Site Preparation and Planting

Edition:
Dr. Alvaro Vidiella, NZ Avocado

Collaborators:
Jerome Hardy, Primor Produce Ltd.
Dr. Henry Pak, NZ Avocado
Glenys Parton, NZ Avocado
Colin Partridge, Southern Produce Ltd.
Geoff Thorp, Riversun Nursery
Stephen Wade, Lynwood Avocado Nursery

Reviewers:
Roger Barber, Whangarei grower
Dr. Theo Bekker, Westfalia Technological Services, South Africa
Sue Culham, Whangarei grower
Rob Freeman, Far North grower
Dr. Anton Hough, Schagen Nursery, South Africa
Dr. Jan M. van Niekerk, Westfalia Technological Services, South Africa

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1 INTRODUCTION

This document is intended to be used as a guideline when planting avocado trees in order to establish a healthy productive orchard in New Zealand conditions. This update contains technical guidelines to plant avocado trees in order to establish a healthy productive orchard in New Zealand conditions. This document should be used alongside advice and assistance sought from people with knowledge and local experience in orchard planting and in managing avocado trees. Many of the decisions made at planting will impact significantly on the success of the orchard in the future. We encourage you to seek assistance from consultants, nurserymen and experienced local growers to assist with the decision making process you must go through from the moment you decide to plant trees until the trees go into production.

Mainly local practice and literature have been reviewed and summarized in this document. Some international sources have also been reviewed to complement some subjects. The document has been reviewed by a variety of experts who have contributed to make it a better document. This is a live document, and as such your feedback, comments, corrections, new sources of information are encouraged and appreciated. Please contact us and we will consider your suggestion in as soon as is practicable.

The document focuses mainly on how to prepare the soil and how to plant the trees. It also addresses, to some extent, how to care for the trees while they are young. Matters including site selection, irrigation system design, and installation and establishment of block perimeter shelter are dealt with in the corresponding chapters of the New Zealand Avocado Growers’ Manual.

2 PLANTING TIME

The main factors that must be considered when deciding which is the best time of the year to plant avocado trees are:

- Their roots are particularly sensitive to wet conditions.
- They grow better in warm temperatures.
- They are particularly susceptible to frost damage.

Plantsing in autumn: in areas that are not frost prone, planting in early autumn results in a tree with its root system already partially established by the following spring. This means the plant will benefit from the first favourable conditions in spring, potentially resulting in extra growth that season. These plants must be well protected against even light frosts and the soil must be well aerated through the winter for the plants to develop adequately. It should be noted that the problem with planting at this time of the year is that these plants will not like the cold winter air temperatures and the cold and wet soils.

Plantsing in spring: in frost prone areas, planting in spring allows the plants to reach the following winter in the most favourable condition to withstand frost. However, the earlier the plants are planted in the spring, the more the plants will need to be protected against cold temperatures that first spring. As the root system would not have developed outside the potting medium shortly after planting, soil moisture control will be crucial. This relates to both, excess water as well as lack of water. Remember that more trees die of excess watering than of lack of water.

Plantsing in summer: Planting in summer provides avocado plants with relatively high temperatures in the soil which their roots enjoy. However, due to the presence of a weak root system and high evapotranspiration conditions, soil moisture control will be crucial in these conditions as well.

3 PREPARING THE SOIL

The soil that receives the plants has to be in the best possible condition. Trying to improve the conditions of the soil once the plants are established is much more expensive or may even be unviable.
The most important things to consider before planting are soil structure and drainage. Both of these characteristics have to do with allowing the roots to receive as much air as possible. Avocado roots are particularly sensitive to hypoxia (reduced aeration), making it very difficult to grow avocado plants successfully in soils with heavy texture, compacted, or that suffer from waterlogging.

The block intended for planting must be inspected carefully for wet spots. Any sign of waterlogging, such as areas where grass is not growing well or the flora is different, must be detected. Slopes are not necessarily well drained, internal drainage may reach the surface at a determined height and water can run there until the hill on top is totally drained (Figure 1). The bottom of slopes is usually wetter due to the accumulation of runoff and subterranean water (Figure 2). On top of this, clay tends to accumulate at the bottom of the slopes, so some of the soils in these areas are usually heavier.

Figure 1. Slope profile of an Avocado block, the graph below corresponds to the slope profile of the yellow line on the picture. Trees have suffered from tree decline in that area where the soil is expected to be wetter for a longer period of time than uphill.
Water logging leads to time periods where trees are deprived of oxygen in the soil (leading to hypoxia) and also assists spores of avocado root rot to move through the soil profile. Check this video to understand better why Phytophthora spore movement is favoured by waterlogging http://www.youtube.com/watch?v=hsdYr5gR4Ag. Avocado roots under waterlogging conditions are more susceptible to root rot infection and the ethylene they as a sign of stress is used as an attractant by these spores.

Another important characteristic to be considered is the availability of nutrients in the soil. In many cases it will be necessary to amend and fertilize the soil to ensure the plant has access to the nutrients it needs for its development.

Therefore, to adequately prepare the soil to receive the avocado plants in the best possible way, it is important that a comprehensive soil assessment and an appropriate soil improvement plan are carried out by an expert.

3.1 Soil assessment

The main objective of soil assessments is to determine whether any of the soil characteristics will hinder tree development. Those characteristics are mainly related to:

- The potential for hypoxia (reduced aeration) of the soil. Hypoxia is favoured by:
  - Heavy soil texture
  - Compact soil structure
  - Low drainage capacity
  - Water table not deep enough and raising periodically into the root zone
  - Shallow underground watercourses that run through the area

- The availability of plant nutrients

The assessment should be done on the entire block and usually holes are dug at regular intervals or in specific locations to determine the variation of the soil’s main characteristics.

Below are some guidelines that can help to understand a particular soil and how you to deal with it. However, professional advice will usually be required on how to do a proper soil assessment and on the actions needed to optimize the performance of the trees.
3.2 Working on soil structure

Soil structure refers to how soil particles gather into aggregates (clods). This determines the porosity of the soil, which refers to the size and distribution of air spaces in the soil. The best structure is thought to be a granular structure where clods of different sizes are separated by numerous spaces full of air, allowing for good root aeration. The most unfavourable structure is referred to as a massive structure, where the whole soil is one single clod, with very little air spaces in it. Another common type of structure is a grained structure, where the soil particles (usually large particles, mainly sand grains in sandy soils) are loose, not united into aggregates.

The main factors that determine the soil structure are:

- **He texture** (the size distribution of its particles, i.e., the proportion of sand, silt and clay particles. For more practical information about soil texture visit ftp://ftp.fao.org/fi/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e06.htm).
- The amount of organic matter.
- The chemical composition.
- The history of compaction.

In general simplified terms it can be said that:

- Small particle size soils (usually referred to as heavy soils) tend to have a less aerated soil structures.
- Large particle size soils tend to have grained structures that may lead to poorly aerated soils.
- High organic matter content usually leads to a more aerated soil.
- Relatively high proportions of iron and aluminium oxides or sodium ions lead to massive soil structure, with poor aeration.
- A soil that has been compacted by machinery (typical of a replant situation) is usually a poorly aerated soil (Figure 3).

Figure 3. Soil largely compacted after pan breaking with large excavators.
It is important to do a complete assessment of the physical and chemical characteristics of the soil by an expert regarding all these factors before planting since there are certain tools that, depending on the situation, can be used to improve the characteristics of the soil structure. These include:

- Deep ripping.
- Cultivating to different extents.
- Mixing of horizons with different characteristics.
- Amending the soil with organic matter, gypsum or lime.

Again, undertaking any of the above activities after planting the trees is more expensive than doing it before the trees have been planted and in some cases it may even be impossible to carry out once the trees have been planted.

Sometimes, the structure of the soil will be optimal and no work will be needed to improve it. The trees can be planted directly in these soils by just digging the holes.

Special care must be taken in contoured areas. The soil in these areas is usually quite compact and the layers of the soil have usually been altered dramatically. Some contoured soils require substantial work on their structure before they can be planted.

![Image of contoured area](image)

Figure 4. Arrow shows a contoured area where the trees have struggled.

Soil structure is vital for successful avocado production so it is recommended that before planting an assessment of the structure of the soil is carried out by an expert. Related to soil structure is the bulk density of the soil that can be determined in the lab.
3.3 Working on drainage

The amount of air in the soil will not only depend on the structure of the soil, that is on the size and distribution of spaces in the soil, it will also depend on the proportion of those spaces that are filled with water. In a waterlogged soil, a soil saturated with water, all the spaces in the soil are full of water and there is hardly any air for the roots.

The most common cases of waterlog prone soils are:

- **Heavy soils**: (small particle size soils, with a high proportion of clay and silt size particles). These soils contain small spaces that tend to retain high amounts of water. The water in these soils does not run off them easily, so a high proportion of their spaces remains full of water for a long time resulting in very little air being available to the roots.

- **Impermeable subterranean soil layer (clay rich layers, pans, etc.)**: If there is a relatively impermeable subterranean soil layer, water will accumulate on top of it resulting in a poorly aerated soil. These relatively impermeable layers can be formed by accumulation of clay in a layer, or by compaction due to accumulation of substances such as iron oxides, among other causes.

- **Surface or subterranean running water**: There may be a flow of rain or irrigation water from other areas into the soil, causing the water table of the soil to rise, reaching the root zone. Soil located in a drainage route can remain saturated due to receiving large amounts of water flowing from its vicinities for a relatively long time.

The drainage of a soil can be improved in several ways. The most common examples of improving drainage are:

- The construction of artificial drainage networks. (see video of laser drencher ) http://www.youtube.com/watch?v=iVWLG8LYtEQ&feature=share&list=PL553BB72B6DB148CB

- Breaking the continuity of the subterranean impermeable horizons (pan breaking) (Figure 6).
• Deep ripping of the soil to depths of 0.5 to 1.5 m (Figure 7).
  o Ripping should not be done when soil is wet as the ripper tine goes through the wet soil like butter and does not shatter the soil as intended. Drier soils shatter better.
  o It is usually recommended to rip first in one direction, separating passes about 1m from each other and then to cross rip again at an angle of less than 60 degrees to the original rip direction. Ripping should be directed towards the main drainage system of the block.
  o Then the soil should be evened by cultivation. This also helps reduce compaction of the top soil by the heavy machinery used during ripping. Cultivation following the maximum slope of the block should be avoided to reduce erosion.
• Planting the avocado trees on top of humps or ridges created by accumulating the top soil in the planting rows. Some consultants consider that planting on mounds or ridges should be strongly considered in any areas where soils have a high clay content (volcanic soil can have a high clay content). In particular, South Auckland, Mangawhai, Maungatapere, and Kerikeri.

Figure 6. Pan breaking in the Far North.
Some of the above activities are carried out with heavy machinery (e.g., a 25 tonne excavator). This machinery will most likely compact the top soil where they have driven on. As a result, in many instances it is extremely important that the top soil is cultivated to achieve an adequate structure after the heavy machinery has finished.

Once the soil has been prepared it is usually necessary to wait for some weeks until it settles properly. This is especially important when humps have been prepared.

Excess rain runoff from hard surfaces or water traps, e.g., roofs, sheds, or blocks of bush, etc., must be channeled away from any plantings. Tree decline can happen even on good soils because runoff from the areas mentioned above can saturate the soil in some areas of the orchard for long enough.

3.4 Working on fertility

Soil nutrient deficiencies can normally be remedied by fertilization after the trees have been planted. However, soil preparation before planting provides an opportunity to remedy obvious deficiencies and, where necessary, to incorporate nutrients (particularly phosphorus) at depths which are not easy to reach once the trees are planted.
Soil nutrient levels recommended for an avocado planting are:

- Phosphorus (Olsen): >25
- Potassium: > 0.6 to 0.8 me/100g
- Magnesium: 1.5 to 3.0 me/100g
- Calcium: >10-15 me/100g

Seek advice from an expert to fertilize or apply the amendments necessary to optimize the fertility of the soil.

4 DIGGING THE HOLE

Once the soil is ready to receive the trees the holes can be dug.

As a general rule, the holes need to be slightly deeper and wider than the tree bag.

The hole can be dug manually with a shovel or mechanically with an excavator or auger (Figure 9).

![Figure 9. Hole digging with an auger.](image)

The walls of the holes must be checked before planting for compacted walls that would hinder the development of the roots. This is particularly important when the holes have been dug with an auger. The border of the rotating auger in many cases compresses the walls of the hole leaving a compact layer of soil around it. These compacted walls must be broken with a spade or similar tool before planting. Some nurserymen recommend that holes be dug with spade to avoid this problem.

If the soil is particularly poor, little amounts of fertilizer (only slow or controlled release fertilizer and never more than a small handful) can be placed in the hole of the tree by mixing the fertilizer with the soil that came out of the hole and using that to fill the spaces between the tree hole and the potting mix.

Organic matter can also be added to the soil used to fill in the hole, in the same way as the fertilizer mentioned above. Whatever organic matter is added it must be mature. In case of only fresh organic matter being available, it must be added weeks in advance of planting the trees. This is due to the roots of the avocado tree being very sensitive to high concentrations of salts in the soil solution: and fresh manure and other sources of organic matter usually have high concentrations of salts. The concentration of salts in fresh manure decreases gradually after it is exposed to the air or after it is washed through by rain or irrigation water.

If the hole is not dug immediately before planting, its walls will be drier than the rest of the soil and extra care must be taken so that the roots of the tree don’t suffer from desiccation during early establishment.
5 HANDLING THE TREE BEFORE PLANTING

5.1 Tree reception from nursery

As soon as possible after tree reception from the nursery the trees must be thoroughly inspected to check the following physical aspects:

5.1.1 Root system

Upon plant reception from the nursery partially open some tree bags to inspect the roots of the trees. Try not to damage or destroy the bag on doing this as you will need the bag to do its job until planting time. Packing tape or duct tape can be used to restore the bags if necessary (Figure 10). The roots of the rest of the trees should be inspected during planting. The roots should be checked for the following:

- Root distribution should be uniform from top to bottom in bag.
- Root system well branched, coming from the entire perimeter of the axis and without signs of J-rooting or of being root bound.
- Root system must be healthy, with a high proportion of white growing tips.

![Figure 10](image_url). Tree reception from the nursery and root inspection (photo on the left Les Blagrove). A: Healthy root system. B: Healthy but root bound root system at the bottom of the bag, possibly overwintered in nursery or kept for some reason. Some nurserymen recommend cutting bottom 20 mm-30 mm of root ball before planting. C: Root system with a high proportion of dead roots.

5.1.2 Main stem

- The main stem should be formed to a straight central leader adequately staked.
- The graft union must be smooth and healthy looking.
- It is generally recommended that the graft union must be at least 15 cm from soil surface to avoid infection by rotting fungi, and not higher than 35 cm.
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- The stem diameter at soil surface must be at least 10 mm.
- Branching should commence at least 30 cm from the soil surface
- The tree should be 60 to 150 cm in height from soil surface

5.1.3 Leaves

- The leaves should be glossy, green, without any deformity or discoloration or signs of malnutrition (Figure 11).

5.1.4 Pests and diseases

- Trees must be free from obvious symptoms of pest, disease or of any other disorder. Special care must be taken to detect the following:
  - Tree decline symptoms: lack of active growth, light green or yellow leaves, and defoliation.
  - Six Spotted Mite:
    - Symptoms: yellowish leaves with characteristic brownish colour of the leaf tissues on the bottom of the leaf along the main veins, and defoliation (Figure 12).
    - Presence of Six Spotted Mites mainly at the bottom of the leaf close to the main veins.

Figure 11. Healthy plants before delivery.
5.2 Transporting the trees

Trees must be transported in a closed vehicle to avoid damage by the wind and the sun.
Trees should always be picked by the bags and never by the trunk.

5.3 Tree storage

Avoid storing the trees for too long before planting them. If you think you won’t be able to plant the trees immediately after receiving them, consult with the nursery about the possibility of keeping them in their facilities until you are ready. The nursery is in most cases the best place where those trees can be kept before planting.
If you must store the trees until they are planted you must try to:

- Store them keeping them upright
- Store them on a surface where no water will accumulate, remember that avocado roots cannot be under water, they need air to be able to survive. Many of the roots will be at the base of the bag so you must avoid any surface where any amount of water can accumulate, keeping the roots under water for even short times.
- These trees will also be sensitive to desiccation. You must be very careful to keep them well watered. The potting mix that nurseries use is generally very porous and will dry in a very short period of time. When you water them, you must make sure that all the potting mix has been wetted. It is very important that you spend as much time as you need to ensure that you have completely wetted the potting mix. Hand watering with a garden hose is generally much better than using overhead watering. With overhead watering, water tends to get deflected away from the bag by the leaves, and the bag edges can bend inwards preventing water to enter the bag. You must check the moisture of the potting mix and repeat the watering as soon as you detect signs of desiccation. As long as no water accumulates on the surface where the bags are deposited, the potting mix of the bags will be aerated well enough so it is unlikely (but possible) that excess irrigation in this case will cause decline. Unlike as when the trees are already planted, during storage many more trees die of lack of water than of excess of water.
- The trees can also be sensitive to sunburn. This will happen if the trees are exposed to extreme sunlight not being used to it, so keep the trees out of direct sunlight. Nurseries usually harden off the trees by gradually exposing them to sunlight before they deliver them. However, it is always better to put the trees in a place where they will be protected from direct sunlight at least during the central hours of the day. If you don’t have proper shelter for the trees, consult with the nursery to ensure that your trees are properly hardened off before delivery. Consider also that planting bags can become very hot if exposed to the sun killing the roots in contact with it. Some nurseries have started to use white bags to reduce this problem.
- These trees will also be sensitive to wind so it is a good idea to shelter them from wind as well until they are planted.

6 PREPARING TREES AND HOLES FOR PLANTING

6.1 Wetting the potting mix

The potting mix must be holding as much water as possible when the trees are planted. The best way to achieve this is to immerse the whole tree into water until no more bubbles raise from the potting mix to the surface (Figure 14).
Figure 14. Soaking the potting mix by immersing the entire bag in water (Photo Les Blagrove).

Phosphorous acid 40% can be added to the soaking solution at a rate of 25ml per litre (2.5 %) to protect the roots from root rots.

As is explained in section 8.1, it is important to note that it will be crucial that the soil around the tree is soaked as soon as possible after planting either by irrigating or by a rain event. This should always happen, and how fast this needs to happen after the trees have been planted will depend on how wet the potting mix is and on how wet the soil is when the trees are planted.

6.2 Preparing the planting hole

The area around the hole should be free from weeds. This can be achieved by hand weeding the area using or by using a herbicide in the weeks prior to planting. It is important that the correct herbicide should be used that will not have a negative effect on the avocado tree or persist in the soil for long periods of time.
The soil should not be too dry before planting. It will generally be easier to work with it if it is not too dry and the plants will appreciate the moist soil until they can be watered properly. It is generally recommended that the soil is watered a week before planting if the soil is too dry, though it is much more important that the soil is soaked after planting, regardless of how wet the soil is during planting, with a few exceptions.

If the hole has been prepared previously check that the soil on the walls of the hole is loose. It is important that no hard layer has formed on the surfaces of the hole that can potentially create a barrier for the roots to develop properly. If you notice that the walls of the hole have a layer, break it with a spade or similar tool.

Check that the hole is deep enough to contain the whole root area of the tree. It is important to take the extra time to deepen it if it is not deep enough.

Fertilizer must not be added directly into the hole. It is better to add the fertilizer mixed very well with the soil that will be used to refill the hole (remember, only slow or controlled release fertilizer and always in small quantities, never more than a very small handful).

Fresh manure must not be added directly in the hole at all. Mature (aged) organic matter can be mixed with the soil that will be used to refill the hole. The ratio of soil to mature organic matter should be lower than 1 part of organic matter to 5 parts of soil.

### 7 PLANTING THE TREE

Once the tree has been soaked and the hole prepared, the tree can be placed in the hole.

- Cut off the base of the bag and remove it.
• Cut along the side of the bag from the bottom to the top, without cutting the top end of it.
• Be careful not to cut into the potting mix and damage the roots.
• Place the tree in the hole.
• Turn it so that most of the leaves face north to shade the trunk as much as possible during the central hours of the day. (See further in the document about trunk painting).
• Finish cutting along the side of the bag and remove it taking care not to disturb or damage the roots.
• Check for signs of massive amounts of dead roots (dark brown roots, they are easily squeezed and the inside is also brown and watery). This is usually a sign of overwatering and in the worst case of fungal root rot infection (like Phytophthora cinnamomi). If there are large numbers of dead roots but overall the root system is active and the canopy looks healthy there is a chance that the tree will have no problems in the future, but at this point the best thing to do would be to consult with the nursery and an expert. If you finally decide to plant these trees, mark them with a proper permanent tag (like a cattle ear tag), identify them with a unique number or code and take as many photos as you can, keeping a record of the tree identity in the photo (a good idea is to take a photo of the tag before you take photos of the plant so you know that all the photos after the tag photo belong to that plant). This practice will help you follow the plant’s evolution.
• Check for any signs of root bounding or J roots. In such cases where you identify a tree that is root bound or suffering from J roots note it, take photos and consult with the nursery or an expert. If you decide to plant them, cut across the roots with a knife and eliminate j-roots or distorted roots with secateurs. Mark these trees (with a permanent tag as described before) and any other trees that suffered root damage. If you see any sign of drooping in the following hours, particularly in the morning or evening. Consult with the nursery or an expert. Again, take as many photos as you can to keep a record of what has happened to that tree.
• At this point check the height at which you want the tree to be planted. The top of the potting mix should protrude about 1 to 2 cm above the rim of the planting hole. This allows for later soil subsidence and ensures that the collar of the tree doesn’t end below the soil surface, with the possibility of water accumulating around it. It is important that water does not form a puddle around the collar of the tree because it is very sensitive to rots. For this reason soil or mulch must not come in contact with the collar of the tree. However, at the same time, do not expose more than 2 cm of the potting mix or you will end up drying the more superficial roots in the potting mix. Some consultants recommend that the trees are kept 4 to 8 cm above the ground level so that when the ground settles the tree neck is still protruding from the ground, especially when planting clonal rootstocks.
• Next gently fill the space between the potting mix and the hole with topsoil. Care must be taken at this point because avocado roots are very fragile. Being very brittle, the young avocado roots break easily. Incorporate the topsoil with care. You must ensure that you don’t leave major air spaces as roots won’t grow there.
• Once you have filled the hole, gently pat the soil with your hands to settle it firmly around the potting mix. Avoid stamping the soil firmly or with your feet. This will result in excessive compaction of the soil where the roots need to develop in the next weeks. Remember avocado roots like loose soil to grow into. In addition, when planting clonal rootstocks, stamping with your feet will put too much lateral pressure on the union of the roots with the main axis of the young trunk, potentially breaking that union.
Figure 16. A: Planting the young tree. Cut and remove the bottom. B and C: Cut along the side of the bag leaving a portion uncut at the top. D: Insert the tree in the hole. Check that the hole is deep enough. E: Completely cut the bag and remove it. F: deposit the plant in the hole. (Photos Westfalia)

Figure 17. Fill the hole around the plant gently tapping the soil with your hands.
8 SOIL MOISTURE (IRRIGATION)

Keeping the right amount of water in the soil for these young trees is not easy and is crucial. It is important to ensure that the trees don’t dry out and that they don’t get excess water. In both cases the result is that roots don’t absorb enough water and the symptoms of both extremes are therefore very similar, if not identical, the plant will wilt. Even if there is plenty of water in the soil, if the roots are dead because they have not had the right environment, the plant won’t be able to absorb enough water and will show the same symptoms as if the soil had no water.

It is a fact that more young avocado trees die of excess irrigation than of lack of moisture in the soil. Work carried out in New Zealand, California and Spain on the establishment of clonal trees (and particularly on Dusa) show that excess irrigation of newly planted trees has been a major cause of tree death in many orchards (Figure 18).

![California orchard showing trees on the left planted at the same time and in the same conditions as trees on the right but on different irrigation sectors. The trees on the left were overwatered for some time due to a deficiency in the irrigation system. The trees on the right were watered properly, according to the plan.](image)

8.1 The soil must be soaked immediately after planting

It is extremely important that the soil is soaked immediately or soon after planting.

The importance of this will be higher if:

- The potting mix was not adequately soaked at the time of planting.
- The soil was relatively dry at the time of planting.
- The planting holes are not dug immediately before planting.
- The weather expected for the following days is relatively dry, hot and sunny.
- The individual tree shelter is not in place.
- The trees are not mulched.
- The trees are on humps.
The potting mix will dry very fast and the roots will die if there is not enough water in the surrounding soil.

You must apply enough water to wet the surrounding soil to a distance of at least 40 to 50 cm from the potting mix. Once this volume of soil is wet you must stop the irrigation and allow for excess water to drain. This will happen in the next one to two days. Some days will pass until you need to irrigate again.

![Image](image-url)

**Figure 19.** The soil must be soaked as soon as possible after planting.

### 8.2 Soil moisture control after planting

At this stage, it is very important to make sure that the soil does not get too dry but it is also crucial to make sure that watering is not too frequent because the plants may die from excess water.

As a general rule, with avocados in our conditions it is better to do large infrequent irrigations (e.g., 50 litre per plant every 10 days) than small frequent irrigations (e.g., 5 litres per plant every 2 days). In theory, large infrequent irrigation will soak the soil that the roots will explore in the following months and that will be feeding moisture into the potting mix in the first days, but leave enough time between irrigation events to allow the soil to dry enough for the roots to receive the right amount of air.

Irrigation in the first weeks will probably be more frequent because most of the roots (all of them the first days) will be in the potting mix which can dry up very fast. As roots start to grow into the soil around the potting mix (which can happen as soon as 4 to 5 days after planting if soil temperatures are high), irrigation events can be less frequent.

It is at this point when any device you have to monitor soil moisture will play a crucial role.

It would be useful to put tensiometer stations across the planting. These tensiometer stations could consist of 1 to 3 tensiometers placed at different distances from the plant and at different depths. There is no real perfect design for this but a reasonable setup could be the following:

- Main station: 3 tensiometers (Figure 20).
- Tensiometer 1: in the potting mix about 3 cm from the exterior border (the side) of the potting mix and 10 to 15 cm deep.
- Tensiometer 2: 7 to 15 cm away from the potting mix at 10 to 20 cm deep, about midway the depth of the potting mix.
- Tensiometer 3: 7 to 15 cm away from the potting mix at 20 to 30 cm deep, at about the depth of the bottom of the potting mix.
- Secondary station: 1 or 2 tensiometers (Figure 21).
  - Tensiometer 1: 7 to 15 cm away from the potting mix at 10 to 20 cm deep, about midway the depth of the potting mix.
  - Optional: Tensiometer 2: 7 to 15 cm away from the potting mix at 20 to 30 cm deep, at about the depth of the bottom of the potting mix.
- Ideally there should be 2 main stations per block and 2 secondary stations per hectare. So in a 2 ha block you would place 2 main stations and 4 secondary stations. Distribute the stations homogenously in the block to try to capture all the diversity that you think may occur between areas that require more or less irrigation. The stations should be placed on trees that are of average size relative to all the trees that are planted.

![Main tensiometer station, with tensiometers at 10 cm from the potting mix and 15, 20 and 45 cm deep. Notice that the tensiometer that was originally placed in the potting mix had been moved to the soil since the roots had already grown into the adjacent soil.](image_url)
Unfortunately the use of these tensiometers is not very simple since there can be quite a bit of variation in their behaviour so you must follow these management guidelines with flexibility and with the help of someone with experience with tensiometers and new trees. After the first irrigation done immediately after planting which has soaked the soil, the tensiometers should read less than 10 kPa (notice that most tensiometers will never read below 5 or even 10 kPa). If this is not the case, the soil may not be wet enough or there could be something wrong with the tensiometers. Check that the tensiometers are properly installed (no air bubbles, etc. follow the set up instructions carefully). If the problem remains, remove the tensiometer and place it in a different place around the tree. Seek help from someone with some experience if you are unsure.

- As days go by, the tension of the tensiometer in the potting mix should raise faster than the tension of other two tensiometers. In the first days, water for the second time when at least one of the tensiometers in the potting mix reaches 25 to 30 kPa. All the tensiometers should read less than 10 kPa when the irrigation has finished. If the readings between the tensiometer stations are very different, something not uncommon, try to find out why those differences exist. It there are definitely different areas regarding soil types, wind exposure, drainage, etc., consider dividing the block into sub-blocks regarding irrigation needs. Remember again that more trees die from excess watering than from lack of watering.

- Monitor the growth of the roots out of the potting mix regularly by removing the layer of mulch and by digging 5 to 10 cm along the wall of the potting mix to see if the roots are exploring the soil around it. Once the roots have started to explore the soil around it (they are 10 to 20 cm into the soil) you can start irrigating when the tensiometers in the soil reach 25 to 40 kPa (Figure 22 and Figure 23).

One thing that must be noted is that some clonals tend to droop in the midday heat. This is generally normal and is not a sign of lack of moisture in the soil. Tree recovery in the evening or late afternoon, is an indication that the soil moisture is adequate. However, these observations must be backed up with tensiometer readings, and if you notice a discrepancy between observations and tensiometer readings, consult with an expert.
These management guidelines are based on research carried out in other countries and on New Zealand anecdotal experience and there is generally a high variability in the response of the tensiometers depending on the characteristics of the system plant-soil-tensiometer. Despite the high variability there is no doubt that the use of the tensiometer system will help make a better informed decision about when and how much to irrigate.

We can currently access other instruments to monitor soil moisture like capacitance probes. Hopefully some of the research work that NZ Avocado is currently planning will give us some more information about how we can manage soil moisture in different circumstances in New Zealand.
9 STAKING OR SUPPORTING THE TREE

When just planted it is important to avoid movement of the potting mix in relation to the surrounding soil. Avocado roots are very brittle and this movement would break the young roots delaying (or even preventing) the establishment of the roots in the surrounding soil.

Once the root system has developed in the soil, it is important that the trunk has some freedom to move since that movement will help the trunk to develop the strength needed to hold the canopy once the support is removed.

In the early planting and establishment phase a stake is usually used to hold the tree in place. Alternatively the tree can be tied to the 4 stakes that support the individual shelter (Figure 24).

If a stake is used, place it facing the prevailing winds so that the wind pushes the tree away from the stake and is not continually rubbing the tree against the stake. Rubbing will wound the trunk, hindering tree development. A common way of protecting the tree from rubbing the stake is to twist several times the tie material between the trunk and the stake. In addition, a rubber patch can be attached to the stake in the contact area with the trunk.

Clonal rootstocks have a different root system compared to seedling rootstocks. The root system of clonal rootstocks originates from adventitious roots that form horizontally from a young stem.
compared to a seedling where the root system is generally formed from a pivoting main root. This difference seems to influence the ability of the tree to establish a strong root system that will support stress from the canopy in windy conditions or under heavy crop loads (Figure 25 right). It is thought that clonal rootstocks have a disadvantage in this sense and therefore will need to be staked more firmly than seedling rootstocks, and may need a longer stake (upto 2.1 m) to remain staked for longer.

It has also been observed in some circumstances that the trunk of some trees on clonal rootstocks is too flexible, bending under stress from the canopy (Figure 25 left). This is has also been given as a reason to stake the clonal trees more firmly.

At this point remember to leave enough movement after some strong roots have developed into the surrounding soil to allow for the trunk to develop into a strong trunk. It is always important to leave some movement for the trunk to develop the fibres that will allow it to support the weight of the canopy once the stake has been removed, and probably also to develop the right amount and type of roots.

It is not difficult to girdle a trunk with ties. It is therefore important that the material used for the ties is relatively elastic to prevent girdling and that the material is degradable so that any forgotten ties (which is easier than what it seems) will rot before they girdle the trunk.

10 SHELTER

10.1 Lateral shelter

In New Zealand conditions it is common to put individual shelters around young avocado trees (Figure 26). Shelters are thought to provide a better microclimate for tree growth (specially providing frost protection), give protection from sunburn for the trunk of the young tree, and, if closed on all sides, provide protection from rabbits, hares or other browsing animals.
Individual shelters are usually constructed from 50 by 50 mm ground-treated battens forming a 1.25 m square with shade cloth on the four sides. This will allow adequate protection for one to two full growing seasons. The height of the battens should be 1.5 to 2.3 m long, which allows for 30 to 50 cm burial of the batten and 1.2 to 1.8 m height for the shelter. The structure can be stabilized with 25 by 25 mm square battens nailed to the tops.

The enclosure should reach the ground to prevent damage from rabbits, hares, possums or beetles. The shade cloth is usually stapled to the battens leaving one side open for access (Figure 27).

Individual shelters are usually established before the trees are planted so that the tree is protected from the first day it is in the orchard.
In some circumstances some growers prefer to use other types of protection (Figure 28).

Figure 28. Top left, centre and bottom: Different frost protection shelters. Top right: Protection against hares, rabbits and other animals.

10.2 Top shelter

Frost protection cloth, hessian or shelter cloth should be placed over the top of the shelter in the autumn immediately before frosts are expected (Figure 29).
The top of the individual shelters can be covered with frost cloth to protect from frost in winter and to protect from sunburn during the summer if the plants have not been properly hardened off in the nursery.

The top cloth can be placed in the form of a dome or a cap over the individual shelter. This can be done by fixing a 2.5 mm gauge wire diagonally across the top of the individual shelter. The ends of the wires are inserted into holes drilled into the tops of the posts. The frost cloth is usually stapled to the posts and the stabilizing battens.

10.3 Small hedges

Some growers have planted Bana grass (Pennisetum purpureum) as an ‘easy to grow’ shelter option (Figure 30). Bana grass grows well in areas north of Auckland and should be planted in the late spring/early summer the year before tree-planting. This plant needs warmth, water and fertiliser to grow and will only put on substantial growth in the summer months. The hedge formed by the Bana grass will provide very effective shelter 2-3 m high and can be planted every 2-3 tree rows. Stems laid in shallow moist trenches will shoot from the nodes. Once the trees have grown, Bana grass is easily controlled by mowing and applying glyphosate.
Figure 30. Newly established orchard with Bana grass hedge as shelter in Mangawhai. Left, early stages of the shelter. Right, well established 3 years old hedge.

11 SUNBURN

Sunburn to the trunks occurs when trunks not used to exposure to direct sunlight are exposed to direct sunlight. The live tissues of the trunk die and a wound is formed that can significantly hinder the development of the branches that are above the wounded area (Figure 31).

Sunburn is common in unhardened off young trees that are exposed to direct sunlight. Hardening off is usually started in the nursery by gradually exposing the trees to direct sunlight (Figure 32), but this process needs to finish in the field.
To avoid sunburn before planting, the trees must be kept in a shaded area and once planted they must have individual shelters around them.

If the trees will be exposed to the sun because no individual shelters have been built to protect them, tree trunks must be painted to avoid sunburn. A common painting formula is 50% diluted, white, acrylic, water soluble, outdoor paint. This solution can be easily applied with a knapsack sprayer. Some consultants recommend that the tree trunks should always be painted, and that it should be done systematically in the nursery, before delivery.
Figure 33. Young trees with painted trunks planted in California.

12 MULCHING

Mulch helps to suppress weeds, retain moisture and control soil temperature. Mulching simulates the litter of the rainforests where avocados evolved and is thought to provide an ideal environment for root growth.

The trees can be mulched with a coarse natural material such as cereal stubble, pine bark, peelings or chips to a depth of 10-15 cm immediately after planting (Figure 34). Pine bark can have an acidifying effect on the soil. Work done by Westfalia in South Africa has also shown wood chips (specifically avocado) is better than wood shavings.

The mulch should be kept 10 cm away from the trunk to avoid collar rot.

Some growers have found that mulching needs to be done on an annual basis for the first 3-4 years to keep the 10-15 cm mulch base spread to the drip line until the tree can “self-mulch” by its own leaves and pruned branches. The number of application will depend on the type of mulch used. For example when using pine bark (compared to pine shavings) it usually needs to be spread once a year until the trees are approximately 3-4 years old (or start producing enough of their own leaf litter to cover the roots to drip line). Original Hass trees tend to have their own skirts which will prevent the wind to blow away the mulch. Some growers leave these skirts until the trees are big enough to shelter each other.
WEEDING
Keep the area inside the individual shelter free of weeds by hand weeding and mulching. Herbicides are not recommended around the young trees inside the individual shelters at any stage.

Weeds on the outside of the cages can be carefully treated with non-residual herbicides (e.g., Glyphosate).

The working row can be mowed.

NUTRITION
Once the plant has been planted, it is important to implement a nutritional plan in which mainly nitrogen and any other element present at low rates in the soil is applied at the right rates and frequency as recommended for avocado trees.

Please refer to the section on nutrition in the grower’s manual for advice on fertilizer strategies for young trees and seek advice from an expert to design an appropriate fertilizer strategy.

An example of a successful young tree program as used by Westfalia:

- Foliar feeding (leaf sprays) with Nitrosol or a similar fertilizer for 1-2 months after planting until the roots have started to grow into the soil.
- Thereafter granular complex avocado specific granular fertilizers can be applied to the soil 40 cm around the stem, being careful to avoid contact with the stem.
- Continue with foliar feeding monthly with Nitrosol and Zinc (2 g Zinc oxide/litre of water).
• Boron (1 g Solubor per litre of water) should be applied every two months.
• Half the fertilizer in winter.
• Increase the quantity of fertiliser as the size of the trees increases.

15 FLOWERS AND FRUIT SET DURING THE FIRST SEASON

Some trees will flower intensely the first spring they are in the block. At this stage it is usually more important to induce vegetative growth than to produce fruit. It is therefore generally recommended to eliminate most of these flowers to avoid stress to the tree and to produce a bigger canopy to promote a larger yield the year after. If during flowering, the trees show considerable vegetative growth, flowers could be left on the tree. If in doubt, seek advice from someone with experience to make the decision.

Maluma has shown a certain tendency to “flower to death” the first season. It has flowered very intensely in several orchards in New Zealand in its first season. These trees have suffered intense defoliation after which they have recovered with a degree of difficulty. It is therefore highly recommended when dealing with young Maluma trees to remove most or all the flowers in the first season.

If trees set relatively heavily in their first season, they will definitely grow less and could suffer some stress than if they had no fruit. Alternatively leaving flowers on will result in some fruit to harvest (Figure 35). If in doubt as to whether it is better in your circumstances to remove the fruit, seek advice from someone experienced to make a decision.

Figure 35. Fruit on young tree. Notice the little vegetative growth.
16 PEST CONTROL

The most important pests that affect young trees are six spotted mites, grass grub beetles, Fullers rose weevil, and the bronze beetle. Cicadas can also cause significant damage to the stems of young trees. It is recommended that advice is sought to monitor new orchards and to implement control measures in the event a pest is detected.

17 CATTLE, DEER, HARES, POSSUMS, OR RABBITS.

Cattle or deer will quickly strip a young tree of its branches. No grazing should be allowed inside the block and it is important that the block is properly fenced from neighbouring pastures or bush.

Some areas are prone to damage by hares, possums or rabbits and the following protective measures should be taken:

- Ensure complete enclosure of the individual tree shelter at ground level.
- Apply a repellent dithiocarbamate spray, like Thiram, to the new tree.
- Apply poison pellets like Pindone distributed around the tree.
- A slurry of water plus fresh cow dung sloshed over trees with a big paint brush has been used to deter mammalian pests. Note that cows will not eat the tall grass growing out of a cowpat for a long time.
- Peg a wire mesh of about 50 cm diameter around the young tree trunk.

18 TREE DECLINE

Tree decline is one of the most important causes for hindered growth and death of young trees in New Zealand. If tree decline symptoms are detected, seek the advice of an expert. Tree decline is common in replant situations so some of the measures detailed in the following section about replant situations will probably need to be adopted.

The following scale can be used to assess young tree health (Figure 36):

0. EXCELLENT: Tree foliage dense and excellent colour of mature and young leaves.

2. VERY GOOD: Tree foliage with many young and mature leaves but less dense than in Excellent, and/or slightly pale leaves.

5. GOOD: Tree foliage with young healthy leaves but few mature remaining leaves.

7. POOR: Tree foliage with not very healthy looking young leaves and with very few to none mature remaining leaves.
9. VERY POOR: Tree foliage with very few or no young or mature leaves

10. DEAD TREE

The causes of tree decline are usually related to low soil aeration in the root zone. In most decline situations low soil aeration of the root zone is due to a combination of unsuitable soil structure, which reduces the amount of air in the soil, and excess amount of water for relatively long periods of time. These conditions reduce the health of the roots making them more susceptible to infection by root rot fungi like Phytophthora and Pythium.

19 REPLANT SITUATIONS

Special care must be taken when planting trees in sites previously planted with avocado trees. In most replant cases the original trees had most likely been removed because they were sick with clear decline symptoms (Figure 37). If this was the case and even if the cause of the decline of the trees has been dealt with (e.g., the drainage has been completely modified and there is certainty that the new drainage system will be more effective) all the possible measures that increase soil aeration and reduce the chances of root rots should be implemented.

![Figure 37. Sick orchard due to be replanted.](image)

19.1 Tolerant rootstocks

Internationally and in trials set in replant situations in New Zealand the tolerant rootstocks Dusa and Bounty appear to be performing significantly better compared to the most commonly used Zutano seedling rootstocks.

Horticultural evaluation of these rootstocks is still underway and it will be some time before we can say with certainty that they perform well enough on virgin soils or replant situations. Nevertheless, with the information we currently have, planting tolerant rootstocks seems the best option in replant situations after comparing the initial performance of these trees with the performance of Zutano seedlings in the trials set in New Zealand.
It is important to understand that these rootstocks are tolerant and not resistant to these conditions. This means they need to be helped in every possible way to perform to their highest potential. Hence the guidelines set out below should be followed carefully also when planting these tolerant rootstocks.

19.2 Soil preparation

Soil must be thoroughly prepared. Drainage and soil structure are many times critical in these situations (probably the original cause of tree decline in the first instance) and must be properly assessed and attended to prior to any planting (see the corresponding sections above).

One of the methods of increasing aeration of the top soil, widely practiced around the world, is by planting the trees on humps (Figure 38). This practice has been followed by several growers in New Zealand with relative success in pretty difficult soils and in combination with other measures (Figure 39, Figure 40).

Figure 38. Hump and hollowing in Chile.
The humps are formed by accumulating the top soil originally found in between the tree rows on the area that will form the tree rows. This is usually done using a plow attached to a tractor or with an excavator. The humps usually reach up 30 to 60 cm from the bottom of the hollow. The increase in aeration in the hump is significant and is thought to have a major influence on the avoidance of tree decline symptoms.

For some time after being formed, humps are very easily eroded. Erosion can be prevented with mulching. The top of the hump should be flattened. Pointed tops usually erode faster under our heavy rainfall conditions.

19.3 Irrigation

Irrigation will be crucial in a replant situation. The instructions previously presented for irrigation of new plantings must be followed carefully. On top of this, it is highly recommended in replant situations to consider the following:

- Introduce as many forms of soil moisture monitoring devices or methods as possible.
• Make sure the soil dries enough between irrigation events by following the higher thresholds for the tensiometer readings.

In surveys conducted around the establishment of Hass trees on tolerant rootstocks in New Zealand it has been determined that much of the tree decline problems that these trees suffered in our orchards were due to excess irrigation.

19.4 Mulching the young trees

There seems to be no controversy about the fact that mulching should be regarded as standard best practice in avocado orchards, at least when talking about young avocado orchards.

Mulching appears to have several benefits on root rots control by:

• Improving soil health through increased microbial activity, and therefore making topsoils more suppressive to root rots.
• Providing a more aerated root environment as a result of the use of coarse mulch.

However, it must be considered that soil moisture in mulched trees must be monitored carefully. Mulches conserve soil moisture by reducing evaporation from the soil surface and by increasing the water holding capacity of some soils; therefore, mulched soils are usually wetter than unmulched soils. Diseases favoured by wet soil conditions such as root rots can be exacerbated by mulch shortly after mulch application. It is important that a strict control method of soil moisture content is followed. Coarse grain mulches can be used to reduce excess soil moisture.

Often big trees are being removed from the block and these old trees are usually used as a source of mulch for the new trees.

Figure 41. replant situation, old trees ground on site to provide mulching for the old trees and the new trees that are being interplanted in this far north orchard.
19.5 Fungicides

Young trees established in replant situations should be protected against root rots with systemic fungicides. Some South African nurserymen consider it unconceivable not to treat regularly any newly planted tree with fungicides, even in virgin soils.

Applying Aliette or phosphorous acid foliar sprays every 4-6 weeks is recommended by Westfalia in South Africa (they selected Dusa and own its intellectual property) and is being practiced by several growers in New Zealand with apparent success.

The usual rates for spraying non-bearing avocados are:

- Aliette WG: 0.25 to 0.50% (250 to 500g to 100 litres of water).
- Phosphorous acid 40%: 0.5 to 0.75% (500 to 750 ml to 100 litres of water).

An example of a foliar application recommendation that combines fungicides and fertilizer claimed to be successful by some consultants in NZ conditions:

- 500 ml per 100 l of water using a 40% phosphorous acid solution is advisable in all circumstances where trees are not showing active growth (not only replant) and many growers do it over the autumn/winter/spring months regardless. It is suggested to include Nitrosol Original (or other high quality proprietary foliar product). Nitrosol Original can be included at the same rate 500ml per 100litres PLUS an adjuvant such as Latron B or Spread-Wett as otherwise the spray mix ‘beads’ on the leaves. Spray to ‘run-off’ as often as fortnightly but, if tip burn starts to occur it’s a good idea to withdraw the phosphorous acid.

Lower rates should be used on healthy looking plants. Higher rates should be used for plants with symptoms. The trees should be wetted almost to the point of run-off.

The treatment should commence as soon as possible after planting. The foliar sprays should only be applied in the late afternoon. The application should continue until trees can be injected.

Even trees on clonal rootstock like Dusa and Bounty should be protected against this disease to ensure development of strong, healthy roots.
The product is absorbed through the foliage. If the plants have lost most of their foliage, the product should be applied by drenching the roots. Two commonly used drenching methods are:

- Phosphorous acid 40%: 3% (3 l to 100 l of water) applying 200 ml per plant
- Phosphorous acid 40%: 0.3% (300 ml to 100 l of water) applying 2 litres per plant

In both cases the product must run into the soil and reach the roots.

Drench the plants every 6 to 8 weeks. Once the plants recover and start flushing, protection must continue with foliar applications.

Application of Metalaxyl (commercial product Ridomil) to the bottom of the planting hole has been common practice in the past and some consultants consider that it should be applied in every situation.

19.6 Other

Other practices that should be investigated and are usually followed in New Zealand orchards are:

- Application of fresh cattle or chicken manure in the planting hole 6 months prior to planting has been recommended due to the fungicidal effects of ammonia. In addition, the application of organic matter is supposed to increase the population of antagonistic organisms which help control root rot fungi.
- Application of calcium. Soils that are known to impede the development of Phytophthora usually contain high concentrations of calcium and calcium seems to have a certain fungicidal effect. In New Zealand avocados are mostly grown on leached, low calcium soils. Liming is commonly recommended to increase the concentration of calcium in our soils.

20 REFERENCES


