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THE CALCIUM ACCUMULATION PATTERN IN AVOCADO FRUIT AS INFLUENCED BY LONG-TERM IRRIGATION REGIME

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OPSOMMING

Fisiologiese probleme by vrugte wordgewoonlik geassosieer met die kalsium inhoud van die vrugte. Problems van die aard watbelangrik is vir die Suid-Afrikaanse avokado uitvoerder word deels toegeskryf aan boord toestande. Die moontlike verband wat bestaan tussen beproeiing en kalsium akkumulasie, is gedurende die 1982/1983 seisoen ondersoek.

Kalsium in die vrugbereik 'n maksimum konsentrasie 7wekena vrugset. Ditneemdan vinnigaftot 16wekena vrugset waarnadit konstant bly totdat die vrugte gepluk word. Konsentrasie verskille a.g. v. verskillende besproeiingsvlakke was alleenlik duidelik tussen 7 en 16 weke na vrugset. Waarbesproeiingteen 'n grondvolgspanning van 55 kPa toegepas is, is die hoogste kalsium konsentrasie verkry, terwyl meergereelde besproeiing (d.w.s. aanvulling by 35 kPa grondvogspanning) en minder gereelde besproeiing (aanvulling by 80 kPa grondvogspanning), laer kalsium konsentrasies teweeggebring het. Waar besproeiing minder gereelde plaasgevind het, het die kalsium konsentrasie die grootsteafname getoon. Dit blyk dus datenige invloed wat kalsium konsentrasie op vrugkwaliteit het, gedurende die vroeë vrug ontwikkelingstadium plaasvind en daar word voorgestel dat besproeiing gedurende die tydperk optimaal moet wees.

SUMMARY

Fruit physiological problems have often been associated with fruit calcium levels. The physiological problems that are important to the South African avocado exporter, have been related in part to orchard conditions. The possible link between irrigation and calcium accumulation during the 1982/1983 season-was therefore investigated.

Calcium within the fruits reached a maximum concentration 7 weeks after fruitset, declining rapidly until 16 weeks after fruit set and thereafter remaining fairly stable until picking. Concentration differences due to irrigation regimes were only evident between 7 and 16 weeks after set. Irrigation at a soil moisture tension of 55 kPa resulted in the highest calcium concentration, while very frequent (replenishment at 35 kPa soil moisture tension) and occasional (replenishment at 80 kPa) were lower, particularly the latter which showed the most rapid decline. Any influence of calcium concentration on fruit quality would seem to occur early in fruit development, and it is suggested that optimal irrigation be practised at this time.

INTRODUCTION

The quality of avocado fruits after periods of long storage is of paramount importance for the exporter. Fruits which are soft on arrival, or which ripen too rapidly create marketing problems, while those with internal physiological disorders are probably even more damaging, as the buyer only becomes aware of the problem after purchase. Studies of South African avocado fruit quality ¡n France during 1981 (Bezuidenhout & Kuschke, 1982) and 1982 (Bezuidenhout, 1 983) indicated more than 20% of fruit to have some degree of physiological disorder. In addition, more than 50% of the possible reasons for the problems were statistically assigned to unknown orchard factors.

Storage disorders have for some time been coupled to the calcium content of fruits (Bangerth, 1979; Mill away & Wiersholm, 1979). Infiltration of calcium has been shown to prolong the softening times of avocados (Wills & Tirmazi, 1982), and Tingwa & Young (1974) found slower ripening with higher endogenous levels of calcium. Poovaiah (1 979) found that senescence effects in ripening tomatoes could be slowed down by calcium, and attributed the effect to prolonged membrane integrity.

Bangerth (1979) indicated that transpiration (and by implication tree water relations) may play a vital role in calcium uptake and distribution. Shear (1980) indicated that excessive soil water may also impede uptake. It was therefore decided that the effect of irrigation on calcium uptake, particularly during flowering, fruit set and early fruit growth, prior to meaningful summer rainfall, should be investigated. This may indicate whether poor or inadequate irrigation practices could, via calcium uptake, be a contributing factor to poor fruit quality.

MATERIALS AND METHODS

Healthy Fuerte avocado trees, which are part of a long-term irrigation experiment, were chosen for the study. Fruits were analyzed from three of the irrigation regimes, where irrigation was applied at soil moisture tensions of 55 kPa (control) 35 kPa (very frequent irrigation) and 80 kPa (occasional irrigation). The amount of water applied was calculated from soil moisture retention curves to be sufficient to re-wet the soil to field capacity toa depth of 600 mm.

Fruit was picked throughout the 1982/1 983 growth season, from soon after fruit set until mid-way through the normal harvest period. Although fruit set in the avocado can occur over an extended period, a period corresponding to a maximum fruit set was identified, and thereafter all fruit picked corresponded to this set. Six fruits were picked from each irrigation regime. Due to the small mass of fruits on the first two dates, a combined sample of 10 fruits per replication was used on these occasions. Half the fruits were picked from' the northern and half from the southern sides of the trees. Fruit was picked 14 times during the season.

Immediately after picking, fruit was massed (for plotting fruit growth curves) peeled, the seed removed and the fruit flesh divided into proximal and distal sections. Thereafter fruit was dried to constant mass at 70^{o}C. The samples were finely ground before analysis.

Analysis was done by the soil science and chemistry department of the CSFRI, Nelspruit. The method used for calcium analysis was as follows: To a 0,5 g fruit sample was added 5 ml cone. HNO_3, and 2ml H_2O_2. The mixture was left overnight for digestion of organic material. Thereafter, 60% $HClO_4$ was added, and once the solution had clarified, was made up to 25 ml with distilled water. Quantification of calcium was done by atomic absorption. Known standards were included in every 10 samples as a check. Results were calculated in meq 100 g dry mass^{-1}.

RESULTS

While the próxima I and distal sides of fruits were initially analyzed, it was found that the pattern of calcium change through the season was similar. As fruit physiological problems are usually first visible and most severe in the distal side of avocado fruits only this data is presented for the sake of clarity.

The calcium concentration results are depicted graphically in Fig 1. The general trend indicates that calcium concentration for all irrigation regimes increased rapidly very early in the fruit growth pattern (first 7 weeks) only to decrease during the following 8 to 10 weeks, and remaining at a relatively low and stable value until final fruit picking. These results are in accordance with the findings of Tromp (1978) and Quinlan (1969) who found the vast majority of calcium uptake to occur within the first 6 weeks of fruit development. In fact, the work of Quinlan (1969) on apples shows a calcium accumulation curve almost identical to that found in Figure 1.

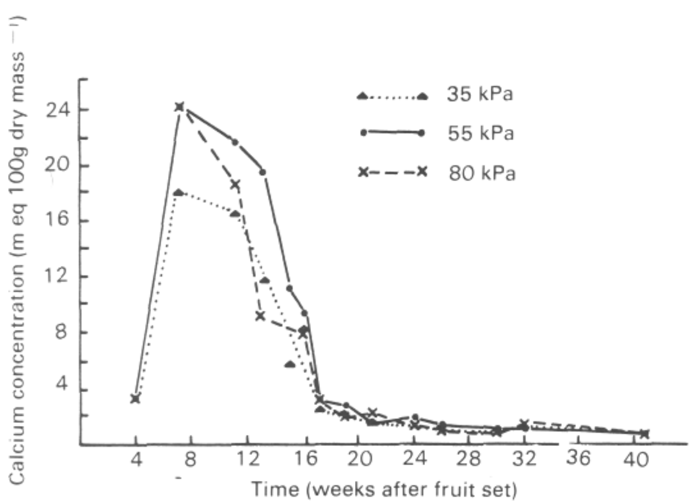

Fig. 1 Effect of irrigation regimes (replenishment at specific soil moisture tensions) on fruit calcium concentration during the fruit growth season.

Overall, the 55 kPa regime seemed to have higher calcium content than the other regimes. This was particularly noticeable between 7 and 16 weeks after fruit set. Surprisingly, considering the supposed effect of water stress (Bangerth, 1979) the treatment with the least supplementary irrigation appeared to take up calcium well during the first 7 weeks after fruit set, having the same concentration as the 55 kPa regime at this stage. The very frequent irrigation schedule (35 kPa), however, showed a tendency to a lower concentration at this stage, although it was not statistically significant. A very rapid decline in fruit calcium concentration occurred after 7 weeks, which seemed to have been more pronounced in the 80 kPa regime than in either of the other two treatments, which may be important. At 1 3 weeks after fruit set the 55 kPa treatment was significantly higher than the 35 kPa with the 80 kPa treatment even lower than the 35 kPa treatment. Whether this is physiologically significant is not known. From week 16 onwards, no differences between the treatments were found.

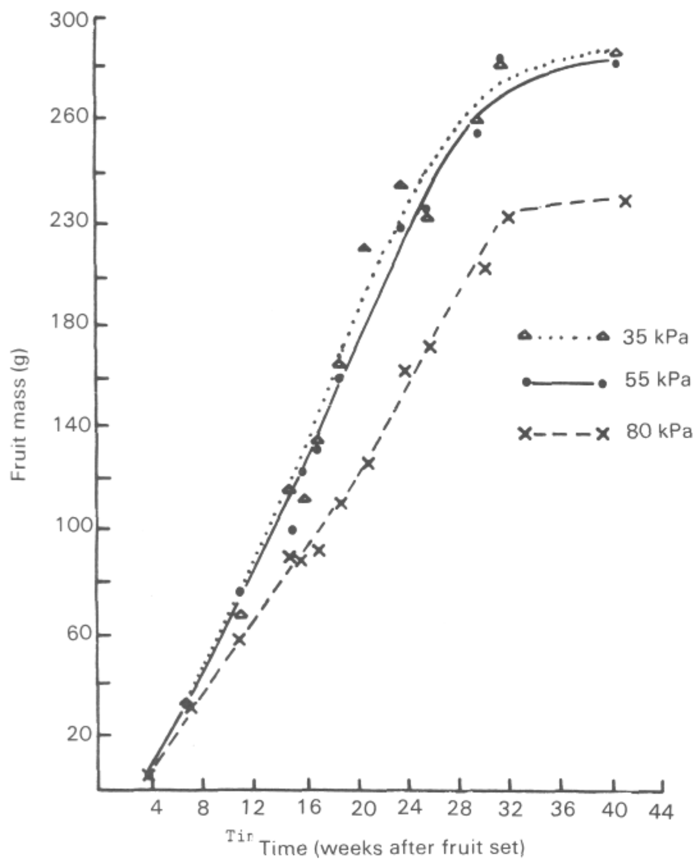

FIG. 2: Fruit growth for three irrigation regimes (soil moisture tension level at water replenishment)

Examination of the fruit growth curves in Figure 2 may be useful in explaining at least some of these trends. The growth curves are sigmoidal as was previously shown by Robertson (1971) and Barmore (1977). The initial portion of the curve is probably due predominantly to eel I division, while the following, steeper portion is due to the addition of greater cell growth. The 35 kPa and 55 kPa growth curves were essentially similar, while the 80 kPa treatment showed a somewhat slower growth rate which was evident from as early as 8 weeks after fruit set. This resulted in an approximately 50 g difference in final mass.

In order to place the events in chronological perspective, 4 weeks after fruit set corresponded to 22-9-1982.

DISCUSSION AND CONCLUSIONS

Wilkinson (1968) explained the trends of calcium uptake on the basis of rapid calcium uptake during the cell division stage of fruit growth, followed by slower uptake or even loss, during cell expansion. Although the avocado shows cell division throughout its growth phase, maximum cell division occurs during early growth (Barmore, 1977), thereafter slowing down with cell expansion becoming predominant. The initial rapid uptake could therefore be explained by the link between actively dividing cells and calcium accumulation. Bangerth (1979) reported that actively dividing cells act as calcium sinks. The fruit growth curves would seem to indicate that cell expansion (and perhaps also division) was probably not occurring as rapidly in the 80 kPa treatment as the others, which may explain the higher calcium levels at 7 weeks after fruit set. As the fruits increased rapidly in size, uptake presumably did not keep pace with the rapidly expanding and dividing cells, resulting in calcium dilution. The initial advantage of the 80 kPa treatment would seem to have been lost, because although the fruit expanded more slowly, uptake was presumably also more limiting. The steep decline in calcium concentration, particularly in the 80 kPa treatment probably indicates an imbalance in uptake as opposed to growth which could cause a deficiency at a critical time.

The lower calcium concentration in the 35 kPa treatment which was accompanied by a slower rate of decline is more difficult to explain. This fruit growth curve was similar to that of the 55 kPa treatment. Other work, however, indicated that the leaf area of the growth flush coinciding with fruit growth was larger than that of the 55 kPa treatment. The total canopy water demand was similar to the 80 kPa regime and higher than the 55 kPa treatment, in early 1984. There is no reason for this to have been different to the previous year. Coupled with the actively growing state of the new leaves at this time (which would later have decreased) leaf-fruit calcium competition may initially have been greater, resulting in a lower maximum value of fruit tissue calcium concentration than either the 55 kPa or 80 kPa regimes.

It was noticeable that the calcium concentrations of all treatments were almost identical to each other from approximately week 16 onwards. This would imply that if calcium *per se* affects fruit physiology, events of importance occur early in the life of the fruit. This could prove to be important if calcium concentration is used as an early prediction of physiological problems.

The results indicated that both very frequent but sparse as well as only occasional but heavy irrigation are liable to affect the pattern of calcium accumulation adversely. The trends and levels during the period of 7 to 1 3 weeks after fruit set did coincide with trends in fruit browning potential at the time of picking, This early stage is a vital period for fruit development, and membrane and other characteristics could well have been affected. Any cultivation practices devised to ensure maximal calcium levels at this time would be beneficial. However, not only total calcium levels are important, Roux & Slocum (1982) favor the idea of calcium acting as a second messenger in response to various stimuli, which in turn results in plant growth changes. Thus even sufficient total calcium may be prevented from fulfilling its physiological role by environmental and physiological factors such as water stress.

In conclusion, it would seem that there are indications that irrigation regimes can affect fruit calcium concentrations at a critical period in fruit development.

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