Mineral distribution in avocado trees with reference to calcium cycling and fruit quality

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ABSTRACT


Ca, Mg and K distributions in vigorous and non-vigorous (resulting from moderate Phytophthora cinnamomi infection) cultivar ‘Fuerte’ and ‘Hass’ avocado trees, and of Ca in the orchard soil, were determined. Ca concentrations were generally highest in the leaves, bark and small branches and roots, lower in the immature reproductive organs, and very low in the mature fruit and wood. These results are consistent with previous observations of Ca distribution being governed by organ transpiration and auxin export. Mg concentrations showed a similar pattern of distribution to Ca, but differences between organs were less extreme. K concentrations, on the other hand, were highest in the reproductive structures. The leaves contributed the greatest percentage of the tree total for all three elements and the fruit very little (with the exception of K). ‘Hass’ trees generally contained higher Ca, but lower Mg concentrations than ‘Fuerte’; this also applied to the mature fruit flesh. Non-vigorous trees generally showed higher Ca, but lower Mg tissue concentrations than vigorous trees. K concentration was not affected by vigour. A tentative Ca cycle in the avocado orchard is presented, as well as possible ways of modifying fruit mineral composition to favour better fruit quality.

Keywords: avocado; calcium; fruit quality; magnesium; potassium.

INTRODUCTION

The significance of Ca in fruit and vegetable quality has been recognised for many years (Shear, 1975). Recent research has shown that Ca is essential in several important plant processes, such as cell wall and membrane function (Hepler and Wayne, 1985). This has a direct bearing on several aspects of fruit quality, particularly those influenced by cell wall and membrane integrity, such as fruit softening (Poovaiah et al., 1988) and other disorders (e.g. bitter pit of apples) resulting from cell structure collapse. Research on apples

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has indicated that K and Mg are also important in determining bitter pit incidence, and that the (Mg+K)/Ca ratio is more suitable for bitter pit prediction than fruit Ca concentration alone (Holland, 1980). Bower and Cutting (1988) have reviewed flesh disorders in avocado fruits, certain of which have been linked to low fruit Ca content.

There are therefore significant advantages in the manipulation of fruit mineral concentrations. This has been attempted in apples and good success has been achieved in the reduction of bitter pit through Ca orchard sprays (Van der Boon, 1980). Similar experiments in avocado have not been as successful in the control of mesocarp disorders (Veldman, 1983), but post-harvest dips in Ca solutions have shown greater promise (Eaks, 1985; Wills and Sirivathanapa, 1988). Other alternatives may exist for the manipulation of avocado fruit mineral concentrations; these include cultural practices such as fertilisation, orchard floor management (Perring and Pearson, 1986; in apples), irrigation (Bower, 1985) and possibly pruning of the spring vegetative flush (Biran, 1979). However in order for such treatments to be fully understood and developed, a knowledge of mineral distribution in the tree and cycling within the orchard is required.

The aim of the present experiment was to obtain detailed information on Ca distribution in avocado trees, and to present a Ca cycle for the avocado orchard along similar lines to that of Himelrick and McDuffie (1983) for apples. The distributions of Mg and K were also determined because of their potential influence on fruit quality. The research was conducted on vigorous and non-vigorous cultivar 'Hass' and 'Fuerte' trees in an attempt to identify some factors which may influence tree and fruit mineral composition. It was not intended to establish statistical differences between cultivar, vigour or plant tissue, but rather to establish tentative norms for Ca, Mg and K concentrations in tissues, with a view to proposing and ultimately manipulating the Ca cycle of an avocado orchard.

MATERIALS AND METHODS

Plant material. – The experiment was conducted in a commercial orchard near Pietermaritzburg (latitude 29°26′S, longitude 30°18′E), at an altitude of ~750 m. The climate was warm subtropical, with relatively low, predominantly summer rainfall of ~750 mm per annum. The trees were grown on West Indian seedling rootstock in a typical dystrophic oxisol (Hutton form, Farningham series) with ~45% clay in the B21 horizon.

Twenty 'Hass' and 20 'Fuerte' trees were selected in July (mid-winter) and their performance monitored during a full season. Ten trees of each cultivar were vigorous and apparently free of infection from Phytophthora cinnamomi root rot. The other 10 trees were classified as non-vigorous, and rated 4 on
the 0 (vigorous and healthy) to 10 (dead) scale. Trees in each category were selected on the basis of uniformity of fruit mineral composition, vegetative growth, flush timing, canopy density, crop load, canopy spread and height, and stage of flowering. They were also on the same soil form and series, generally on the same contour and away from orchard boundaries.

In May of the following year (at crop maturity), one tree in each category was chosen and the following samples collected.

1. Twenty mature fruit from the outer 50 cm of canopy, between 1.5 and 2.5 m above ground, and from all quadrants of the tree. Fruit pedicel, skin, flesh and seed were analysed separately.
2. Two hundred leaves sampled as above.
3. Forty branches <2 cm diameter (30 cm long) collected at random, with wood and bark analysed together.
4. Framework branches harvested at random, and bark and wood separated. Smaller branches were sampled with a pruning saw, while cores of bark and wood were taken from larger branches. Sample size was 20 subsamples; 10 branches at 10 cm diameter x 30 cm long, and 10 cores at 5 x 20 cm.
5. Trunk. Ten core samples (5 x 20 cm) were taken above the graft union, and wood and bark separated.
6. Large roots were collected from a pit running NW–SE. Ten root sections (10 x 30 cm) were taken and bark and wood separated.
7. Small roots, 1–2 cm diameter, were taken from under the tree canopy with an auger between 30 and 50 cm depth. Sample size was 50–60 root pieces of 5–20 cm length.
8. Fine roots with root tips, sampled as for small roots.
9. Flowering trusses (~2 kg) were sampled at the start of flowering the next spring (September). Florets and flower stalks were analysed separately.
10. One hundred fruitlets were sampled 6 weeks after full bloom in the same way as mature fruit.

Masses of the individual tree components were determined as follows. Floral trusses, fruit, leaves and twigs were manually counted on a representative portion of the tree (25% canopy to ground slice), weighed and then multiplied by four to indicate the whole tree total. The above-ground wood and bark masses from small and large branches, and trunk, were estimated by counting the small branches, then sampling and weighing representative portions to estimate total wood and bark, and the wood:bark ratio. However, to avoid excess tree destruction, measurements of girth and length of the limbs were taken to estimate wood volumes. Bark volumes were estimated by calculating the surface area of the limbs and measuring average bark thickness from sample sections. Limited resources prevented accurate total root mass determinations. However, results on avocado by other workers (e.g. Venning and Lincoln, 1959; Gregoriou and Kumar, 1982), in combination with actual measurements of root size and distribution taken in the pits and during auger
sampled, were considered to provide reasonably accurate root results. However, because only one tree in each category was sampled and the rootstocks were of seedling origin, the root results cannot be used as completely reliable norms.

Leaf longevity in each category was estimated by marking leaves on developing flushes and observing monthly.

All samples were taken between 08:00 and 10:00 h, between 14 and 18 May, during fine stable weather. Fresh masses were determined and the samples dried to constant mass at 80°C. They were then milled through a 0.5-mm screen for analysis.

Mineral analysis. – Duplicate samples of 0.3 g were digested for 90 min at 400°C with 2.5 g catalyst powder (Kjeldahl pak), 3 ml concentrated H$_2$SO$_4$ and 4 ml H$_2$O$_2$. Digested samples were made up to 100 ml with distilled water, and analysed for Ca, P and N in an autoanalyser (Technicon II) using standard methods (Horwitz, 1980). Subsamples were checked using atomic absorption spectroscopy and were found to be within 10% of autoanalyser results. Ca, Mg and K were determined in duplicate samples by atomic absorption after ashing the samples for 6 h at 450°C, dissolving the ash in 1 N HCl and washing through filter paper with deionized water.

Duplicate soil samples were taken at regular intervals from a 1.2-m pit. Soil pH was determined by adding 50 ml 1 N KCl to 10 g soil, stirring and allowing to stand for 2 h. Exchangeable Ca, Mg, K, and Na were measured by adding 50 ml 1 N ammonium acetate and 0.1% SrCl$_2$ to 2 ml air-dried soil, shaking for 30 min, filtering and analysing the supernatant by atomic absorption. Exchangeable acidity was determined by adding 50 ml 1 N KCl to 10 g soil, shaking for 4 min, filtering and titrating the filtrate against 0.01 N NaOH.

The cation exchange capacity (CEC) was determined from the sum of exchangeable Ca, Mg, K, Na and acidity.

RESULTS

Whole tree tissue dry mass. – Improved vigour increased the dry matter production of all tissues analysed, so that vigorous ‘Fuerte’ trees had 43% greater mass and vigorous ‘Hass’ 34% greater mass than the respective non-vigorous trees (data not shown). This was attributed mainly to greater above-ground masses in the vigorous trees. Crop mass increased far more than vegetative mass with improved vigour. Thus the vigorous crop load for ‘Fuerte’ was 375% greater, while vegetative mass increased only 40%; for ‘Hass’ the figures were 295 and 30%, respectively.

Calcium. – The order of Ca concentration in the various organs was not affected by cultivar or vigour. In general, leaves and bark had the highest Ca
concentration (Table 1). Bark concentrations were highest in the branches and decreased down the tree, so that root bark had ~30% that of branch bark. Wood had considerably lower concentrations than bark and concentrations also decreased from framework branches to trunk, and then roots.

Reproductive tissues generally had medium to low Ca concentrations, with the smallest reproductive structures (florets and fruitlets) having the highest Ca levels. The skin had the highest concentration of all mature fruit tissue, while the flesh generally had the second or third lowest concentration of all the tissues analysed.

Non-vigorous trees of both 'Fuerte' and 'Hass' had higher Ca concentrations than vigorous trees in most of the tissues analysed; the most notable exceptions were the framework branch bark and 1–2-cm roots. Tree average concentrations were 6 and 19% higher in non-vigorous 'Fuerte' and 'Hass', respectively, than in vigorous trees of the same cultivar. Ca concentrations in 'Hass' reproductive structures were consistently higher than 'Fuerte', irrespective of vigour. Trends were less consistent in the leaf, bark and wood tissue.

Most of the Ca (mass per tissue) was found in the above-ground vegetative tissue (Table 1). Leaves contained 30–40% of the total tree Ca. Branches had ~40% of the total, with ~75% of this Ca in the framework branches. The roots contained ~10–15% (mostly in the small and fine roots), while the trunk had only 4–8%. Reproductive and associated tissue contributed very little (~3%) to the whole tree Ca content.

Magnesium. – The Mg distribution pattern was very similar to that of Ca (Table 2), although concentration differences between tissues were not as great. Tissues of more vigorous trees generally had higher Mg concentrations than those of non-vigorous trees. There were no obvious cultivar differences.

Leaves had the highest Mg concentration. Concentrations in the bark were also fairly high, but there was very little concentration gradient down the bark (from branches to roots). This was also observed in wood tissue, but concentrations here were the lowest detected.

Six-week-old fruit had fairly high Mg concentrations. Concentrations in the mature fruit flesh were lower than whole 6-week-old fruit and this supports other data (not shown) that flesh Mg concentration decreases with fruit maturity. However the decline was not as great as that observed for Ca. Cultivar had little effect on fruit Mg, but reduced vegetative vigour was associated with lower Mg concentrations.

Leaves contained ~40–50% of the total tree Mg (Table 2). The branches contained ~20–30% of the total, the trunk 3–5% and the root system 15–20% (mostly in the small and fine roots). In contrast to Ca however the reproductive and associated tissues contained a greater percentage of the total Mg, and
<table>
<thead>
<tr>
<th></th>
<th>Concentration (mg kg(^{-1}) DM)</th>
<th>Mass per tissue (g)</th>
<th>Percentage of tree total</th>
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<tr>
<td></td>
<td>'Fuerte'</td>
<td>'Hass'</td>
<td>'Fuerte'</td>
</tr>
<tr>
<td></td>
<td>2450</td>
<td>4150</td>
<td>4200</td>
</tr>
<tr>
<td>Flower stalks</td>
<td>2100</td>
<td>3400</td>
<td>3350</td>
</tr>
<tr>
<td>Fruitlets (6 weeks)</td>
<td>4250</td>
<td>6750</td>
<td>6400</td>
</tr>
<tr>
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<td>750</td>
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<td>Mature fruit seeds</td>
<td>700</td>
<td>700</td>
<td>900</td>
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<td>1900</td>
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<tr>
<td>Fruit stalks</td>
<td>1650</td>
<td>1850</td>
<td>2000</td>
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<tr>
<td>Leaves</td>
<td>10900</td>
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<td>8750</td>
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<tr>
<td>Branches (1–2 cm)</td>
<td>8450</td>
<td>9100</td>
<td>6750</td>
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<td>2400</td>
<td>2400</td>
<td>2750</td>
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<td>13300</td>
<td>10550</td>
<td>12900</td>
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<tr>
<td>Trunk wood</td>
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<tr>
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<tr>
<td>Large root wood</td>
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<td>1100</td>
<td>1300</td>
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<tr>
<td>Large root bark</td>
<td>2950</td>
<td>3500</td>
<td>3100</td>
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<td>Roots (1–2 cm)</td>
<td>4750</td>
<td>3850</td>
<td>4650</td>
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<tr>
<td>Fine roots+tips</td>
<td>3600</td>
<td>3900</td>
<td>5150</td>
</tr>
<tr>
<td>Total (whole season)</td>
<td>2342</td>
<td>1611</td>
<td>1833</td>
</tr>
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</table>
TABLE 2

Mg concentration (mg kg⁻¹ DM), mass per tissue (g) and percentage of tree total of tissues from vigorous (vig.) and non-vigorous (non-vig.) 'Fuerte' and 'Hass' avocado trees

<table>
<thead>
<tr>
<th></th>
<th>Concentration (mg kg⁻¹ DM)</th>
<th>Mass per tissue (g)</th>
<th>Percentage of tree total</th>
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<tr>
<td></td>
<td>'Fuerte'</td>
<td>Non-vig.</td>
<td>'Fuerte'</td>
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<td>2150</td>
<td>2000</td>
<td>2100</td>
</tr>
<tr>
<td>Flower stalks</td>
<td>1600</td>
<td>1400</td>
<td>1550</td>
</tr>
<tr>
<td>Fruitlets (6 weeks)</td>
<td>2150</td>
<td>2150</td>
<td>2350</td>
</tr>
<tr>
<td>Mature fruit flesh</td>
<td>1200</td>
<td>1100</td>
<td>1400</td>
</tr>
<tr>
<td>Mature fruit seeds</td>
<td>950</td>
<td>950</td>
<td>1100</td>
</tr>
<tr>
<td>Mature fruit skin</td>
<td>2550</td>
<td>2150</td>
<td>2300</td>
</tr>
<tr>
<td>Fruit stalks</td>
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<td>1300</td>
<td>1450</td>
</tr>
<tr>
<td>Leaves</td>
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<td>4850</td>
<td>6050</td>
</tr>
<tr>
<td>Branches (1-2 cm)</td>
<td>2400</td>
<td>2550</td>
<td>3100</td>
</tr>
<tr>
<td>Framework branch wood</td>
<td>450</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Framework branch bark</td>
<td>3450</td>
<td>2900</td>
<td>3300</td>
</tr>
<tr>
<td>Trunk wood</td>
<td>250</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>Trunk bark</td>
<td>3200</td>
<td>2950</td>
<td>3350</td>
</tr>
<tr>
<td>Large root wood</td>
<td>250</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Large root bark</td>
<td>3050</td>
<td>2500</td>
<td>3000</td>
</tr>
<tr>
<td>Roots (1-2 cm)</td>
<td>1950</td>
<td>1700</td>
<td>2150</td>
</tr>
<tr>
<td>Fine roots + tips</td>
<td>2150</td>
<td>2000</td>
<td>2300</td>
</tr>
</tbody>
</table>

Total (whole season) | 902 | 515 | 743 | 409
<table>
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<th></th>
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<th>Mass per tissue (g)</th>
<th>Percentage of tree total</th>
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<tbody>
<tr>
<td>Florets</td>
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<td>19000</td>
<td>16200</td>
</tr>
<tr>
<td>Flower stalks</td>
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<td>16100</td>
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<td>Fruitlets (6 weeks)</td>
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<td>Mature fruit skin</td>
<td>11350</td>
<td>11350</td>
<td>9100</td>
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<tr>
<td>Leaves</td>
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<td>7350</td>
<td>8150</td>
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<tr>
<td>Branches (1-2 cm)</td>
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<td>Large root bark</td>
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<td>Roots (1-2 cm)</td>
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<td>Total (whole season)</td>
<td>2779</td>
<td>1498</td>
<td>1790</td>
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this applied particularly to the florets and fruit flesh (0.7–2% for Mg compared to 0.2–0.7% for Ca).

Potassium. – K concentration was not consistently affected by tree vigour (Table 3) and in general ‘Fuerte’ tissues had higher concentrations than ‘Hass’.

In contrast to Ca and Mg, the floral structures had the highest concentrations of K. Leaves showed moderately high concentrations, the bark and small branches and roots intermediate, and the wood low concentrations. Fruitlets from vigorous ‘Hass’ had more K than those from the non-vigorous trees, while the opposite was true of ‘Fuerte’. However, concentrations in the mature fruit flesh were affected little by tree vigour, while concentrations in ‘Fuerte’ fruit flesh were higher than those in ‘Hass’.

The total K content of the sampled trees was relatively high when compared to Mg, but about the same as Ca. The floral structures contributed significantly to the total tree K, so that the florets contained 3.1–6.3% of the total and the mature fruit flesh 2.0–8.7%. This tended to be at the expense of the leaves, although these still provided the greatest single contribution (23–29%).

Soil. – Soil pH varied between 4.9 and 5.2. Total CEC decreased from 15.6 cmol (+) kg⁻¹ in the top 20 cm of soil to 11.5 cmol (+) kg⁻¹ at 100 cm, while Ca decreased from 2.2 to 0.8 cmol (+) kg⁻¹ over the same depth.

DISCUSSION

Ca transport from roots to above-ground tissues occurs almost exclusively in the xylem (Biddulph et al., 1961). An ion exchange mechanism involving anionic sites on the xylem wall has been implicated, such that allocation to plant organs is governed to a certain extent by its use in metabolic processes. However the transpirational flow is a major determining factor in the rate and direction of Ca transport, particularly if the cation exchange complex of the xylem wall is saturated, or if the Ca is chelated (Van der Geijn et al., 1979). Thus tissues which transpire heavily are more likely to accumulate Ca (Boyer, 1985). Low transpiring tissues, such as fruits, will obtain most of their water requirements through the phloem, which typically contains very little Ca (Wolterbeck et al., 1987). In addition, Ca transport is thought to be positively influenced by auxin (IAA) transport in the opposite direction (Banuelos et al., 1987), so that tissues with high metabolic activity (and presumably IAA export) may show higher Ca influx.

The Ca results obtained in the present investigation can be explained in the light of these observations. For example, high leaf and fruitlet Ca concentrations probably resulted from their greater transpiration (as a result of high
surface area: volume ratio) and relatively high metabolic activity, while the
opposite was the case for the wood. Differences in transpiration can also ex-
plain the differing Ca concentrations in the fruit skin and flesh. The decrease
in fruit Ca concentration with development was probably a dilution effect
caused by the inability of fruit Ca uptake to keep pace with fruit growth (Wit-
ney et al., 1990).

The higher Ca concentration in the non-vigorous trees is best explained by
the mechanism of root Ca uptake. The roots were almost certainly moderately
affected by Phytophthora root rot, which tends to encourage root branching
and the generation of new roots above areas of root necrosis. This response
would increase the area of Ca uptake, since it is thought to be passively ab-
sorbed, mainly through unsuberised root areas such as root tips and sites of
root branching and emergence (Ferguson and Clarkson, 1976). The generally
greater vigour of ‘Fuerte’ trees may also explain why this cultivar contained
lower Ca concentrations in most of the tissues analysed, although differences
in the efficiency of Ca uptake by the roots may also have been a factor.

Increased vegetative vigour would have suppressed fruit Ca concentrations
through a superior ability of the vegetative component to compete for Ca
(greater transpiration, IAA export and structural requirement) than in the
non-vigorous trees. In addition, vigorous trees produced a greater proportion
of indeterminate fruits, which are more exposed to competition by the spring
vegetative flush (Witney et al., 1990). Again, the greater vegetative vigour of
‘Fuerte’ would have resulted in increased vegetative:reproductive competi-
tion during fruit set and initial fruit growth, with a detrimental effect on fruit
Ca concentration and yield.

Mg is thought to be passively accumulated by plant roots in much the same
way as Ca (Mengel and Kirkby, 1978); however once in the plant it is prob-
ably accumulated in tissues more in response to metabolic requirement than
on a water utilisation basis. Therefore the pattern of Mg accumulation was
very similar to that of Ca, except that the more vigorous and metabolically
active tissues had comparatively higher concentrations. Thus the fruit tissues
contained more Mg and the wood relatively less.

K uptake into the root cortical cells is primarily active, with transport oc-
curring in both the phloem and the xylem (Mengel and Kirkby, 1978). There-
fore K concentrations were higher in the more active tissues, such as fruit,
and this accounts for the far greater contribution of these tissues to the total
tree K than in the other elements analysed.

Several avocado fruit quality characteristics are thought to be influenced
by fruit Ca concentration, including premature softening and mesocarp dis-
colouration (Bower and Cutting, 1988). Research in apples has indicated that
the (Mg+K)/Ca ratio is more reliable for bitter pit prediction than Ca con-
centration alone (Holland, 1980), with a lower ratio being associated with
lower bitter pit incidence. In the present investigation, these ratios were 24
and 9 for vigorous and non-vigorous 'Fuerte', and 9 and 7 for vigorous and non-vigorous 'Hass', respectively. Industry experience is that 'Fuerte' fruits are generally more susceptible than 'Hass' to premature softening and mesocarp discolouration following cold storage, and previous investigations (Witney et al., 1990) indicated that fruit from vigorous and from 'Fuerte' trees ripen more rapidly than those from non-vigorous or from 'Hass' trees. Therefore, this ratio may also be important in predicting avocado fruit quality. Further investigation in this area is warranted, particularly if the potential exists to predict fruit storage suitability at an early stage, or at least prior to harvest.

Based on the above, the potential exists to improve fruit quality through manipulation of the \((\text{Mg} + \text{K})/\text{Ca}\) ratio. Of the three elements, Ca presents the greatest difficulty for manipulation of its concentration in the fruit, primarily because of its relative immobility in the soil and the plant, and its dependence on water use for distribution between plant tissues. Therefore a greater research effort on Ca than on Mg or K is warranted.

It is concluded that knowledge of the Ca cycling within the avocado orchard, on similar lines to those used by Himelrick and McDuffie (1983), would be of benefit in understanding the fate of Ca and in establishing management strategies to improve fruit Ca accumulation. This has been at-

![The Calcium Cycle of an Avocado Orchard](image)

**Fig. 1.** Ca budget and typical Ca concentrations of a vigorous 'Fuerte' orchard (following Himelrick and McDuffie, 1983).
tempted in Fig. 1, using the results obtained in the present investigation, plus
the following assumptions. The plant Ca values are for 12-year-old 'Fuerte'
trees with an apparent Phytophthora rating of 0. A planting density of 156
trees ha\(^{-1}\) (8×8-m spacing) was used. Tree mass was taken as being negligi-
ble at planting, with a similar annual mass accumulation up to the 12th year.
A reasonable yield target for fruit mass was taken to be 15 t ha\(^{-1}\) (Wols-
tenholme, 1985). Initial fruit set was estimated at 1\% and final fruit set at 0.2\%
(Whiley et al., 1988).

An accurate liming and fertilisation history of the orchard was not avail-
able, and for much of the orchard's life irrigation was only applied during
water stress. Thus Ca added through irrigation water was considered negligi-
ble, although this may have to be reviewed in well irrigated orchards. Addi-
tions of Ca from rain and dust are thought to be considerably less than those
quoted by Himelrick and McDuffie (1983), because of the local non-calcare-
ous soils and surrounding mountainous, high-rainfall topography. The ma-
jor additions from these sources would be through ash fall during sugar cane
and grass burning, and during other farming activities such as liming of nearby
fields. The Ca on the exchange complex and in the soil solution are adapted
from those of Macvicar and Prefect (1971), and are approximately mid-range
of those measured in the present orchard soils.

In summary, the present investigation indicates several ways whereby av-
ocado fruit quality may be improved. The potential for genetic improvement
is evidenced in the higher Ca and lower K concentrations in 'Hass' than in
'Fuerte' fruit flesh, and this may warrant further investigation. Manipulation
of vegetative vigour also shows promise, and research in this area should con-
centrate on reducing the vigour of the spring flush so that competition with
the developing fruit during this crucial period is reduced. Consideration should
also be given to the selection of soils with adequate exchangeable Ca or soil
amendments pre- and post-planting (liming, mulching, etc.). However, this
should be considered as an interim measure only.

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