Mango growing in Western Australia

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**Introduction**

The mango (*Mangifera indica*), sometimes called the 'king of fruits', by volume is the second largest tropical fruit crop in the world after bananas and fourth in total fruit after bananas, citrus and apples. It is native to north-eastern India and Burma. India, the main producer, accounts for 65 per cent of the world's mango crop, which is estimated at 16 million tonnes (FAO 1995). Cultivation of mango has occurred for some 4000 years and the tree has great cultural and religious significance in some countries.

The mango is a densely-foliaged evergreen tree, some varieties of which grow to 20 metres tall and live for 400 years or more. Once established, it serves as a useful windbreak, shade tree and ornamental, with attractive perfumed flowers. Its growth is marked by flushes of new bronze-pink leaves, three to five times a year. These turn green on reaching maturity. Flowers are produced on terminal panicles and occur during the early part of the dry season in the tropics and during spring in the warmer temperate regions.

Unripe fruits are used in pickles, chutneys, salads or consumed fresh. Ripe fruits are eaten raw as dessert, whole, or in fruit salads. They may also be frozen, dehydrated, canned or made into jellies, jams, juices and incorporated into yoghurts and iced confectionery.

The mango is a good source of sugars, vitamins A and C and minerals.

**The industry**

Australian mango production has seen dramatic growth over the past 10 years. Mangoes are now at the stage where they are one of the major horticultural crops in Australia. Queensland is currently the state which produces the majority of mangoes however significantly increasing volume is now coming from the Northern Territory and a dramatic rise in production is occurring in Western Australia.

Due to the geography of Western Australia it is possible to produce fruit from September through to April, some seven to eight months. Kununurra produces early, followed by Broome, Carnarvon and Gingin.

Some gaps in the production cycle still exist between Broome – Carnarvon and Carnarvon – Gingin however, with the planting of late varieties and increased storage of fruit it will be possible to achieve continuous supply for seven months.

**Climate**

As the mango originated in a monsoonal tropical environment with a period of drought, it is well suited to many parts of Western Australia. The mango will tolerate a wide range of climates, from warm temperate to tropical. It crops best in areas of low rainfall and low relative humidities at flowering, fruit setting and harvesting, and with a warm to hot climate during fruiting.

The mango is susceptible to cold. Young trees may be killed by temperatures below 0.5° Celsius. Older trees will survive a few degrees of frost, but may be severely damaged. In areas susceptible to frosts such as Gingin, selection of planting sites is critical. Ideally, a northern facing slope is the most suitable. Adequate frost protection is also essential.

Mangoes will tolerate temperatures up to 48° Celsius, without serious damage to established, irrigated trees, however sun damaged fruit and fruit drop can be caused by excessively high temperatures combined with low humidity.

Mature trees can tolerate prolonged periods of moisture stress as well as having a high tolerance to flooding.

Flowers may be damaged by rain and cold winds in winter and early spring. Hot dry winds can reduce fruit setting.
Cyclones also can seriously damage the crop, but fruit is usually harvested before the cyclone season. In the West Kimberley and Pilbara, severe cyclones may defoliate trees. The result is often a poor crop in the following season, especially from young trees. Cyclones rarely occur at Kununurra, but strong wind squalls preceding the first ‘wet’ season storms often cause the loss of large quantities of fruit.

Exposed fruits on the western side of the tree may suffer from sunburn. Some varieties such as Glenn are highly susceptible to sunburn. This can be limited by row orientation.

Soils
Mangoes will grow on a wide range of soil types from light sands to heavy clays. They do best in areas where soils are one to two metres deep, well drained and slightly acidic. However mangoes also grow well in Carnarvon where soils are alkaline.

Most commercial mangoes in northern Western Australia are grown on neutral to alkaline soils, whereas in the Northern Territory and Queensland they are grown mostly on acidic soils.

On the light levee soils of the Ord River Irrigation Area, trees grow more vigorously than on the heavy Cununurra clays.

In Kununurra many new plantings are going onto the heavy Cununurra clays due to the absence of the giant termite. Generally however on the heavier soils nutritional management becomes more of an important issue as this has a great bearing on fruit quality. Fruit quality is greatly affected by nutrition. Light sandy soils, whilst tending to have low nutritional status, lend themselves to easy nutritional management.

Mangoes have only a low to moderate tolerance of saline soils. Research is currently being conducted to identify salt tolerant rootstocks.

Propagation
Growers are strongly advised to plant grafted trees in the Kimberley from a Kensington Pride tree, which has been identified as possessing high and regular yielding attributes. This is particularly so for more tropical climates where low temperatures contribute less to floral initiation. Although in Carnarvon seedling trees will also initiate earlier flowering, grafted trees produce more regular yields. Grafted trees are generally less vigorous and this needs to be considered before planting in Gingin.

Most of the coloured Florida type varieties are monoembryonic and must be grafted. They do not produce fruit true to type from seed.

For information on mango propagation, see Farmnote 6/81 ‘Propagation of mangoes’.
Varieties

Selected Kensington Pride trees (sometimes known as ‘Peach’ or ‘Bowen’ mango) are high yielding and produce good quality fruit, but this may be smaller and of poorer colour than some of the new varieties. Unselected seedlings of this variety tend to be irregular in bearing in the Kimberley.

More than 80 varieties of mangoes have been tested at various locations throughout the State.

Results from variety trials planted at Kununurra, Broome and Carnarvon have identified a range of regular-cropping, market acceptable varieties with good fruit size (each 350 to 700 grams), which extend the present harvest (Table 1).

A range of other varieties are suitable for niche markets (Table 2). That is, good markets are available for small volumes but they will not compete well on the large volume markets with varieties such as Kensington Pride.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Timing</th>
<th>Market acceptability</th>
<th>Yield</th>
<th>Area suitability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana</td>
<td>Early</td>
<td>Moderate</td>
<td>Moderate Regular</td>
<td>Kununurra</td>
</tr>
<tr>
<td>Haden</td>
<td>Mid-Late</td>
<td>High</td>
<td>High Irregular *</td>
<td>Kimberley</td>
</tr>
<tr>
<td>Irwin</td>
<td>Mid</td>
<td>Good</td>
<td>High Regular</td>
<td>Kimberley</td>
</tr>
<tr>
<td>Keitt</td>
<td>Late</td>
<td>Good</td>
<td>High Regular</td>
<td>Carnarvon</td>
</tr>
<tr>
<td>Kensington Pride</td>
<td>Mid</td>
<td>High</td>
<td>Moderate Irregular</td>
<td>All</td>
</tr>
<tr>
<td>Kent</td>
<td>Late</td>
<td>Good</td>
<td>Moderate Irregular</td>
<td>Carnarvon</td>
</tr>
<tr>
<td>Palmer (Zillare)</td>
<td>Late</td>
<td>Good</td>
<td>Moderate</td>
<td>Carnarvon</td>
</tr>
<tr>
<td>R2E2</td>
<td>Mid-Late</td>
<td>High</td>
<td>Moderate Regular</td>
<td>All</td>
</tr>
<tr>
<td>Tommy Atkins</td>
<td>Mid</td>
<td>Good</td>
<td>High Regular</td>
<td>Kimberley</td>
</tr>
</tbody>
</table>

* Haden has proved to be irregular as a young tree but tends to be more regular bearing as the tree matures.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Timing</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nam Dok Mai</td>
<td>Mid</td>
<td>Good flavoured Thai variety.</td>
</tr>
<tr>
<td>Keow savoy</td>
<td>**</td>
<td>Superior green eating variety. Not suitable as a ripe fruit.</td>
</tr>
<tr>
<td>Willard</td>
<td>Mid</td>
<td>Highly coloured small fruit, high yielding.</td>
</tr>
<tr>
<td>Brooks</td>
<td>Late</td>
<td>Good flavour, high yielding with small fruit.</td>
</tr>
<tr>
<td>Heidi ##</td>
<td>Mid-Late</td>
<td>Good colour and flavour.</td>
</tr>
</tbody>
</table>

**Keow savoy is currently under evaluation in Kununurra.

## Heidi is currently under evaluation in Carnarvon and Kununurra. It is covered by PBR.

In Kununurra, the early market attracts the highest returns and there has been an emphasis on early varieties. Banana is currently the earliest of all the varieties assessed.

For information on mango varieties, see Miscellaneous Publication ‘An evaluation of mango cultivars and their commercial suitability for the Kimberley’.

Existing trees may be topworked by grafting to new varieties, following the procedure in Farmnote 6/81 ‘Propagation of mangoes’.

Top working
Planting

Mango trees should be planted as four- to 18-month-old seedlings or grafted plants from April to October, when they are relatively dormant. In Gingin, plant in early spring after the risk of frost has passed so that the young trees can establish enough roots to allow them to withstand the hot summer and following cold winter. In the inland Pilbara, plant in March, April, August or September. Near the coast, plant from March to September.

The best planting time in the Kimberley is May to August. This is particularly so at Kununurra and areas of similarly extreme climatic conditions, where a well-developed root system is essential to ensure the tree’s survival from October to the onset of the ‘wet’ season. Another planting window occurs during January and February with the arrival of the monsoonal rains. At Broome, where conditions are less extreme, mangoes may be planted all year round. Ideally, trees should be sun hardened before planting. Spraying trees with a protective coating of kaolin (Sunstop®) has been shown in Kununurra to decrease the incidence of sunburn on newly planted trees.

Prior to planting, use 300 grams of fertiliser containing phosphorus, potassium and trace elements, or use well-rotted animal manure. Mix with the topsoil and place at the bottom of the hole. Refill with topsoil and plant the trees deep enough to allow the root-ball to be covered completely with soil. On Kununurra clay, backfilling with sand will prevent air pockets but on large clay plantings this may not be practical. Successful establishment has been achieved in these situations by having the soil well watered before planting.

At planting, leaves may be cut back to reduce the total leaf surface area, reducing the rate of water loss through transpiration. This technique helps to reduce transplanting shock, and results in quicker recovery.

Spread a natural mulch, leaf litter, hay, bagasse or composted manure around the plant to conserve moisture and suppress weeds. Avoid the mulch touching the trunk to minimise disease risk. If plants are established on trickle irrigation, black polythene mulch will help to reduce water requirements and control weeds. In hot areas, cover with a natural mulch to reduce heat absorption.

Bana grass is a suitable windbreak for mango trees. It grows four to five metres tall, but should be planted at least six metres from the centre of the outside mango rows to allow vehicle access and make Bana grass root control easier. It should have its own water supply.

In wind-prone regions place hessian or shade cloth around the mango plants to protect them from strong winds. A white water-based paint applied to exposed branches, and also to the trunks of young trees, will help protect them from the sun. Water two to three times a week until the plants are established.
Spacing

Tree spacing will affect yield, growth and management practices of an orchard.

Block plantings provide natural protection from wind, but avoid planting the trees too close together.

Fruit is borne on the ends of branches, too close a spacing may severely limit fruit production in mature trees. At Carnarvon, space the rows 4.5 metres or nine metres apart and the trees five metres apart within the rows. When trees in the 4.5 metre rows start to touch, remove alternate rows, and alternate trees diagonally within the row so that those remaining are 10 metres apart on a triangle. If required, when trees are ready for thinning, alternate trees may be ‘topworked’ (re-grafted) to superior new varieties.

Planting high density hedge rows in Carnarvon has proved to be successful in attaining very high yields. However this system does require additional capital outlay to establish and manage.

In Gingin cool weather severely restricts growth of the trees which ideally lends itself to high density plantings. Row spacings of six to eight metres and tree spacings of 2.5 to 3.5 metres should be considered.

In Kununurra trees tend to be vigorous due to the warmer climate. This limits the potential for high density plantings with current technology. For lighter soils row spacings of 10 metres and tree spacings of five metres are recommended. On the heavy clay soils vigour is reduced so row spacings of eight to nine metres may be used with tree spacings of four to five metres. Less vigorous varieties such as Irwin may be planted at a higher density.

Mangoes are able to tolerate waterlogging and moderately saline conditions better than most tropical tree crops, but for best results, irrigation water should contain less than 1000 ppm total salts.

Plant physiology studies indicate that a period of cold stress before flowering should promote flower bud production, instead of shoot growth. In Carnarvon and Gingin trees are stressed enough by cold conditions. To save water, Carnarvon growers often do not water mature trees from April to June inclusive. In all areas, it is essential to provide adequate water from the first sign of flower spikes, until harvesting. In Kununurra, Kensington Pride only crops well after a cool winter. Under normal winter or dry season temperatures, imposing water stress does not necessarily lead to the promotion of good flowering however, it can reduce the chances of a vegetative flush just prior to flowering thus increasing the tree’s potential for a good flowering.

Total crop water requirement for a mature mango orchard is about 12,700 kL/ha/year in Kununurra and 11,200 kL/ha/year at Broome, at optimum (65 per cent) canopy cover. In Carnarvon it is estimated that a mature orchard will require 17,000 kL/ha/year.

The critical time for irrigation is during fruit development. Water stressing the trees at this time of year can lead to reduced yield.

Trees up to four years old should be watered every one to three weeks throughout the dry months.

In most growing regions under-tree sprinklers provide the most efficient irrigation delivery system. Local irrigation consultants are able to advise on specific sprinkler types for individual situations.

In Kununurra on the heavy clay soils, furrow irrigation is often used. Although this system is not as efficient as under-tree sprinklers, it does offer significant cost advantages.

For information on mango irrigation, see Farmnote ‘Mango water requirements Western Australia’.

High density planting

Irrigation

The mango is relatively tolerant of dry conditions due to its deep root system. However, most feeder roots are concentrated in the top 75 to 80 centimetres of soil.
Weed control

To assure maximum growth potential of newly planted trees good weed control is essential. On newly planted trees a heavy mulch layer of straw or bagasse will initially give excellent weed control. This has the added advantage of reducing the risk of herbicide damage to young trees and improving irrigation efficiency whilst adding organic matter to the soil.

Herbicides effectively control under-tree weeds in mango orchards. Regular slashing between trees gives good inter-row control of weeds. Soil cultivation to control weeds may damage surface roots.

To control short-lived weeds, knockdown herbicides such as paraquat (Gramoxone®), diquat (Reglone®), or mixtures of these chemicals such as SpraySeed®, or Triquat® are effective.

Spray paraquat at a rate of 1.5 litres per 200 litres water plus 300 millilitres wetting agent per hectare. Paraquat is more effective against grasses. When broad-leaved weeds are a problem, apply diquat at 300 millilitres per 200 litres of water with the paraquat.

Glyphosate (Roundup®), a translocated herbicide, controls perennial weeds. Use up to 1.0 litres per 100 litres water. Glyphosate is more expensive than paraquat and diquat. Glyphosate however does not give good control of leguminous weeds such as those found on the Cununurra clays. Basta® has given some control of these types of weeds.

Glyphosate, paraquat and diquat are contact weed killers and have no action in the soil. Ensure that the spray does not touch the leaves of the mango or the green trunks of young trees. In summer, chemicals may be inactivated by strong sunlight so they should be applied early morning or in the evening.

As the trees grow, their canopies shade the soil and retard weed growth, reducing the need for spraying.

Nutrition

Only generalised recommendations of mangoes’ fertiliser requirements can be made. It is important that for good nutritional management regular leaf samples are taken. Nutritional levels will change in the tree during the season. It is therefore important to sample the trees at the same time each season. The most stable time of year for sampling is just prior to flowering. Take leaf samples from the last mature flush, ensuring that the shoot is dormant at that time.

Table 3. Optimum leaf levels of various nutrients for all areas

<table>
<thead>
<tr>
<th>Major element</th>
<th>Per cent of dry weight</th>
<th>Minor element</th>
<th>Parts per million of dry weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>0.8 to 1.6</td>
<td>Zinc</td>
<td>20 to 150</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.09 to 0.15</td>
<td>Copper</td>
<td>10 to 20</td>
</tr>
<tr>
<td>Potassium</td>
<td>0.8 to 1.5</td>
<td>Boron</td>
<td>30 to 100</td>
</tr>
<tr>
<td>Calcium</td>
<td>1.5 to 3.0</td>
<td>Manganese</td>
<td>60 to 500</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0.25 to 0.80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A number of commercial laboratories, and the Western Australian Chemistry Centre carry out leaf analyses.

Young trees in all areas will require a basal fertiliser at planting time and small regular NPK applications to ensure maximum growth during the juvenile phases. However, when fruiting commences nutrition must be closely monitored. Traditionally regular applications of nitrogen have been applied to mango trees in Carnarvon and in the Kimberley. It has become recently apparent that this practice is contributing to poor quality fruit. Green fruit, uneven ripening, poor blush, excessive vigour and soft nose are characteristics of excessive nitrogen. Levels need to be maintained in the low to mid-range area (Table 3) for good quality fruit.

Zinc deficiency (severe → mild)
**Carnarvon area**

For the first three years, fertilise young trees every three months with 40 grams of urea per tree, per year of age, that is, up to 120 grams of urea applied four times per year in the third year. From the fourth year, apply fertiliser after flowering to increase fruit size, and after harvesting to provide strong shoot growth on which the following year’s crop will be borne. Do not apply during the stress period of flower initiation in April and May. Once trees are fruiting monitor nitrogen levels closely.

**Kimberley area**

In the Kimberley area, maintain the soil’s available phosphorus level at 40 to 50 ppm. This can be achieved by a once a year wet season application of double super. Adjust potassium applications by monitoring with leaf analyses. Cununurra clays tend to be relatively high in potassium so generally less is required than on the lighter sandy soils. Soils in the Kimberley region are deficient in zinc and copper, therefore regular applications of these trace elements is essential. For mature trees apply rates of 20 to 30 grams of zinc and copper sulphate every two months. Regular foliar applications of zinc chelate on young, fast growing trees will ensure adequate levels are maintained in the growing points. Calcium deficiency is often a problem in most areas of the Kimberley. If nitrogen levels are high and calcium levels are low then there is a high risk of fruit disorders such as soft nose and possible internal breakdown. Foliar applications of calcium chelate have been shown to raise calcium levels in the leaves but many of these problems can be avoided by reducing the nitrogen level in the tree.

**Pests**

Western Australia has relatively few mango pests, however, with the growth of the industry pest pressure is likely to intensify and several new pests have emerged in recent years. Two serious mango pests have been introduced recently to Australia, the Papaya fruit fly and mango flower hopper. Currently neither of these pests have been identified in Western Australia.

Strong quarantine measures have been imposed to prevent mangoes being imported from areas infested with the mango seed weevil. Western Australia is free of this major pest.

Orchard hygiene is important in minimising the risk of fruit fly infestations.

Good pest monitoring and control is essential for fruit quality and maximum yields. Some pests such as red shouldered beetle and fruit spotting bug can build up numbers very rapidly and cause significant economic loss if not monitored. Selecting the correct chemical and application method is essential for good pest control.
Control methods are those registered in Queensland and some of these chemicals are not registered in Western Australia. Growers wanting to use chemicals that are not registered for that use in WA must apply for an off-label from the National Registration Authority for Agricultural and Veterinary Chemicals (NRA). NRA permit application forms are available from Agriculture WA. (08) 93683815

### Table 4. Mango pests occurring in Western Australia

<table>
<thead>
<tr>
<th>Pest</th>
<th>Occurrence</th>
<th>*Control</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean fruit fly</td>
<td>WK,C,GG</td>
<td>Dimethoate</td>
<td>Can be a serious problem if not controlled.</td>
</tr>
<tr>
<td>Cerasitis capitata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Javis fruit fly</td>
<td>K,WK</td>
<td>*Dimethoate</td>
<td>Only occurs after first rains. Late varieties more susceptible.</td>
</tr>
<tr>
<td>Dacus johnstoni</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit spotting bug Amblyopus sp.</td>
<td>K,WK,C,GG</td>
<td>*Endosulphan</td>
<td>Cause stem and tip dieback, and black spotting on fruit.</td>
</tr>
<tr>
<td>Flower thrips</td>
<td>K,WK,C,GG</td>
<td>*Endosulphan</td>
<td>Fruit drop and scarring.</td>
</tr>
<tr>
<td>Franklinella sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red banded thrips</td>
<td>K</td>
<td>*Endosulphan</td>
<td>Currently only a problem in nurseries.</td>
</tr>
<tr>
<td>Selenidius vibroscens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flower eating caterpillar</td>
<td>K,WK</td>
<td>*Endosulphan</td>
<td>Cause fruit drop and scarring. Greater problem in the WK.</td>
</tr>
<tr>
<td>Acyrthosiphon ligatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red shouldered beetle</td>
<td>K</td>
<td>*Carbaryl</td>
<td>Causes severe defoliation and flower death.</td>
</tr>
<tr>
<td>Monographia australis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large tip borers</td>
<td>K,WK,C</td>
<td>*Methidathion</td>
<td>Chews new growth flushes only a problem on young trees.</td>
</tr>
<tr>
<td>Pencillaria prosnektre</td>
<td></td>
<td>*Endosulphan</td>
<td>Cause sooty mould.</td>
</tr>
<tr>
<td>Pink wax scale</td>
<td>K,WK,C</td>
<td>*Spray oils,</td>
<td>Leaves residual on the fruit, can cause tree death in nurseries.</td>
</tr>
<tr>
<td>Crepeptide blumbertron</td>
<td></td>
<td>*Methidathion</td>
<td></td>
</tr>
<tr>
<td>Mango scale</td>
<td>K,WK,C</td>
<td>*Spray oils,</td>
<td></td>
</tr>
<tr>
<td>Pseudacoccus diastata</td>
<td></td>
<td>*Methidathion</td>
<td></td>
</tr>
<tr>
<td>Appleapex tuberculatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mango hopper</td>
<td>K,WK,GG</td>
<td>*Carbaryl</td>
<td>Cause sooty mould and twig wilt.</td>
</tr>
<tr>
<td>Calyptrades acuminata</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit piercing moths</td>
<td>K,WK,C</td>
<td>Pick fruit at mature green stage</td>
<td>Pierce ripening fruit causing fungal rots to enter.</td>
</tr>
<tr>
<td>Oliobes sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green ants</td>
<td>K,WK</td>
<td>Spot spray</td>
<td>Cause sooty mould and picker discomfort.</td>
</tr>
<tr>
<td>Oechna xylophila</td>
<td></td>
<td>*Chlorpyrifos</td>
<td></td>
</tr>
<tr>
<td>Giant termite</td>
<td>K,WK</td>
<td>Trap cropping and #Mirex baiting</td>
<td>Causes tree death.</td>
</tr>
<tr>
<td>Mastotermes dentinarius</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

K = Kununurra, WK = West Kimberley, C = Carnarvon, GG = Gingin.
*Restricted use only. Soon to be deregistered.

### Diseases and disorders

In Carnarvon, late crops of cool stored mangoes are often affected by Phomopsis mangiferae disease which causes stem end rot and large spots on the fruit. Control of this disease can be difficult.

In Perth, flowers, leaves and fruits may be affected, especially in very wet and cold winters, by lesions caused by anthracnose. Mancozeb sprays from flowering to harvest should give some control. Anthracnose is present in most growing regions of Western Australia. However in Kununurra, Carnarvon and the inland areas near Broome conditions during flowering and fruit development are generally not favourable for the disease. If the fruit from these regions requires extended storage then precautionary dips in Prochloros (Sportak®) solution at 55 millilitres per 100 litres of water for two minutes will be necessary. Sportak® is registered for use on mangoes in Western Australia.

In coastal areas of Broome and in Gingin, anthracnose has the potential to be a greater problem. Bacterial black spot occurs in all growing districts of Western Australia. Generally it is not a major problem in the drier areas such as Kununurra and Carnarvon, however, it is a significant problem in Gingin. The disease can severely affect flowers, vegetative growth and fruit.

Copper sprays and efficient windbreaks to reduce tree damage and minimise points of entry to the bacterium are the main means of control. There are no bactericides currently registered for controlling the disease.

Recently a new mango disease, mango scab, has been identified in Darwin. This has the potential to affect fruit quality when allowed to spread unchecked. Surveys in mango growing districts of Western Australia have failed to find the disease present. If established in Western Australia it could cause serious economic loss in areas such as Gingin.
In Carnarvon, Broome and, to a lesser extent Kununurra, fruits of late varieties of mangoes are often affected by internal breakdown varying from a small to a large proportion of the fruit, particularly after hot weather but no disease pathogens have been identified in this condition and no treatment is available. Producers know this disorder as ‘jellyseed’.

A more serious condition, spongy stem end (stem end cavity), is increasingly affecting Kensington Pride fruit. The flesh, usually below the stem, separates, giving the appearance of a sponge. This tissue often becomes fibrous and woody. The disorder is more prevalent in later-harvested fruit. External appearances are often characterised by a dark sunken section on the skin near the stem of the fruit. No conclusive explanation for these disorders is available, however, it may be related to low calcium levels in the fruit.

In Kununurra and Carnarvon hot drying winds may cause marginal leaf necrosis (death of leaf edges). This effect may be worse on alkaline soils.

**Pruning**

When a young Kensington Pride tree is about one metre tall, remove 20 to 30 millimetres of the terminal shoot to promote branching. If this is not done, the tree will grow four to five metres tall as a single stem and will be subject to wind buffeting. Three side branches should be allowed to grow from beneath the point of topping. When these have made 40 to 60 centimetres of growth, repeat pruning of terminals to induce further branching. Ensure that your pruning maintains wide branch-crotch angles - up to 90° to minimise wind damage. This structural pruning is essential in the early years of tree development to assure a strong structured tree and to maximise the number of terminals (potential fruiting sites). Significant yield increase can be achieved on young trees if they are intensively pruned.

Fruit is borne on new season’s growth and usually on the tips of the outer branches of the tree. Therefore, it is only necessary to lightly thin trees by removing weak, overcrowded or broken branches, keeping the centre of the tree open. Cut off branches which are too near the ground.
Pruning in the tropics

In the tropics mango trees tend to be extremely vigorous. The tendency is to want to reduce the size by heavy pruning but this can be detrimental to yield for several seasons after pruning. This is primarily due to the lack of a growth check, e.g. cold temperatures. Light pruning of trees in the tropics just prior to flowering (see tip pruning: flowering and fruiting) has shown promise. Research is currently under way in the tropics to address these issues.

Pruning in the subtropics

Cool winter temperatures in the subtropics generally impose a growth check on the trees. Postharvest pruning is a common practice in these regions. The frequency and severity of the pruning will be a matter of judgement depending on the timing and extent of the previous season’s growth. For cropping not to be detrimentally affected by maintenance pruning, a following growth flush must occur.

Hedging

Hedging is a management system whereby trees are planted at a close spacing growing into each other and maintained as a hedge rather than as individual trees. Trees may be mechanically pruned annually to maintain size. This system has proven to be successful in Carnarvon, giving very high yields. However, fruit colour may not develop as well due to high amounts of shading.

Flowering and fruiting

Greenish white flowers, tinged with pink are borne on large panicles which develop from terminal buds on the outer stems. A tree may bear over a million flowers but most of the flowers do not have functional female parts, so only a few fruits are borne on each panicle.

The flowers are self- and cross-pollinated. Various insects such as flies, bees and ants transfer the pollen in cross-pollination.

Flowering in the Kimberley occurs from June through to September. In Carnarvon, flowering usually starts in mid-June and continues through to early October.

Kensington Pride mango trees generally crop lightly on windward-side branches and also on heavily shaded branches.

Promotion of better flowering is an area which has received large amounts of attention over recent years. The use of Paclobutrazol (Cultar®) has shown to generally improve flowering in poor seasons. Methods and accuracy are critical in applying this chemical. Contact your local horticulturist for latest recommendations on rates. In tropical areas a pre-flowering tip pruning has been shown to improve flowering on Kensington trees. This is where the trees are lightly pruned back to mature wood just prior to flowering.

Harvesting and packing

Mango trees grow broad and relatively tall. The foliage is dense, and the fruit difficult to pick. To harvest most of the fruit, traditionally ladders and hydraulic platforms have been used. This method, whilst convenient, is expensive and has led to the recent development of semi-mechanised harvest aids. Harvest aids are either self-propelled or tractor-pulled trampolines whereby fruit is harvested onto canvas whilst being sprayed with a detergent solution to minimise sap burn.

Maturity testing

Determining the mature green stage for harvesting mangoes is a difficult task. Often the temptation is there to pick the fruit too early due to high market prices at the beginning of the season. Several maturity indices are currently used by industry but none of the indices is completely accurate.

1. Flesh colour. This method is derived from the basis of internal flesh colour and fruit shape. Fruit are said to be mature when the internal flesh colour is light yellow. Colour charts are available for this. This is the most commonly used in-field method. It is, however, destructive and is not useful at the market as immature fruit will still colour internally after harvest.

2. Dry matter. Dry matter at harvest is a commonly used maturity indices in Queensland and the Northern Territory. It has been found that there is a correlation between dry matter and Brix (sugar levels). Dry matter is calculated by measuring a fresh sample of fruit then oven drying it and calculating the remaining dry matter as a percentage of the total weight. The recommended dry matter for Kensington is 14 per cent. This method can be used on the market floor, however, there is some concern over the accuracy of this method as dry matter can be manipulated by irrigation management.

3. Specific gravity. Although this method has been well researched, it is currently not used commercially in Australia. Fruit with an SG greater than one are said to be mature, this means they will sink in water, while immature fruit will float. This method has the potential to be used for sorting the fruit on a grader once it has been harvested.

4. Heat sums. This method being developed by the NTDPI is still in its early stages however, it appears to have great potential as an accurate non-destructive method for determining maturity. The method is a calculation of the daily accumulated heat taken from the time of floral emergence.
Heat sum = $(\text{max } ^\circ \text{C} + \text{min } ^\circ \text{C}/2) - 12 ^\circ \text{C}$. (Diczbalis et al. 1997). For Kensington an accumulation heat sum of 1600 hours has been found to indicate optimum maturity.

**Preventing sap burn**

Sap burn is the largest single quality problem with mango. Poor harvesting and handling techniques will result in a high incidence of sap burn which will severely downgrade the fruit quality. The sap in Kensington Pride consists of two components, an oil and a protein component. The oil component of the sap is mostly responsible for the burning of the skin. The oil component is at its highest concentration in the spurt sap which is exuded immediately the stem is snapped. All harvesting and handling techniques used should be aimed at eliminating the potential for the sap to come into contact with the skin of the fruit.

**Skin browning**

Harvest aids and the use of detergents have greatly reduced the incidence of sap burn on mango however, a new problem has become increasingly more noticeable, being brown markings on the surface of the skin of the fruit. This is commonly called skin browning. Several forms of skin browning have been identified as well as their causal agents. Hygiene is the single greatest method of minimising skin browning. Care needs to be taken that equipment used in the harvesting and handling procedure is maintained clean at all times. Fruit should never be packed when wet as this is a primary cause of skin browning.

**Grading**

Fruit are graded into lines according to their blemish level. Charts are available to assist in determining the amount of blemish level for each grade of fruit. Some growers participating in group marketing have already set standards for each grade.

Do not send immature fruit, windfalls, deformed or sunburnt fruit to the fresh fruit market.

For chutney production, harvest immature green fruit when it is still possible to cut through the seed with a knife.
**Expected yield**

For establishing a new mango plantation, estimating yield is important for planning and budgeting. Yields can vary considerably depending on climatic conditions, pests and diseases, variety, pruning and the use of growth regulants.

The mango's fruit yield can vary from year to year. Many varieties, including the Australian standard Kensington Pride, suffer from irregular bearing. This is characterised by a heavy crop one year followed by one or more light crops. At Kununurra, Kensington Pride mangoes may produce as many as five light crops in succession. In such circumstances, individual fruits are usually large - 8 to 12 fruits per 6.5 kilogram tray. In seasons of heavy cropping, individual fruits tend to be smaller - 15 to 20 fruits per tray.

Yield can fluctuate dramatically from season to season with Kensington; 150 per cent variations in yield are not uncommon. This can be reduced to some extent by the use of grafted trees, and Cultar®. In the Kimberley, varieties such as Irwin have proven to have more regular yielding patterns.

| Table 5. Expected yield for each variety (data from Kununurra) |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Year 3 (kg) | Year 4 (kg) | Year 5 (kg) | Year 6 (kg) | Year 7 (kg) | Year 8 (kg) | Average mature tree |
| Kensington  | 6  | 19  | 32  | 45  | 57  | 70  | 70  |
| Irwin       | 8  | 27  | 47  | 66  | 85  | 105 | 110 |
| R2E2        | 0  | 11  | 22  | 33  | 44  | 55  | 71  |
| Haden       | 3  | 12  | 21  | 30  | 39  | 48  | 104 |
| Keitt       | 0  | 14  | 28  | 42  | 56  | 70  | 107 |
| Kent        | 2  | 6   | 10  | 15  | 19  | 23  | 69  |
Keep fruit in the shade at all times and handle gently from tree to shed and during packing.

To create and maintain a good reputation for quality production in the market, pay close attention to grading. Grade for size and blemish level.

Pack in single layer trays which hold 6.7 to 7.5 kilograms of fruit - 8 to 24 mangoes. Commercially available tray liners are available. These are made of compressed paper which is ideal to absorb any ooze sap. Do not use woodwool as it predisposes the fruit to fungal rots. Pack the fruit with the stem end down. This position prevents ooze sap contaminating the fruit. Stickers identifying the brand are important. They should be distinctive in colour and simple in design. Fruit is generally removed from its tray for retail display and therefore cannot be identified without a sticker. Mango packs should be tight to avoid movement. Some shrinkage will occur in transit. Cartons should be marked with the grower's name or number, variety and fruit count.

**Ripening and storage**

Removal of field heat is critical in maintaining fruit quality and for achieving maximum storage life. For this reason forced air cooling is recommended for producers in Carnarvon and the Kimberley.

For maximum storage life the fruit should be stored at 13° Celsius. This is the most suitable temperature for transportation without the risk of causing chill damage to the skin.

Fruit is generally put into ripening rooms at the market and gas ripened. This gives more uniformed ripening throughout the tray. It is currently not recommended to pre-ripen Kensington before leaving for market, although this is commercially practised in some parts of Queensland.

Optimum temperatures for ripening mangoes range from 20 to 23° Celsius. If temperatures are high, fruit will not develop yellow background colour. Rather it will tend to ripen in a less attractive dull yellow/green colour. If temperatures are too low then sometimes fruit flavour can suffer.

Commercially, ripe Kensington Pride mangoes may be stored for three weeks by dipping in a prochloraz (Sportak®) solution for controlling anthracnose and other postharvest rots then maintained at 13° Celsius. Both in storage and transport, the temperature must not fall below this level, unless under strictly controlled conditions where the temperature is gradually reduced. The critical minimum storage temperature for most other varieties has not yet been determined. Processed mangoes or mango pulp can be stored at 0° to 1° Celsius for up to six weeks. In the home, sliced mango can be stored in a freezer at minus 18° Celsius for up to 18 months.

**Processing**

Mango is an extremely versatile fruit when it comes to processing. The flesh can be used for canning, juicing, drying, freezing and as fresh slices for the pre-prepared fruit salad market. Currently large opportunities exist in the canning industry with one large cannery in Queensland having a market for several thousand tonnes per annum. Due to economies of scale it is unlikely that in the near future canning will be an option for Western Australian producers. Although opportunities exist for small scale dried mango production, large scale production at this stage would be difficult due to cheap product being available from the Philippines and Thailand. Frozen or preserved pulp offers significant opportunity for Western Australia providing the raw material for use in fruit juice, yoghurt fruits and ice confectionery. Industry experts consider it unlikely that Australia would be competitive in exporting mango fruit pulp. Recent developments in the pre-prepared fruit salad market also offers opportunities for processing of seconds. Although the technology is relatively new for maintaining the shelf life of pre-cut fruit, it does have significant market potential.
Processed mango products

References and further reading


