Appendix C. Draft article for ‘Talking Avocados’ -

REVIEW OF PREHARVEST MINERAL NUTRITION EFFECTS ON AVOCADO POSTHARVEST QUALITY IN AUSTRALIA

Project AV19004

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Providing consumers with good quality avocados is essential for the Australian industry to retain and grow markets. However, around half of the thousand consumers surveyed in 2017 were dissatisfied with the quality of avocados available. Previous studies suggest that one avenue for improving fruit quality is to ensure that fruit have an optimal balance of nutrients by the time of harvest. This is more likely to result in robust fruit less disposed to developing decay and disorders in the supply chain. In light of this, project AV19004 was tasked with examining existing published evidence of the relationship between mineral composition and fruit quality in order to provide recommendations for orchard practices and/or further research.

Table 1. Fruit mineral nutrients in the peel or flesh associated with increased (+) or decreased (-) expression of postharvest quality defects in avocado fruit. Blank spaces indicate no association or no information available.

Defect name	Mineral nutrient										
	N	P	K	Ca	Mg	B	Mn	Si	Zn	N/Ca	(Ca+Mg)/K
Body rots	+	+	+/-	-	+/-	-		-		+	-
Stem end rot	+		+	-	+/-			-		+	-
Diffuse discolouration	+/-	+/-	+	-	-	-	-				+/-
Vascular browning	+			-		-					-
Vascular leaching	+		+/-	-	-					+	-
Pulp spot		+	-	-					-		
Discrete patches	+		+		+						-
Endocarp black spot						-					

Minerals associated with postharvest quality and their management

Calcium

Elevated levels of calcium in avocado flesh have been linked to delayed ripening, greater firmness after storage and a reduction in quality defects (including rots) and physiological disorders. However, concentrations of calcium in flesh and skin tissues vary widely. Even within the same tree there can be a three-fold difference between individual fruit. The development of postharvest body rots in 'Hass' fruit has been more consistently correlated with the nitrogen/calcium ratio than to calcium concentration alone. 'Hass' has shown substantial development of postharvest body rots with flesh nitrogen/calcium ratios of 40-45 at harvest as compared to little or none when ratios were 33 or lower.

Calcium uptake and transport in plants occurs via a transpiration driven process. Solution in the transpiration stream travels from roots via the water conducting xylem vessels to leaves, flowers and fruit that are actively transpiring. Uptake is greatest at the root tip, which is also the first point of attack of Phytophthora root rot. This is a particularly important factor to consider in Australia, where Phytophthora root rot is rife. Also, other mineral ions, such as sodium (Na^+), potassium (K^+) and magnesium (Mg^{2+}), compete with calcium (Ca^{2+}) for uptake at the root tip.

Calcium is deposited where the water exits the plant. For the first eight or so weeks after fruit set, the avocado fruit possesses functional stomata. Water will transpire though these, leaving calcium behind in the fruit. However, after this period, stomata on the fruit become dysfunctional and form lenticels. Thereupon, the principal way in which calcium can accumulate in the fruit is finished. Since this mineral is relatively immobile in the plant, it is virtually "game over" for increasing fruit calcium levels.

Transpiration rate is driven by Vapour Pressure Deficit (VPD). The drier, hotter and windier it is, the higher is the VPD and transpiration potential. Accordingly, humid, cool and still conditions during the eight week period after fruit set means less calcium deposition in fruit. However, contrasting conditions do not necessarily guarantee high calcium. This is because as the VPD increases, so too does the likelihood that the plant will close stomata to conserve moisture.

During this critical time period after fruit set, there must be: (i) sufficient calcium in the soil solution, (ii) balance between soil nutrients, (iii) good soil moisture, (iv) healthy root systems, (v) adequate transpiration, and (vi) absence of strong vegetative growth which could divert xylem flow away from fruit.

Increasing rates of soil-applied calcium in various forms have been shown to provide little or no increase in avocado fruit calcium levels. Foliar calcium application has been investigated, but results have been inconsistent. Moreover, calcium absorption by leaves is unlikely to have any bearing on fruit levels due to the poor mobility of calcium between plant organs.

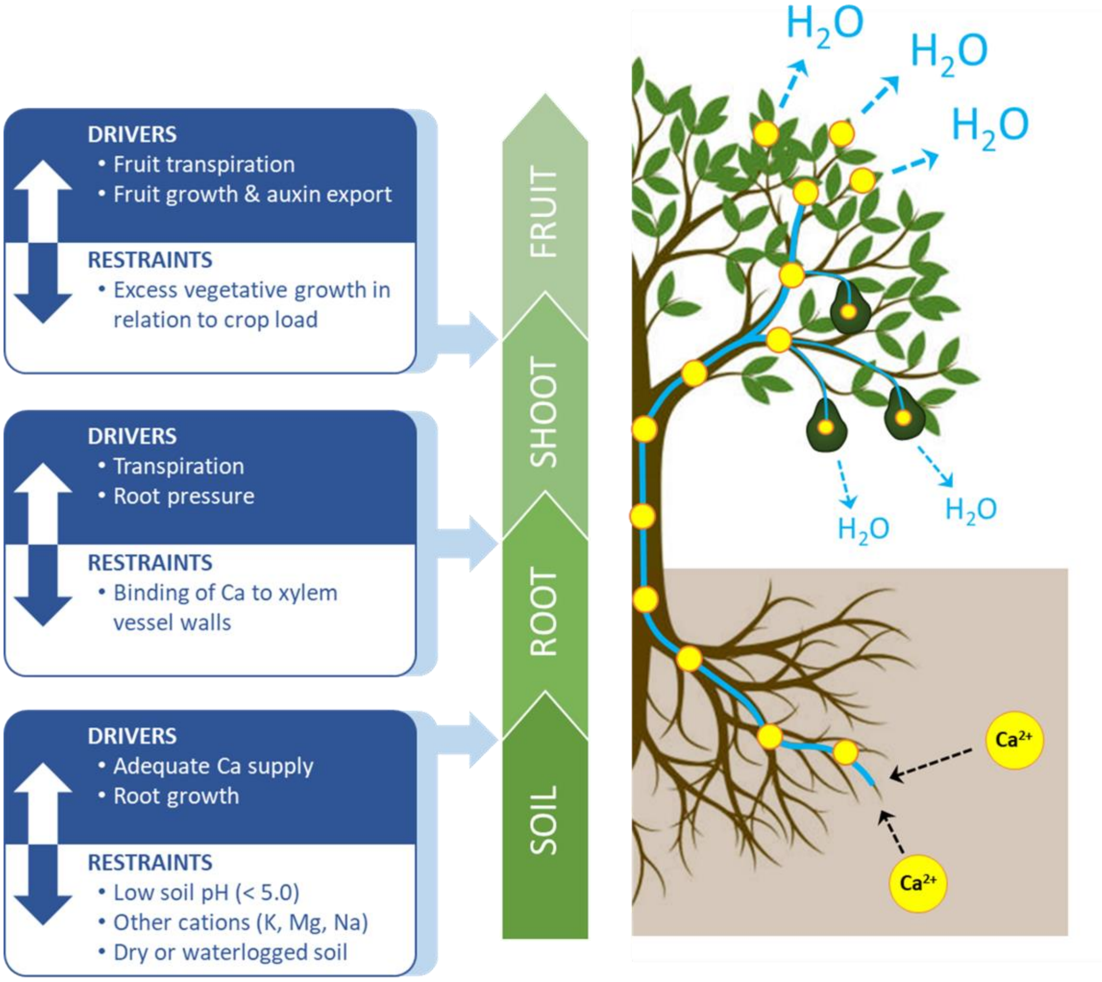

Figure 1. Processes of calcium accumulation in avocado fruit.

Nitrogen, tree vigour, canopy management and the use of plant growth regulators

Together with calcium, nitrogen plays a crucial role in determining fruit quality. Hence, management of these two minerals is inextricably linked. Nitrogen is key to managing vegetative vigour. Moreover, whilst nitrogen is needed to feed flowering, fruit set and fruit retention, high levels in avocado fruit have been linked to greater susceptibility to postharvest rots, vascular browning and diffuse flesh discolouration.

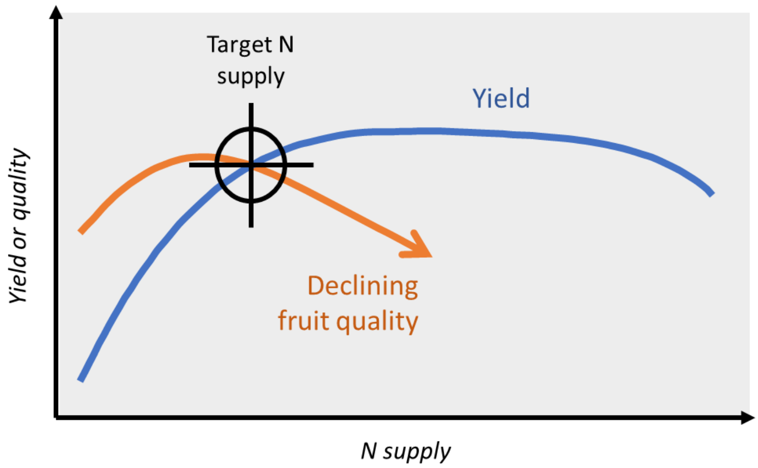

Figure 2. Nitrogen supply management for balance between avocado fruit yield and quality.

A balanced ratio of vegetative to reproductive growth is credited with enhancing fruit quality. Avocado trees with low vegetative vigour and/or high crop load tend to bear fruit with high calcium levels and fewer postharvest diseases and disorders. Pruning that limits vegetative growth at the critical time of fruit set and early fruit development has been shown to generate larger fruit with relatively higher fruit calcium levels and fewer postharvest body rots, whilst producing similar total yield to unpruned trees. However, pruning that stimulates vegetative regrowth at this critical time can have a negative impact on fruit quality because it diverts resources, including calcium, away from developing fruit.

In warmer climates, flowering commences after the previous season's fruit have been harvested. However, trees grown in cooler climates often have overlapping crop cycles and managing the demands of both can be challenging. Differing nitrogen requirements of trees during 'on' and 'off' flowering years also need to be managed.

The plant growth regulator paclobutrazol applied as a foliar spray suppresses vegetative growth. In concert, it has been shown to increase fruit calcium levels and reduce body rot severity, without sacrificing yield. However, this plant growth regulator should only be used on vigorous healthy trees, with well managed nitrogen levels.

Potassium

Oversupply of potassium in the soil has been shown to limit calcium and magnesium uptake and reduce the concentrations of these nutrients in the fruit flesh, which can lead to quality problems.

Work with 'Hass' in Californian orchards found that optimum leaf potassium for high-yielding trees is 0.8% and that yield is suppressed above 1% leaf potassium. This finding suggests scope to reduce the upper limit of 2% currently recommended in Australia with a view to improving fruit quality.

The antagonistic effect of potassium on calcium uptake and the fact that most potassium accumulation in avocado fruit occurs during the later stages of development, implies that potassium fertilisation should be delayed to later stages of fruit development.

Boron

Higher flesh boron levels in 'Hass' fruit have been linked with lower incidence and severity of diffuse flesh discolouration and vascular browning, absence of a postharvest flesh browning disorder near the stem end of the seed cavity and lower severity of body rots. However, growers need to be mindful of the narrow window between boron deficiency and toxicity. In this regard, it is advisable to seek expert advice.

Other factors influencing fruit mineral status

Variety

Lower nitrogen/calcium ratios were measured in 'Shepard' fruit as compared with 'Hass' harvested from the same site. 'Shepard' is typically a relatively smaller tree with a compact growth habit and tends to flower when the spring vegetative flush is well advanced. Hence, the ability of this variety to readily accumulate fruit calcium may be a result of relatively low calcium demand from vegetative tissues during early fruit development.

Rootstock

In Australia fruit harvested from 'Hass' and 'Shepard' trees grafted to Mexican race rootstocks (e.g. 'Duke 6', 'Duke 7' and 'Thomas') had generally inferior quality and nutrient status than those grafted to Guatemalan (e.g. 'Anderson 10' and 'SHSR-03') or West Indian x Guatemalan (e.g. 'Velvick') race rootstocks.

Soil

Avocado trees are sensitive to soils that are both too wet and too dry. They initially respond to both conditions by closing their stomata. The functionality of stomata can be slow to recover after drought stress. Moreover, extended water deficit can cause trees to produce permanent plugs, called tyloses, in their xylem. Both responses restrict water flow and therefore reduce nutrient supply through the tree. Waterlogging aids the spread of Phytophthora root rot and asphyxiates feeder roots, again resulting in impeded nutrient uptake.

In Australia, free draining soils that help manage Phytophthora root rot tend to have inherently low nutrient holding capacity and high potential for the leaching of soil-applied nutrients. Addition of compost and mulch engenders higher soil organic matter. In turn, this enhances soil moisture availability and improves the soil's ability to hold nutrients. Both outcomes lead to better retention and availability of nutrients. Moreover, enhancement of a soil environment where soil biology (microorganisms) can flourish also has beneficial outcomes in suppression of pests and diseases.

Monitoring mineral status

Leaf analysis is a useful indication of fruit mineral levels for nitrogen, potassium and boron, because these are relatively mobile in the plant. However, leaf analysis is not a good indicator of fruit calcium because calcium is relatively immobile in the plant and the period during which it can accumulate in fruit is finite, whereas in leaves it continues to accrue. High leaf calcium is more a reflection of greater leaf age than it is of nutrient status.

Soil analysis is a useful indicator of soil calcium availability and can also alert growers to imbalances among calcium, magnesium and potassium, changes in soil pH, salt build up and toxic levels of boron, all of which can adversely affect fruit quality.

Mineral analysis of fruit flesh provides direct information on levels of individual nutrients, the nitrogen/calcium ratio and the balance between calcium, potassium and magnesium. This information can inform the prediction of fruit robustness and potentially be used to channel fruit into short, medium or long supply chains to market.

In California, research has indicated that mineral nutrient levels in the cauliflower stage of flowers are a better predictor of yield than are leaf nutrient levels. This stage is easy to identify and so carries less risk of sampling the wrong tissue at the wrong time. Moreover, it may allow sufficient time to take corrective action that will benefit the imminent crop.

Conclusion and recommendations

High fruit calcium, adequate boron and modest levels of nitrogen and potassium have consistently been linked to better fruit quality. Figure 3 depicts orchard practices that will help achieve fruit mineral status conducive to robust fruit.

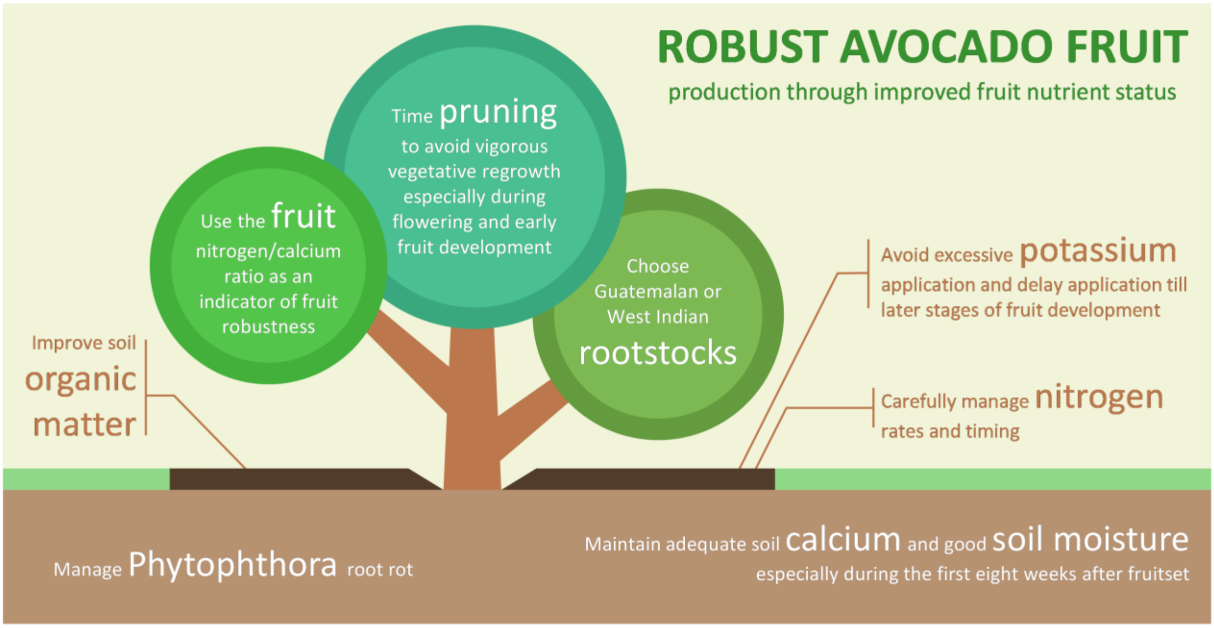

Figure 3. Orchard practices for improving avocado fruit quality through mineral nutrition.

A more detailed report called "AV19004 Technical Grower Summary . . . " can be found in the Best Practice Resource.

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