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CALCIUM ACCUMULATION IN AVOCADO FRUITS: EFFECT OF CULTIVAR AND TREE VIGOUR

G W WITNEY, B N WOLSTENHOLME & P J HOFMAN
DEPARTMENT OF HORTICULTURAL SCIENCE, UNIVERSITY OF NATAL, PIETERMARITZBURG

SUMMARY

The seasonal trends of Ca in Fuerte and Hass avocado fruits from vigorous and non-vigorous trees were studied. Non-vigorous trees, with moderate root infection by Phytophthora cinnamomi, produced fruit with significantly higher Ca concentration and Ca content than vigorous trees of the same cultivar. This appeared to be related to less competition from the spring vegetative growth flush. Fuerte fruits had significantly less Ca than Hass fruits throughout the growing season. Management implications are discussed with a view to increasing fruit Ca for better storage ability and reduced post-harvest problems.

OPSOMMING

Die seisoenale tendense in Ca-inhoud en -konsentrasie van Fuerte en Hass avokadovrugte van geilgroeiende en nie-geilgroeiende borne is bestudeer. Laasgenoemde borne met 'n matige wortelbesmetting met ***Phtytophthora cinnamomi*** *het vrugte met hoër Ca-konsentrasie en Ca-inhoud as geilgroeiende borne gegee. Hierdie verskynsel is hoofsaaklik aan die verminderde kompetisie van die lente vegetatiewe groei toegeskryf. Vrugte van Fuerte het laer Ca as Hass vrugte gedurende die groeiseisoen getoon. Boordbestuursimplikasies word bespreek met die doel om verhoogde Ca-peile in vrugte vir langer opberging en beter na-oes vrugkwaliteit te kry.*

INTRODUCTION

In recent years the mediatory role of calcium ions (Ca^{2+}) and of the calcium-binding protein calmodulin in plant development has been recognised. Calcium appears to function as a "second messenger" in plant cells. Many recent reviews and books on the role of Ca^{2+} in plants have appeared, e.g. Cheung (1982,1983), Marme (l983), Marme & Dieter (1983); the special issue of Plant, Cell & Environment (vol. 7, no. 6, 371 - 489, 1984); Hepler & Wayne (1985), and Poovaiah (1985).

In fruits and vegetables, Shear (1975) listed 35 physiological disorders associated with Ca nutrition. The best researched of these are bitterpit of apples and blossom-end rot of tomatoes. Other reviews (Atkinson, Jackson, Sharpies & Waller, 1980; Himelrick & McDuffie, 1983; Smith, 1984; Poovaiah, 1985) emphasize the Ca nutrition of target organs such as fruits, rather than whole plant nutrition.

It is generally agreed that Ca-related disorders mostly arise from internal Ca distribution problems, and its allocation between mature and growing regions of the plant. The cytosol has very low levels of free Ca^{2+}. Most transport occurs by mass flow in the xylem, and by chromatographic movement along Ca-exchange sites in xylem walls. Competition between sinks is intensified when Ca^{2+} in xylem is low and transpiration great (Clarkson, 1984). Plants must be continuously supplied with Ca since little or no redistribution occurs to new growth zones after accumulation (Poovaiah, 1985).

Low levels of Ca in avocado (*Persea americana* Mill.) fruits have been associated with rapid softening after harvest (Tingwa & Young, 1974; Wills & Tirmazi, 1982), and with susceptibility to chilling injury (Chaplin & Scott, 1980). Sprays of Ca $(NO_3)_2$ to orchard trees were unsuccessful in controlling pulp spot, a post-harvest disorder associated with low fruit Ca content (Veldman, 1982).

suppressed respiration and polyphenol oxidase activity.

The South African avocado industry is heavily dependent on sea export to Europe. The fruit is often stretched to the limit of its conventional storage life, and premature ripening, pulp spot and other disorders are common (Ginsberg, 1985). This study was motivated by the need to investigate orchard factors affecting avocado fruit Ca content through the growing season. The only field study of Ca accumulation in avocado fruits is that of Bower (1985) in a long-term irrigation trial, which emphasized the need for optimal irrigation early in fruit development.

MATERIALS AND METHODS

Forty trees, 20 Fuerte and 20 Hass on seedling rootstocks in a 12 year old dryland orchard near Crammond, Natal, were selected in June, 1983. The locality is representative of warmer avocado production areas, with relatively early fruit maturity. Ten trees of each cultivar were vigorous and apparently free of infection with *Phytophthora cinnamomi* root rot. The other trees were non-vigorous, and rated 4 on the 0 to 10 scale widely used ¡n *Phytophthora* research.

At two weekly intervals initially, with the first sample 2 weeks after peak fruit set, samples of 10 fruits from each of the four categories of cultivar and vigour were collected, weighed, dried to constant mass at 80°C, milled through a 0,5 mm screen, and stored in air-tight glass containers for subsequent analysis. Sample intervals were later increased to 3 weeks. Sampling was terminated after 25 weeks when fruits of both cultivars had less than 80% moisture (Swarts, 1976) and were therefore "legally" mature, although Hass fruits would normally not be harvested for another 8 weeks or so.

Calcium analyses were conducted on all fruits sampled. Duplicate samples of 0,3 g were digested for 90 min. at 400°C with 2,5 g catalyst powder (Kjeldahl pak), 3 ml cone H_2SO_4 plus 4 ml H_20_2. Digested samples were made up to 100 ml with distilled water, and analysed in an autoanalyser using standard methods. Subsamples were checked using atomic absorption spectroscopy, and found to be within 10% of autoanalyser results. Results were expressed as mg Ca kg^{-1} DM.

As a measure of shoot growth activity, the percentage of shoots showing obvious extension growth was estimated every 2 to 3 weeks for each cultivar and vigour category. Meteorological readings of temperature and relative humidity (thermohygrograph), and rainfall were taken on a weekly basis.

RESULTS AND DISCUSSION

Whole fruit Ca concentrations for the two cultivars and vigour classes during the 1983/84 growing season are summarised in Fig. 1.

Category means (cultivar and vigour) were significantly different (P = 0,01) for each sampling date. Coefficients of variation between means ranged from 3,83% in week 6 to a high of 8, 29% in week 19 samples. Both cultivar and tree vigour significantly affected avocado fruit Ca concentration.

Whole fruit Ca concentrations were relatively low at week 2, ranging from 1 685 mg kg^{-1} DM for vigorous Fuerte to 3 275 mg kg^{-1} DM for non-vigorous Hass fruits (Fig. 1.) Peak concentrations were found at week 6, viz. 4 830 and 7 790 mg kg^{-1} DM respectively. This was followed by a rapid and then much slower decrease as fruits increased in size. At legal maturity (week 25) Ca concentrations varied from 690 to 1 570 mg kg^{-1} DM for vigorous Fuerte and non-vigorous Hass respectively. These trends are similar to those reported for apples {Quinlan, 1969; Tromp, 1978) and avocado (Bower, 1985).

Overall means for each sampling time were statistically significant (P=0,01) only for the first six sampling dates (Table 1.). This indicates that the most marked changes in Ca concentrations were during the earlier part of the season.

content than fruit from vigorous trees. Even at fruit maturity, when Ca concentration changes were minimal, fairly marked differences existed.

Changes in total fruit Ca content through the growing season are shown in Fig. 2.

TABLE 1

Mean Ca concentration (mg kg^{-1}DM) of Fuerte and Hass avocado fruits from vigorous and non-vigorous trees

	Weeks after fruit set									
	2	4	6	8	10	13	16	19	22	25
Mean* L.S.D. (P=0,01)	2596	5020 234,6	6230	3330	1974	1631 C.V.	1393 15,7%	1214	1161	1145

*Means underscored by the same line are not statistically different (P=0,01)

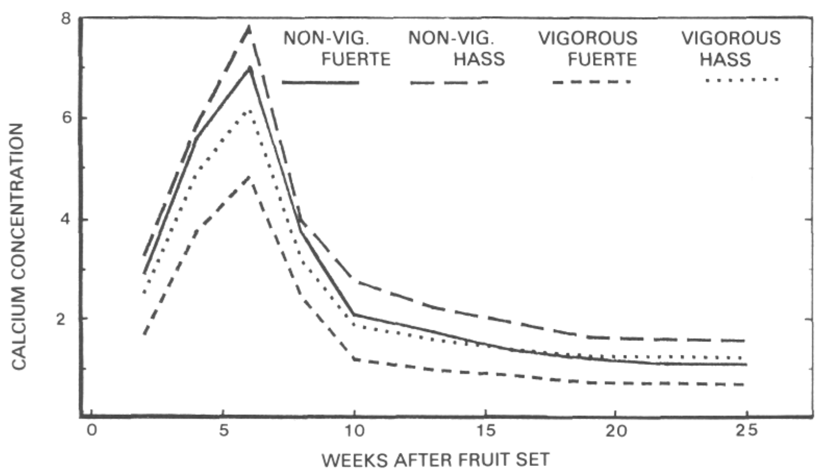

Fig. 1. Seasonal calcium concentration (X 10^3 mg kg^{-1}) of avocado fruits for trees of two cultivars and two vigours.

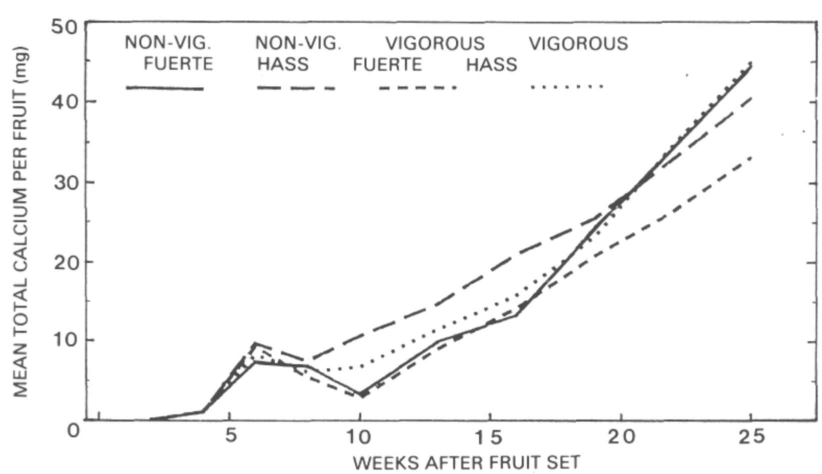

Fig. 2. Seasonal calcium accumulation curves for avocado fruit for two cultivars and two vigours.

The trend for both cultivars and vigour categories was for a rapid rise to week 6, followed by a small decline to week 8 (Hass) or week 10 (Fuerte), and thereafter a steadily increasing trend to between 33 and 47 mg per fruit at week 25. The decline between weeks 6 and 8 or 10 corresponded to the rapid decline in Ca concentration at this time (Fig. 1), and suggests that a net export of Ca may have occurred at this period. Such Ca losses from fruits have been documented previously (Weirsum,

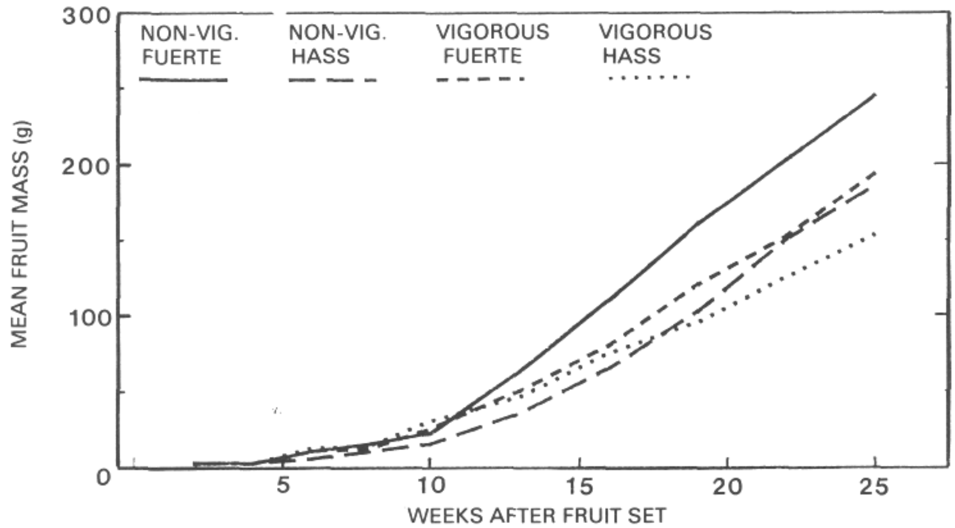

Fig. 3. Seasonal mass accumulation of avocado fruits for two cultivars and two vigours.

VIGOURS

Slow initial fruit growth was followed by a long period of rapid increase in fruit mass. The final slowing down of fruit growth to give the typical sigmoid growth curve (Schroeder, 1953) was less marked i nth is hot production area with early autumn fruit maturity. However, the rapid increase in fruit mass caused a steady dilution of Ca concentration, in spite of generally increasing total Ca content. With the onset of cooler temperatures and the associated decline of fruit growth rate (Van den Dool & Wolstenholme, 1983) further stabilisation of Ca concentration would be expected. It is also pertinent to note that the generally larger Fuerte fruits underwent more Ca dilution than Hass fruit.

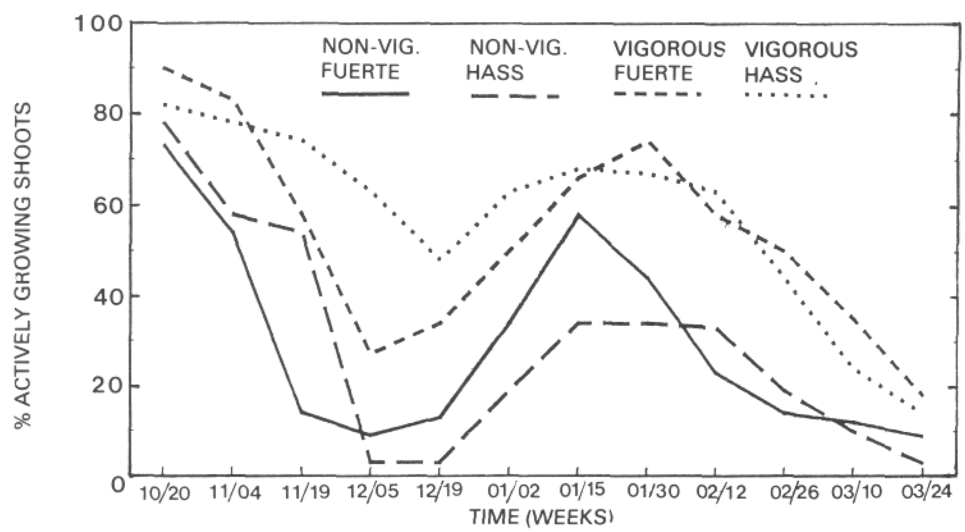

Fig. 4. Average percentage actively growing shoots of avocado trees of two cultivars and vigours.

Fig. 4 indicates that two major growth flushes occurred.

The spring growth flush was more vigorous, and occurred during and after fruit set. The summer growth flush in January and February coincided with rapid increases in fruit mass. Differences between vigorous and non-vigorous trees were noted, especially in respect of flush duration. Vigorous trees had dense canopies, large leaves, large transpiring surfaces, and relatively large leaf sinks for Ca and other metabolites, and thus detrimental to both Ca uptake of nearby fruitlets as well as to their overall competitive ability and fruit set.

CONCLUSIONS

The main conclusions arising from this work are that non-vigorous trees are more likely to have high-Ca fruits at maturity than vigorously growing trees; that Fuerte fruits are likely to have lower Ca contents and concentrations than Hass fruits; and that although Ca concentrations peak at about 6 weeks after fruit set and thereafter decline, total fruit Ca content appears to increase steadily except for a short period 6 to 8 or 10 weeks after fruit set.

In view of the importance of high fruit Ca concentration at maturity for prolonged fruit storage and good fruit quality, what options are available for influencing avocado fruit Ca concentration? The prospects for orchard Ca sprays, although so far disappointing (Veldman, 1983) should be further pursued as they are successful in apple orchards (Terblanche, Woolbridge, Hesebeck & Joubert, 1979). Post-harvest Ca dips, although technically successful (Eaks, 1985), are impractical for cosmetic reasons. It appears that scion and rootstock breeding for Ca efficiency is the long-term solution, but that orchard management manipulations offer scope for short-term advances.

It is well known that the vegetative : reproductive balance is easily tipped in favour of excessive vegetative growth during the spring growth flush in avocados, especially in Fuerte with consequent poor fruit set and also, from this study, low fruit Ca content. Manipulation of irrigation and of leaf N status to de-emphasize the spring growth flush should improve the chances of good fruit set and good fruit quality. The potential of the new growth retardant paclobutrazol (PP333) must also be investigated (Anon., 1984).

Evidence from apple trees suggests that ammonium nitrogen fertilisation reduces Ca uptake in comparison with nitrate nitrogen sources (Fukumoto & Nagai, 1983). Avocado growers who have in the past applied predominantly NH_4-N fertilisers, partly as an aid to combatting *Phytophthora cinnamomi* (Pegg, 1976), may have inadvertently aggravated fruit Ca problems. Finally, there is evidence that high soil Ca status, achieved by organic mulching and liming, has many benefits in avocado orchards (Broadbent & Baker, 1974) and may also contribute to achieving adequate Ca movement to fruits.

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