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# Macadamia grower's guide 2024

YOUNG TREES

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# Macadamia grower's guide: young trees

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# About this guide

Managing young trees aims to give them the best possible start to enable a long and productive life. 'Young trees' covers the period from approximately 3 months after planting until the orchard produces commercially viable yields, usually 4–5 years later. The period of orchard development for young trees corresponds with stage 1 in the macadamia integrated orchard management (IOM) framework. *Young trees* (IOM stage 1) follows on from *New orchards* (IOM stage 0).

NSW DPIRD maintains up-to-date resources for macadamia growers on the Nuts webpage (https://www.dpi.nsw.gov.au/agriculture/horticulture/nuts).

The macadamia grower's guide project (2022–24) provides up-to-date resources for macadamia growers. The online resources allow for timely updates incorporating evolving macadamia management practices and new research findings.

- The *Macadamia grower's guide: new orchards* is about site selection, orchard design and planting.
- The *Macadamia grower's guide: young trees* describes the management of young trees, including pruning.
- The *Macadamia grower's guide: bearing trees* focuses on keeping bearing trees in peak production.
- The *Macadamia grower's guide: nutrition and soil health the foundations* and *the next level* cover soil, nutrient additions and managing the orchard floor to support productive orchards.
- The *Macadamia grower's guide: cultivars* describes the macadamia cultivars available for planting and their use in Australian growing regions.
- The *Macadamia integrated orchard management guides* bring together the management of the canopy, orchard floor, and drainage to promote and sustain high productivity.
- The Macadamia plant protection guide provides regular updates on managing pests and diseases.

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# Contents

# Overview

## Young trees in integrated orchard management

Young tree management starts once the recently planted tree produces new roots and shoots. Growers manage their developing orchards to become high-producing systems when mature by:

- protecting trees from stress that reduces growth
- training and pruning to guide tree development
- promoting favourable soil conditions for healthy root systems.

Since 2016, the Australian macadamia industry has used the integrated orchard management (IOM) framework to manage orchards. The IOM framework describes the optimal stages of development (brown line) and potential decline (green line) of macadamia orchards. Young trees are in IOM stage 1 (Figure 1).

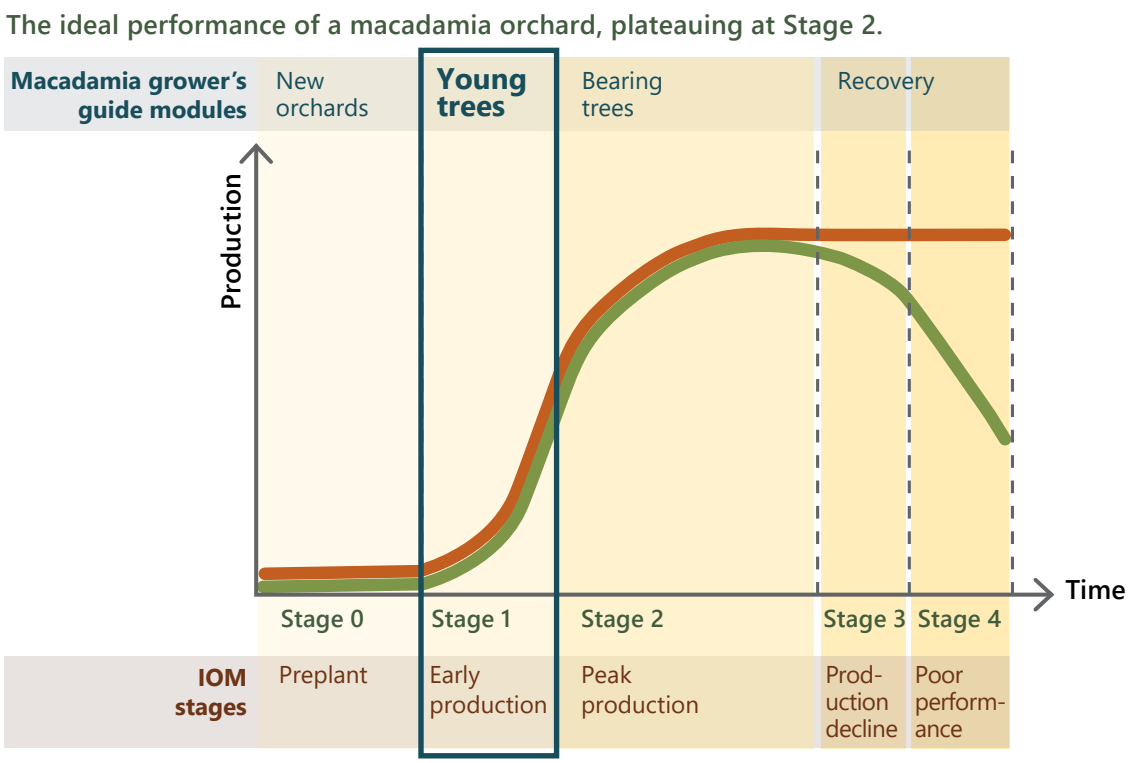


Figure 1. Integrated orchard management (IOM) stage 1 is from newly established plantings through to approaching peak production.

At the start of IOM stage 1:

- Planted trees have produced their first flush of new leaves.
- Tree canopies are not touching within the row.
- Ground cover plants produce more biomass than the trees.

Towards the end of IOM stage 1:

- Macadamia trees are the dominant vegetation.
- Tree canopies join up within the row.
- Nuts develop throughout the canopy.
- Inter-rows have dense, living ground cover.

Successful IOM stage 1 orchards have:

- Healthy trees.
- Training and pruning practices that are guiding tree growth to support future production.
- The foundations of nutrition and soil health in place where:
  - soil pH is in the target range ($5.5–6.5_{Ca}$)
  - there is an active program to build up organic matter
  - the drainage system minimises soil erosion and poorly drained areas
  - results from monitoring soil and trees are used to help inform how the soil is managed alongside the general nutrition recommendations for young orchards.

# Growth in young trees

## Growing

Trees produce new shoots and leaves in flushes of new growth. Macadamia leaves grow in groups (whorls) of 3 or 4 leaves. The whorls grow from a single point (node) on the shoot (Figure 2). Three buds develop at the base (axil) of each leaf, from which multiple branches or flower racemes can grow.

Figure 2. Macadamia leaves grow in whorls of 3 or 4 leaves, with multiple buds at the base of each leaf.

The many close buds can produce undesirably complex branching and dense growth. Growers must balance the immediate energy benefits of lush, leafy growth with developing a canopy structure capable of long-term productivity. Training young trees directs their growth into bearing trees with canopy structure (Figure 3) that, with good ongoing management, can sustain peak performance for decades.

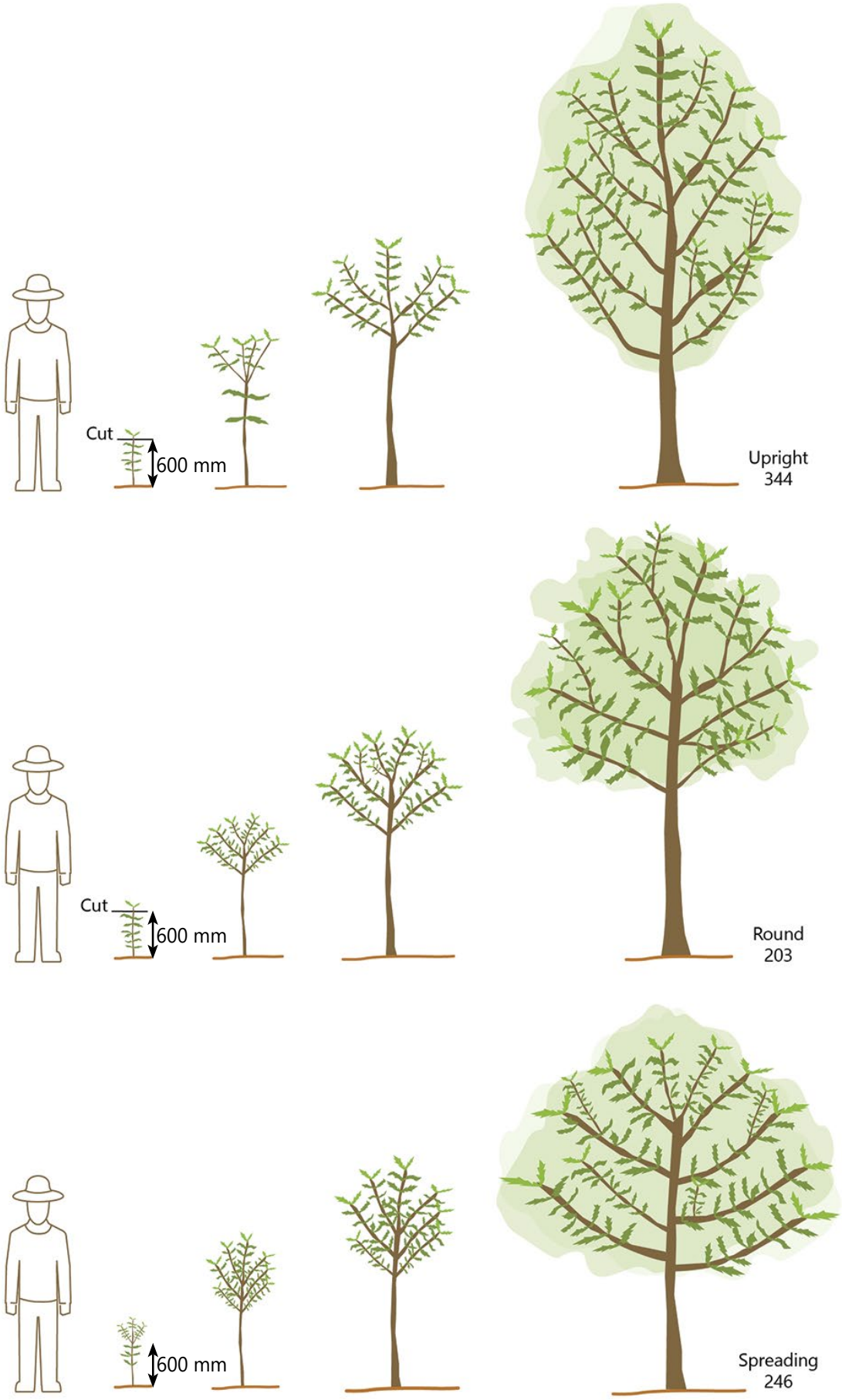


Figure 3. Developing canopy architecture in young trees.

## Energy

Through photosynthesis, trees convert solar energy into carbohydrates that fuel healthy metabolism and growth. Most of the carbohydrates that trees create are quickly used for growth and various functions within the tree. When there is extra, the unused carbohydrates get stored as energy reserves, called total non-structural carbohydrates (TNSC). For young trees, TNSC reserves support new growth and survival in tough situations, such as drought or extended overcast conditions, by providing extra energy alongside what their sunlit leaves produce daily. New flushes use TNSC, while hardened flushes contribute to TNSC and the immediate energy requirements of the tree.

## Growth cycle

Macadamia trees have a cyclic growth pattern that responds to environmental cues such as rainfall and temperature (Figure 4). The general pattern is earlier and accelerated in the tropical north and later and slower in more temperate southern areas. For young trees, the main goal is to develop a strong trunk and root system that supports a balanced canopy through successive leaf and root flushes.

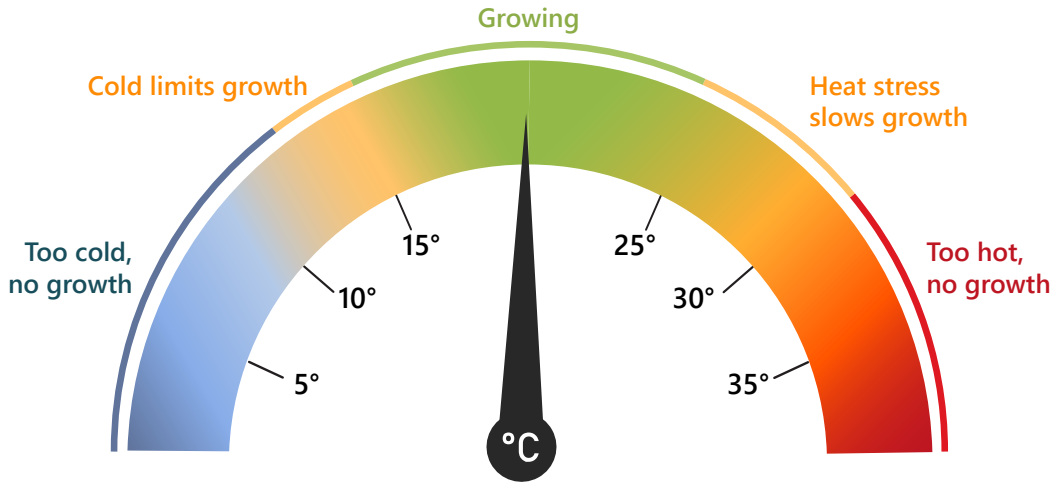


Figure 4. Temperature affects macadamia growth rates. Source: Trochoulias and Lahav (1983).

Timing pruning correctly is crucial. Allow time after a new flush hardens for root development and TNSC accumulation before the next pruning. This ensures that new flush growth is stimulated equally between the canopy and the root system. Where the 2 are not balanced, trees can be top-heavy and topple over in strong wind (Figure 5). Until trees are ready to produce a crop, there is no need to focus on flowering cycles.

### *Flushing/vegetative growth*

Individual macadamia leaves can live for many years. Leaves are most productive soon after they reach full size and harden. Flushing replenishes the supply of young leaves the tree needs to remain healthy and productive. Flushing is suppressed by low temperatures in winter and excessively high temperatures in summer. Typically, a flush of root growth follows on from a leaf flush.

Mild water stress suppresses normal flushing. In young trees, try to provide minimal water stress to promote as much growth as possible in the canopy and roots.

Figure 5. Young trees with well-developed canopies and less-developed root systems are prone to blowing over.

# Training and pruning

Training and pruning involve cutting back the tree. Training determines the tree branching details. Most training occurs in the first 4–5 years after planting and might remove only a small proportion of the canopy. Pruning continues for the tree's life to manage size, flushing, flowering and fruiting.

The aim is to develop robust trees that cope with environmental stress and have enough branches and flowering sites to produce high yields. Effective training and pruning balances the risks of cutting away too much material and not cutting away enough. Cutting too much will set back the tree's growth. Not cutting away enough will not sufficiently guide the branch architecture and favour canopy growth over root development.

Cultivar growth habit has a huge influence on training and pruning strategies. Whether the cultivar is upright, spreading, or round will influence which limbs require maintenance. There are also subtle differences between cultivars with similar growth habits. For example, A203 in Bundaberg is susceptible to leaning over in continuous wind, so it requires a different pruning strategy from 344. Ensure you understand the natural growth habits of the cultivars you are training. Refer to *Macadamia grower's guide: cultivars* for more information.

As a 'rule of thumb', do not take more than 20% of the canopy in a single training or pruning session.

To successfully train and prune young macadamia:

- **Start early** (Figure 6).
- **Expect to come back** and work with each tree many times.
- **Grow a robust root system** that will later support strong production by trimming back excessive new leafy growth.

- **Remove conflicting branches** growing across other branches or towards the tree's centre (Figure 7).
- **Do not fight the tree's natural growth habit**, as not all macadamia cultivars grow the same way (Figure 8 and Figure 9).
- **Shape the tree for stability** in wind and flood, keeping the canopy compact and strong (Figure 10).
- **Avoid training and pruning when the tree is under stress**, such as very hot, cold, wet or dry conditions.

Figure 6. Training in the nursery before planting. A 'heading cut' to develop branching at buds below the cut.

Figure 7. A conflicting branch crowding the tree centre (left) and after limb removal (right).

Figure 8. A classic dominant leader shape tree.

Figure 9. A multiple leader tree.

Figure 10. A strong, compact canopy reduces the risk of severe damage in wind.

## Training

Training young trees sets up the branching structure to develop robust and productive mature trees. The principles of setting up the tree at planting are very similar. Ideally, the tree has been delivered from the nursery as a dominant single-leader plant. The first step is to cut the leader where we want the first branches to develop, usually at knee height or 500–700 mm (Figure 3).

Cut the stem just above the leaf whorl. Three buds (primary and secondary) will be in each leaf axil (Figure 11). The upper primary buds will form upright shoots, while the 2 lower secondary buds will develop flatter-angled shoots.

As the tree grows, we develop more branch structure by cutting back the 'lanky branches' (>1 m long limbs) to stimulate new shoots lower on the branch. Keep the new branches that will eventually become bearing wood and remove limbs that crowd other limbs or grow at narrow crotch angles. Also remove any heavier branches on the outer edge of the canopy that are more vulnerable to breaking in strong winds.

Training shapes trees to have:

- an upright trunk
- no low branches (for access, visibility and tree shaking at harvest)
- an established dominant leader or multiple leader form
- more flatter-angled than upright branches.

Removing unwanted limbs is the most common training practice for young trees (Figure 12). Removing these limbs early is much easier than waiting years and facing a large limb that might be dangerous and difficult to remove. Sucker growth from below the graft union (Figure 13), should be removed at all stages of the tree's life.

Figure 11. The development of a tree without branches after cutting the single stem, with primary and secondary buds emerging.

Figure 12. A limb for a removal training cut. Removing the limb now saves a lot of cost and time if the limb were left to develop into an older branch.

Figure 13. Remove sucker growth from below the graft union. The red rectangle is highlighting the sucker growth to be removed.

## Pruning

Prune to contain excess vigour, which is the tendency to produce many leafy (vegetative) shoots. Unmanaged, high vigour leads to taller trees with less well-developed root systems that are more at risk of wind damage and water stress. Pruning the young tree directs growth towards developing the intended tree shape with strong roots and branches and a more productive canopy.

Tip pruning, a form of limb rejuvenation cut, is the most common technique used in young trees. Buds below the cuts will develop new leaves over the next 4–6 weeks, increasing the supply of carbohydrates and supporting root growth. On the coastal floodplains of NSW and Central Queensland, and in Bundaberg, growers use tip pruning to develop resilience in strong wind.

Figure 14 shows the tip pruning of a 'lanky tree' with long, whippy branches to create a more wind-resilient tree. Shortening the branches helps the canopy tolerate strong wind that might otherwise topple the tree, encourages growth into the root system, and makes the trunk thicker relative to the remaining canopy. Where trees are allowed to grow a larger canopy and are not supported with staking, they are often damaged by wind and storms.

Figure 14. Tip pruning brings the canopy of a 'lanky' young tree back to a more compact form, promoting the development of stronger roots and trunk.

## Cut to direct future growth

Cut placement directs future growth. There are 2 main types of cuts: limb removal (Figure 15, left) and limb rejuvenation (Figure 15, right). Limb removal cuts away an entire limb or shoot, **directing growth to other limbs**. Cutting part of a limb or shoot is called limb rejuvenation because this **directs growth to lower buds** on that limb.

Figure 15. A limb removal cut (left) at the base of the branch and a limb rejuvenation cut (right) is mid-way along the branch.

### Limb removal

The limb or shoot is cut off at the origin on an older branch, just above the collar (Figure 16). Limb removal cuts are sometimes called thinning. These cuts do not (usually) stimulate new growth near the cut.

Use limb removal to:

- skirt low branches
- remove competing or conflicting limbs (Figure 13)
- remove limbs with narrow branching angles
- increase light within the canopy
- balance the canopy in windy sites
- control undesirable regrowth.

Limb removal does not increase shoot growth as much as limb rejuvenation. Instead, the development of other limbs is encouraged. Sometimes, removing lower limbs allows other limbs to 'relax' into the newly available space.

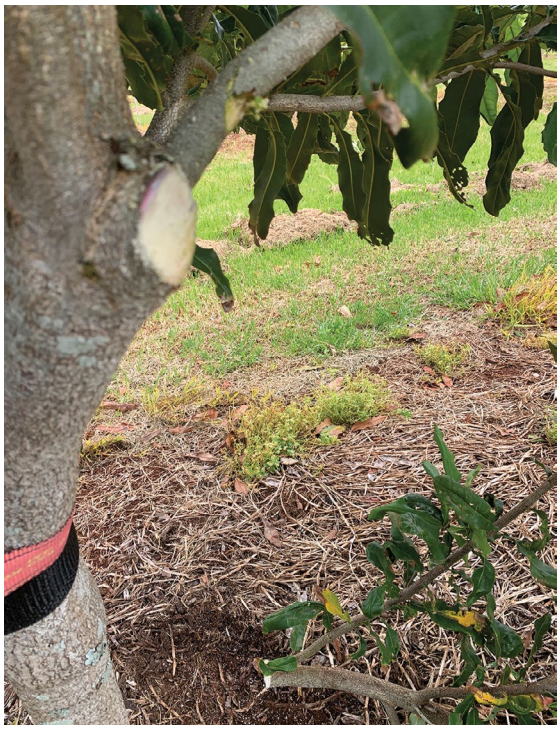

Figure 16. Limb removal cuts are made just above the collar.

## Limb rejuvenation

Limb rejuvenation cuts remove parts of shoots or limbs (Figure 17) and are sometimes called heading. Growth increases on the limb from the buds below the cut, creating more branching. Growth is much quicker with limb rejuvenation as it is enhanced in the lower buds, whereas with limb removal, the growth is distributed across the remaining branches.

Figure 17. An example of limb rejuvenation cuts in a young tree.

Limb rejuvenation cuts:

- shorten and strengthen branches
- induce further branching from buds directly below the cut
- direct growth into branches favourable to the desired tree shape
- reduce competition to a leader (an upper branch desirable to dominate).

The number and length of shoots increase on the limb below the limb rejuvenation cuts. The new growth is affected by the cultivar's habit, the cut's severity, the cut shoot's age and growth stage, and orientation.

### *Severity of the cut*

The severity of the cut describes how much of the shoot the cut removes. A more severe cut removes the most material, and a less severe cut removes just the tip. Strong shoots have well-developed buds along their topmost three-quarters. Buds towards the base of the shoot tend to be less well developed. At the training stage, growers want to develop a strong, productive tree structure. A severe cut is usually performed on 'whippy' or 'lanky' limbs, about halfway down these limbs Figure 14. This serves 3 purposes:

1. It creates a stronger, more wind-tolerant branch structure that will support flowering limbs.
2. It creates new growth from the buds immediately below the cut, which will develop into more productive wood.
3. It will promote a stronger, thicker trunk section, which will help with wind tolerance.

The strongest regrowth usually occurs when a cut removes between half and three-quarters of the shoot, retaining some well developed buds. More severe cuts that remove more than three-quarters of the shoot lead to slower regrowth. Less severe cuts that remove less than half of the shoot stimulate many buds, with the response at each bud less vigorous.

#### ***Shoot age***

The greatest stimulation occurs with cuts to 1-year-old wood. Usually, vigorous shoots develop from the 3–4 buds immediately below the cut. The growth response might be less vigorous after cuts into older wood.

### *Growth stage*

Pruning during flushing stimulates regrowth quickly. After a flush is complete, pruning might produce little or no immediate new shoots, but might produce more growth overall because the effect will influence the next vegetative phase. Avoid pruning in late autumn and winter in wet weather when tree sap flow is reduced.

### *Shoot orientation*

Young trees benefit from all limbs, including upright limbs, being strengthened through 'tipping' (Figure 18). In young trees, rejuvenation cuts to upright limbs allow more horizontal branches to develop. Later in bearing trees, rejuvenation cuts to upright limbs are not recommended because they tend to produce dense regrowth at very narrow angles with low fruiting potential.

Sometimes new shoots (water shoots) develop below a previous cut, growing at narrow or near vertical angles and crowded together. Remove these undesirable shoots later with limb removal cuts.

Figure 18. Tip pruning of young trees helps build a stronger trunk and root system. It is also a form of upright limb rejuvenation.

# Protecting trees

## Wind

Wind damage appears as:

- air gaps between the trunk and the soil (Figure 19)
- broken branches after strong, gusty wind (Figure 20)
- suppressed growth
- leaning trees (Figure 21).

Figure 19. A gap between the trunk can lead to damage from rubbing as the tree moves in the wind.

Figure 20. A broken branch snapped by wind.

Figure 21. Trees can develop a lean away from the prevailing wind direction.

Wind damage to young trees might also result in root breakage or even trees being blown over. Where wind damage is likely, physical support, such as a trellis, staking or pruning (such as the 'bundy system') to protect young trees from wind damage is usually installed or started during orchard establishment. Consider other options if wind damage occurs despite the selected wind protection strategy. Refer to *Macadamia grower's guide: new orchards* for more information on wind protection.

## The Bundy system

The Bundy system is a pruning system that replaces physical support for certain cultivars, particularly those that naturally grow into a spreading shape. It is not suitable for upright-shaped cultivars. It involves trying to encourage growth on the tree to strengthen the windward side (Figure 22). The high side (left) is the windward side and the low side (right) is the leeward side. The arrow on the left represents the predominant wind direction; notice how the canopy is more full on that side. This also makes the side away from the wind (leeward side) less heavy and, therefore, less prone to toppling over. A nearly 45-degree hedge was performed (the red line represents the cut) on the 203 cultivar. This activity will be performed regularly in the first few years to help strengthen the trunk and create a strong root system that matches a strong canopy.


Figure 22. Protect young trees where wind damage is likely.

## Frost

Frost risk is an unfavourable site characteristic (refer to *Macadamia grower's guide: new orchards*). In orchards planted on sites at risk of frost, tree blocks need open space downslope to allow cold air to drain away to lower areas to reduce frost damage to young trees. The bark and new flush on young trees are particularly susceptible to frost damage (Figure 23). Severe frosts can kill trees. Low daytime temperatures suppress vegetative growth. Refer to *Macadamia grower's guide: new orchards* for more information on protecting trees from frost.

### Wrapping

Wrapping means applying physical protection to keep the cold air off the trunk. Materials vary, including builder's insulation foil, corrugated cardboard, newspaper, or plastic sleeves (Figure 24). The wrapping also protects the trunk from whipper-snippers, herbicide damage and animals such as hares.

Figure 23. A frost-affected macadamia tree. Photo: Chris Cook, Dymocks Arapala Macadamia Farms.

Figure 24. A young tree is protected by wrapping with a plastic sleeve.

Where frost is likely, loosely wrap the trunks of the young trees before winter. The wrapping should extend from the ground to above the graft or bud union. Strip off leaves below the graft or bud union before wrapping. Make the wrapping tighter at the top to prevent cold air from entering. Remove the wrapping in spring after the risk of frost has passed. Trees might benefit from wrapping for up to 3 winters until they are robust enough to tolerate frost. Ensure wrapping does not restrict the growth of the trunk. Also, frequently check between the wrapping and the trunk for signs of damage, such as from macadamia twig girdler. Sometimes ants build nests inside the wrapping, creating a wet environment on the lower stem that might form a canker.

## Heat

The optimum temperature range for growth and photosynthesis is 15–25 °C. Irrigation strategies, including overhead sprinklers, can reduce heat stress to some extent by evaporative cooling and keeping relative humidity in the orchard higher than the surroundings. A well-vegetated inter-row substantially reduces reflective heat within the orchard.

## Pests

Young, non-bearing trees are especially vulnerable to pests and diseases because they have smaller canopies and fewer leaves. The thresholds to initiate pest and disease control treatments need to be much lower as pest numbers that cause damage to 10% of the leaves on a mature tree could damage up to 100% of a young tree's foliage (Figure 25). A damaged young tree cannot capture much energy from the sun and must use its' limited stored carbohydrates to grow new leaves. Unchecked, ongoing pest damage to leaves will cause a decline in tree health and might kill young trees. Some damage to young trees from pests and diseases, such as phytophthora, can affect trees for life.

Figure 25. Pests, such as monolepta (left), can damage all the leaves on a young tree (right). Photos: Glen Uebergang.

The most likely pest and disease problems for young trees are:

- grazing by hares (Figure 26) or wallabies
- pests such as macadamia felted coccid, macadamia leaf miner, macadamia twig girdler, monolepta, scale and mealybug (which encourages sooty mould)
- phytophthora disease.

Figure 26. Hares in a young orchard can be a problem as their chewing on the trunk can ringbark the tree.

## Prevention and monitoring

Preventing excess damage from pests relies on frequent monitoring. Weather influences the frequency of inspection. Warm and wet conditions favour many pests. Aim to inspect young trees every 1–2 weeks. For example, the turnaround time from having a few monolepta to a monolepta plague is rapid, and growers need to be especially vigilant for this pest.

Look for:

- **Frass**: a sawdust excretion from the chewed wood, generally at branch junctions (Figure 27), within the gap between a tree guard and trunk or around leaves, from macadamia twig girdler. The larvae feed under webbed shelters cluttered with excreta and damaged foliage. Twigs weakened by the girdling readily snap off. Macadamia twig girdler is most prevalent in summer and autumn. There are many natural enemies of twig girdler, including wasps. Many growers manually control macadamia twig girdler by piercing the larvae within the tree without spraying. Trees can usually tolerate a small number of twig girdlers.

Figure 27. Twig girdler in young macadamia is easily identified by frass at the entry point. Photo: Chris Fuller, Nutworks.

- **Damaged leaves, particularly in new flush**: monolepta chew the leaves, creating dried-off ends of leaves and eventually destroying whole leaves (Figure 25). Macadamia leaf miner will tunnel under the leaf surface, causing the leaf to crinkle and die. They can retard tree growth and, if severe enough, lead to dieback. Regular pruning can promote the prevalence of macadamia leaf miner as it feeds on new flush. Macadamia leaf miner has some biological control through a native parasitic wasp.
- **Scale insects underneath leaves and on the leaf stalk**: infested leaves turn khaki green, and severe infestations on branches and twigs cause the tree to lose vigour. Scale insects have many natural enemies. Overusing broad-spectrum pesticides significantly reduces populations of these natural enemies.
- **Sooty mould**: a black coating on leaves and stems, which can be associated with scale insects.

- **Distorted or stunted growth**: this can indicate felted coccid, potentially proceeding to dieback and death of young trees. Felted coccid moves to new sites with budwood and nursery trees. Thoroughly inspect all plants for this pest, especially nursery stock as these are the main sources of new infestations. Limited dispersal occurs as the crawlers move to different parts of the plant and adjoining plants. Generally, natural predators can control felted coccid, but when introduced to new areas, populations often explode, with severe damage occurring before lady beetles, lacewings, and wasp parasites can effectively control them (especially where broad-spectrum pesticides are used). Where populations become too high, tree death is possible.

Refer to the *Macadamia plant protection guide* for more information on protecting your orchard from pests.

# Diseases

## Phytophthora

Phytophthora (*Phytophthora cinnamomi*) is the main disease affecting young trees' growth. It is less likely where adequate soil preparation occurs before planting and management supports healthy soil (Refer to the *Macadamia grower guide: nutrition and soil health – the foundations*). The disease can appear as yellow leaves and ooze sap (Figure 28) exuding from the trunk. Phytophthora is difficult to eradicate once present in the orchard. No single practice alone can control phytophthora disease.

Phytophthora management relies on:

- careful site selection for new orchards (refer to *Macadamia grower's guide: new orchards*).
- a strategic plan for good soil and tree health management (refer to *Soil health and nutrition modules*)
- ensuring nursery plants are clean before delivery
- ensuring new plants have a well-developed root system (refer to *Macadamia grower's guide: new orchards*)
- regular monitoring
- well designed drainage throughout the orchard
- trunk applications of phosphoric acid, with a penetrant (for example, Pulse® Penetrant) after a hardened leaf flush (refer to *Macadamia plant protection guide*).

Figure 28. Ooze sap exuding from the trunk is a symptom of phytophthora disease.

## Botryosphaeria canker

Not often seen in young trees, this disease will find its way through low sap flow and injury to young plants. It is most likely where physical damage, such as from hail stones, has created an entry point for the disease. Avoid training young trees when wet, cool weather is persistent. The disease is also often associated with poor root development, so ensure the soil is healthy, well drained and within the correct pH range ($5.5–6.5_{Ca}$). Refer to *Macadamia grower's guide: nutrition and soil health – the next level* for more information on protecting trees from disease.

Botryosphaeria will often appear as a single branch dying back. Cut that branch back to below the dead area. If you see wedging, it is most likely to be Botryosphaeria. Keep cutting back the branch until there is no wedging (Figure 29). Destroy material that has wedging. New growth should extend from the clean-cut areas. Ensure that soil health has been enhanced to support this new growth.

Figure 29. Brown wedging on a trunk cross-section is a clear sign of Botryosphaeria canker. This tree is beyond help and requires replacement.

## Remove weak trees

An important way to increase the average performance of young trees is to remove and replace weak trees. A weak tree is one you wonder about pulling out because it looks sick: the answer is yes, pull it out. Plant a replacement tree; the sooner, the better for uniformity.

**Phytophthora works from the ground up.**
**Botryosphaeria works from the top down.**
**Both are influenced strongly by soil health and tree health.**

# Nutrition and soil health

## Applying nutrients

Provided soil amendments are applied before planting, fertiliser is usually unnecessary for the first few months after planting with pre-plant nutrient applications (refer to *Macadamia grower's guide: new orchards*). Wait until after trees have put on new growth, which has hardened, darkening to a mature leaf colour (Figure 30). Then, apply small amounts of nutrients every couple of months during the growing season (from spring to autumn).

Figure 30. New flush (light green) and hardened flush (dark green).

Apply approximately 50 g of a mixed fertiliser per tree during years 1 and 2 (after planting) every couple of months through the growing season. Use a fertiliser with a nitrogen:phosphorous:potassium (N:P:K) ratio of 15:4:11 (plus micronutrients) or similar quantities of nutrients from organic sources, which will be a larger volume of material per application. In years 3 and 4, increase the amount by about 40% to 70 g of fertiliser (or equivalent organic source) per application, per tree. Never apply large, single doses of nutrients as this increases the risk of nutrient losses, could reduce tree vigour, and, in severe cases, can kill trees.

Hand-spreading fertiliser is an excellent opportunity to assess tree health. Compound fertilisers can be more effective than blends at applying uniform nutrient levels to each tree. Keep the material 100 mm from the trunk to limit damage to the bark and vascular tissues.

If irrigation is available, water in well after each application of solid fertiliser. Fertigation is another option for applying some nutrients via the irrigation system. Nutrients are usually applied monthly or more frequently where the soil cation exchange capacity (CEC) is low.

Many growers apply pelleted poultry manure, blood and bone or similar organic fertilisers as well as inorganic fertilisers. In addition to contributing to nutrient resources, organic materials improve soil health, increase soil organic matter, and might increase the cation exchange capacity. Refer to *Macadamia grower's guide: nutrition and soil health, the foundations* for more details.

## Building organic matter

Orchards gain organic matter in 3 main ways:

1. applied as organic inputs such as composts, manures or mulches sourced from offsite
2. released into the soil by living plants as root exudates, where plants release sugars into the soil to feed microorganisms that boost nutrient availability in their root zone
3. cycling biomass within the orchard through pruning, chipping and mowing, and the turnover of root material in the soil.

Building soil organic matter, especially in the tree row, should be a priority in a young orchard. Some techniques to build organic matter are:

- applying compost to the tree rows (Figure 31)
- growing healthy plants, including cover crops, in the tree and inter-rows, and letting this grow to >300 mm before mowing
- throwing mown material from the inter-rows to the tree rows.

Figure 31. Applying compost to the tree row.

## Ground cover

In young orchards, light availability does not limit the growth of ground cover. Aim for living ground cover throughout the orchard to contribute to building organic matter, and protect the soil and drainage profile. Maintain a grassed or multi-species inter-row area and mulch the tree rows. While plenty of light is available within the tree row of young orchards, it is an excellent opportunity to plant multiple species of diverse ground cover that can:

- add to the soil organic matter
- have extensive root systems that aerate the soil
- produce flowers that encourage beneficial insects
- contribute to the nitrogen levels in the soil with legumes
- protect soil from erosion.

Newly planted trees compete poorly with other plants for water and nutrients. Minimise the presence of other plants within 500 mm of the trunk until the trees are well established and have pushed several new flushes. Low ground cover plants or non-living ground cover, such as compost, near the trunk will benefit established trees.

Mulch suppresses weeds, reduces soil moisture loss, maintains a more even soil temperature and improves soil structure. Grow mulch materials in the inter-row area to cut, throw, or rake to the tree rows. Let the inter-row cover grow to at least 300 mm high before cutting to provide a reasonable volume of mulch for spreading. Additional mulches such as coarse straw, sugar cane mulch, composted nut husk, and chicken or cow manure can be placed along the tree rows. Extend the mulched area to just beyond the edge of the leaf canopy at 50–100 mm deep.

Control weeds that grow through the mulch. There are many approaches to weed control. When using herbicides to control weeds, ensure the chemical does not contact any part of the tree (Figure 32), including the trunk. Remove all leaves below the

graft or bud union before spraying, and use flat fan, coarse droplet jet nozzles and a spray hood to reduce herbicide drift. Trunk wrappings for frost protection double as protection against herbicide contact.

Only use registered herbicides. There are herbicide options for different situations. Pre-emergent herbicides are not widely used in macadamia because they only work where the soil is bare, undisturbed and free of weeds, mulch and debris. Bare soil is undesirable in the orchard, while mulch, living plants, and organic debris enhance soil health.

Post-emergent herbicides include:

- **Non-selective knockdown herbicides** are the most commonly used in the macadamia industry. These perform best when applied to young, actively growing weeds but can harm macadamia trees. Young trees are very vulnerable to damage from any contact with non-selective herbicides.
- **Selective grass herbicides** can be useful where there is a dominant weed species or unwanted grass.

Systemic herbicides that plants mobilise throughout their tissues are more hazardous to young trees than non or partially systemic herbicides that mainly affect the part of the plant contacted.

Do not cultivate within at least 1 m of the edge of the leaf canopy. Be very careful using brush-cutters because of the risk of damage to the trunk. Frost-protection trunk wrapping (Figure 33) can provide some protection from wayward whipper-snipper lines.

Figure 32. Herbicide damage to a young tree.

Figure 33. Young trees protected by tree guards.

# Watering

Trees need water to survive and grow. Water stress suppresses growth. Rainfall meets some of the trees' water needs. Watering to supplement rainfall is usually essential when establishing new plantings.

An irrigation program aims to supply the trees' immediate needs and maintain soil moisture above a desirable minimum without overwatering. The critical decisions are how much and how often to water. The aim is to keep the area around the root ball moist but not saturated. Water stress, from too little or too much water, slows tree development. Overwatering also increases disease problems and nutrient losses.

## How much

Irrigation systems are not usually perfect, and the performance of most systems declines over time. Attention to performance, troubleshooting issues as they emerge, cleaning lines and timely renewal of components are ongoing tasks for any system.

Factors that can contribute to irrigation inefficiency include:

1. leaks
2. low or uneven water pressure
3. blocked emitters of sprinklers or drippers
4. evaporation
5. surface run-off
6. deep drainage to below the root zone.

To compensate for inefficiencies in the irrigation system, apply more water than the minimum amount the tree should need. How much extra to apply is highly variable. In practice, this means monitoring trees and soil for signs of under and overwatering and using that information to refine the irrigation plan.

In the first year after planting, trees need moisture close to the trunk because root systems take time to grow out of the planting zone. Where long-term irrigation is not planned, growers should cart water (Figure 34) to the young macadamia plants in dry times. This practice might continue up to 6 months after the planting to the wet season.

Figure 34. A water cart is essential for keeping the new trees' root balls moist for the first few months of establishment.

Irrigation systems use drippers or sprinklers in the micro-spray (or restricted) mode. How much water to apply in an irrigation cycle depends on starting moisture, infiltration and movement of water through the soil profile. Surface run-off is an inefficient use of water that can cause soil erosion and nutrient losses in some areas and boggy areas elsewhere. Deep drainage is also inefficient as it removes nutrients from the root zone. Try to stop irrigation cycles as soon as surface run-off or deep drainage occurs and use as many irrigation cycles as needed to apply the total volume.

As the trees grow, apply water to a larger area extending further from the tree. For example, in years 2–5, convert to mini-sprinklers or add extra dripper lines to water as much of the root area as possible (Figure 35). This might result in using longer, less frequent watering cycles. Soils with high organic matter retain more moisture after irrigation, which also helps extend the time between irrigating. Build up organic matter by applying compost and throwing mown material from the inter-rows to the tree rows.

Figure 35. Mini-sprinkler (left) and dripper (right). Photos: Chris Fuller, Nutworks.

### Monitoring soil moisture

Understand the soil's water infiltration and drainage rates and the needs of your cultivars. Consider installing soil moisture monitoring meters to measure moisture within the soil. There are many options with varying levels of complexity and reliability. The goal is to have a system that informs how often to water (the frequency) and how long to water for (the duration). For young trees, the main objective is to prevent the root ball from drying out. Soil moisture monitoring systems can be very useful, especially with irrigation systems. Refer to *Bearing trees* for more details on the options for monitoring systems that can help optimise irrigation.

## How often

Watering frequency depends on the supply capability of the irrigation system, soil type, temperature, evaporation and tree size. Growers might have to water every 3 days for the first few months and then weekly for up to 6 months after planting. Drier weather conditions will influence the required watering frequency as trees grow.

## Troubleshooting irrigation

No matter how much care and expense has gone into the design and installation of an irrigation system, expect problems to emerge. The main issues to look for and correct are underwatering (Table 1), overwatering (Table 2) and water quality (Table 3).

Table 1. Why are some trees not getting enough water and what to do.

| Check for: | Strategy to resolve: |
|---|---|
| Blocked, non-operational or restricted emitters. Inspect emitters during the irrigation cycle and look for trees growing slower than their neighbours. | • Clear, fix or replace emitters.<br>• Flush the system (lines and filters) regularly to reduce blockages.<br>• Check the actual solubility of all fertigation products in your water. |
| Leaks: look for extra green areas of ground cover. | Find and fix leaks. |
| Water pressure problems: pressures that are too low can lead to the upper parts of the block receiving less than the planned water quantity in the irrigation cycle, and pressures that are too high can burst or damage fittings, reducing the evenness of watering. | • Investigate and resolve the cause. Schedule regular service and maintenance programs for the irrigation system.<br>• Flush the system (lines and filters) regularly to reduce blockages (Figure 36). |
| Is irrigation water draining through to below the root zone? Look for water coming through subsurface drains after irrigation cycles or monitor soil moisture to 1 m deep. | Use shorter duration, possibly less frequent, irrigation cycles. |

Table 2. Why do some trees get too much water and what to do.

| Check for: | Strategy to resolve: |
|---|---|
| Missing or damaged emitters. | Fix or replace emitters. |
| Delivery rates exceeding infiltration capacity, leading to surface run-off and water pooling in some parts of the block. | Shorter irrigation cycles or lower water delivery rates. |
| Soil that remains saturated long after the irrigation cycle finishes. | Investigate drainage issues, considering the position in the landscape, run-on, subsurface flows, and impaired drainage. Solutions might include watering less, changing the irrigation block layout and subsurface drainage. |

Table 3. Water quality issues, what to look for and strategies to resolve.

| Check for: | Strategy to resolve: |
|---|---|
| Leaf margins burnt and scalded ground cover plants near emitters. | Check the water electrical conductivity (EC) and ensure it is below 1,000 micro-siemens. |
| Discoloured leaves. | Check the water pH and ensure it is between 5.5 and 6.5. |

Figure 36.  Flush the system (lines and filters) regularly to reduce blockages.

# Fix weak links in orchard operations

Towards the end of IOM stage 1, usually 3 to 4 years after planting, is a strategic time to correct any emerging issues in the orchard system before peak production demands arrive.

## Access

Access issues that cause delays in orchard operations become more painful as production increases. Check for damaged roadways and prioritise fixing concentrated surface water flows on track surfaces and persistently wet areas. Minimise traffic on the orchard in wet weather, as driving on wet tracks is a leading cause of damage. Committing to the annual maintenance of access roads helps manage the workload and spreads out the ongoing costs. If the intention is to have pollination services once the orchard transitions to IOM stage 2, have access tracks around the orchard perimeter to allow for even distribution of hives at the appropriate stocking rate, typically 4–6 hives per hectare.

## Water supply

Review the irrigation system's efficiency:

- Are pumps and delivery lines supplying enough water to deliver the scheduled irrigation reliably? Does anything need upgrading?
- How much labour is going into running and maintaining the irrigation system? Is it excessive? How is staff time spread across tasks, and what can be simplified?
- Is tree performance consistent, or are some areas doing better than others? Is this related to irrigation, and if so, how can it be improved?

The performance of most irrigation systems degrades with age. This decline is slowed by adequate maintenance and relieved by appropriate upgrades to components. Both actions are most useful when informed by monitoring that identifies problem areas as they arise.

Flushing lines, mainly where there is potential for the build-up of calcium deposits, is essential to keep the system working as intended. Flushing lines might be required as often as monthly in highly calcareous water sources. Regularly checking sprinkler output is also important. Monitor water quality, ensuring electrical conductivity (EC) is below 1,000 mS and $pH_{Ca}$ is between 5.5 and 6.5, as this affects nutrient availability and the performance of some pest treatments.

## Drainage

As trees grow, there will be more:

- shading of the orchard floor that reduces the vigour of living ground cover, especially in the tree rows
- branches funnelling stem flow (concentrated water running down the trunks of trees)
- soil movement in heavy rain, with some areas filling with sediment while others, especially on steeper slopes, lose topsoil.

Monitoring and maintaining drainage infrastructure and slope-specific ground cover should be a priority as trees reach a size where shading becomes significant. Early pruning in response to declining living ground cover ensures that pruning needs remain moderate, manageable, and beneficial for tree productivity. Waiting until after living ground cover dies will mean recovery requires more intense pruning that can reduce short-term yields.

## Equipment and buildings

Service equipment as required. Calibrate sprayers annually because poor spray coverage is costly in crop quality when unresolved, and it is one of the most straightforward issues to resolve.

Review the capacity for harvest handling and the potential need to store nuts on-farm.

## The team

Running a successful farm and team requires clear and open communication. Task delegation is a vital component. Elaborating on the plans and expected productivity should motivate the team to succeed and can empower individual team members.

Identifying the qualities of each employee helps with delegating tasks. While some workers might be excellent at irrigation maintenance and operations, it is sometimes helpful to allow them to experience other areas of the farm, preventing complacency and potential boredom.

Smaller farm operations might only bring in casual staff at peak times. Ideally, keep the same casual staff over time as they will get to know the farm and its operations. Changing staff frequently might result in a lot of time spent training the new employees.

Encouraging long-term employees to complete courses for their career development, such as irrigation courses and Certificate 3 in horticulture, might inspire them to engage more enthusiastically and skilfully with farm operations and be interested in the business's outcomes.

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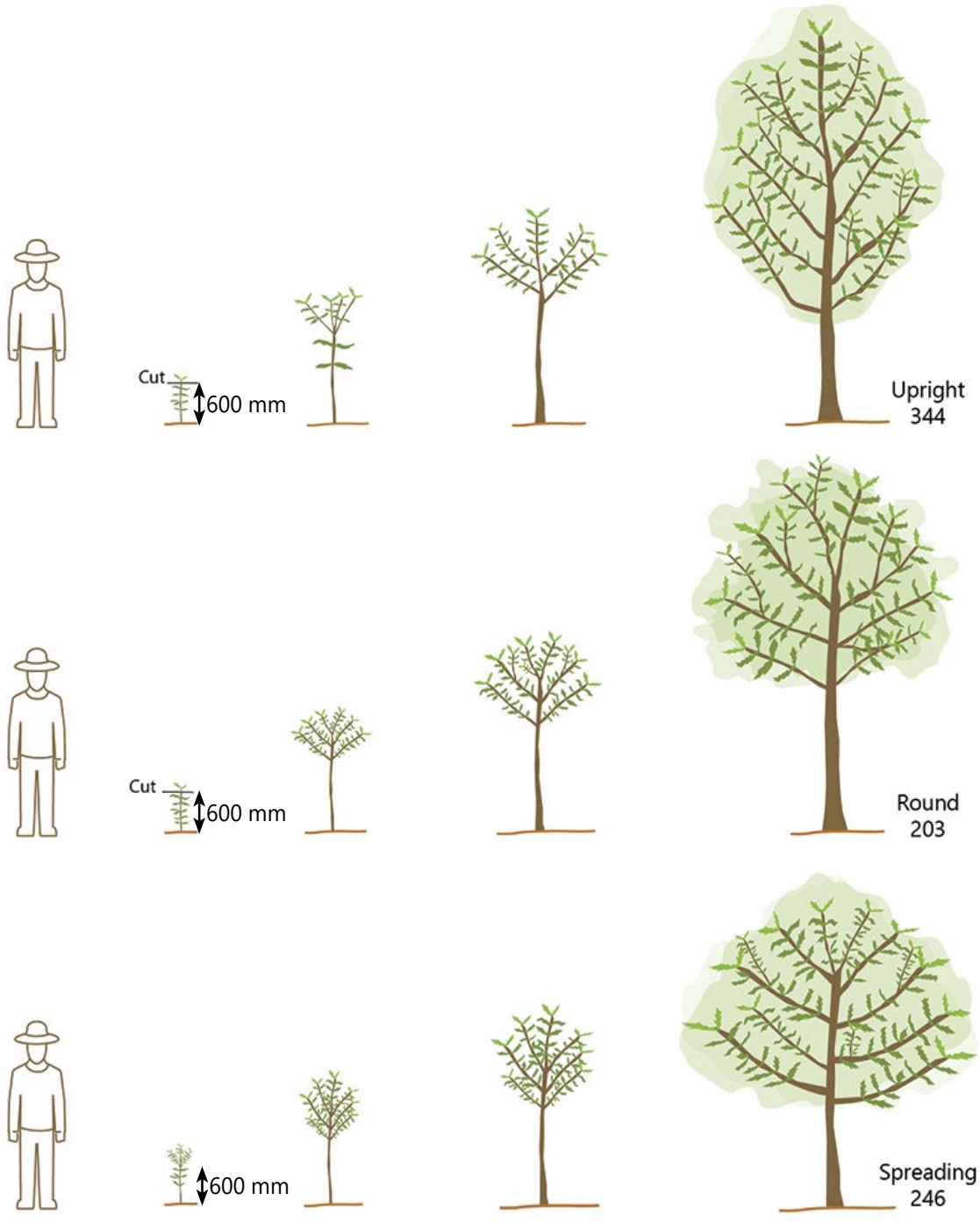


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