Department of Primary Industries
Department of Regional NSW

NSW GOVERNMENT

# Macadamia grower's guide 2023

NEW ORCHARDS

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Hort Innovation
Strategic levy investment
MACADAMIA FUND

www.dpi.nsw.gov.au

ISSN 0727-6273
ISBN 0 7345 0241 9
Job no. 17050. PUB23/852.



**Funding**

This project has been funded by Hort Innovation, using the Macadamia Research and Development Levy and contributions from the Australian Government and co-investment from NSW DPI. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian horticulture.

The project *Macadamia digital grower's guide* (MC19001) is a strategic levy investment under the Hort Innovation Macadamia Fund.



**Image acknowledgements**

Large cover photo: newly planted orchard with tree guards and mounded for reducing erosion and allowing clean water diversion.

Smaller photos left to right: mounded tree rows in a flood plain orchard; trellising supports young trees at a wind-prone site; mounding to direct surface water flow along the inter-row.

Unless otherwise stated, the images in this guide have been sourced from the NSW Department of Primary Industries.

**How to cite**

Bright J and Alt S. 2023. New orchards. In: *Macadamia grower's guide.* NSW Department of Primary Industries, Orange, 50 pp.

**Thank you**

The authors would like to thank Chris Fuller, Chris Searle, Stephan Vander Walt, Daniel and Belinda Blanco, Michael McMahon, Scott Norval and Simon Andreoli for their valuable time to discuss not only the principles of orchard establishment, but also soil health and nutrition. Also thank you to members of the program reference group (Scott Allcott, Chris Searle, Chris Fuller, Tim Salmon, Graham Wessling and Chris Cook) for their guidance.

Thanks to Kevin Quinlan and Dr Amanda Warren-Smith for their help with getting this to publication, and NSW DPI, Hort Innovation, and all the macadamia growers whose levy money has made this possible.

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# Macadamia grower's guide 2023

## New orchards

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# About this guide

*Macadamia grower's guide: new orchards* looks at the processes involved in selecting the right land for macadamia production, through to planting trees. It explains the favourable site attributes, and more importantly, the unfavourable attributes and what can be severely limiting constraints. Other aspects covered include obtaining approvals (e.g. clearing and water licencing), design elements, preparing for planting, planting and early pruning. From an integrated orchard management (IOM) perspective, *Macadamia grower's guide: new orchards* looks thoroughly at stage 0 through to early stage 1.

The Macadamia Grower's Guide project (2022–24) provides up-to-date resources on best management practices for macadamia growers. Online resources allow for updates incorporating new research findings and evolving macadamia management practices.

NSW DPI maintains current information for macadamia growers. More up-to-date information could be available online at https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts

# Contents

# Overview

A successful macadamia orchard will operate for decades and could become a multi-generational project. The orchard should generate wealth and create worthwhile employment while minimising environmental effects. A promising start is when the proposed new orchard sits comfortably above a triple bottom line of net economic, social and environmental benefits.

Economic sustainability means the orchard will be financially viable in adverse conditions. Financial planning makes clear the tolerable lower end for yields and prices. Social good comes from creating jobs and careers and minimal conflict with neighbours. Environmental benefits arise from:

- preserving and building the fertility of the land
- allowing space for natural areas with native vegetation
- minimising offsite effects such as sediment or nutrient losses and chemical contamination from spray drift.

Early in the planning and developing phases, there are relatively few decisions to make, but the long-term repercussions of these decisions are very high. Cutting corners or accepting serious compromises in site selection can lead to low productivity and the need for costly, long-term fixes throughout the orchard's life. Good planning will save time and money in the long term and support productivity.

Some key actions when developing a successful new orchard include:

- selecting a favourable site
- seeking specialist advice
- being diligent in financial planning
- buying high-quality trees for planting.

The pre-plant activities of developing new orchards are Stage 0 in the macadamia integrated orchard management (IOM) framework (Table 1). In this stage, good decision-making is critical to promote the chances of achieving a high-yielding orchard. Poorer choices can bias the new orchard towards a longer lead time into peak production and possibly lower long-term yields (Figure 1).

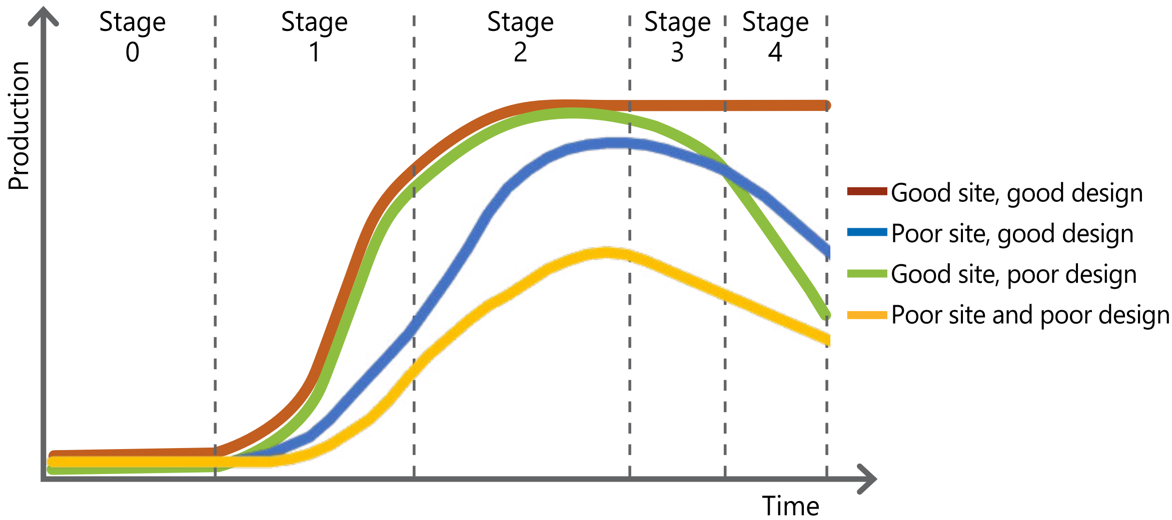



Figure 1. Orchard stages in integrated orchard management, comparing the different scenarios, where the best and most enduring results are most likely through combined effects of a good site and good design of the orchard.

Table 1. The macadamia integrated orchard management framework defines the stages of orchard development.

| Orchard stage | Orchard characteristics |
|---|---|
| Stage 0<br>Pre-plant and plant | • Drainage planning and installing drainage infrastructure and access tracks.<br>• Soil testing and applying amendments that are best incorporated.<br>• Set out tree rows.<br>• Planting trees and ground covers. |
| Stage 1<br>Early production | • Trees are getting larger.<br>• Between rows there is plenty of light to the orchard floor and living ground cover.<br>• Yields are heading towards what is expected as average yields for industry.<br>• Towards the end of Stage 1, tree canopies will be joining up within the row. |
| Stage 2<br>Peak performance | • Tree canopies are now fully joined within the row, but their height is less than or equal to the row width.<br>• Orchard floor still has living ground cover.<br>• Non-living ground covers are an increasing part of the total ground cover.<br>• Everything is 'humming along nicely'. |
| Stage 3<br>Declining production | • Yields are not as good as expected for the season.<br>• 'Red flags' are becoming apparent.<br>• Canopy is starting to join up between the rows.<br>• Trees are taller than the row width.<br>• It is difficult to spray all of the productive canopy because of the height.<br>• Exposed roots appear.<br>• Scouring from water flows is seen. |
| Stage 4<br>Poor performance | • Yield over several seasons has declined substantially compared to peak yields.<br>• Canopies might be competing strongly for available light by growing upward.<br>• There is full shade to the orchard floor.<br>• Many roots are exposed.<br>• New water courses have created gullies.<br>• All or most of the red flags are evident. |

# New orchard phases

Thorough preparation for planting takes time. Expect approximately 2–3 years of preparation activities before planting.

The activities involved with establishing a new orchard fall into 3 phases (Table 2). It is better to get through all the components of each phase before starting the next phase.

Table 2. The phases of establishing a new orchard. Source: Chris Searle, MacAvo Consulting.

| Big decisions | Preparation | Planting and establishing |
|---|---|---|
| Identify potential sites | Drainage and block design | Inspect trees before dispatch from the nursery |
| Assess sites | Select varieties and order trees | Plant trees |
| Confirm water availability, quantities and flow rates | Clear the current vegetation from the site's development zones | Install sprinklers and drippers |
| Secure access to the chosen site | Site levelling | Fertilise inter-rows and drainage lines |
| Soil survey | Soil amendments and preparation | Monitor tree health |
| Obtain or initiate regulatory approvals | Mounding and drainage infrastructure (surface and sub-surface) | Troubleshoot watering:<br>• Are all trees receiving enough water?<br>• Find solutions for excessively wet areas. |
| Secure a processor to market the future product | Apply top-dressed nutrients to mounds | Replace dead trees |
| Consider dehusking and storage options | Spread seed for ground covers | Manage pests and diseases |
| Order equipment with substantial lead times, e.g. custom spray equipment | Check with the nursery regularly | Fertilise trees after the first flush hardens |
| Communicate with neighbours regarding plans for the orchard. Identify sensitive boundaries and plant non-pest host-specific, bushy, native buffer trees on those boundaries. | Get organised for planting:<br>• book the truck for tree delivery<br>• plan the drop locations<br>• confirm the planter machine<br>• organise planting equipment and labour<br>• plan how to water trees manually if there is no irrigation | Early pruning |
| Identify and book contract services:<br>• irrigation design and installation<br>• land preparation<br>• tree planter | Prepare equipment for weed and pest management | Mowing and mulching |

# Assess sites

Favourable site attributes make developing a new orchard and its ongoing management easier. Unfavourable site attributes are challenges likely to make the orchard more expensive to establish and operate. Accepting severely limiting site constraints might reduce potential yields and increase the time to reach peak production.

## Favourable site attributes

### Water

The capacity to water trees helps establish young trees in dry seasons. Without irrigation, the climate must supply all water needs via rainfall and soil storage. Irrigation can be essential for productive yields in challenging climates or suboptimal soils. Areas with average annual rainfall less than 1,200 mm will need supplementary irrigation. Possible water sources for irrigation include dams, groundwater, river pumping and irrigation schemes.

Some regulations limit the volumes of water stored on farms and used for irrigation. Currently, most orchards in central and south-east Queensland use irrigation. NSW growers are generally more limited in their access to water for irrigation and rely more on strategies such as increasing organic matter to boost soil water-holding capacity.

A review of the water resources for a potential orchard site should cover the:

- physical availability of water, e.g. quantities and flow rates
- water requirements of the orchard, which are affected by:
  - average rainfall
  - row spacing
  - irrigation type
  - soil properties
  - rainfall
- irrigation water quality
- licencing requirements
- costs to use water for irrigation.

### Deep, well-drained soils

Macadamias need a minimum depth of 0.5 m, preferably 1 m or more, of free-draining soil. Favourable sites have soils without hardpans – impermeable clay or rock layers or poor drainage that leaves them too wet for too long.

The more free-draining soil there is above the water table, the better. In less favourable sites, mounding, surface and sub-surface drains can sometimes achieve the minimum depth of free-draining soil but will add to establishment and maintenance costs.

Obtain a soil map of the broader area and consider investing in a soil survey to map the orchard site. Soil surveys can:

- identify the extent of potential problems such as pH, fertility, salinity, acid sulfate soils, shallow topsoil, soil type changes and poor drainage
- indicate the most favourable areas of the site
- target where remedial soil practices are needed.

A detailed soil map produced from the soil survey will be valuable when designing blocks, matching irrigation systems to the soil type, depth and water infiltration rates across the site and tailoring management throughout the orchard's productive life.

Soil surveys usually involve digging soil pits or taking cores in a grid pattern at 50–100 m spacings across the area. The spacing is closer if the site has varied topography or soils, and further apart when the site is more uniform. Soil core sampling at medium to high densities is especially helpful in guiding variable rates of soil amendments. Soil pits reveal more about soil structure and sub-surface drainage. A desktop survey often precedes fieldwork. Do not rely solely on aerial or drone images to map soils.

A soil survey is essential to ensure there is enough suitable soil for:

- mounding tree rows
- correctly grading the slopes of the tree row and inter-row areas.

Mounding is only practical when there is enough suitable soil. Do not include heavy clay, hardpan or dispersive soils in tree mounds or expose these soils in the inter-row. Doing so will inhibit tree and ground cover growth and create inter-rows prone to erosion.

Mounding takes soil from the inter-row areas to form continuous ridges for the tree rows. The mounded soil increases the usable soil volume available for tree roots on sites where the depth of free-draining soil is inadequate.

Mounding also directs surface water along the inter-row to stable watercourses (Figure 2) to prevent surface water from eroding channels within the tree blocks. Mounding to direct surface water is standard on all soils, not just those with drainage problems.

Figure 2. Mounding to direct surface water flow along the inter-row.

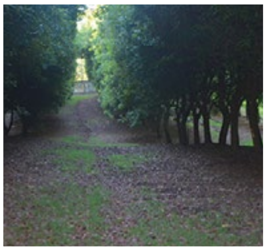
Central Queensland flood plains have similar issues to NSW coastal flood plains regarding soils and management strategies. Some soils in the Bundaberg region have low fertility and might need more soil amendments initially. Soil tests will best predict the amendments and rates required.

## Gentle slope

Slope describes the steepness of the land. Everything to do with managing an orchard is easier on gentle slopes (Table 3). Measurements of a slope are expressed in 3 ways:

1. Angle – the internal angle (in degrees) at the lower corner of a triangle formed by the base of the slope and the horizontal run.

Table 3. Slope-specific management guidelines.

| **Slope range** | Flat to gentle | Moderate | Steep | Too steep |
|---|---|---|---|---|
| |  |  |  |  |
| | A flat to gentle slope. | A moderate slope. | A steep slope. | A too steep slope. |
| Suitability | Preferred. | Workable with higher management costs. | Do not plant on these slopes. If already planted, manage the canopy to promote living ground cover. | Do not plant. Consider decommissioning blocks on these slopes. |
| Slope as percentage | 0–12% | 13–21% | 22–30% | >31% |
| Slope as ratio | 0:10 to 1:8 | 1:9 to 1:4.5 | 1:5 to 1:3 | >1:3 |
| Slope in degrees | 0–7.5° | 7.6–12.5° | 12.6–17.5° | >17.5° |
| Minimum ground cover (living and non-living) | 80% | 90% | 95% | Not suitable for macadamias. |
| Maximum proportion as non-living ground cover | 100% | 40% | 5% | |
| |  |  |  | |
| | Mulch cover >80%. | Mixed living and non-living ground cover >90%. | Living ground cover >95%. | |
| Orchard floor priority | Building soil organic matter. | Dense living ground cover in the inter-rows. | Living ground cover up to the tree trunks. | |

2. Ratio – the rise relative to the run (Figure 3), expressed as 1 in 10 or 1:10.
3. Grade – the ratio expressed as a percentage, e.g. a slope with a rise of 1 m over a 10 m run is a 10% slope.

Slopes with a 0.5–8.0% grade are preferred, and 8.1–15.0% are acceptable. Slopes of less than 0.5% are challenging to manage.

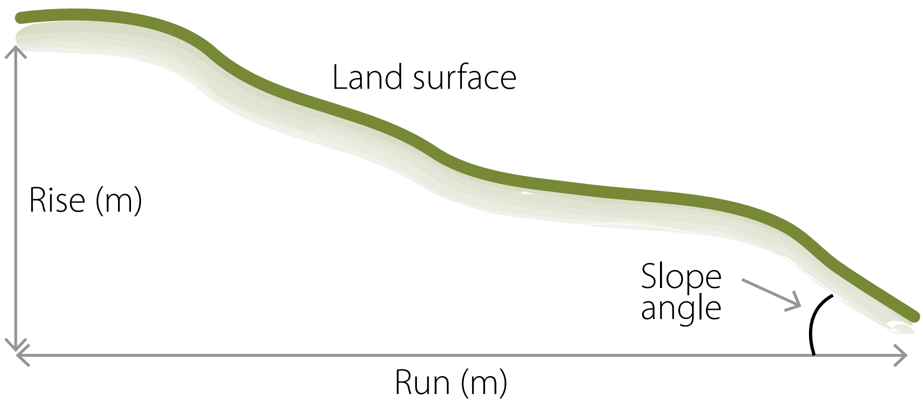



Figure 3. Slope is the relationship between the rise (elevation) and run (horizontal distance).

Soil erosion risk increases on steeper slopes and more living ground cover is needed. Consider the ongoing pruning costs and other activities to maintain the ground cover percentages required for slope-specific management. For more information, refer to *Macadamia integrated orchard management drainage* (2022).

### North or north-easterly aspect

Aspect is most important on sloping land. It is the orientation of terrain to a compass direction. North or north-easterly aspects are best in Australia because they provide more sunlight during winter. Favourable sites allow most tree rows to run approximately north-south. Southerly slopes are less promising because they tend to be shaded and cold in winter. Westerly slopes suffer more from heat stress in summer.

## Unfavourable site attributes

### Proximity to neighbours

Orchard operations can affect neighbours with noise, odour, spray drift and run-off. Think realistically about the possibility of future conflict with neighbours. Neighbouring dwellings can influence where to build sheds and other infrastructure.

Having close residential neighbours can restrict the timing of many standard orchard practices. If neighbours are on all sides of the orchard, the grower might have to split spray applications to prevent spray drift on downwind neighbours. For example, on a day with a westerly wind, spraying might only be possible on the west side of the orchard, and the eastern side must be left unsprayed to prevent spray drift.

Some potentially productive land might need to be set aside for buffer zones. Consider establishing non-pest host native vegetation in the buffer zones to reduce spray drift and noise (Figure 4). Check with the local, state and, in some cases, federal authorities for specific requirements.

| Challenge | Severely limiting site constraint |
| --- | --- |
| Spray application relies on wind direction being away from neighbouring residences. | Neighbouring residences to all sides. Spraying the whole orchard is not practical in any wind conditions. The number of splits required to spray applications can make timely coverage and efficacy of pest treatments challenging. |

Figure 4. This vegetation buffer is native trees, hedged to maintain orchard access and promote dense foliage. A buffer of trees can reduce the effects of spray drift, noise and dust on a neighbouring property.

## Steepness

Slopes over 22% are not suitable for new plantings. Slopes over 15% are undesirable because they increase risks for machinery and operators. For safety, rows must run up and down, not across.

Slopes over 15% will have higher operating costs over time. Although some orchards operate on steep slopes, they are challenging and expensive. Higher costs arise from:

- constructing and maintaining more drainage infrastructure
- frequent pruning to maintain light for living ground cover
- losses of nuts, nutrients and soil in heavy rain
- potential root exposure
- repairs for machinery traversing steep slopes
- impaired access and harvest efficiency in wet conditions.

| Challenge | Severely limiting site constraint |
|---|---|
| Orchard blocks on steep slopes >15%. | Harvesting and general orchard operations are restricted, becoming unsafe with wet surfaces, and frequent pruning is needed to maintain enough living ground cover. |

## Stoniness

Check the soil for stones of a similar size to macadamias. These stones will cause recurring, expensive damage to harvesting and dehusking equipment. Clearing larger rocks will add to establishment costs. Rocks below the surface ('submarines') can emerge later. Large amounts of rock can mean there is less useable soil. Orchard design must work around substantial rock outcrops.

| Challenge | Severely limiting site constraint |
|---|---|
| Efficient harvesting to keep operating costs down. | Issues from stones and rock regularly interrupt harvest operations (Figure 5), compromise nut quality and cause expensive damage to equipment. |

Figure 5. This stony orchard in Hawaii relies entirely on harvesting by hand.

## Rock or clay layers in the soil

Shallow topsoils and soil layers that impede root growth are unfavourable. Impermeable soils restrict root growth, while hard and compacted layers and rocks reduce the soil volume available to the tree.

Any soil layers that do not absorb water within one hour are too impermeable for macadamia. Test the infiltration of hard layers by drilling to the top of the obstruction, pouring 5 litres of water into the hole and recording how long the water takes to drain. The soil must already be moist to perform this test (to reduce sideways water absorption from the hole). If the initial hole is dry, fill it with water and wait for it to drain completely before undertaking the test.

Hardpan layers are typically hard to drill through and easily identified during soil coring. Finding these layers within 0.5 m of the surface is a severe constraint to tree growth and makes it likely that mounding is needed. Impermeable soil within 0.35 m of the surface makes it impossible to construct adequate tree mounds without increasing row width to gather enough topsoil or importing soil.

Rock layers that do not impede drainage might also cause problems. Trees might grow well for the first few years but suffer in dry years (Figure 6). The trees can develop phytophthora disease, have more issues with bark pests and can die. Bark pests target plants with reduced sap flow, such as trees unable to access enough water.

Figure 6. An underlying rock shelf is beneath this now-dead tree at Canaiba, NSW.

| Challenge | Severely limiting site constraint |
| --- | --- |
| Quickly draining water away is critical for macadamia on flood plains. Tree row mounds should be 600 mm high after settling (Figure 7) to give the tree root system enough well-drained soil. | There is not enough suitable soil to form tree row mounds. Within a few years of planting, trees are growing slowly with poor root systems, phytophthora disease appears, and trees blow over in storms. |

Figure 7. The forest clearing in the background was done to square up the macadamia block.

## Trees and forest

Avoid clearing forests to establish a macadamia orchard. Ideally, a new orchard changes the site from another agricultural land use. The presence of forest or many trees on the site increases the cost of site preparation and the regulatory requirements to develop the site (see Land clearing).

Clearing woody vegetation can be expensive, adding $10,000–$20,000/ha to development costs, mostly in additional labour for root and stick picking. Ideally, restrict clearing trees to squaring up orchard blocks or straightening drain lines.

Established vegetation can save on planting costs in buffer zones. Plan to manage timbered areas by allowing space for mowed areas around the vegetation for fire breaks and to deter rats.

| Challenge | Severely limiting site constraint |
| --- | --- |
| Prepare the site for planting without overspending. | Heavily timbered areas are costly to prepare, and land clearing is subject to regulation. |

## Too small

Ensure there is enough room on the site. Be realistic about setting aside enough land for all the other functions that require space such as waterways, drains, water storage, access roads, sheds, nut processing and storage, buffer zones, exclusion fencing (e.g. pig fencing) and environmental protection areas.

Can the site support sufficient production area to make the operation profitable at regional average yields (Figure 8)? The *Macadamia industry benchmarking report 2009–2021* contains financial models relating to orchard establishment and viability under numerous nut-in-shell (NIS) prices. From the benchmark project, there are only reliable data for the 4 largest growing regions. For others, such as Margaret River (WA), Atherton Tablelands, Mackay, Emerald, Maryborough (Qld) and Clarence (NSW), growers should seek advice from local industry representatives.

| Average farm size (ha) | Average tree age (years) | Average cost/ha | NIS t/ha | SK t/ha | %SKR |
|---|---|---|---|---|---|
| Central Queensland | | | | | |
| 86.07 | 15 | 10,039 | 3.14 | 1.02 | 34.96 |
| South-eastern Queensland | | | | | |
| 28.87 | 26 | 10,404 | 2.85 | 0.89 | 33.28 |
| Northern Rivers NSW | | | | | |
| 24.27 | 26 | 8,130 | 2.57 | 0.80 | 33.42 |
| Mid-north Coast NSW | | | | | |
| 19.15 | 22 | 8,895 | 2.32 | 0.82 | 38.02 |

Figure 8. Regional average yields per hectare and cost of production per tonne nut-in-shell. NIS/ha is nut in shell at 10% moisture content per hectare. SK/ha is sound kernel/hectare. %SKR is per cent sound kernel recovery. Data: Mulo and Bignell (2022).

| Challenge | Severely limiting site constraint |
|---|---|
| Predicted operating costs must be below predicted revenue at realistic prices and regional average yields. | The orchard can only be profitable if it produces consistent top-of-industry yields during pricing fluctuations. |

## Acid sulfate soils

Acid sulfate soils (ASS) are former wetland sediments that can produce sulfuric acid when exposed to air. They occur on coastal flood plains. These soils might be already acidic or could become so if disturbed. Seek specialist advice if the site appears on acid sulfate soils risk maps or if the soil survey discovers acid sulfate soils. Refer to NSW DPI Primefact *Considerations for developing and managing macadamia on flood plain soils*.

| Challenge | Severely limiting site constraint |
|---|---|
| Providing adequate mounding and drainage for the tree rows. | Acid sulfate soils at shallow depths can limit the drainage system, plantable area and block design. Acid sulfate soils can not be included in tree mounds or areas with subsurface or surface drains. |

## Frost risk

Macadamia does not do well in frost (Figure 9 and Figure 10). Young macadamia trees die in heavy frosts. Select land that is, or will be, free of frost risks. In a frost zone, do not plant at the bottom of slopes where frost will accumulate. Allow space for drainage of cold air below the trees. Some farms use frost fans to push the cold air further down the valley.

| Challenge | Severely limiting site constraint |
|---|---|
| Severe or frequent frosts can kill young trees. | Heavy frosts are likely in an average year. |

Figure 9. A frost-affected macadamia orchard. Photo: Chris Cook, Dymocks Arapala Macadamia Farms.

Figure 10. A frost-affected macadamia tree. Photo: Chris Cook, Dymocks Arapala Macadamia Farms.

## Flooding

Check the frequency and extent of historical flooding through the proposed planting site. Refer to the NSW DPI Primefact *Considerations for developing and managing macadamia on flood plain soils* for help ensuring a new orchard site is on less vulnerable land.

If possible, get access to flood levels for your region. Flood reference material for river heights and historic rainfall can be obtained from the Bureau of Meteorology.

| Challenge | Severely limiting site constraint |
|---|---|
| Severe or frequent flooding can kill young trees. | Frequency and depth of water are at a level that make it difficult to conduct farming practices. |

## Nut processing availability

Securing a processing pathway is vital. Contact potential processors and investigate the options for processing nuts before planting the orchard. Do not assume processing capacity will be available on short notice. Factor in additional transport costs if using a processor a long distance from the orchard. Consider if any processing components, such as dehusking, will be done on-farm.

Figure 11. A system for storing nut-in-shell on-farm might be essential as volumes increase.

# Approvals

## Land clearing

Farmers can receive fines for improper land clearing. Check with regional authorities and local and state governments on compliance requirements. Obtain any necessary permits before starting work.

## Waterways

Any works on a third order stream (Figure 12) require a permit. Third-order streams and above are recognised as likely to contain valuable fish habitat. On flood plains, seek advice before working on any permanent or temporary watercourse.

## NSW flood plains

Seek approval from the local council before preparing land on NSW flood plains. A development application might be required, particularly when working in acid sulfate soil environments, alongside natural watercourses or near existing drainage networks. Refer to the NSW DPI Primefact *Considerations for developing and managing macadamia on flood plain soils*.

## Water licences

Check whether the site is eligible for a water licence for irrigation through the relevant state government departments:

- for Queensland, start here https://www.business.qld.gov.au/industries/mining-energy-water/water/authorisations/licences
- for NSW, start here https://www.environment.nsw.gov.au/questions/irrigation-licence

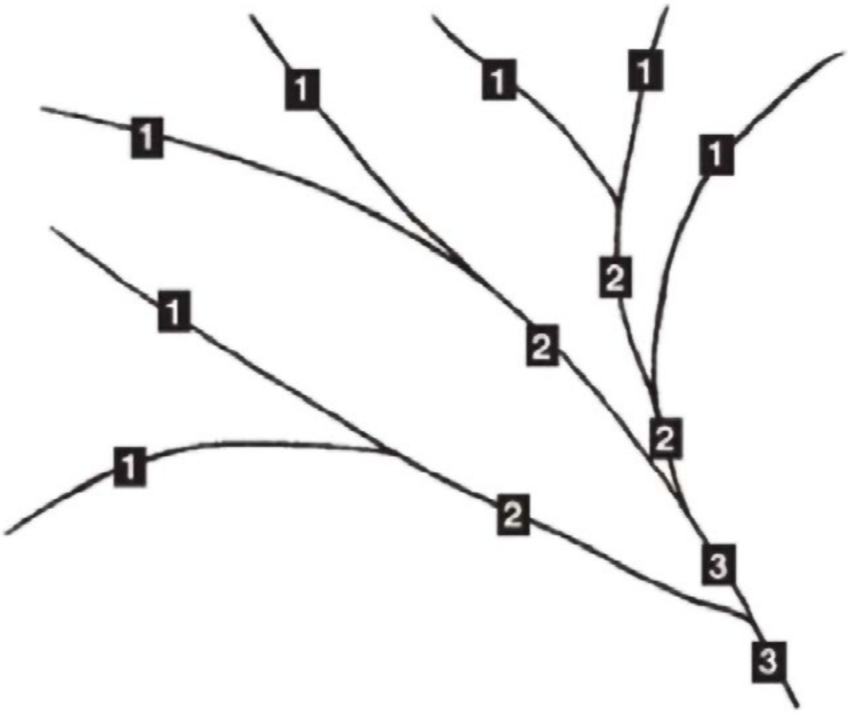



Figure 12. Stream order increases from the top to the bottom of a catchment. A first order stream has no concentrated flows of water entering it. When 2 first order streams meet, they become a second order stream downstream of the confluence. When 2 second order streams meet, they become a third order stream downstream of that confluence, and so on.

# Design elements

Good orchard design achieves maximum productivity with minimal environmental effects. The challenge is to balance operational needs with the constraints of the landscape (Table 4). Landscape constraints might mean compromises with operational efficiencies need to be made. Identifying these landscape constraints will assist with evaluating the block's suitability for macadamia production.

Table 4. An ideal orchard would have all operational efficiencies in place. The degree and amount of landscape constraint affect the suitability of the land for macadamia production.

| Operational efficiencies | Landscape constraints |
|---|---|
| Grassed watercourses | Drainage lines |
| Buffer zones | Acid sulfate soil |
| Diversion banks | Run-on stormwater |
| Water access | Dam placement options |
| Manageable blocks | Slope steepness and length |
| Building facilities, sheds | Management of increased run-off |
| Vehicle access | Wet areas |
| Minimal loss of soil, nut and nutrient inputs | Safe discharge of clean stormwater |

Using LiDAR mapping and modelling for potential soil erosion at different stages of orchard development are powerful tools for evaluating design options before site preparation begins. For most growers, this will not be a DIY activity.

Preserve strategic belts of existing vegetation for wind protection and buffer zones for neighbours. Start clearing woody plants from orchard block areas at least 12 months before planting.

## Watercourses and dams

Disturb gullies, creeks and depressions as little as possible. To keep them stable, leave a buffer of trees along gullies and creek banks. Do not plant orchard trees in drainage lines (Figure 13). Erosion is likely to occur under the trees, exposing roots and reducing yields. Growers may later remove the trees to allow enough space and light for a grassed watercourse. Seek professional advice on dam siting and construction.

## Drainage

Drainage refers to water movement across the surface and within the soil. Good management of drainage is essential for a healthy orchard system. Drainage and block design are interdependent. Building up orchard resources and soil health with active soil erosion is impossible. **Focus on getting the drainage right throughout the orchard before planting**.

Critical aspects of managing drainage are:

1. Controlling run-on water flowing into orchard blocks.
2. Safely conveying concentrated flows along stable watercourses.
3. Site-specific (within the block) ground cover management.

Most drainage problems affecting orchards are not apparent until trees mature. The orchard design must predict drainage problems and prevent them from occurring. It is easier and cheaper to construct adequate drainage infrastructure before mounding. Get ground cover established as soon as possible after each disturbance. Preventing soil erosion is better for the orchard than attempting to repair it later.

Uncontrolled water run-off and consequent soil erosion are the leading processes in orchard decline (Figure 14). They remove valuable nutrients, nuts, and topsoil, exposing roots to desiccation and machinery damage. The most common problems arise through inadequate ground cover and the trees not being set back far enough from drainage lines and fences.

Figure 13. Planting trees in natural drainage lines can create problems as the orchard matures.

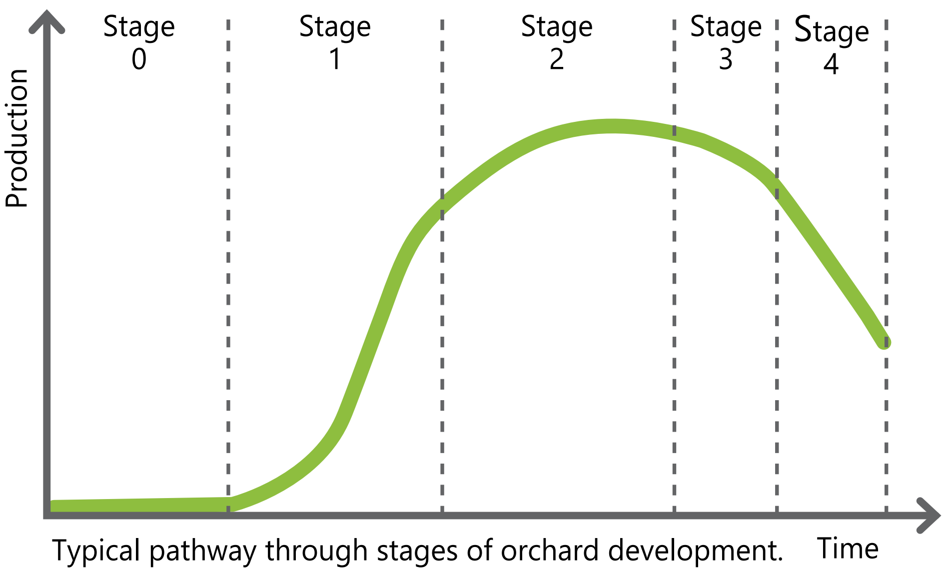



Figure 14. Uncontrolled water run-off and consequent soil erosion are the leading processes in orchard decline.

Exposed roots are the number one integrated orchard management 'red flag' for tree decline, phytophthora disease and decreased productivity. Trees with exposed structural roots are likely to have few feeder roots and be susceptible to ponding within the orchard, exacerbating waterlogging and trunk canker problems.

Poorly drained soils can impair tree growth and productivity. A soil survey will identify most soils with impaired sub-surface drainage. Other poorly drained subsoil areas might only become apparent after prolonged wet conditions. Avoid planting in poorly drained areas unless attempting to remediate them with sub-surface soil drains. Seek specialist advice on the layout, depth and spacing of sub-surface drains. Plan for the ongoing maintenance of sub-surface drainage systems by installing frequent risers for cleaning equipment to access all the drains.

A long-term productive orchard needs to continually build the soil by adding nutrients and organic matter to the existing soil material. Building the soil can only occur where soil loss processes are minimised by:

- protecting blocks from run-on water by diversion banks at the top of blocks (and within blocks where the slope runs are long)
- maintaining stable grassed watercourses through the orchard
- mounding and grassed inter-rows
- meeting the ground cover requirements for slope-specific management
- mitigating poorly drained soils.

The *Macadamia integrated orchard management drainage* guide (2022) details how to achieve a good drainage network. Use LiDAR and soil maps to identify potential problem surface flow areas and design drainage features to manage these or avoid planting there. Most watercourses and diversion drains require a minimum 15 m gap between macadamia trees to remain grassed and stable. What might look like a lot of space when establishing drain width, will appear small when the trees are mature. Grassed access ways filter run-off, trapping some soil and nutrients that could otherwise become pollutants downstream.

# Block design

The early design process will establish areas to set aside for major drainage lines, buildings, dams, and access roads. Allow enough space for turning at headlands. Usually, 14–16 m is adequate, with more needed where the rows meet the headlands on an angle. This process might constrain the location and sizes of the tree blocks.

## Row direction

Row direction needs to suit the slope. For safe machinery operation, rows on slopes should run up and down the slope. On moderate to steep slopes of 13–22%, rows must run up and down the slope to allow safe machinery use.

Run tree rows in a north-south direction where possible. This orientation maximises sunlight interception on both sides of the tree rows, particularly during winter, while the tree height is 80% or less of the row width. If trees grow taller than the row width, the top of the canopy will intercept almost all the sunlight. Then, tree row orientation becomes irrelevant to productivity as the previous east–west productive canopy up the sides of the tree have now been lost or positioned higher up the tree where spray machinery might not reach. Also, living ground cover that protects the soil will diminish, and processes that lead to orchard decline (Table 1) increase.

Sometimes, a north-south orientation is incompatible with the orchard's drainage network. It is more important to have an optimal drainage system than to preserve the north-south orientation.

Protect tree rows from run-on with diversion drains at the top of each block. Well-designed surface drainage features can integrate with access tracks and provide a minimum of 10 m access at the end of rows needed to turn machinery. The design needs of an irrigation system also influence row direction. Seek specialist assistance to integrate block design with irrigation design.

## Row lengths

Long rows up to 800 m long, or the distance required to typically fill up the harvester bin, are more efficient for machinery. Longer than this, the size of harvester bins becomes the limit, and harvesting requires extra machinery passes. The volume and speed of run-off water increase as it moves down long slopes, contributing to soil erosion. This can limit the safe length of rows for long-term soil stability. Breaking up long slope runs with diversion drains prevents soil erosion in the lower areas. Access tracks often run above the diversion drains.

## Mounding

There are 2 main reasons to construct mounded tree rows:

1. to form inter-row drains, typically 200–300 mm high, with easy-to-maintain, mowable and harvestable profiles
2. to achieve a minimum depth of 600 mm of friable soil for trees to grow.

Align cross-slope tree mounds with other drainage features to safely convey the water they collect (Figure 15). Ensure the mounded tree rows do not allow water to pond by creating slope along the rows. In this layout, the mounded rows will make each inter-row function as a small diversion drain.

Figure 15. Cross-slope tree mounds run water from each row to a grassed watercourse. These mounds are approximately 200 mm high.

### *Inter-row drains*

Ensure the slope from the base of the inter-row drain to the top of the tree row is less than 14% or harvesting becomes difficult.

An 8 m row spacing with a 600 mm mound equates to a 15% slope (Figure 16), which creates difficulties at harvest. Nuts accumulate in the drain line and are not all picked up by harvesters.

A 9 m row spacing with a 600 mm mound has a slope of 13.33% (Figure 17), which is much easier to manage. Higher mounds require wider row spacing to achieve the correct slope.

Figure 16. A 600 mm mound with 8 m row width creates a situation where the slope between the tree and inter-row is steep and the inter-row base is narrow, making it challenging to harvest.

Figure 17. Mounds with the same height as Figure 16, but the inter-row is 1 m wider (9 m), creating a better harvesting environment.

## Spacing

Tree spacing means the distance between rows (row width) and between trees within the row. The more common spacings currently used are:

- 8 m wide rows with 4 m between trees in the row
- 9 m wide rows with 3.5–5.0 m between trees in the row.

Be cautious of closer plantings. The Australian macadamia industry now understands that traditional planting spaces (e.g. 7 × 4 m) were too close for acceptable canopy and orchard floor management where there was no pruning.

The closer the spacing, the more rigorous the pruning regime will need to be as the trees grow. A no-pruning regime has created many orchards with orchard floor problems and unproductive canopy centres.

All macadamia varieties and all spacings require pruning. The aim is to keep the tree height less than the row width. Closer plantings deliver earlier yields but pruning requirements commence earlier and extreme measures such as row removal might be required later.

Think about production on a per hectare basis rather than per tree. Mature orchards will approximately equalise their yields per hectare regardless of the number of trees, all other influences aside. At maturity, the canopy area will be between 38,000–42,000 $m^3$/ha if tree height is equal to or less than row width, regardless of whether they are on 8 × 4 m or 10 × 10 m spacing. Yield depends more on canopy volume than the number of trees per hectare. Whichever spacing is selected, use it consistently throughout the orchard. Machinery set-up often works with specific spacings; different spacings in the same orchard can increase machinery and labour costs.

Mounding the tree rows can increase the row width needed to form functional, harvestable inter-row drains. Harvesting is more efficient from flat-bottomed inter-rows. High mounds with narrow row widths are steep and challenging to harvest compared with the same mound height and wider inter-rows.

## Roadways

Orchards require all-weather access for spraying, harvesting and other operations. Locate access roads on ridgelines where possible. Consider access for beekeepers to all parts of the orchard to distribute hives evenly for better pollination, rather than placing all the hives at one convenient location.

# Siting buildings

The orchard will need storage facilities for equipment, inputs and consumables, processing and storage of harvested nuts, worker amenities, and waste disposal facilities. Allow space to meet the needs of the mature, productive orchard and budget for the future development of harvest and handling facilities within 3–4 years of planting.

Consider having the capacity to store nut-in-shell for some time (Figure 11). On-farm storage might become more critical as production increases, and processors' ability to take consignments may get congested. Refer to the *Macadamia grower's guide: harvest and handling* for information on storing nut-in-shell on-farm.

Site chemical and fuel storage areas and waste disposal areas away from watercourses. Construct and operate them within the legislative and duty of care requirements. Site the processing facilities as far as possible from neighbours to reduce noise issues. Allow space for bulk organic matter amendments and compost pads to be delivered.

## Variety/cultivar selection

There is no perfect variety or cultivar of macadamia. Technically, varieties are natural variants, while cultivars result from selective breeding. Cultivar selection for a new orchard is a balance of compromises. The choices depend on various factors that people will weigh differently.

The usual process for selecting varieties is:

1. Identify the best varieties for sound kernel recovery per hectare of production (Table 5).
2. Research the tree or nut characteristics for each variety that might affect saleable yields (e.g. sticktights, marketability, and sound kernel recovery). Seek the opinions of local growers, consultants and nursery tree suppliers at events such as MacGroups and benchmark meetings.
3. Check with the intended processor, who might have preferences for specific varieties.
4. Identify the varieties from the shortlist that suit the proposed tree spacing and management system, e.g. upright varieties suit close-planted orchards.
5. Choose multiple varieties to spread risks and the harvesting workload through a range of nut drop periods; there is no minimum number of varieties to be selected. Having multiple varieties will improve yields through cross-pollination and offset disasters when a variety might have a limited yield in a given year, e.g. from prolonged wet weather, as other varieties will be flowering at a different time.
6. Design the arrangement of the varieties within the orchard.

## Variety arrangement

Several issues (Figure 18) influence the arrangement of macadamia varieties throughout the orchard. These need to be balanced according to priorities to arrange tree varieties.

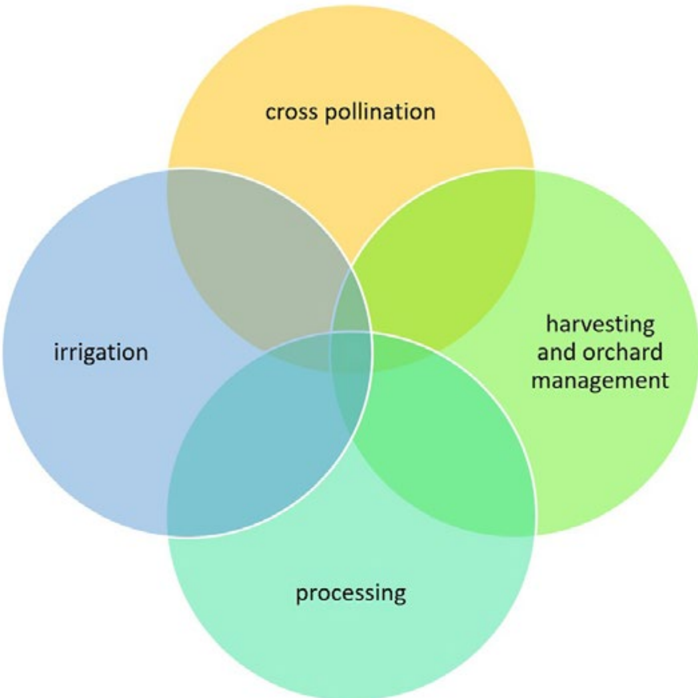



Figure 18. Factors influencing the arrangement of macadamia varieties throughout the orchard.

Table 5. A summary of the features of some macadamia cultivars. Source: Kojetin et al. (2022).

| Cultivar | Kernel recovery (%) | Shape | Size | Density | Flowering | Nut drop |
|---|---|---|---|---|---|---|
| A4 | 44–48 | round | medium | open | late | mid–late |
| A16 | 38–42 | spreading | small | dense | late | late |
| A29 | 36–40 | upright | large | open | mid | early |
| A38 | 36–40 | upright | medium | open | late | late |
| A203 | 32–37 | spreading | medium | open | late | mid |
| A268 | 35–40 | spreading | medium | open | late | mid |
| 246 | 34–40 | spreading | large | dense | early | mid |
| 344 | 34–39 | upright | large | dense | early | early |
| 660 | 34–39 | upright | medium | dense | early | early |
| 741 | 35–43 | upright | large | open becoming dense | mid | early |
| 816 | 44–47 | upright | large | dense | late | early |
| 842 | 36–41 | upright | medium | open becoming dense | early | mid |
| 849 | 40–46 | spreading | medium | dense | mid | mid |
| Daddow | 37–40 | round | large | open becoming dense | early | late |
| H2 | 31–35 | round | large | dense | mid | mid |
| Beaumont | 32–38 | spreading | medium | dense | late | late |
| MCTI | 42–50 | spreading | medium | open | mid | late |
| MIVI-G | 42 | spreading | large | open | mid | late |
| MIVI-J | 45 | spreading | large | dense | late | late |
| MIVI-P | 35 | round | small | dense | mid | late |
| MIVI-R | 38 | spreading | medium | dense | mid | late |

## Cross-pollination

Cross-pollination is where the pollen from one variety fertilises the flower of another. Cross-pollination might increase the number of nuts, kernel recovery and nut size. The current recommendation is to inter-plant at least two varieties within each large block of trees to benefit from cross-pollination. Match the flowering periods of the varieties, or cross-pollination will not occur. Arrange the varieties in alternate sub-blocks of 4 to 10 rows so nuts can be harvested and supplied to the processor as separate varieties if required. Other strategies include alternating varieties within the row (Figure 19) and, to a lesser extent, grafting a pollinator limb onto trees either in-field or before planting. If varieties are mixed within the row, ensure they have similar characteristics to allow for ease of management.

Figure 19. Alternate trees within row of A16 and A4, varieties that flower at the same time and require similar management and support cross-pollination. Photo: Chris Cook, Dymocks Arapala Macadamia Farms.

## Harvesting and orchard management

Match the nut drop periods of the two (or more) varieties in each block. Pest and disease infestations will generally be similar for varieties with similar flowering and nut development patterns, making pest monitoring and treatments more efficient. Late flowering varieties can be more vulnerable to pest damage because pest populations build up through the season. Similarly, nutrition and irrigation timing might be more compatible. Nut drop is still relevant for harvest but is less of an issue with access to tree shakers and hormone treatments that can trigger condensed nut drop.

## Irrigation

Water demand varies between varieties. Some varieties have higher needs for moisture than others, making it hard to achieve appropriate irrigation for both varieties in the same irrigation block. Some orchards are designed to have single varieties in irrigation blocks.

## Processing

Avoid mixing hybrid varieties (such as some HVA varieties) with *Macadamia integrifolia* varieties (such as HAES and Daddow) in a block. Processors might require these to be consigned separately. Seek advice on this from processors.

## Rootstocks

Purchase trees grafted or budded onto rootstocks. The most common rootstock is Hinde (H2) because of its ease of propagation and ability to produce vigorous and uniform seedlings. Recently the South African standard Beaumont has gained popularity as a rootstock.

Top performing new rootstock cultivars in recent experiments, now in farm trials, include A268, Own venture and A4. This trial examined several rootstock varieties with the same 741 variety above the graft (scion). Researchers are yet to establish rootstock and scion compatibility for other scion varieties.

Trials of a dwarfing rootstock, Hancock (Figure 20), are investigating its value in reducing pruning and other management costs. Growers interested in new rootstock varieties could try these for 10–20% of new plantings.

Figure 20. Hancock dwarfing rootstock (left) compared with larger H2 (right). Both trees are the same age and with A29 scion. Photo: Noah Seccombe, Django Macadamias.

***'Do not use seeds of any variety as this is highly unlikely to produce useful planting stock. It is best to return to well known good seed sources for rootstock selection'*. Malcolm Smith, Macadamia rootstock program.**

## Ordering trees

Determine how many trees of each variety are required based on the block design (row width, spacing within row, block sizes). Order trees from a specialist macadamia nursery at least 2 years before the intended planting time. In 2021, the waiting period from ordering to receiving trees was over 2 years.

Nursery propagation of grafted macadamia trees is a specialist job. Ask other growers about their experience with the tree quality and service from specific nurseries. Check the quality of trees at the prospective nursery. Look for:

- trees that are in good quality potting mix
- trees that are off the ground
- the overall health and consistency of trees
- the shape of the trees
- signs of pests or disease, e.g. felted coccid (Figure 21) and mites
- firm pots indicating good root growth; loose mix in the pots suggests few or poor roots
- many roots coming out the bottom of the pot, which could mean the trees have been allowed to become pot-bound
- a nursery with good drainage and hygiene measures.

Figure 21. Felted coccid pest on a nursery plant. Photo: Chris Fuller, Kin Kin Native Bees.

Favourable options are nurseries that:

- grow the trees in pots with a capacity of 6 L or more
- keep trees in the pot for no more than 2 years.

Most macadamia nurseries train trees to a central leader. Confirm this with the nursery and specify if you have a different strategy for varieties that do not suit a central leader framework. Communicate regularly, about every 3 months, with the selected nursery during the waiting period. Visit the nursery occasionally to check the progress of the plants.

Inspect the trees before they leave the nursery:

- Take particular care not to bring pest insects into the new orchard.
- Ensure nursery trees are consistent sizes as variation can become an issue in machine planting, which relies on uniformity to achieve the correct planting depth.
- Ensure there are no 'J' roots (Figure 22), which is a clear sign the plant has sat in the nursery for an extended period, i.e. beyond 2 years.

Refer to the Australian Plant Production Standard Macadamia nursery stock specification for more detail on what to look for in nursery trees.

Figure 22. A tree with 'J' roots from being in the pot too long.

## Tree supports

Damage can occur where young tree trunk movement, generally from wind, at the soil surface is excessive (Figure 23), creating gaps between the trunk and the soil. Trunks can develop wound spots at ground level that promote disease. Where needed, plan strategies to support growing trees.

On the coastal flood plains of northern NSW, staking (Figure 24 and Figure 25) or trellising (Figure 26) trees have replaced windbreaks (Figure 27) to protect young trees. Both staking and trellising have proven their worth through many east coast lows and other storms. Consider the materials needed well in advance and decide whether to install them before or after planting.

Figure 23.  Movement of the tree trunk from strong winds damages the trunk at the soil entry point.

Figure 24.  Young trees supported with stakes.

Figure 25.  Fibreglass stakes are another option to the more expensive wooden stakes and trellising.

Figure 26.  Young trees supported by a trellis.

Figure 27. A casuarina wind break on the NSW coastal flood plains.

Staking requires at least two stakes per tree; one to the north and one to the south in north–south rows. Trellis systems typically have a post at every fourth tree. The post should be 2.4–2.8 m long, installed at least 1.8 m tall, with 0.6–0.9 m in the ground. Move the wire up as trees grow. Insulation such as T-tape can be placed over the wire to secure the tree to the wire without damaging the tree trunk.

Bundaberg growers use pruning techniques to develop more growth to the leeward side. This strategy has mostly replaced planting windbreaks and the need for tree support.

Windbreaks are now rarely planted because they:

- are expensive to establish
- take up space
- are only helpful in the first few years until the tree rows form continuous canopy lines
- provide habitat for rats
- drop sticks and branches that must be removed pre-harvest
- compete with orchard trees for water and nutrients (especially *Eucalyptus* spp.)
- are expensive to remove.
- can host pest insects, e.g. tallowwood can host fruit spotting bug (FSB).

When installing windbreaks:

- seek advice on plant selection
- use shrubby rather than tall trees
- consider multi-row plantings if space permits as these provide better wind protection

- avoid fire-susceptible species
- avoid hosts of orchard pests
- deep rip to a depth of 600 mm before planting, lifting the toolbar every 30 m on downslope runs to prevent scouring the rip line
- mulch, fertilise, protect from grazing and maintain a weed-free area around the plantings until well established.

The zone of orchard protection from a windbreak extends for 6 times the windbreak's height minus the orchard tree height, e.g. a 14 m high windbreak protects 3 m high young trees for 81 m from the windbreak.

## Irrigation

Design the irrigation system to deliver water to every tree every day, within 4 hours. For mature trees, this might be approximately 75 L per tree, but it will vary with soil infiltration rate, climate and tree size. Some over-capacity and redundancy make the system more capable of adapting to changes and problems. Less capable irrigation systems will require more labour to operate and under-service the trees in dry conditions. In drier areas with water available, consider installing irrigation systems that address both the tree requirement and inter-row needs (Figure 28).

In irrigation, the term 'drainage' is used as a metric for irrigation efficiency. One hundred per cent drainage means that all areas of the irrigation block receive the same amount of water in each irrigation cycle. In practice, this is difficult to achieve. Typically, downslope areas end up receiving more water than upslope areas. Drainage efficiency is better in bottom-fill (where the water delivery line is at the lowest point of the irrigation block) than in top-fill designs (where the water delivery line is at the highest point of the irrigation block). However, bottom-fill arrays are more expensive to install. Irrigation equipment suppliers might provide free irrigation design advice as part of an agreement to purchase irrigation equipment.

More information on irrigation is in the *Macadamia grower's guide: irrigation*.

Figure 28. This system will irrigate the required amount for the tree via the small riser in the background and the inter-row via the tall riser in the foreground.

### Equipment

Organise the operating equipment for the young orchard early. Mowing and spraying commence soon after planting, if not before. Be prepared to apply nutrients to trees and inter-rows when needed. Some equipment might have extended lead times, especially if customised. Have separate spray equipment for herbicides and tree sprays.

### Labour requirements

Typically, a farm up to 30 hectares can efficiently be run by 1–2 people, who will need a range of skills, including being:

- competent in using multiple machinery implements
- mechanically minded
- able to schedule and implement irrigation and nutrition applications
- knowledgeable in canopy management, e.g. pruning.
- aware of incremental costs of production and price fluctuations.

### Staging

Staging orchard development is an important choice when resources are scarce. It is better to establish part of the orchard well than all of it poorly. Develop the most promising areas first. Delay planting poorer areas until cash flows from the better areas commence.

Poorer areas will likely have more management needs than the better areas. Learning from establishing better areas can create a more capable farm team. Staging also gives time for considering whether to plant the poorer parts of the site. Look carefully at why the area is considered poorer. Does it have the potential to support a high-performing orchard? What will the extra development and ongoing management costs be?

# Prepare

## Clearing woody vegetation

Preserve the existing vegetation in the buffer zones. Clear the woody vegetation from other areas, then cutter-bar and stick-rake where necessary.

Stack the cleared timber into windrows for chipping or burning because woody material left in the planting area can:

- allow bark beetle to breed and eventually infest the macadamia trees
- host Armillaria root rot disease and cause tree losses.

Leave gaps in the windrows every 30 m to allow safe drainage of run-off water.

## Soil preparation

Form access roads and install some drainage features, usually dams and grassed waterways, leaving diversion bank construction until after row forming.

Start improving the soil at least 12 months before planting. Before mounding, soil preparation might involve:

- discing to knock down pasture or cane debris
- deep ripping
- laser/GPS levelling

- aeration
- mounding
- spreading and incorporating lime or other pH amendments
- improving the nutrient and organic matter levels of the soil with a green manure crop.

## Avoid disturbing unfavourable soils

Did the soil survey identify and map constrained subsoil areas? Does this affect the safe working depths? All operators must understand the hazards and how operations might change if the actual works reveal differences between the soil survey and planned works.

### *Cultivation*

The main purpose of cultivation is to incorporate soil amendments. Add these across the block area (not just the tree rows) before forming tree row mounds or inter-row drains. The incorporation of lime is best, but not perfectly, achieved by rotary hoes, although soil structure can degrade through overuse.

Cultivation also aerates compacted soils. Tined implements or spike aerators are best for remediating compaction.

Sow a deep-rooted green manure crop such as forage sorghum or tillage radish in the cultivated area if mound forming is not immediate.

## Soil amendments and nutrients

Assess the current soil conditions and nutrient status to decide which amendments and soil preparation techniques to use to prepare the soil to support macadamia trees and ground cover plants. Use soil test information to plan soil amendments and application rates. Table 6 shows the favourable ranges for soil chemistry attributes.

If possible, find a consultant with sound local knowledge of macadamia nutrition and the soil types in your area. Successful soil sampling, soil test interpretation and fertiliser choices require specialist skills.

Some growers prefer to DIY the soil sampling and rely on the analysing laboratory to interpret the results and make recommendations using computer models. Discuss the results with a consultant or local farm supply agent and determine the required amendments.

Be cautious of advisors predicting soil amendment requirements without visiting or testing at the site. Deciding on amendments and their rates without site investigation is risky because soils can be highly variable.

Apply most soil amendments up to 6 months ahead of planting. Ideally, apply them over the whole orchard site. Where cost is prohibitive, apply the amendments at least to the tree blocks or tree rows. Re-test soils after mounding and apply any additional liming materials, phosphorus, copper and zinc fertilisers at least 3 months before planting.

Mounding processes can influence the location and timing of applying amendments. Different nutrients or amendments are:

- applied to the tree row before mounding to be concentrated deeper in the mound
- broadcast to be more uniform throughout the constructed mound
- applied to the top of the new mound to be concentrated in the topsoil.

Apply the more soluble nutrients such as nitrogen, potassium and boron no more than a few weeks before planting. Spread these nutrients over the whole site to help grow inter-row ground covers.

Table 6. Favourable ranges for soil chemistry attributes. Refer to the *Macadamia grower's guide nutrition and soil health – Part 2: the next level* for further information on correcting soil nutrient imbalances.

| Soil attribute | Favourable condition |
|---|---|
| pH | Target ranges: pH 5.5–6.0$_{Ca}$ (acidic soils) or 6.0–6.5$_{Ca}$ (alkaline soils) |
| Soil organic matter (SOM) or soil organic carbon (SOC)<br>SOC is 40% of SOM<br>SOC = SOM ÷ 1.75 | Approximate healthy values for ECEC:<br>• sands: ECEC 1–5, SOC 1.25%<br>• sandy clay loams: ECEC 10, SOC 1.5%<br>• clay loams: ECEC 14, SOC 2.5%<br>• heavy clays: ECEC 20, SOC 3% |
| Nitrogen | 15–30 ppm |
| Phosphorus | 60–85 mg/kg |
| Potassium | 2–10% of ECEC |
| Calcium | 65–80% of ECEC |
| Magnesium | 10–20% of ECEC |
| Sodium | <2% of ECEC |
| Chloride | <200 mg/kg |
| Conductivity EC | <3 dS/m |
| Micronutrients | If pH is not in the target range, correct this first and then re-test before acting on soil test results. |
| Boron | 1–2 mg/kg |
| Copper | >3 mg/kg |

## pH correction

The macadamia pH targets are pH$_{Ca}$ 5.5–6.0 for acidic soils and 6.0–6.5 for alkaline soils. Pre-plant pH correction should bring the whole depth of tree mounds into the target range. Where this is not possible, ensure at least the topsoil (0–100 mm) is brought into the target range.

### *Acidic soils*

The only opportunity to apply high rates of lime mixed through the soil (incorporated) is before planting. Later, incorporating lime is far too destructive to tree roots. High rates of lime (>3 t/ha) can be applied before mechanical soil preparation. There are maximum safe incremental rates for surface-applied lime to continue pH correction after planting (see *Macadamia grower's guide: nutrition and soil health – Part 2: The next level*).

### *Alkaline soils*

Correcting alkaline soil pH uses fertilisers that provide nutrients in forms that create acidity once in the soil. Selecting which fertiliser, or fertiliser combinations, must be guided by the current nutrient status to avoid creating nutrient imbalances or toxicities. It is also essential to avoid overcorrecting the pH. (See *Macadamia grower's guide: nutrition and soil health – Part 2: The next level*).

### Add organic matter

There is an opportunity to value-add by adding organic matter in the same operation as cultivating to incorporate other amendments or mounding. Fine, mature composts are best for this purpose. The decision about what forms of organic matter to add is a compromise of quality, price and availability. There can be up to a year lead time to access some organic materials, such as mill mud (waste from sugar refining).

Organic matter can also be added to the surface of the tree rows or mixed into the planting holes. Unscreened, chipped green waste is a cheap source of organic matter but can come with contaminants such as plastics, metal parts and weeds such as nutgrass.

## Construct drainage features

Drainage features protect tree blocks from run-on water, safely convey water collected from the block and enable well-drained soils.

### Levelling

Laser or GPS-guided levelling is the precise use of earth-moving equipment to set up the orchard blocks. Levelling occurs before constructing mounded tree rows and shaping inter-rows. The uniform level starting point facilitates the construction of mounds and drains to the design shape. Construct grassed watercourses and major components of the drainage system at the same time.

Well-executed levelling minimises the depth of cutting and volume of soil moved. The highest quality soil is in the top 100 mm. Avoid removing this entirely from any production areas; stockpile and respread the topsoil if necessary.

The usual steps in preparing macadamia blocks are:

- fill hollows and cut down humps
- allow for wide headlands of 15 m from the last tree to the edge of the drain, or more where the tree rows meet the headland on an angle
- cut headlands (non-production areas) down to 300 mm below paddock level
- cut drains down to 500 mm below the paddock level
- create wide watercourses to take water from the drains.

There is often overlap between headland/turning areas for machinery used for tree and inter-row preparation and areas for grassed watercourses and diversion banks. Be prepared to repair the profiles of drainage features, as damage might occur when shaping the tree and inter-rows.

Seek expert advice if sub-surface drainage is needed. The layout and depth of sub-surface drains can make enormous differences in the results.

## Install irrigation mains

Irrigation mains are installed underground, usually at around 600 mm depth. This should be deep enough to avoid being accidentally ripped up by machinery and shallow enough to give easy access for maintenance. Risers bring water to the surface to feed the lateral lines. Mark out the locations of irrigation lines and risers using an accurate GPS.

## Mark out the tree rows

There are several ways to mark out tree rows, the simplest being GPS when there is an accurate planting plan. GPS-enabled tractors facilitate fast and precise work. With a more conceptual and equally accurate planting plan, set up the first row parallel to a fence or boundary and work from there. Otherwise, determine the row direction, e.g. north to south, using a compass or compass app on a mobile phone.

For the first tree point (where the first tree will be planted), allow enough space for tractor-trailer equipment to turn easily, plus half a mature tree canopy. Stand at this point and send an assistant out with a string to the endpoint (the last tree in the row) or at least 100 m. Use line of sight to put the string line at the exact compass bearing (Figure 29). Put a peg at each end of the string and tie the string tightly to the end pegs. Place pegs at the correct spacings along the string line, e.g. every 4 m using a tape measure or 4 m long PVC pipe.

When doing the second row, ensure both end pegs are exactly the intended row width from the first and last tree points of the previous row, e.g. 8 or 9 m.

Figure 29. Pegging out a macadamia block using stringline.

# Prepare the tree rows

## Soil working

### *Deep ripping*

Consider deep ripping to a depth of at least 600 mm (unless there are subsoils that should not be disturbed) along each future tree row. Ripping will help drainage where the soil structure contributes to poorly drained soils above the water table. It will not help where the rip line is below the water table. If ripping down slopes, lift the toolbar for 1 m every 30 m to avoid water scouring down and eroding the rip lines. Be wary of deep ripping on some clay soils where ripping can cause the soil to shear/glaze either side of the rip line and create an impermeable side.

## Establish living ground covers

Ground cover reduces the risk of soil erosion by preventing raindrop splash on bare soil (often the first mobilising force that initiates soil erosion) and slowing overland water flow. Higher percentages of ground cover also increase rainfall infiltration, reducing run-off.

Broadcast fast-growing annual grass seeds to quickly cover disturbed soils and reduce erosion risk. These will die off and allow creeping grasses such as carpet grass, couch and Kikuyu to establish. Sweet smother grass tolerates low light conditions and will persist and protect the soil surface as the tree canopies develop. Taller grasses, such as Rhodes grass, can provide more mulch for the tree rows. Some growers use multi-species inter-row plantings to encourage biodiversity and enhance soil conditions. Consider irrigating to help the living ground covers establish.

Apply thick mulch to the tree rows to protect and build the soil. Spread initial mulches before planting to avoid damage to young trees. Later, mow and throw inter-row ground covers to the tree rows to top up the mulch layer. When using a mechanical planter, the planting strip will need to be free of mulch and vegetative material. Once planted, there is an opportunity to mow and throw mulch material to limit evaporation around the new plants.

Heavy mulching could prevent or reduce the need for spraying in the tree rows. Spot spray the tree planting sites if necessary. Avoid herbicide strips along the tree rows, as these can trigger erosion, especially on steeper slopes.

# Plant

## Confirm planting technique

Usually, the decision on how to plant the trees is made well before planting (Table 7). The chosen planting method influences the timeframe for the planting operation and the number of people required. Specialist tree planting equipment needs to be booked well in advance.

Table 7. Options for planting macadamia trees.

| Technique | Advantages | Disadvantages |
|---|---|---|
| Water auger | Creates a slurry of soil in the planting hole, with minimal soil moved out of the hole. There is no need to water in the trees. | Specialist equipment. |
| Soil auger | The planting hole is the correct depth. Rough up the sides to prevent scalding of the hole (creating a smooth surface of the hole that tree roots might not grow through). Some augers have spikes on the attachment to achieve this. | Scalded holes can restrict root system development (Figure 30). |
| Mechanical planter | Fast, accurate and requires less labour. | Different size trees might cause problems, e.g. big trees too high out of the ground (Figure 31) and small trees too deep. |
| By hand | Attention to detail ensures good tree placement. | Slow and labour-intensive. |

Figure 30. Tree roots constrained by glazing in the planting hole caused by an auger. Photo: Graham Wessling, CL Macs.

Figure 31. Mechanical planters can not accommodate inconsistent trees sizes. Note the potting mix exposed above the soil. These trees will need to be manually replanted.

Confirm the delivery date for trees and the drop locations one month and again one week before the due date. Find out the status of trees on arrival, e.g. will they need de-leafing or the grafting tape removed, or is this done at the nursery?

On receiving the trees from the nursery, do not leave the pots in an on-farm nursery for too long, as this could create root-binding, j-rooting and an opportunity for soil pathogens to enter the plant and spread. In these cases, once planted, there might be slow tree decline leading to death in the orchard.

## OH&S

Planting operations involve having people out in big, bare paddocks. They need access to drinking water, a toilet, a first aid kit, sunscreen and other personal protective equipment (PPE) such as hats and gloves.

## Labour

Macadamia plantings on any scale are more efficient with a team of people. Table 8 gives an example of the team needed for planting with a mechanical planter.

Table 8. A model for the personnel needed for planting operations. Note: this is a guide only. Source: Chris Searle, MacAvo Consulting.

| Task | Requirements | How many (15–16 in total) |
|---|---|---|
| Unload the truck and move pallets | Forklift license | 1 |
| De-leafing and de-taping trees* | Take lower leaves and grafting tape off trees before planting | 5–6 |
| Move trees onto the planter | Best forklift operator available (as this often holds up operations) | 1 |
| Feed trees into the chute on the planter | Fitness and strength (this is a hard, manual job) | 2 |
| Firm in trees after planting and correct tree positioning (if required) | Rotate people through the day from the de-leafing task (as this is a tiring task) | 2 |
| Hand-plant trees at the ends of rows and near irrigation risers | Fitness and an eye for detail (as these people ensure the trees line up in the row and between rows) | 2 |
| Lay out and connect irrigation laterals | Driver's license and basic plumbing skills | 1 |
| Sort out problems and make decisions | Supervisor with team management skills | 1 |

* Ideally, have the nursery de-leaf and de-tape trees before delivery.

## Machinery

On and around the planting days, multiple activities can be happening at the same time. Plan to avoid hold-ups where the same equipment is needed for more than one task or have enough capacity to do the jobs at the same time.

Table 9. Suggested machinery to have available for planting, assuming a machine planter is used. Source: Chris Searle, MacAvo Consulting.

| Machine | Purpose | How many |
|---|---|---|
| ATV or similar | Rolling out irrigation lines | 1 |
| Spare vehicle | Fetch and carry materials such as planter bags, spare clips and joiners | 1 |
| Forklift tractor | Unload the truck and load the planter | 2 |
| Tractor with trailer | Take trees on pallets to the planting area if the ground is too wet for the truck to get close | 1 |

## Other equipment

Avoid having planting operations slowed down because staff do not have the resources they need for the tasks. Consider how people will do each task and what resources they need. Table 10 gives an example list of small tools and equipment for a planting operation.

Table 10. Handy small tools and equipment to have for planting days. Source: Chris Searle, MacAvo Consulting.

| Item | Purpose | Quantity |
|---|---|---|
| Stanley-type utility knives | Cutting away grafting tape | 10 |
| Gardening gloves | For people de-leafing and planting | 15 + spares |
| Timber stakes to tie drip tape off | For tensioning drip tape | 2 per row |
| Rope (thin and strong) | For tying to drip tape | At least 10 m |
| Field bins or one-tonne bulk bags with tops cut out | Collecting rubbish, e.g. planting bags, pallet wrap | 10 |

# Early pruning

There are many considerations when developing a pruning method for young trees. Factors influencing pruning include wind, early yield volumes and the preferred canopy architecture for the mature trees.

Some growers start pruning immediately after planting to increase visibility (for monitoring irrigation performance), hang irrigation lines and provide access for shakers in the mature orchard. Early pruning might be done 3–4 times in the year after planting, training the trees to:

- a single dominant leader
- a crotch height of 1.0–1.2 m above the ground
- eliminate unwanted branching that could be a problem later
- maintain structure through continuous windy conditions such as those experienced in central Queensland.

# Drainage repairs

Even in orchards with well-designed and constructed drainage features, it is common for some scouring out of waterways and inter-rows to appear after the first few heavy rainfalls. Repair this damage as soon as possible because it will probably worsen. Reshape the profile of drains and waterways, bring in more soil if needed, and re-establish living ground covers.

To stop the problem from recurring, investigate the causes of the failure. Failures result from overloading the drainage feature. The amount and speed of water flow interact with the surface protection. To stabilise a drain, increase the surface protection or reduce the volume or velocity of water moving through it.

## Not enough ground cover

Bare soil is not a stable surface for flowing water. Flow lines need to be protected.

Living ground covers are usually the best form of protection. Dense ground cover with well-developed root systems provides better protection than sparse vegetation.

Investigate any issues that might be impairing the growth of ground covers. In new orchards, sometimes living ground covers do not have enough time to establish before the rainfall (Figure 32). Place hay bales or coir logs at intervals across the flow line to slow water down and catch moving soil. Remove these once there are dense ground cover plants to make mowing easier.

Some areas, such as places with high vehicle traffic or high-velocity water, cannot sustain living ground covers. Use other forms of armour such as rock, concrete or a reinforcing matrix installed into the soil.

## Too much water

When channels are too small to accommodate the water gathered, overtopping and spilling into undesirable areas can happen. Options include:

- increasing the channel volume by increasing bank heights or channel width
- reducing the amount of water collected to that point by diverting run-on water from upslope.

Figure 32. This newly formed grassed watercourse had scoured out, losing some soil from the centre. The surface has been smoothed and re-sown with grasses to stabilise the flow line.

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# Glossary

| | |
|---|---|
| Broadcast (fertiliser application) | When fertiliser is spread evenly over the whole orchard soil surface. |
| Compaction (soil) | Increasing soil density by packing soil particles closer together. It is commonly caused by heavy machinery traffic, particularly on wet soil. |
| Erosion (soil) | The mobilisation and transport of soil material. Soil erosion is a natural geologic process that is often accelerated by human activities. |
| Flush (leaf) | The mass production of new leaves on a tree. |
| Flush (roots) | The mass production of new roots on a tree. It is typically post-leaf flush. |
| Husk | The outer covering of a seed or fruit. It is generally green during fruit development and dries out at maturity. It is removed in the process of dehusking. |
| KR | Kernel recovery. The amount of kernel harvested, includes premium, commercial and reject kernel. |
| Lime (Aglime) | A soil additive made from pulverised limestone or chalk, primarily composed of calcium carbonate. |
| Micronutrients | Elements required by plants in very small amounts. These include boron (B), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), molybdenum (Mo) and chloride ($Cl^-$). |
| Monitoring | A process of systematically checking the tree, flowers, and nuts (both attached and fallen) for pests and diseases and recording progress to make decisions on pest and disease management strategies. |
| Nitrogen immobilisation | The process in which nitrate and ammonium are taken up by soil organisms and therefore become unavailable to crops. |
| NIS | Nut-in-shell. Usually reported at 10% moisture content. |
| pH (power of hydrogen) | A quantitative measure of the concentration of hydrogen ions in a solution indicating acidity or alkalinity on a logarithmic scale between 0 and 14. On this scale, a pH of 7 is neutral, which means it is neither acidic nor alkaline. A pH value of less than 7 means it is more acidic, and a pH of more than 7 means it is more alkaline. |
| Phytophthora | A soil-borne water mould (oomycete) that causes disease. *Phytophthora cinnamomi* is the most common species in macadamia in Australia. Initial symptoms usually occur in the root system but can spread throughout the tree and cause significant crop loss. |
| Salinity | The amount of salt dissolved in a body of water or soil. |
| Soil aggregate | The arrangement of primary soil particles (sand, silt and clay). |
| Soil organic carbon (SOC) | A measure of the carbon component of the organic matter in the soil. |
| Soil organic matter (SOM) | Any living or dead animal and plant material. It includes living plant roots and animals, plant and animal remains at various stages of decomposition, and microorganisms and their excretions. |
| Soil pH | The measure of acidity or alkalinity in the soil. |
| Soil structure | Describes the arrangement of the soil and is determined by how individual granules clump, bind together or aggregate. |
| Soil texture | Refers to the proportion of sand, silt and clay-sized particles that comprise the soil. It is used as a basis for soil classification. |
| Sound kernel recovery (SKR) | Fully matured kernel that is free from any defects such as insect damage mould, decay, immaturity, discolouration, germination or rancidity. Usually reported as a per cent. |

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