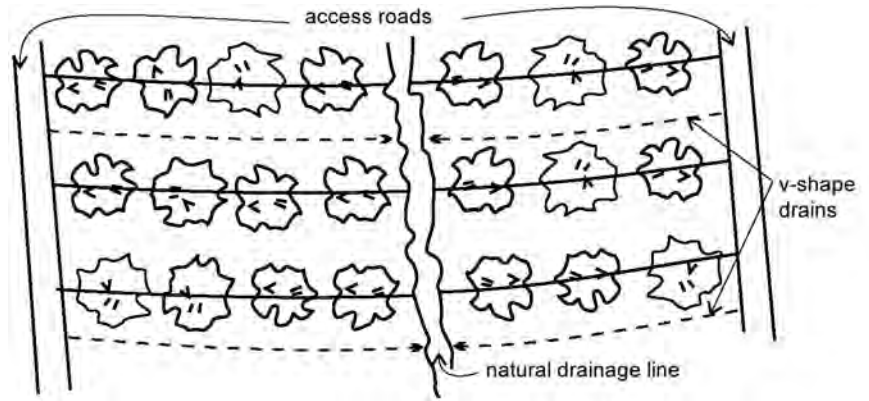


Figure 6. V-drains for across slope rows (plan view)

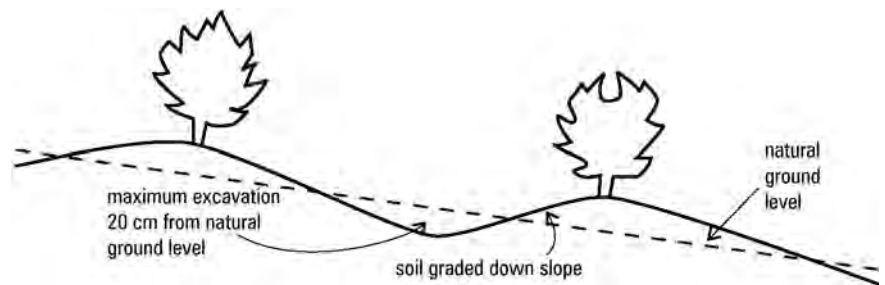


Figure 7. V-drains for across slope rows (cross-section view)

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).

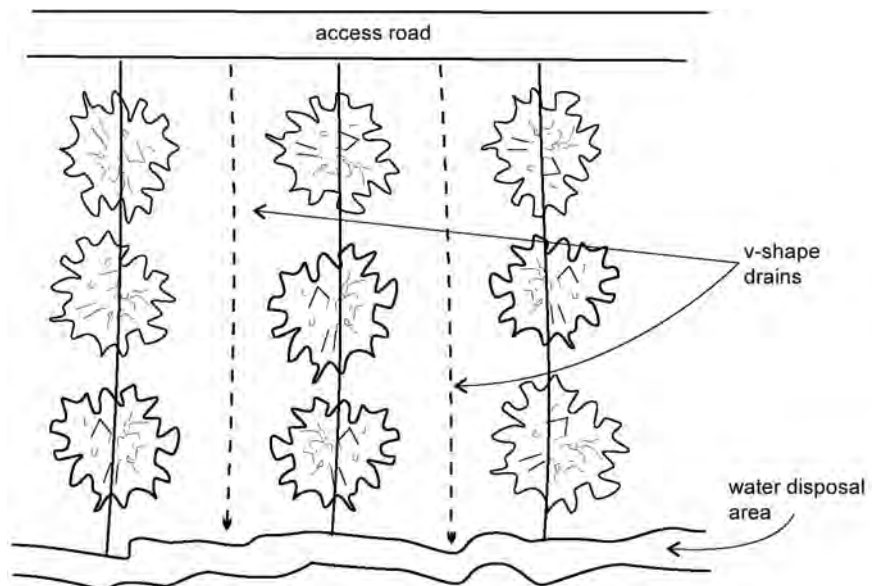


Figure 8. V-drains for down slope rows (plan view)

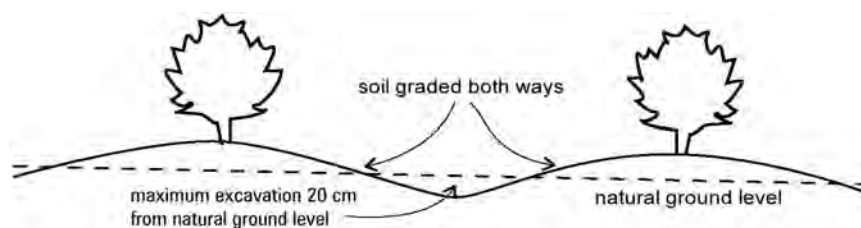


Figure 9. V-drains for down slope rows (cross-section view)

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



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.

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 interpretation 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

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.

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.

NOTE

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

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.

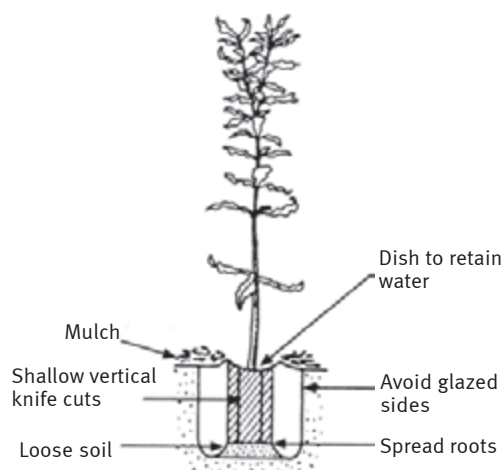
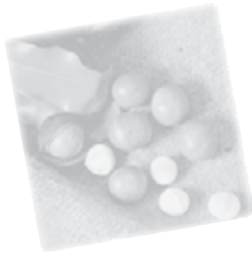


Figure 10. A correctly planted tree

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.

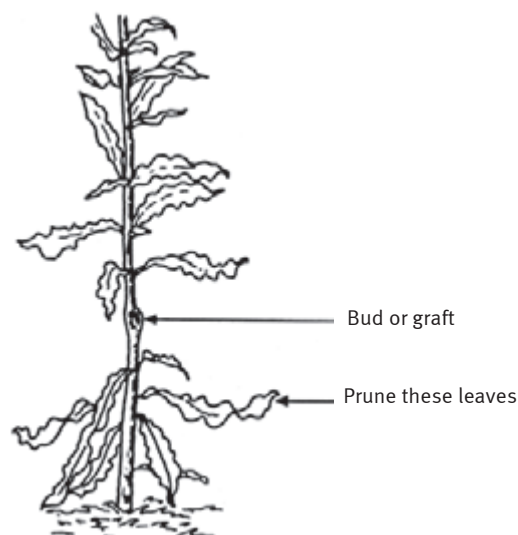


Figure 11. Remove the leaves below the graft or bud



Figure 12. Staking of a blown over tree after straightening

NOTE

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

CAUTION

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

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.

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).

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.

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.



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

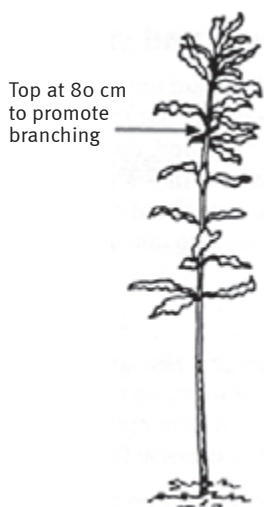


Figure 13. Pruning action where there are no lateral branches below 80 cm

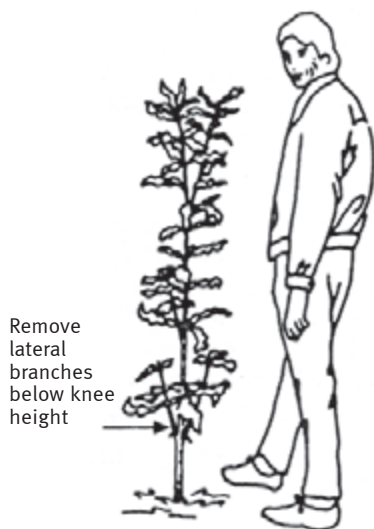


Figure 14. Pruning action where lateral branches are too close to ground level

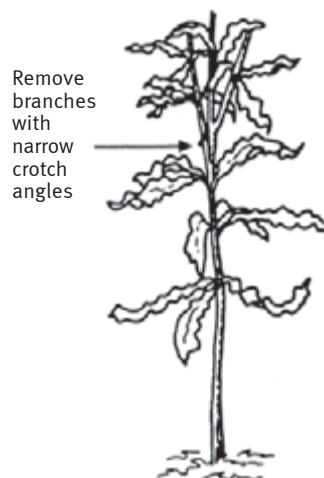


Figure 15. Pruning action where there are branches with narrow crotch angles with the bark folded into the crotch

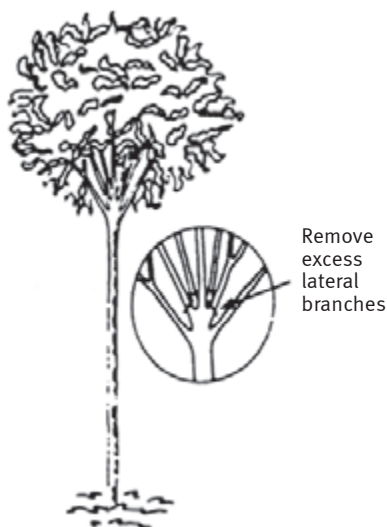


Figure 16. Pruning action where there are multiple lateral branches at a node, none of which is a dominant leader

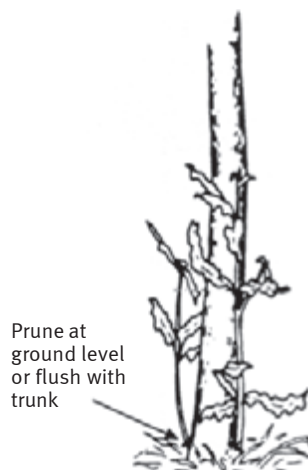
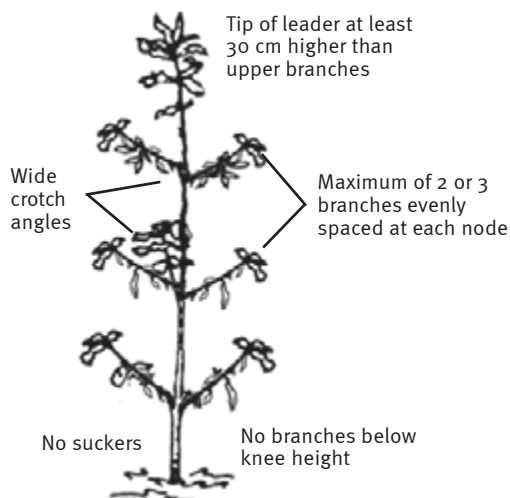


Figure 17. Pruning action where there are suckers coming from below ground level or shoots on the rootstock

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.

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.

WARNING

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

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

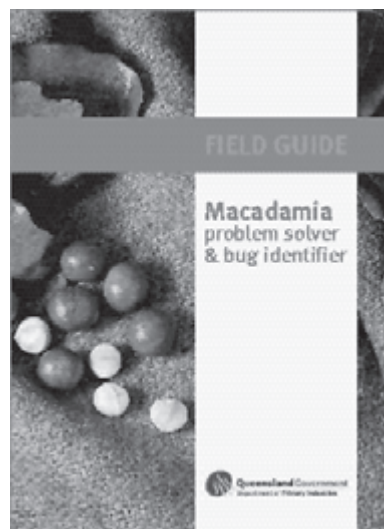
The only major disease of young trees is trunk canker.

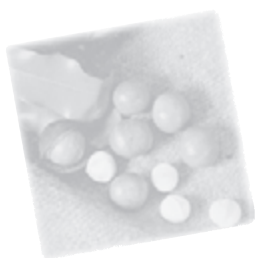
Where cankers are small, pare back affected bark and wood with a sharp knife, and thoroughly soak trunks with a registered copper fungicide mixed with white, water-based paint. This helps to maintain contact with the fungicide and seals the wound. Where cankers are more extensive, and paring back affected 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.

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;



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

- 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

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.

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.



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.

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

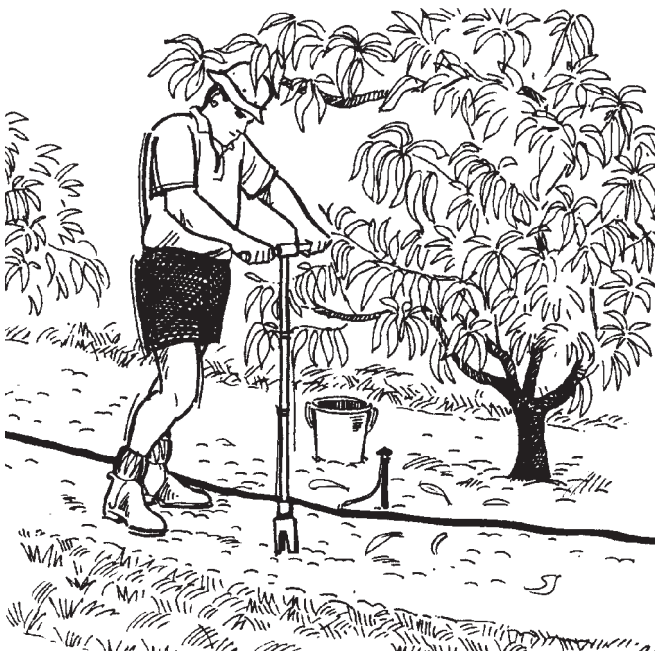


Figure 19. Soil sampling

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.

- **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.



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

Fertiliser timing

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

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.

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).

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.

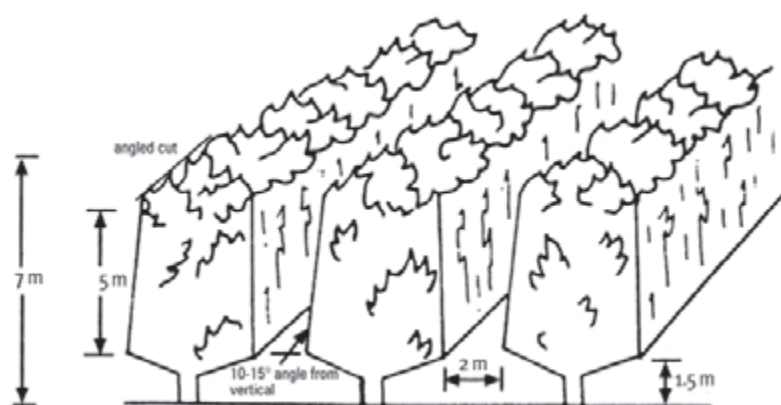
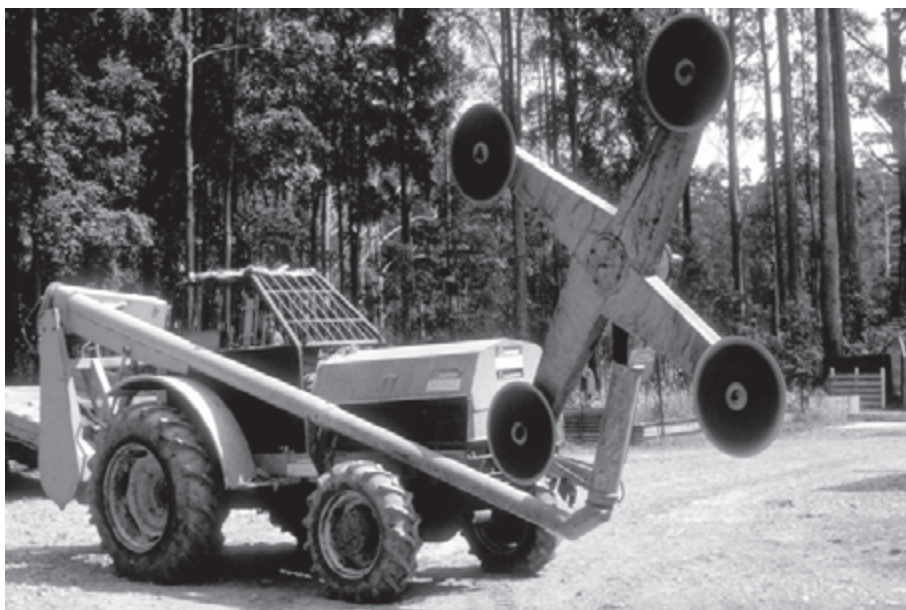


Figure 21. Suggested tree shape

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

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.

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

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.

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



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



See *Consultants and contract services* on page 187.

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

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.

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.



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

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

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.



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



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.

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

Spray application

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.

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

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



Rat damage to nuts

- 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

Racumin® 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.

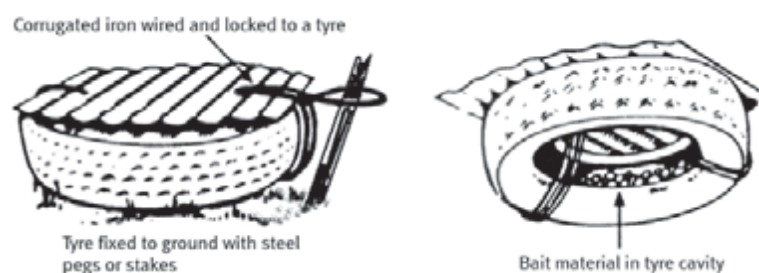


Figure 22. Car tyre bait station for rat control in macadamia orchards

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

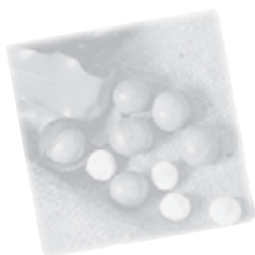
As the roots of some windbreak trees can extend for up to 50 m from the trunk, deep rip at least every second year between the perimeter windbreak trees and the macadamia trees to reduce competition for water and nutrients. Rip lines should be at least two metres from the edge of the macadamia canopy. 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, addition 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.

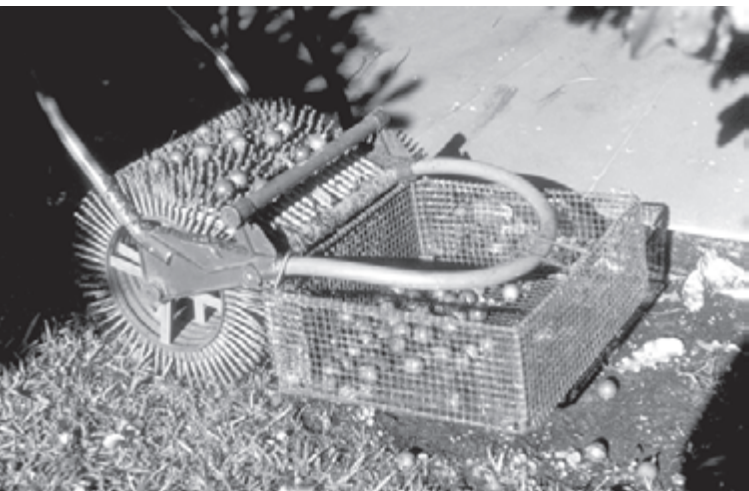
Nuts are harvested after they have fallen to the ground. Most farms use mechanical harvesters. Hand harvesting off the ground is practised on some smaller orchards and where steep slopes preclude the safe use of mechanical harvesters. It may also be necessary on occasions during extended wet weather. 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.

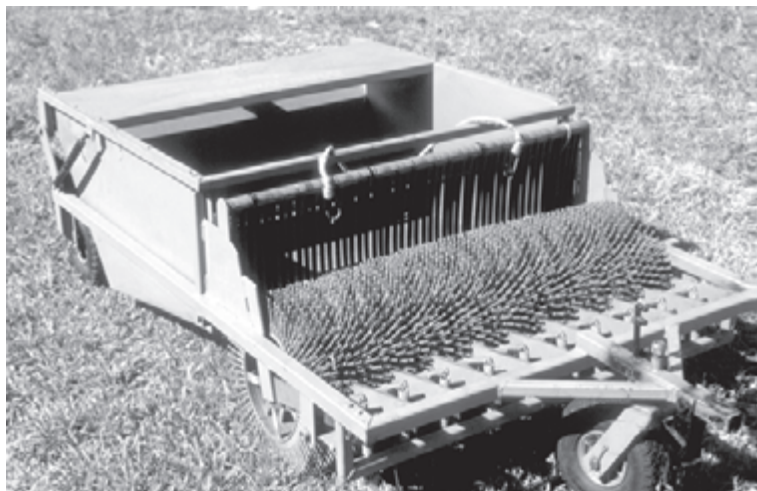
Harvest nuts at least every four weeks, particularly during extended wet weather or where nuts are exposed to direct sunlight. The less time the nuts are on the ground, the less the deterioration from mould, rancidity and early germination, and the better the kernel quality. Ensure pick-up is efficient 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.

WARNING

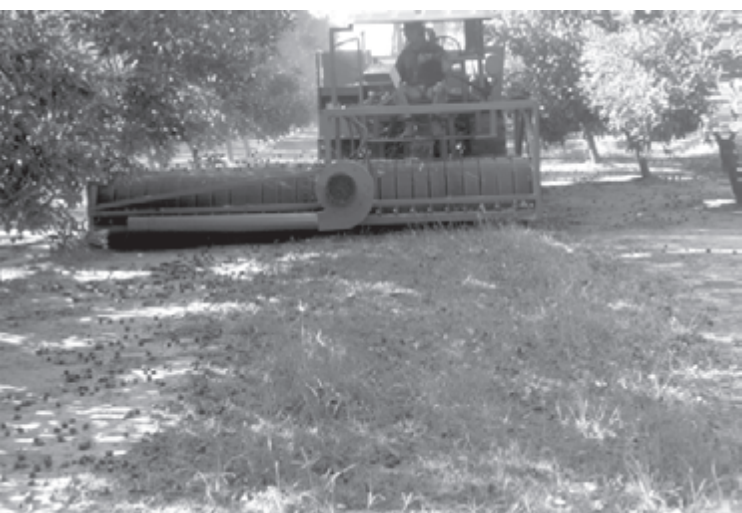
Rat baiting needs to be carefully managed to ensure that rat baits do not contaminate nuts during harvesting. Only use rat baits in approved bait stations and monitor stations regularly to ensure that the bait has not spilt onto the ground where it may be picked up by mechanical harvesters.



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 90°C 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 post-harvest 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

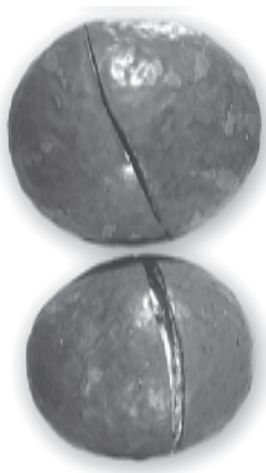
Dehusk nuts within 24 hours of harvest to prevent deterioration from sweating and overheating. This is particularly important where NIH is wet or husks are green. Remove any rocks, sticks or leaves before dehusking, either mechanically or by hand. Rocks in particular can severely damage equipment. If 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.

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



Germination crack



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

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.

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.

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 Macadamia 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.

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.

Nut-in-shell drying and storage

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 30°C (or more than 5°C 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 essential 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 sophisticated 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.

