Agronomic Manual for Pomegranate (*Punicaceae Punica granatum* L.).

Introduction

The pomegranate (*Punica granatum*) is native to Iran through the Himalayas to northern India. The fruit was naturalized throughout the Mediterranean region through ancient times and today the main areas of world production are Turkey, Spain and California. Around the world pomegranates are generally grown in Mediterranean climates, often with very warm dry summers.

More recently there has been renewed interest in the consumption of pomegranate fruit (*Punica granatum* L.) juice which has been reported to have many positive health benefits. These include a reduction in blood pressure as well as a reduction in atherosclerosis and oxidative stress (Balasundram *et al.* 2006; Basu and Penugonda 2009; Mertens-Talcott S. *et al*. 2006; Syed *et al.* 2007). The benefits are largely reported to be the result of the juice's high level of antioxidant capacity (Ricci *et al.* 2006). The principle antioxidant polyphenols in pomegranate juice include the ellagitannins and anthocyanins. The levels of these compounds in the juice have been reported to vary depending on the method of juice extraction, the cultivar and the level of antioxidants in the juice has also been reported to change during fruit maturation and ripening (Basu and Penugonda 2009; Mousavinejad *et al.* 2009; Shwartz *et al.* 2009).

Pomegranates are a new crop in Australia. The new industry will provide both fresh fruit and fruit processed for juice with the positive health benefits reported earlier helping to drive demand.

The Tree

The tree is an attractive deciduous large shrub/small tree, up to 4 to 5 m high. The flowers, fruits and autumn foliage are ornamental and it is often planted in home gardens as well orchards.

Pomegranate Tree, Condobolin, NSW

The tree is usually deciduous, but in certain areas the leaves will persist. The branches are stiff, angular and often spiny. There is a tendency for stems to sucker from the base. Pomegranates are long-lived, there are specimens in Europe known to be over 200 years old. The vigour of a pomegranate declines after about 15 years.

The Flowers

The common cultivar, Wonderful has flowers which are an attractive scarlet colour, however there are other cultivars where the flowers are white or variegated. The flowers are about 5 cm across, have 5 to 8 crumpled petals and a red fleshy, tubular calyx which persists on the fruit. The flowers may be solitary or grouped in twos and threes at the ends of the branches. Flowers occur on spurs of 2 to 3 year wood and also on new wood.

Pomegranate flowers

The pomegranate is self-pollinated but can also be cross-pollinated by insects. Cross-pollination increases the fruit set. Wind pollination is insignificant.

The Fruit

The fruit is a false berry. It consists of many close packed red grains (arils), and segments which are separated by a non-edible white pith. The arils contain a seed surrounded by an edible juicy pulp. The arils are filled with sweetly acid, red juice red. In each sac there is one angular, soft or hard seed.

The fruit is nearly round, about 10 to 15 cm wide and is crowned at the base by the prominent calyx. The tough, leathery skin or rind is typically yellow overlaid with rich red in the cultivar Wonderful. High temperatures are essential during the fruiting period to get the best flavour. The pomegranate may begin to bear in 1 year after planting out, but $2^1/_2$ to 3 years is more common. Under suitable conditions the fruit should mature some 5 to 7 months after bloom. In Australia Fruit matures from March to May.

Pomegranate fruit whole the inside arils

Fruit are easily bruised and should be carefully handled during harvest. The fruit will crack when too mature, or if there is too much rainfall in autumn, high humidities, poor watering, or high winds (Burt, 2007).

The fruit must be picked with clippers. Clip the stem close to the fruit. The fruit will not ripen off the bush and so must be harvest when the Total Soluble Solids (% TSS) and size meets the market requirements. Yields are 10 to 20 t/ha, with 100 to 200 fruit per plant.

Postharvest storage

The fruit can be used or sold either as whole fruit as arils or juice. The fruit can be held in cool storage (5 – 7 °C) before the arils are extracted. The fruit will suffer chilling injury if they are stored at temperatures below 5 °C (Figure 3). Pomegranates will store for about 1 to 2 months at ambient temperatures, or kept for seven months at 0 to 5 °C and 80 to 85 per cent relative humidity. The main postharvest problems are dehydration or the development of fungal infections in the calyx end of the fruit and also the development of internal rots (Figure 2).

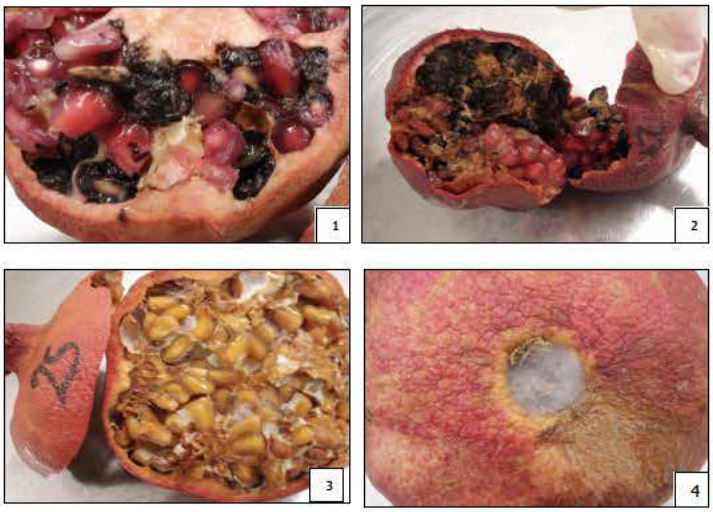

Figure 2. Rotten fruits (1, 2 and 3) and infection on the calyx (4) by *Botrytis cinerea*

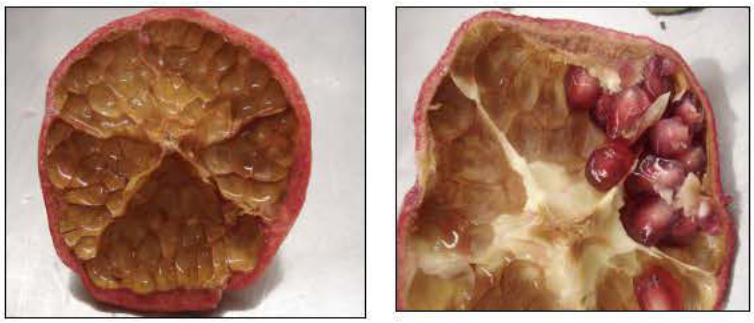

Figure 3. Internal browning produced by chilling injury in fruits stored for 6 months

The juice can easily be extracted from the separated arils. The juice is also used to produce Grenadine, which is used in cocktails and to produce wine. After extraction, the waste material can be used for pharmaceuticals and cosmetics.

Seasonal Fruit Growth Pattern

The total period of fruit growth has been reported to be about 110 days (14 wks) for the variety, Wonderful (Shulman *et al.* 1984). The growth pattern of the fruit is a single sigmoid pattern and the rate of fruit development varies with variety, growing location and season (Gil *et al.* 1996; Shulman *et al.* 1984). The juice yield is about 35% at harvest depending on climatic conditions.

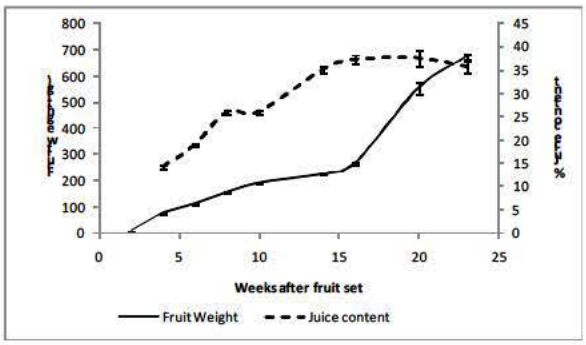

Figure 1. Changes in pomegranate fruit weight and juice content over the 2008 and 2009 season in Condobolin, NSW.

Fruit Production

Fertilising

Pomegranates grow best in well drained soils. They require moderate levels of fertiliser. This is best applied during the growing season. The WA department of Agriculture (Burt, 2007) suggest that for the first four years it is best to apply a good, mixed fertiliser each month from August to March. One suitable commercial product contains 15% N, 2.2% P, 16.6% K, 1.2% Mg, 8% S and six trace elements. Apply a total of 0.5 g per tree in year 1, 0.75 kg in year 2, 1.0 kg in year 3 1.5 kg in year 4, 2.5 kg in year 5 and 3.0 kg from year 6 onwards.

Extra applications of zinc sulphate at 2g/L may need to be sprayed onto plants grown on alkaline sandy soils. Extra manganese and iron sprays may also be needed.

It is helpful to do a leaf and soil analysis so that you have a guide to the nutrient uptake by the trees. The results must be compared with other fruit trees, as there are no comparable standards for pomegranates.

Table 1. Desirable nutrient concentration for pomegranate leaves and fruit

Nutrient	Optimum concentration (leaf)	Units (dry wt)	Optimum concentration (fruit)	Units (fresh wt)
Nitrogen	2.25	%	170	mg/100g
Phosphorus	0.15	%	8	mg/100g
Potassium	1.7	%	260	mg/100g
Calcium	1.9	%	3	mg/100g
Magnesium	0.5	%	3	mg/100g
Iron	110	mg/kg	0.30	mg/100g
Manganese	40	mg/kg	0.40	mg/100g
Zinc	30	mg/kg	0.15	mg/100g
Copper	10	mg/kg	0.12	mg/100g
Boron	70	mg/kg	0.15	mg/100g

Data from: MJ Malakouti (2006) Quality Indices and Optimum Levels of Nutrient in Fruits Grown on the Calcareous Soils of Iran, 18th World Congress of Soil Science, Philadelphia, Pennsylvania, July 9-15, 2006, USA

Irrigation

The pomegranate has good drought tolerance and is also able to withstand short periods of waterlogging. Mature plants with low level sprinklers or drip irrigation need about 5 to 8 megalitres of water per hectare per year (ML/ha/yr) from September to April in Western Australia (Burt, 2007).

Knowing the crop water requirement is essential for effective irrigation scheduling. The crop water requirement can be estimated from the pan evaporation rate, an appropriate crop factor and an estimate of the crop area (Pande *et al*. 2003; Boland et al. 2002).

Daily crop water use[1] (mm) = Pan evaporation[2] x Crop factor[3] x Wetted Area[4]

1. *Crop water requirement (in L per plant per day)*
2. *Pan evaporation (in mm)*
3. *Crop factor (i.e. 0.8 for matured pomegranate cultivations)*
4. *Wetted area (in m^2) (i.e. 4 m^2)*

The estimated crop water requirement using the pan evaporation data at the Agricultural Research Station at Condobolin is given in Table 2. This data gives the grower a guide to daily water use through the season and this can be validated throughout the season using soil moisture probes located in tree rows in the orchard.

Table 2

Prediction of crop water requirement (Based on Data of 2007/08)

	Mean Temp. (^oC)	**Mean RH (%)**	**Pan Evaporation** (mm/day)	**Rainfall** (mm/day)	**Crop Water Requirement** (L /plant/day)
October	23.3	34.5	7.8	0.7	25.0
November	24.8	41.5	7.8	3.5	25.0
December	25.6	46	7.7	2.9	24.6
January	28.2	40.5	9.3	0	30.0
February	25.0	47.5	7.1	2.8	23.0
March	25.2	36	7.1	0.45	23.0
April	19.3	42	4.8	0.3	15.4

From: www.bom.gov.au/climate/dwo/IDCJDW2032.shtml.

Pomegranates have a higher salt tolerance than most fruit crops. However, the water quality should be less than 1000 mg/kg (ppm) total soluble salts for best results, but plants will tolerate more than 2000 mg/kg (ppm) total soluble salts (Burt, 2007).

Pruning

The pomegranate tree is a shrub and there are many different ways to manage the tree shape. Pruning is best done in the winter. In all methods, it is important to ensure that the fruit are exposed to adequate sunlight but at the same time avoid sunburn and to minimise overlapping branches to prevent wind rub on the fruit. Initially pruning aims to encourage side shoots to develop a small compact shrub that is easy for harvest. It is also important to remove suckers and water shoots, especially at the base of the stem as these are unfruitful, waste resources and provide shade and potential sources for fruit rubbing.

It is also useful to support the trees using a trellis. Some work on the benefits of various types of trellising systems has been done in Israel and it may be worthwhile seeking reports of this type of work. The trellis helps the tree to support the weight of fruit, and keeping the habit of the tree open for light and spray penetration.

Pests and diseases

Aphids and Scale insects can damage the leaves and stems but there are currently no registered insecticides for pomegranates in Australia.

Heart rot is often found in parts of the fruit and this is not obvious until the fruit is opened. It is believed to be caused by the fungal pathogen, Alternaria sp which initially attacks the flower.

Other postharvest decay-causing pathogens are *Aspergillus* sp. and *Alternaria* sp., and they may cause the disease called "Heart rot". The fungi can grow within the fruit without external symptoms except for slightly abnormal skin colour. If the mass of blackened arils reaches the rind, it will cause softening of the affected area. Infection begins in the orchard, especially following rain during flowering and during early fruit development (Kader, 2006). It is difficult to control and orchard hygiene (eg. remove old fruit) is critical to reduce the latent spore load at flowering (Burt, 2007).

Weeds

Mowing or spraying to manage weeds is preferred to cultivation in older plantings to avoid root damage. Planting or a cover crop mixture of legumes and grasses in the inter-row is advisable to manage weeds and improve soil structure (Burt, 2007).

Weeds in the inter row area can be controlled using a directed glyphosate spray provided suckers have been removed prior to spraying. Sucker removal is important otherwise glyphosate can be translocated into the trees and will kill them.

Crop protection chemicals registered or available to growers under Minor Use Permits for use in pomegranate (*Punica granatum*) production in Australia (as of 30 Oct 2009)

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Overview

According to WA Agriculture (Burt, 2009), "Pomegranates have few pest and disease problems…**Mediterranean fruit fly** occasionally damages fruit where the fruit is cracked...The presence of this pest in Western Australia means that the whole fruit cannot be exported to countries where this pest is not found. **Aphids** can result in a twisting of young shoots and leaves… **Scale** insects can damage the leaves and stems…**Parrots** will attack the fruit if the shell is cracked…**Rats** can damage the fruit…**Root knot nematodes** can damage the roots…Heart rot is often found in parts of the fruit and this is not obvious until

the fruit is opened. It is believed to be caused by the fungal pathogen, ***Alternaria sp*.** which initially attacks the flower. It is difficult to control".

Only two insecticides (fenthion & endosulfan) and one herbicide (fluazifop-p) are registered specifically for use in pomegranates in Australia. No fungicides are registered in Australia for pomegranates. In addition, only one other insecticide (dimethoate) is available for use under permit. Non-selective herbicides while not specifically registered in pomegranates, are available to grower under general use directions.

INSECTICIDES

(Queensland) Fruit fly (*Dacus tryoni*)

Fenthion, dimethoate

They are mostly used as a quarantine measure when fruit has to be moved either from a quarantined area or when stipulated as an export condition. These two old organophosphorus insecticides are the only chemicals currently registered or available under permit for use in Australia. Fenthion is registered for use both as a foliar spray and as a postharvest dip treatment. Dimethoate is available under Permit PER 10309, issued in Oct 2007 and is in force until Sep 2010 (APVMA, 2009) for use as a postharvest dip treatment only.

Yellow peach moth (*Conogethes punctiferalis*)

Endosulfan

This highly toxic, old organochloride insecticide is the only chemical currently registered for use as a foliar spray in Australia. The chemical is continually under review. Registered use patterns are rapidly disappearing and being replaced by temporary permits until newer, safer control methods become available. An effective registered alternative is highly desirable.

FUNGICIDES

No fungicides are registered for use in pomegranates and no permits exist or have been applied for in the past. As noted in the overview, Alternaria infection during flowering appears to be the cause of some fruit damage but no specific fungicides have been registered or granted a permit for controlling it. The only evidence that disease may be a problem in foreign material being imported into Australia, was interest from an Australian importer (Dal Santo, *pers comm.,* 2009) in establishing a domestic tolerance for cyprodinil + fludioxonil (Switch®). This product is mainly used for controlling *Botrytis spp*. although it is likely to have activity on a range of other fruit damaging pathogens including *Alternaria sp*.

HERBICIDES

Non-selective ("knock-down") Herbicides

As with many perennial tree crops, growers rely heavily on non-selective herbicides for reducing weed burdens. This is done by controlling emerged weeds either during dormancy

or by shielding and spraying when winds and other environmental conditions are favourable. The aim with either method is to minimise the risk of spray coming into contact with green plant material. The major herbicides used for this purpose are glyphosate (Roundup®) as well as the bipyridyls - paraquat and/or diquat in various combinations (Gramoxone®, Spray.Seed® and Reglone®). After application, these herbicides are generally tightly bound to foliage, organic matter and soil (the clay fraction in particular). This extremely tight adsorption prevents these herbicides from being taken up by plants subsequently sown (whether seeds or seedlings). Label recommendations for the use of these herbicide are of a general (not crop specific) nature.

As glyphosate is extremely systemic, it is capable of moving from foliage to roots and therefore killing a broad range of both annual and perennial weeds even if they are well established. However, diquat and paraquat are contact herbicides and their activity damages cell membranes, causing cell leakage before any significant translocation can occur. As a result the bipyridyls are mostly effective only on smaller weeds with poorly established root systems. While glyphosate takes considerably longer to kill weeds, it is rapidly absorbed and translocated.

In-crop use of bipyridyl products such as paraquat (Gramoxone®) are also permitted for post-emergent inter-row spraying where shielded sprayers can be effectively used without any risk of spray drift touching the crop.

Application rates vary widely according to the target weed spectrum and are beyond the scope of this review. Suffice to say manufacturers labels should be referred to for selecting rates appropriate for species and growth stage.

Another non-selective chemical that has a technical fit, is glufosinate-ammonium (Basta®). However, there is no current registration or permit allowing its use in Australian pomegranate production. Like glyphosate, it is considered to have a much higher degree of user safety than the bipyridyl herbicides. It is a contact herbicide like the bipyridyls, though its speed of activity is slower, taking several days typically rather than several hours. Other than these technical distinctions glufosinate does not offer any particular advantages for controlling weeds compared with glyphosate or the bipyridyls.

Selective Herbicides – Pre-emergent

A number of pre-emergent selective herbicides that are used in other tree and vine crops are likely to be selective (effective but safe to the crop) in pomegranate production. However, exactly which ones are safe or not would have to be evaluated in a series of screening trials. There has tended to be a shift away from the use of selective, residual, pre-emergent herbicides in these kinds of crops towards more frequent use of non-selective herbicides. This has been driven both by the greatly reduced cost of non-selective herbicides like glyphosate as well as concern where residual pre-emergent herbicides have shown marginal crop safety. Developing registrations or permits for these kinds of herbicides then is not likely to be an area of great priority for the pomegranate industry.

Selective Herbicides – Post-emergent (grasses and/or broadleaf weeds)

As tree crops can normally be sufficiently protected from physical contact with non-selective herbicide sprays using a range of techniques already described, developing registrations or

permits for these kinds of herbicides is not likely to be an area of great priority for the pomegranate industry.

Selective Herbicides – Post-emergent (grasses only)

In Australia, the Group A herbicides or "ACC'ase Inhibitors" (Acetyl Co-enzyme A carboxylase inhibitors) inhibit the synthesis of fatty acids. There are three chemical sub-groupings, the "fops" (aryloxyfenoxypropionates), the "dims" (cyclohexanediones) and more recently the first "den" (phenylpyrazoles). These herbicides are so selective that some are used for controlling grass weeds in grass crops (cereals). In fact this is the major use of these chemicals in Australia and throughout the world. All have their particular target strengths and weaknesses. Some are more effective on annual ryegrass for example. Some are selective in wheat but not barley and so on. One common feature of all these herbicides, however, is their complete lack of activity on dicotyledon crops and weeds. While there may be other isolated instances in the world, the author is only aware of one peculiar exception to this – In Australia, haloxyfop has been found to control *Erodium spp*. and this claim appears on the Verdict® 520 label. Because of their importance in the broadacre market, there are a lot of different active ingredients from this mode of action grouping that are registered in Australia.

These herbicides are generally very effective on annual grasses but tend to translocate slowly and so are not always effective on larger, more established perennial species. They are also extremely susceptible to being rendered ineffective due to resistance, most notoriously in annual ryegrass. Care therefore needs to be taken not to overuse these herbicides if they are to maintain efficacy when they are used for ryegrass control. One species these herbicides are not effective against is wintergrass (*Poa annua*). Fortunately most non-selective, post-emergent herbicides are effective against this important species.

Within this group, only fluazifop-p (Fusilade® Forte) and to a lesser extent sethoxydim (Sertin® 186) have broad registrations in fruit and vegetable crops in Australia. However, only fluazifop-p is registered for use in Australian pomegranate orchards for the control of a range of perennial and annual grass weeds. As pomegranates are a perennial tree crop, the wide use of very effective non-selective herbicides greatly reduces the risk of group A herbicide resistance developing in common grass weeds.

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Bayer CropScience Australia Ltd – Product label; Basta® – APVMA Approval Code.: 39118

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Bayer CropScience Australia Ltd – Product label; Sertin® 186 EC – APVMA Approval Code.: 31839

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Nufarm Australia Ltd – Product label; Roundup® – APVMA Approval Code.: 31393

Syngenta Australasia Ltd – Product label; Fusilade® Forte 128 EC – APVMA Approval Code.: 58521

Syngenta Australasia Ltd – Product label; Gramoxone® – APVMA Approval Code.: 46531

Syngenta Australasia Ltd – Product label; Reglone® – APVMA Approval Code.: 46534

Syngenta Australasia Ltd – Product label; Spray.Seed® – APVMA Approval Code.: 46516

Syngenta Australasia Ltd – Product label; Switch® – APVMA Approval Code.: 51797