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Avocado culture in Western Australia





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*By Alec McCarthy
Bunbury District Office*

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Disclaimer

This material has been written for Western Australian conditions. Its availability does not imply suitability to other areas, and any interpretation is the responsibility of the user. Recommendations were current at the time of preparation of the original publication.

DESCRIPTION

The avocado is a large evergreen tree of sub-tropical origin. The fruit are high in protein, fats (mono and polyunsaturated), several minerals and vitamins. The Guinness Book of Records lists the avocado as the most nutritious fruit in the world. It is suitable for infants through to the elderly and **does not** contain any cholesterol.

CLIMATE

Avocado trees are quite adaptable, being grown from Kununurra in the north down to Albany in the south. They are being grown commercially in the south-west from Perth down to Pemberton and in Carnarvon.

Avocado trees are frost susceptible, particularly when young, so they are best suited to frost free locations. They are also susceptible to wind damage, sunburn and salt spray.

SOILS

Ideally, grow avocado trees in a rich sandy loam. However, they can be grown quite successfully in a range of soil types from light sands through to well-drained clays, provided suitable management techniques are adopted.

The main requirement is that the soil is free draining and of a good depth, at least 1 metre, preferably 2 metres, because of the avocado tree's high susceptibility to root rot pathogens. Gentle mounding can be employed to improve soil depth and drainage.

Equally, soils must not be salt affected, soil chloride levels should ideally be under 150 mg/kg (reference level from Avoman).

Light sandy soils ideally should be enriched with organic matter before planting (see section on Orchard establishment for more details).

FLOWERING AND POLLINATION

The avocado tree's main flowering flush is during spring, when the flowers are borne on the current year's growth. Avocado varieties are categorised into two types (A or B) depending on their flowering pattern.

- With type A varieties, the female organs are receptive to pollen in the morning, while the pollen is released in the afternoon.
- With type B varieties, the pollen is released in the morning, while the female organs are receptive in the afternoon.

The mean daily temperature during flowering affects how strictly this pattern is displayed - the higher the temperature, the more pronounced it is.

Type B varieties are further influenced by temperature, the female organs displaying a very low receptivity to pollen at average daily temperatures below 18°C during flowering. As a result, B type varieties are less suited to colder climatic regions than A type varieties.

Even though avocados are self-fertile, their unusual flowering habit means that you can increase their fruit set by inter planting type A and type B varieties, thus causing cross-pollination. However, under the climatic conditions of the main commercial regions in Western Australia, satisfactory crops can be set on most varieties without the need for cross pollination ~ provided sufficient pollination vectors are present and active. It is current commercial practice not to plant pollinators when planting a block of the main commercial variety, Hass.

Avocado flowers are pollinated by insect vectors, both flying (the common hover fly is believed to do a lot of pollination) and crawling. Unfortunately, our most common pollinator in horticulture, the European honeybee is not highly attracted to avocado flowers. To improve pollination, you may have to bring bee hives into the orchard during peak flowering (Figure 1), at a rate of two to three hives per hectare (see Bulletin 4298, Honeybee pollination). A recent development in honeybee pollination is the use of 'Bee Tubes' in the place of full hives. These are essentially 'disposable' mini-hives that are hung within the tree rows, they are still experimental but showing promising results and should prove a cheaper option than full hives. For further information on Bee Tubes contact Rob Manning at AGWEST South Perth, for Bee Tube or bee hive orders contact the Pollination Association of WA (see Factsheet 51/2000, Useful contacts for commercial avocado growers).



Figure 1. Bee hives introduced into an avocado orchard to try and improve pollination.

VARIETIES

Only grow known varieties commercially. Avocado trees do not grow true to type from seed, so they must be grafted on to rootstocks.

The main commercial variety in Australia and much of the world is Hass. This variety has generally accepted flavour and has proved to be a reliable cropper in a wide range of climatic conditions. However, it does not grow very well in the more tropical locations.

Table 1. Common avocado varieties and their traits (see also Table 5 for harvesting times)

Variety	Flower type*	Fruit shape	Ripe skin colour	Skin texture	Tree growth	Frost tolerance
Bacon	B	pear	green	smooth	medium, upright	moderate
Fuerte	B	pear	green	smooth	large, spreading	good
Gwen	A	pear	green	rough	medium, upright	sensitive
Hass	A	pear	purple	rough	medium, spreading	sensitive
Lamb Hass	A	pear	purple	rough	medium, upright	unknown
Llanos Hass	B	pear	purple	rough	medium, upright	unknown
Pinkerton	A	pear	green	slightly rough	medium spreading	sensitive
Reed	A	round	green	slightly rough	medium, upright	sensitive
Sharwil	B	pear	green	rough	medium, spreading	good
Shepard	B	pear	green	smooth	medium, spreading	unknown
Wurtz	A	pear	green	slightly rough	medium small, sprawling	good

* A: The female organs are receptive to pollen in the morning; pollen is released in the afternoon.
 B: Pollen is released in the morning; the female organs are receptive in the afternoon.

There are a large number of varieties of avocado, many of which have particular growing requirements. For example, Shepard requires a more tropical climate. Most other varieties are grown in smaller numbers and are used to extend the season before and after Hass.

New varieties from the University of California avocado breeding program have been introduced to Australia and are currently being evaluated. Several of these (e.g. Gwen and Lamb Hass) have shown potential and are available from selected nursery outlets. A Western Australian selected variety, Llanos Hass has also shown potential in early evaluations. Table 1 lists some common avocado varieties and their traits.

ROOTSTOCKS

In the past, most avocado trees in Western Australia have been grown using seedling rootstocks, and this seed was regularly collected from a range of varieties. This has led to variability in the growth and fruiting of avocado trees in many orchards.

There are two main races of avocado rootstocks, Mexican and Guatemalan. There are supporters for, and detractors of, the value of each race as rootstocks.

- The Mexican rootstocks include Mexicola, Topa Topa and Duke. These varieties prefer well-drained soils, but are more liable to show trace element deficiencies and are fairly sensitive to salt. However, some varieties (e.g. Duke 7) display a higher tolerance to *Phytophthora cinnamomi*. Grower comments suggest Mexican rootstocks produce a more intense flowering over a shorter period than Guatemalan.
- The Guatemalan rootstocks that are used include Nabal, Plowman, Velvick, Reed, sometimes Hass and often just selected vigorous seed grown trees. These rootstocks tend to tolerate heavier soils, show a greater ability to take up trace elements and are slightly less sensitive to salt, but some prefer warmer climates and seed can be hard to source (e.g. Plowman and Velvick). Recent research is

suggesting that Guatemalan rootstocks may impart a greater resistance to anthracnose into the fruit.

Unfortunately, a simple recommendation of preferred rootstock cannot be made at present. Research is currently under way to develop and test improved rootstocks for tolerance to *Phytophthora cinnamomi* (e.g. Duke 7, G6 and G755), for greater salt tolerance and improved disease resistance in fruit. There is much work yet to be done before we find the ideal combinations

Some overseas avocado industries (e.g. South Africa) are based on the use of clonally produced rootstocks to combat phytophthora. As yet, clonal rootstocks have not proved popular in this State, reports of low success and poor yields together with the high purchase price have discouraged most growers from using them.

The current recommendation is to plant blocks of trees using a single rootstock. You can plant different blocks using different rootstocks for comparison, but try to avoid mixing rootstocks within a single block. You should be able to water and manage separate blocks individually.

Always buy your trees from a recognised supplier with accredited growing and monitoring procedures. Otherwise you may be inviting unwanted guests into your orchard, for example, dieback or sun blotch viroid.

PROPAGATION

New plants

The production of avocado plants is best left to professional nurseries, because of the problems associated with *P. cinnamomi* and viruses. Should you wish to grow your own plants, you need to start with healthy vigorous seedling rootstock. Seeds should only be collected from known healthy trees of the desired type. Ideally trees should have been checked for sun blotch viroid.

Seedlings should be grown in quality, free draining potting mix in deep pots/bags, they need to be grown in a shade house, on wire benches at least 30 cm above the

ground and be appropriately irrigated to avoid any water stress. The seedlings need to grow to at least pencil thickness – generally about double pencil thickness for best success, they are not suitable for grafting until they no longer have a hollow centre. This can often take up to 12 months. Your chosen scion (fruiting variety) can then be grafted on top using either ‘wedge’ or ‘whip & tongue’ methods during the plants active growing season (commonly spring).

The main limiting factor is sourcing suitable scion material, this needs to be less than 12 months old (i.e. the most recent growth) but not too soft. Better success is generally had if wood is not sourced from flowering or fruiting branches.

Collect a range of shoot thickness similar to the size of the rootstocks, stand in water and preferably use immediately. If you need to store the scion wood, wrap them up in slightly moistened paper and seal in a plastic bag and store in a fridge or esky (with cool blocks). When grafting, try and match the wood size as best as possible between the rootstock and scion and remember to match very closely the ‘cambium’ layer down at least one side of the shoot. The union must then be wrapped up tightly using suitable grafting tape to ensure the union is making good contact and is airtight. It is essential to take extra care with your newly grafted plants as any stress at this stage will reduce your success. Once the union has obviously taken, i.e. the scion is bursting and remaining healthy and/or the union joint is growing and stretching the budding tape, you must carefully remove the tape otherwise it may strangle the new graft.

Reworking established trees

Occasionally producers decide to change the variety they are growing. This can be done by completely removing the old trees and planting new nursery trees or by reworking the old trees. Reworking old trees is only suitable when the ‘to be replaced’ trees are very healthy – never rework an unthrifty tree.

There are several ways of reworking trees – all are various forms of grafting and depend on the size of the tree to be reworked and personal preference/experience. Probably the easiest method is to cut the tree down to a stump about 50 cm above the ground (see Figure 2) and let it re-shoot and then graft several of these shoots (evenly spaced around the stump) just as you would a nursery seedling. If re-shooting does not occur before it starts to get too hot, they will need to be painted with a white acrylic paint to prevent sun burn.

The hard part in the field is to protect the newly attached scion from drying out. This can be done by covering the plant with shade cloth and wrapping the scion with white florist tape (see Figure 3), or placing a plastic bag over the graft and then covering this with a white paper bag or reflective foil – but watch out for birds attacking the set up.

The best advice is to employ someone experienced, or be prepared to experiment and practice (a lot) before getting too ambitious.



Figure 2. Avocado trees stumped down to be reworked.



Figure 3. Reworked avocado tree showing the new shoots from the graft and note the use of white florist tape to protect the graft scion from drying out.

ORCHARD ESTABLISHMENT

Planting distances

The planting distance between trees varies, depending on variety and growing conditions. Close spacing (Figure 4) is most commonly used in Western Australia to maximise early production and to enable early establishment of a favourable micro-climate. However, close spacing will mean that you will have to use some form of tree size control, mechanical, chemical or tree removal, at a later stage or you will have access problems

and the light penetration down to the lower branches will be reduced (Figure 5).

A good medium planting is rows 7 m apart with 4 m between trees for upright trees, and 8 m x 5 m for spreading trees.



Figure 4. An example of a young close planted avocado orchard.



Figure 5. An established avocado orchard showing crowding, these trees are well due for some form of canopy management.

Row orientation

To allow for maximum light penetration into the modern close-planted orchard, plant the rows in a north/south orientation. Should your property's main prevailing winds be southerlies, consider planting in a north-west/south-east orientation.

Pre planting

Carrying out a site assessment before planting is highly recommended, this should look into varying soil types and depths over the planned planting area. You should also carry out soil analysis to determine nutrient levels and the pH of the soil profile, preferably down to 50 cm (by 10 cm increments). You can do this yourself (except the analysis work) or it can be done by AGWEST Land

Management Services for a fee [contact (08) 9368 3716]. It is advisable to partition your orchard into blocks based on varying soil differences.

Any drainage or soil pH problems should be sorted out before planting. Water should not pool on the surface for more than 24 hours and there should be good drainage down to at least 1 m. Soil pH should be in the range of 5.5 to 6.5 (based on a 1:5 calcium chloride test). Lime is best incorporated by ripping or hoeing down to a depth of at least 30 cm. When choosing your lime source you need to know the 'fineness' (good lime sources have over 80% of particles less than 0.6 mm, particles over 2 mm are essentially ineffective), and its neutralising value (good lime sources will be over 75%). The amount of lime required depends on your soil type and organic content and the lime source (the 'neutralising value'). The heavier (more clay) the soil and the higher the organic content the less effect the lime will have on the soil pH. As a simple guide, rates of about 5 tonne per hectare (pure lime i.e. Neutralising factor of 100%), when incorporated evenly down to 30 cm depth, will raise the pH about 0.5 in heavy or highly organic soils and about 1.0 pH point in light sandy soils. It is not normally recommended to apply more than 10 tonnes of lime/ha in any one application. Lime can be applied at any time, but is generally done in autumn to allow the winter rains to help dissolve the lime. It is important to do a follow up check of pH about 6 months after incorporating the lime to check the effectiveness of the application. More information on liming can be found in Avoman or Fertilisers for wine grapes (1997).

Planting

Autumn or late winter to early spring are the suggested planting out times. In sandy soils, it may help to enrich the soil with organic matter a minimum of three to four weeks before planting to build up the organic matter content.

When planting, place the mix listed in the table below into the bottom of the planting hole, mix in well and cover with about 10 cm of soil. Gently tease out any 'bound' roots before planting. Plant to the same depth as in the pot and water in thoroughly after planting.

Planting fertiliser mix for each hole – this is a general purpose mix and should preferably be adjusted based on soil analysis

- 500 g mono superphosphate
- 80 g magnesium sulphate ($MgSO_4$)
- 30 g manganese sulphate ($MnSO_4$)
- 15 g copper sulphate ($CuSO_4$), and
- 30 g zinc sulphate ($ZnSO_4$)

IMPORTANT:

Never place nitrogen or potassium fertilisers into the planting hole prior to planting. Animal manures also should not be placed into the planting hole just prior to planting, if you wish, manures can be incorporated into the soil as part of building up the organic matter, but this must be done a minimum of 3 to 4 weeks prior to planting.

TREE PROTECTION

Wind

Windbreak protection, whether natural or artificial, is a must for a successful avocado orchard. As a minimum, place windbreaks along the edge of your orchard at right angles to the prevailing winds (that is, north/south on the east side if your prevailing winds are easterlies). Ideally, establish windbreaks completely around the orchard and every 100 – 200 m within the orchard.

Suitable trees for natural windbreaks include *Casuarina cunninghamiana* and evergreen poplars (low suckering), deciduous trees are not recommended as windbreaks for avocado orchards as the avocado tree is still carrying a crop during winter in the main growing areas in WA, also pine trees are not particularly suited because they flower and deposit large quantities of pollen over the

fruit near harvesting time that is unsightly and difficult to remove.

Young trees are particularly susceptible to wind damage so special care should be taken in windy areas. One approach taken by growers is to use giant sudax (Figure 6) or bana grass (Figure 7) planted down the rows between the trees. These grow very rapidly providing a quick internal windbreak of about 2 to 3 m, provided they are irrigated suitably. Once the trees start to get bigger or you need to be able to get down your rows with bigger machinery you can begin to progressively remove every second row.

For more information on windbreak planting and costs, see Farmnote No. 43/99, Windbreaks for horticulture on the Swan Coastal Plain.



Figure 6. Example of giant sudax planted between each row of trees in a newly planted avocado orchard, this is an effective temporary internal wind break. Also note the individual tree trunk protectors to enable chemical weed control without killing your young trees. You can also see that the trunks have been painted white to reduce the chance of sun burn.

Figure 7. A stand of bana grass, these are fairly effective as more long-term internal windbreaks as they will last for several years if suitably irrigated.



Sun and chemicals

When trees are young, they are very easily damaged by sun and/or herbicide over spray. It is recommended that growers protect the young green bark of newly planted avocado trees by firstly painting the exposed trunk with a white acrylic paint. Secondly, to reduce the likelihood of spray damage, the use of protective tree trunk guards is also recommended (Figure 6). These could be specially designed plastic tree guards, milk cartons or roof insulation foil stapled into tubes (use the blue backed foil and have the blue facing the inside).

IRRIGATION

Good irrigation design is essential for a successful avocado orchard. Irrigation design is best carried out by a suitably qualified person. You can make substantial savings on water and pumping costs with a well-designed system. The following notes are a basic summary to help you determine the basic water requirements.

- Avocado trees are highly sensitive to salts (Figure 8) and therefore water quality must be very good – ideally total soluble solids should be less than 150 ppm (30 mSm). However, water up to about 400 ppm (70 mSm) can be used under certain conditions (i.e. soil that is flushed with winter rains) and you may have to use regular flushing irrigations.
- Because of its tropical nature, the avocado tree has a low tolerance of water stress, so keep soil moisture within 25 per cent of field capacity. To do this on some sandy soils, you may have to water two to three times a day for mature trees and four to five times a

day for newly planted trees during summer. Remember that a newly planted tree has only a very small root volume (it starts off the size of the pot it was grown in and this only holds a very small amount of water). Research is currently under way to determine what ability the avocado tree has to 'shut down' during high water stress conditions, and thereby conserve water within the tree. It is hoped to be able to more finely tune the irrigation requirements of the avocado tree to enable reductions in water usage and perhaps even control vegetative growth via irrigation controls.

- You can estimate water usage by several means. Some of the cheaper and simpler methods include evapormeters and tensiometers. Using evaporation readings, aim to replace 100–120 per cent of evaporation for an established orchard and 120 per cent for establishing orchards. Some of the more elaborate electronic moisture measuring devices calculate a figure to represent 'moisture content' in the soil, with these systems you should aim to keep the available moisture to within 25% of field capacity. This generally takes some experimentation to achieve.
- An important point to remember is that avocado trees are evergreen and will require irrigation all year, including dry spells during winter.
- On current information, appropriate annual irrigation requirements for avocado trees range from 10,000 kL/ha/year in the cooler areas (Manjimup) to 30,000 kL/ha/year in hotter regions (Carnarvon).



Figure 8. Example of salt stress in an avocado tree, note the scorched margins and tips of the leaves.

Simple irrigation calculator for mature trees using evaporation figures

Planting Density	7 m x 4 m = 28 m ² area per tree
Evaporation Reading	8 mm (not uncommon on a 32°C day)
Crop Factor (replacement rate)	120% = 1.2
Water Requirement	= evaporation x tree area x crop factor = 8 x 28 x 1.2 = 267 litres per tree

If you have one sprinkler per tree with a flow rate of 120 L/hr (you should check this manually under normal load conditions rather than relying on the manufacturers rating) then you would need to irrigate for : $267 \div 120 = 2\frac{1}{4}$ hours.

Adjustments for younger trees

When calculating for younger trees you can substitute the actual tree 'canopy' area for the 'tree area'. The tree 'canopy' area is simply calculated by squaring the canopy diameter. Remember that for young trees the water needs to be applied to the tree roots which may have a restricted area. If your sprinklers are wetting more than the root area you will have to work out proportionally how much is actually getting to the roots and adjust the time accordingly.

Further details on irrigation can be found in Farmnote No. 42/88, Irrigation requirements of avocado.

Sprinkler coverage

How much of the ground you throw the water over varies depending on soil/climate differences and personal experience. As a general rule of thumb, the lighter (sandier) your soil the more of it you should try to wet. In hot, sandy areas north of Perth, avocado orchardist frequently irrigate 100 per cent of their orchard floor. The roots of the avocado tree will grow out into the inter row area if it is kept moist. The benefit of this is an extensive root system that helps the tree cope with the high temperature and windy conditions that can induce fruit shedding.

NOTE: Drip systems are not usually recommended for avocado trees.

Filtration

A good filtration system is essential for all irrigation systems, there are several different systems available. The best one will depend on your irrigation set up and water quality, your irrigation designer can advise you on the best system to suit your needs.

Iron and pipe cleaning

Iron in water is fairly common in WA and can become a problem causing blockages in pipes and sprinklers if not treated properly. There are a range of options available from pre-treatments to chemical and physical methods. Pre-treatments (useful when iron levels are above

1mg/L) include aeration, settling and pH adjustment. Chemical treatments (for controlling algae) include chlorine injections, these can be continuous low level injection or occasional shots of high dose, because of the avocado trees sensitivity to chlorine, the occasional use of a high dose is more commonly used. Physical methods include the use of 'pigs' (to clear blockages in pipes) and regular flushing of lines (to prevent build up of material at the ends of lines) – flushing can be simply achieved by the use of automatic flushers at the ends of lines and then an occasional major flushing in conjunction with a chlorine dose. More detail on these methods can be found in Farmnote 41/90, Blockages in irrigation lines.

CLIMATE MODIFICATION USING IRRIGATION

Avocado trees are of a sub-tropical origin, as such they are heavily affected by the hot and dry conditions often experienced in WA. Such conditions often result in fruit being shed by the tree during summer. One 'experimental' technique that has been employed by some growers with a reported degree of success is to adjust the trees 'micro climate' through irrigation. This is achieved by applying short bursts of irrigation (5-10 minutes) at regular intervals during hot, dry conditions. It is believed this has the effect of slightly reducing the temperature and raising the relative humidity around the trees.

Obviously the ability to employ this technique is dependent on having sufficient supplies of quality water. You will have to monitor soil moisture levels (to ensure you are not waterlogging the soil) – you may have to adjust your major watering cycle. You should also keep an eye on salt accumulation in the soil and plants and perhaps increase frequency of leaching.

FROST CONTROL USING IRRIGATION SYSTEM

Avocados are frost tender, particularly when young, while it is recommended that they are grown in frost free locations this is not always possible. Should you get several mild frosts (-1 to -2°C) you can use your irrigation system (if set up properly) to reduce the severity of these frosts and often eliminate any damage within the orchard from them.

The nature of frosts is that the coldest point is where the air meets the ground mass (or weed tops if you have a cover crop). If this falls below freezing point then the plant sap will freeze causing internal damage. Frost damage can show up as burnt leaf edges, scarred fruit, shoot tip burning, through to complete limbs being burnt. On newly planted trees, a frost can actually burn the tissue so badly in a ring around the trunk that it kills the trees in a similar way to ring barking it (Figure 9).

The principle behind using your standard irrigation system is that water, by nature is more than 0°C, therefore by turning on your irrigation you will keep the temperature around your trees above freezing point.

The trick, however, is to cycle the water through your orchard without the pipes freezing, to not waterlog your soil or to use all your valuable water reserves or to have to get up at 3:00 am in the morning when it's 3°C outside to turn on the irrigation system.

So to use your irrigation system for frost control you need a slightly more than standard automatic controller. The controller needs to be able to be switched on and off via a temperature trigger that can start up a short duration repeat cycle.

The usual temperature for turning the irrigation on is about 3°C (you need to get it going before your pipes freeze) and then turn off when the temperature is about 5°C. The thermometer needs to be in the known cold location of the orchard (or next to the pump if this is in a colder location) but **NOT** where it will be affected by the irrigation (or your pump will be turned on and off till it burns out). The system also needs to be able to continually cycle through your stations, watering for short bursts of about 5-10 minutes each station.

NOTE: An over pressure sensor is a sound investment to prevent pump damage – because occasionally the frost may beat you and your pipes freeze. A water flow meter is also an invaluable tool so you can monitor how much water has been applied (particularly if you are using evaporation rates to schedule your irrigation), it may mean you don't have to irrigate normally for the full time or at all.



Figure 9. Effect of frost on a young avocado tree, the trunk is slightly sunken where the bark in this picture has been scraped back, the tissue underneath the bark will be brown and dead, the tissue below and above this 'frost ring' will still be green – for now. The tree will slowly die off showing evidence of water stress as the cambium ('plumbing tissue') will have been destroyed.

MULCHING

High levels of organic matter in the soil are highly beneficial for good root growth and nutrient uptake, and vastly improve the water holding capacity of sandy soils. Recent research has also shown that a soil rich in organic matter has high microbial activity that can have a positive effect in the fight against *Phytophthora cinnamomi*.

A good mulch layer also acts as an insulator to the sun, keeping the soil surface, and therefore the feeder roots, cooler during summer. In Western Australia, a good mulch layer is almost essential.

There are many types of mulch. The main feature to look for in a mulch is that it is reasonably open so that water and air can flow through easily.

- One common method is to use straw annually for the first few years. Spread the straw about 150 mm thick generously around each tree (as seen in Figure 10 on page 13).
- Any mown cover crop should have the clippings thrown under the tree. Any tree prunings should also be mulched and thrown under the trees.

Add the mulch in late winter to early spring, always keeping the mulch at least 100 mm away from the trunk of the tree. As the tree matures, chip all prunings and leave them under the tree canopy, together with any fallen leaves, these will form a continual supply of natural mulch. After applying mulch it is essential that you monitor your irrigation as the mulch layer may affect the amount of water getting down into the soil.

FROST NOTE: In areas of known spring frosts it is advisable to hold off spreading mulch until after the frost danger.

FERTILISERS

Base your fertiliser application rates on leaf analysis results. Have leaf analyses done annually, using samples taken from late March (Carnarvon) to late May (Pemberton), this is when the summer flush has started to harden.

When collecting leaves, your hands should be clean and the leaves need to be placed into clean bags for forwarding onto a laboratory (make sure you label clearly so you can interpret the results). Many laboratories produce leaf sampling kits that are available from your local fertiliser stockist. Collect about 10 complete mid shoot leaves from the just hardened summer flush from 5 to 10 trees. You should collect from average trees of the same age, variety, rootstock, soil type and management practice. You can compare results from different blocks, but **NEVER** mix leaves from different blocks.

Fertiliser rates depend on many factors, including tree size, variety, soil type and irrigation. Tables 2 and 3 offer base recommendations for the major and minor elements. Adjust these base rates according to leaf analysis results.



Figure 10. Layer of straw mulch under young avocado trees.

Application frequency is again dependent on soil type and irrigation, but as a rule, regular light applications are best. Under WA conditions (i.e. winter rainfall) it is beneficial to lightly apply fertiliser throughout the year. Split your annual rate up so that you apply about two-thirds during the active growing period (approximately November to April) and the balance during winter – early spring.

More detailed information on fertiliser rates (including leaf analysis interpretation) and leaf analysis sampling technique is available in Avoman. Some photographic examples of nutrient disorders can be found in Avocado

pest and disorders (1991) or Plant nutrient disorders 2 – tropical fruit and nut crops (1995).

Boron - Boron is a minor element that requires special mention for avocados. Low levels of boron will severely retard the growth of avocado trees and affect fruit set. Boron is very mobile in the soil, so you need to apply regular light applications to ensure a continuous adequate supply is available to the plant. Sandy soils may need monthly applications. However, it is important to carefully monitor leaf analysis results, since excessive levels of boron are toxic and can severely damage an avocado tree.

Table 2. Base annual application rates of common fertilisers for major nutrient requirements for avocados on sandy and loamy soils

Nutrient	kg/ha		g/m ² of canopy area	
	Sands	Loam	Sands	Loam
Urea	300-400	300-400	30-40	30-40
Superphosphate	150-250	200-400	15-25	20-40
Potassium sulphate	400-500	400-600	40-50	40-60

Table 3. Base annual application rates of common trace element fertilisers for mature avocado trees

Fertiliser	kg/ha		g/10 m ² of canopy area	
	Sands	Loam	Sands	Loam
Manganese sulphate	4.5	7.0	0.45	0.70
Iron sulphate	5.0	7.5	0.50	0.75
Zinc sulphate	2.5	4.0	0.25	0.40
Copper sulphate	1.0	1.5	0.10	0.15
Boron	4.0	6.0	0.40	0.60

GROWTH AND MANAGEMENT

In the past, avocado trees have essentially been left to their own devices, with pruning and training limited to skirting the tree to keep the low branches up off the ground.

Now, with more densely planted orchards, and an increased need for quality fruit, tree management has become an essential component of orchard management. Unfortunately research into best pruning and management of avocado trees is in its infancy.

Currently, the popular practice is to either hedge the trees to a chosen size (height and width) down the rows or to remove selected limbs to allow increased light penetration into the canopy. With both techniques, you

must be careful not to expose the limbs or fruit to too much light, since they are very susceptible to sunburn (Figures 11 & 12). In most areas of WA, these methods of pruning will result in the loss of some fruit, as there is no time when the tree is not in fruit. However, leaving your tree to just keep growing will lead to reduced yield per hectare, increased fungal disease, increased wind damage, higher harvesting costs and increasing difficulty with spray applications.

While pruning is seen by some to be very labour intensive and therefore expensive, hydraulic chain saws, cherry pickers and new mechanical hedging equipment being developed will hopefully reduce the time and cost for this activity.



Figure 11. Sunburn damage on avocado fruit, this is generally seen as a tan or yellow area around a black spot. Fruit damaged this way is not saleable.



Figure 12. Sunburn damage on avocado tree limbs, the damaged tissue will be dull light brown and will sometimes crack while the healthy tissue remains a greenish colour. The damage is deep, destroying the cambium layer, thus restricting sap flow to the non damaged parts.

WEEDS

Weeds can be quite a problem in young orchards as they compete with the trees for precious water and nutrients. They can also harbour pest insects. Control of weeds is most commonly achieved by use of herbicides. It is important though to be very careful when using any non-selective herbicide near young avocado trees as they are very easily damaged or even killed by even relatively small amounts of spray drift. The use of tree trunk guards is recommended for the first couple of years (Figure 6). Generally growers avoid the use of broad spectrum 'systemic' herbicides for the first few years, opting to use 'contact' chemicals or selective chemicals.

A further warning when using glyphosate based herbicides. The root system of avocado trees is very shallow and some problems have been reported with the use of these herbicides on sandy sites. It is suggested that you use these products sparingly and with caution.

NOTE: Always check label directions before use.

PESTS

In Western Australia, we are lucky that we don't have the range of pests that cause problems in some of the other growing regions of Australia or the world. Thankfully avocados are not really affected by two of Western Australia's big problems - the Mediterranean Fruit Fly or birds. Avocados are not though, pest free, so commercial growers will have to combat at least a few pest problems in most years, hence the move to smaller trees which are much easier to spray if required. Listed below are a range of pest problems growers may encounter, this list is not exhaustive but an indication of some of the major pests. Should growers find a pest that is causing product loss and they cannot identify it or suspect it to be a new pest they are encouraged to contact their local Agriculture Western Australia Office or send a sample into AGWEST Plant Laboratories for identification (a fee applies).

Further information and descriptive photographs are available in Avocado pests and disorders (1991), Post harvest diseases of horticultural produce volume 2 (1995) and Avoman.

Vermin

Rats are the main problem here, having an intense liking of avocado fruit, they are particularly bad in areas that have water ways (creeks, dams, etc) near the orchard, but this is not a prerequisite. Rats mainly chew the skin of the fruit leaving a quite characteristic 'raking' effect, they do not normally go very deep into the fruit. Control unfortunately is rather difficult, restricted to trying to remove nesting sites and baiting. Fruit with rat chews cannot be sold.

Rabbit damage is usually restricted to attacking young newly planted trees where they can do quite significant damage in a very short period of time. They will chew new shoots and also strip the bark off green trunks. If you are in an area of high rabbit populations you would be well advised to install either rabbit proof fencing or trunk guards.

Foxes, while possibly helping to keep your rabbits at bay (along with all our native fauna), will actually pull avocados off lower branches, they then usually bury the fruit to speed up ripening before returning to eat them. Fox control is generally restricted to culling.

Kangaroos, while not strictly vermin, can cause damage in an avocado orchard, they have been noted to chew leaves and fruit, but by far the most damage will occur in a young orchard from physical damage as a result of them bounding through, breaking off branches and in some cases complete trees.

Scale

Latania scale and soft brown scale appear on leaves, limbs and fruit. They can reduce the tree vigour if many are present. The major problem with these scales is that they readily infest the fruit, resulting in unsightly fruit that has reduced or no market value.

White and pink wax scale can be a problem in some areas and, in large numbers, they will reduce tree vigour. Generally, the main problem with these scales is the sooty mould that grows on the honeydew excretions. This will regularly cover fruit, and is unsightly and difficult to remove, thus affecting market value.

Scale control - Natural predators, often present in avocado orchards, can achieve reasonable control of scale insects. However, these predators are easily killed by insecticides. You may need to reintroduce them into the orchard repeatedly. Where possible, use so-called soft chemicals like narrow range oils if these pests become a problem.

Spray when the young scale (crawlers) are at peak emergence. This is generally December-January for the wax scale and February-March for Latania scale. This will vary, depending on the location and the season. A complete coverage of all plant parts is essential for successful control. Use a rate of 1 L per 100 L of water for both narrow range and summer oils.

NOTE: Always check label directions before use.

Thrips

Thrips are small sap-feeding insects, about 1 mm long when mature. The main species currently affecting avocado plants in Western Australia is the Greenhouse thrips, which is transparent green when young and black when mature. It is usually on the underside of leaves. Affected leaves tend to turn reddish-brown. When numbers build up, the thrips will also attack the fruit, resulting in bronze (or muddy red) areas on the fruit, particularly where fruit touch each other. This can severely reduce marketability of the fruit.

Thrips are generally only a problem during spring and summer, particularly with periods of high humidity. You will generally find localised areas of heavy infestation, often near natural waterways. If you need to control chemically it is recommended that you treat the infected area only as the chemicals suitable for thrips control will often also harm natural predators. Opening up the trees to allow some air flow will help reduce the impact of thrips.

Garden weevil

The garden weevil (*Phlyctinus callosus*) is an insect about 7 mm long that can attack both leaves and fruit as an adult and roots when a larva. The young develop during winter in the soil and pupate about September. The adults emerge mid to late October depending on weather conditions.

The adults are most active at night and often feign death by remaining still or dropping from the tree when disturbed. They cause a characteristic damage to foliage, scalloping leaf edges and chewing holes in the centre of leaves. Damage to fruit includes scarring of the skin and 'ring barking' of the flower stalk (restricting fruit growth). Farmnote No. 60/91 The garden weevil, provides further information.

Garden weevil control- this is generally best done after peak emergence and should be restricted to areas where damage is occurring. Chemicals required for control of garden weevil will also kill natural predators of other pests which can cause secondary outbreaks of these pests.

DISEASES

The main diseases to affect avocado trees are Phytophthora and Verticillium, both of which principally affect the tree roots. Other diseases of major importance are anthracnose and stem end rot, these principally affect the fruit, with the symptoms showing up mainly post harvest, when the fruit is ripening.

Further information and descriptive photographs are available in Avocado pests and disorders (1991), Post harvest diseases of horticultural produce volume 2 (1995) and Avoman.

Phytophthora

Phytophthora cinnamomi, sometimes called 'jarrah dieback', is a fungal disease that is prevalent in many Australian horticultural regions. Infection starts on the young roots, which die fairly quickly and turn black and rot. Infection can then spread to larger roots. Above-ground symptoms are generally a weak-looking tree with yellowish leaves that hang straight down. Leaf drop will then occur, particularly at flowering, and then branches will start to die back.



Figure 13. A simple mechanical injection tool used to inject phosphorous acid into avocado trees affected by *Phytophthora cinnamomi*.

Phytophthora cinnamomi spreads with water movement in the soil and along water courses. It can also be spread by soil on machinery, boots and plants. Control of phytophthora in an orchard is possible using tree injections of phosphorous acid (Figure 13). Apply this when the tree's root system is actively growing at the end of a leaf flush. Daytime temperatures must also be above 25°C. If you apply phosphorous acid at the wrong time, shoot tip dieback can occur.

It is important to purchase your trees from a quality nursery that operates in a manner that reduces the likelihood of *P. cinnamomi* spread.

If *P. cinnamomi* is suspected of being in the soil before planting, the use of a soil fungicide for the first two years is worth considering.

If you believe your avocado trees are suffering from *P. cinnamomi* it is recommended that you have them tested by a recognised laboratory (AGWEST Plant Laboratories, via your local AGWEST office can carry out this service [a fee is applicable]). To do this you will need to collect a fresh soil sample and root sample from a suspected infected tree. This is usually best done in spring - early summer when symptoms usually start to show.

Verticillium

Verticillium dahliae root rot is generally confined to young plants or single branches on older trees. Young trees are often killed, but the older trees regularly recover after the affected limb is removed (and burnt). The symptoms are leaves wilting and turning brown but remaining attached to the tree for many weeks. There is no cure for this disease. Remove and burn any suspect branches or trees after buds re-shoot lower down.

Avoid planting avocado trees into soil where other susceptible crops such as tomatoes or potatoes have been grown.

Anthracnose

Anthracnose (*Colletotrichum gloeosporioides* or sometimes called *Glomerella cingulata*) is the major post harvest disease of avocados. The varieties Fuerte and Wurtz are very susceptible to this disease. The variety Hass is also susceptible but the spots are not as obvious against the blackened skin of the ripe fruit, however, internal damage is still occurring.

Anthracnose develops once the fruit starts to ripen, particularly at temperatures of 24°C and above. Anthracnose becomes a greater problem in wetter areas and in older orchards as airflow through the orchard becomes restricted. Control with registered copper sprays (copper hydroxide) every 14 days during wet, warm weather. Also use a registered fungicidal dip immediately after harvest and avoid temperatures above 24°C once fruit has started to ripen.

Anthracnose has been noted affecting the tree foliage. This causes small black spots on the leaves and sometimes stems of the avocado tree. It is not a severe problem and generally will only occur in very wet seasons. Control will be achieved by the use of copper sprays as above.

Stem end rot

Stem end rot is another post harvest rot caused by fungal development (principally *Botryosphaeria* sp.). The symptoms are a dark brown rot starting around the stem and progressing into the fruit as internal streaking. Control is the same as for anthracnose.

MATURITY

Avocado fruit will mature on the tree but will not ripen until harvested. Table 5 gives expected maturity dates of the main varieties. There is a short delay from harvest until ripening begins, usually 3 to 10 days. This period is influenced by the variety, the temperature (both at time of harvest and during storage) and how long the fruit is left to hang on the tree. The presence of ethylene during storage will also speed up the ripening process.

USE OF CHEMICALS

When using chemicals in an avocado orchard it is important to remember to only use those chemicals that have a current registration for your planned use. Always read the label and use accordingly, investigate alternative options from less hazardous chemicals to non-chemical methods. Always maintain complete and accurate records of any chemicals used in your orchard. These records should include the block (variety) sprayed, the date, the target pest, the chemical used, the mix rate and volume applied, it is also recommended to keep some basic weather information such as temperature, wind strength and direction. This information will prove useful when monitoring the effect of your chosen control method. An excellent record keeping facility is available in Avoman.

FRUIT YIELDS

Avocado trees should start to yield small crops in year 3 and increase to near full production by year 7 - see Table 4. Tree spacing affects the time to full production and yield per tree.

Table 4. Estimated yields for an avocado orchard planted at a spacing of 7 m x 4 m

Year	Yield (t/ha)	No. of 6 kg trays per tree
3	0.5	0.2
4	3	1.4
5	8	3.7
6	14	6.5
7	20	9.3

Avocado fruit generally do not ripen satisfactorily with an acceptable flavour if the fruit is not allowed to mature on the tree to about 21 per cent dry matter. In Western Australia this is the legal minimum level allowed for marketing.

NOTE: Some varieties attain a better flavour if allowed to mature to a higher dry matter percentage, for example, Hass – 23 per cent plus.

Table 5. Normal harvesting season for the main avocado varieties in the main production areas (temperature will affect harvesting dates).

Variety	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Bacon	■	■	■	■								
Fuerte	■	■	■	■								
Gwen				■	■	■		■	■	■		

continued overleaf.../

Table 5 (continued). Normal harvesting season for the main avocado varieties in the main production areas (temperature will affect harvesting dates).

Variety	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Hass			■	■	■	■	■					
Lamb Hass*								■	■	■		
Llanos Hass*			■	■	■	■						
Pinkerton	■	■										
Reed				■	■	■	■	■	■	■		
Sharwil		■	■	■								
Shepard	■	■	■	■								
Wurtz		■	■	■								

■ = Carnarvon ■ = Perth ■ = Pemberton

* predicted maturity times, new varieties still being tested

CALCULATING PERCENTAGE DRY MATTER

You can estimate dry matter percentage fairly simply using a conventional oven or microwave. Further details can be found in Farmnote 76/2000 Avocado maturity testing.

- Collect a random sample of five fruit you intend to harvest.
- Grate the fruit flesh and weigh this sample fresh.
- Dry the sample completely.
- Re-weigh the dry sample.
- Divide the dry weight by the fresh weight and multiply by 100 to give the percentage dry matter.

HARVESTING

Preferably harvest fruit early in the day, before temperatures rise too high. Where this is not practicable, fruit should be kept shaded after picking and taken to cold storage as soon as possible. It is recommended that fruit pulp temperature should be cooled to below 20°C within 48 hours of harvest. Fruit should also be dry. Traditionally growers cut the fruit from the tree just above the union between the stalk and the fruit using

sharp secateurs. For fruit high in the tree, use tall ladders, hydraulic fruit-picking platforms or specially designed pole secateurs. Avocado fruit, while appearing very hard, is still susceptible to bruising and skin marking, so always take care when handling it.

Fruit plucking, the snapping of the fruit off the fruit stalk, is increasing in popularity as it is quicker than snipping. However, there are concerns about increased post-harvest problems from this activity. If you do choose to pluck fruit, you should monitor the fruit after harvest for disease incidence and take necessary steps if problems start to occur.

GRADING AND MARKETING

Avocados are graded according to size (or weight) and blemish levels. The larger sizes of Grade 1 fruit is most commonly packaged into single layer trays (cardboard) that hold about 5.5-6 kg of fruit (Figure 14). Smaller sizes and Grade 2 fruit is usually bulk packed into 22 L reusable tubs. There are legally enforceable grading standards set in Western Australia for the marketing of avocados. These are set for the benefit of both the industry and the consumer. For further details of the grading regulations, see the Western Australian Government Gazette No. 133 Avocado Grading and Packing Code 1994 or Farmnote 004/2000 Avocados grading and packing code – interpretive notes.



Figure 14. Packing of avocado fruit into trays after a weight grader has sorted the fruit into size groups.

STORAGE AND HANDLING OF FRUIT

Cool avocado fruit to below 20°C (cool room should have 85 per cent or higher humidity) within 48 hours after harvesting. If fruit is not cooled quickly, the ripening phase may be triggered. The presence of ethylene will also trigger the ripening phase, so do not store avocados with ethylene producing products such as apples - see Farmnote No. 3/96 Mixed storage of fruit and vegetables and Farmnote No. 28/88 Storage conditions for fruit and vegetables.

If you plan to store avocado fruit for any longer than four days you need to reduce and maintain the fruit pulp temperature to between 5 and 7°C (maintaining high relative humidity, 85 per cent plus). Do not allow the pulp temperature to fall below 5°C as chilling injury may occur. If avocado fruit are stored correctly, they can be held for about four weeks in this 'hard mature' unripe stage before they need to be allowed to warm up to trigger the natural ripening phase. Ripening can also be triggered by the use of ethylene.

Fruit held below 10°C during the ripening phase may suffer from chilling injury. Keep ripening fruit at 16 to 20°C for optimum results. Once sprung (fruit shoulders have slight give), the fruit can be held at 2 to 7°C (depending on variety) to slow down the softening rate for about one week. For more information read Postharvest diseases of horticultural produce volume 2 (1995).

BRUISING

While the avocado fruit may look and feel like a cricket ball when harvested in the 'hard mature' stage, rest assured that the fruit is highly susceptible to bruising injury. Do not drop the fruit or subject it to excessive

vibration or pressure. These injuries will not show up straight away for you to cull out when grading. Much worse for your reputation and the future of the avocado industry, these injuries become obvious only when the consumer cuts open the fruit to eat. Bruising can result in the fruit being unacceptable to the consumer to eat and thereby potentially reducing future sales. Recent market assessments of fruit by the avocado industry has shown that bruising is one of the major postharvest problems with avocado fruit. So treat your fruit, and therefore your business, with great care.

QUALITY ASSURANCE

The Western Australia avocado industry has a good reputation for producing quality fruit. Several producers and packers have had their operations certified to SQF2000^{CM} standards. A guide to help interested operators attain SQF2000^{CM} certification has been developed by Agriculture Western Australia and the Avocado Growers Association of WA (AGAWA) and is available from AGAWA (see Factsheet 51/2000, Useful contacts for commercial avocado growers).

BUDGETS

Developing a budget for a horticultural enterprise is a fairly complicated exercise. There are many variables from property size and cost to irrigation and equipment needs that can alter the outcome of a budget development. It is generally recommended that you seek out the assistance of an economist with horticultural experience. As a guide, Agriculture Western Australia has produced a publication based on expanding an existing horticultural operation as this removes some of the major variables – Fruit development budget guide for south-west of Western Australia, supplementary (2000).

GROWING AVOCADOS ORGANICALLY

The organic revolution is a large and growing field in commercial fruit production. Avocados, because of their relative low level of pest and disease problems in Western Australia, do lend themselves to organic production. But before you rush out and decide to grow your avocados organically, beware that organic growing does not mean, simply planting the trees and letting them grow without help and then harvesting and selling the fruit. You will most likely produce very poor quality fruit and potentially even get a visit from Agriculture Western Australia over neglected orchard legislation. Be very aware that growing fruit organically is very hard work, often more labour intensive and more costly than the more 'normal' methods. To take advantage of being able to market your fruit as 'organic' (and therefore hopefully receive a price premium) you must be accredited under one of the various organic certifications. There are a range of these available. The main advice to be given when deciding which one to go with, make sure they are well known in your intended market and that they advertise themselves and police their policies.

AVOCADOS AND STOCK (ANIMALS)

Because of the damage stock can do to your trees it is not recommended that stock be allowed to graze in any fruit tree orchard. With avocado trees it is doubly important that you keep your stock out of the orchard and that you do not feed leaves or immature fruit to stock. Avocado leaves and immature fruit particularly have high levels of natural anti-fungal compounds that are toxic to certain animals – particularly horses.

Before you start to worry about your own health, these anti-fungal compounds are broken down naturally as a part of the ripening process.

REFERENCES

- Factsheet 51/2000 Useful contacts for commercial avocado growers.
- Farmnote No. 28/88 Storage conditions for fruit and vegetables (Agdex 201/56).
- Farmnote No. 42/88 Irrigation requirements of avocado (Agdex 235/561).
- Farmnote No. 41/90 Blockages in irrigation lines (Agdex 560).
- Farmnote No. 60/91 The garden weevil (Agdex 201/622).
- Farmnote No. 3/96 Mixed storage of fruit and vegetables (Agdex 201/60).
- Farmnote No. 43/99 Windbreaks for horticulture on the Swan Coastal Plan (Agdex 200/28).
- Farmnote No. 004/2000 Avocados grading and packing code – interpretive notes (Agdex 235/54).
- Farmnote No. 76/2000 Avocado maturity testing (Agdex 235/50).
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