

ASPECTS OF LATE HUNG 'HASS' AVOCADO (*PERSEA AMERICANA* MILL.) FRUIT IN THE NATAL MIDLANDS II. WHOLE TREE STARCH CYCLING

C. KAISER¹ and B.N. WOLSTENHOLME

Department of Horticultural Science, University of Natal, P.O. Box 375, Pietermaritzburg 3200, RSA, Present address : Institute for Tropical and Subtropical Crops, Private Bag X11208, Nelspruit 1200, RSA¹

SUMMARY

When 'Hass' fruit in the cool, mesic, subtropical Natal midlands were tree-stored until November, fruit size on the farm Cooling (Wartburg) increased with most fruit occurring in count 18 in July and count 14 in November. This compared to the majority of fruit at Everdon (Howick) occurring in count 16 in August and count 14 in November. Results also showed that late hanging does not necessarily result in lower yields. In fact in months where fruit were left to hang late high yields were recorded in the third year of the trial. However, a similar trial on 'Fuerte' by Whiley et al., (1992) in S.E. Queensland resulted in a $\pm 15\%$ yield reduction from late harvest over a period of three years.

Annual average trunk bark starch concentrations, sampled monthly, were lower in trees harvested in August, September, October and November (ca. 4.1%) than trees harvested in July (ca. 4.8%). There were no significant differences in annual average trunk bark starch concentrations from August to November. The harvest x month interactions showed that although starch concentrations in July harvested trees reached the highest peaks (ca. 12%) they subsequently dropped to the lowest troughs (ca. 2%). Modelling of starch concentrations indicated that high daily temperatures followed by cool night temperatures will lead to greatest accumulations of starch.

INTRODUCTION

When late hanging of avocado fruit in the cool, mesic subtropical Natal midlands under good management was practised, fruit lipid concentrations on a dry mass basis did not increase linearly but rather plateaued in one case and ultimately decreased in the other (Kaiser & Wolstenholme, 1993). However, the question still remains as to how the energy reserves of the trees as a whole will be affected. Carbohydrate levels have been proposed as the key to understanding performance and management of tree crops (Cull, 1989) and to this end, fluctuations in carbohydrate concentrations have been studied in a vast number of tree types ranging from deciduous (Stassen, 1980; Stassen et al., 1985; Wood & McMeans, 1982; Smith et al., 1986; Yoshioka et al., 1988; DeJong & Walton, 1989; Oliveira & Priestley, 1989) through citrus (Goldschmidt & Golomb, 1982; Goldschmidt et al., 1985; Sanz et al., 1987; Erner, 1988) to avocados (Cameron & Borst, 1938; Rodrigues & Ryan, 1960; Scholefield et al., 1985; Graham, 1991).

In these previous studies the term 'carbohydrates' refers to cumulative sugar and starch levels of the plant. However, Scholefield *et al.*, (1985) maintained that since sugar levels in avocado trees vary little, sugars are not a major storage form, but rather constitute a pool for immediate use within the tree. Thus, direct determination of starch levels in avocado trees will provide an exact measure of fluctuations in storage reserves. In addition, Graham (1991) showed that starch concentrations in the bark and wood samples were similar but fluctuations were more easily identified in stem or trunk bark tissue. Consequently, only trunk bark starch concentrations need be monitored when assessing fluctuating storage reserves in the avocado tree.

MATERIALS AND METHODS

The present study on trunk bark starch concentrations, yield and fruit size distributions was undertaken in conjunction with the lipid and fatty acid study (Kaiser & Wolstenholme, 1993) and the reader is referred to that investigation for further information relating to the experimental sites and management standards. Data collection in the present study also spanned from February 1991 to October 1992.

Fruit size distributions for each treatment were recorded for all harvests. Fruit size was determined gravimetrically and classified on the basis of fruit number marketed in 4 kg export cartons: count 24 & smaller = 170 g and below; count 22 = 171 to 190 g; count 20 = 191 to 210 g; count 18 = 211 to 235 g; count 16 = 236 to 265 g; count 14 = 266 to 305 g; count 12 = 306 to 365 g; and count 10 = 366 to 450 g. Several severe setbacks beyond the authors' control resulted in the irretrievable loss of yield data. Consequently, only total tree yields for Everdon in 1991 are presented. These yields were calculated by adding the products of fruit number in each size class and their respective class centres.

Phenological events, including flowering, root and shoot flushes were studied from February 1991 to October 1992 and recorded monthly for each tree, using a visual rating from 0 to 10. Root flushes were monitored by visually estimating the area covered by white, fleshy feeder roots under a newspaper mulch of 2 m x 2 m covered with black, plastic refuse removal bags, placed permanently over the detritus, under the drip, at the south end of each tree. Visual estimates of vegetative shoot flushing for numbers of trees on both farms were grouped into classes of 'poor', 'medium' and 'good' according to the subjective ratings 0 to 3, 4 to 7, and 8 to 10 respectively. For root ratings, the groupings of 'poor', 'medium' and 'good' were chosen as 0 to 2, 3 to 4, and >5 respectively as the spread of data for rooting were weighted towards ratings of <7. The monthly values of 'good' flowering and rooting and shooting for both farms are presented graphically (Figs 4, 5, and 6). Since no differences in visual estimates of shooting, rooting and flowering were observed between treatments of monthly harvest dates, interactions were ignored.

Three disced bark samples, 2 cm in diameter, were taken from each tree in the middle of each month throughout the duration of the trial (February 1991 to October 1992). These bark samples were taken from the boles and main framework branches of the trees, above the graft union and sampling was done using a mechanical disc-puncher designed by the author. The principle behind the debarker is that a knocker hits against

a modified bell-punch.

Data were analyzed where applicable, according to general randomised block design procedures. The split-plot analysis of starch concentrations for both farms from February 1991 to July 1992 were analyzed independently of data from August 1992 to October 1992. This prevents unnecessary confounding which would certainly have arisen in August, September and October 1992, due to the premature removal of fruit in July 1992 at Everdon (Howick) and the early removal of young fruit by hail in November 1991 at Cooling (Wartburg). Regression analyses of average monthly temperatures versus monthly starch levels were undertaken to determine the effect of average mean and average maximum monthly temperatures on starch levels. After adjusting for temperature the effects of months, farms and their interaction on average starch levels were tested, to determine whether temperature alone accounted for variations observed in monthly starch levels.

The starch extraction technique, involving enzymatic hydrolysis of starch to glucose, followed by quantification of glucose, using an enzymatic glucose-specific colour reaction compared against a standard curve, was adapted from Rasmussen & Henry (1990) with changes as follows: The bark samples were dried in a forced draught oven at 70°C and the percentage dry mass was determined. The samples were then milled, and approximately 0.05 g of each sample was weighed into separate, numbered 10 cm³ test tubes. The exact mass of each sample was recorded for later use in the calculation. A 5 ml aliquot of 80% ethanol was added to the test tubes, which were sealed with rubber bungs and allowed to extract for 30 min. in a water bath at 80 °C. After extraction they were centrifuged in a BHG HERMLE Z510® centrifuge for 10 min. at 3,000 rpm after which the supernatant containing the sugars was decanted. The addition of ethanol, followed by extraction, centrifugation and decanting, as above, was repeated to ensure removal of all free sugars.

Thereafter, 2.5 ml acetate buffer and 50µl Termamyl® were added to the test tubes, which were again sealed with rubber bungs, incubated for 30 min. in a 90°C water bath and then allowed to cool to room temperature. Subsequently, a further 50µl amyloglucosidase (Novo®200L) was added and the test-tubes resealed and incubated at 60°C, for approximately 20 hr. The test tubes were then centrifuged as before for 10 min. at 3000 rpm and 100µl aliquots of the resultant supernatant were transferred to separate, clean test tubes and made up to 5 ml using glucose oxidase colour solution (APPENDIX 2).

The test tubes were sealed and incubated in a water bath for 15 min. at 40 °C and then allowed to stand at room temperature for a further 60 min. The absorbance values were read at 505 nm and compared against a glucose standard curve (APPENDIX 3). The % starch in the bark samples was then determined using the calculation:

% STARCH = $\text{CONC} \times \text{DIL} \times K \times W \times 100$ where,

CONC = concentration of glucose sub sampled for colour development in mg 5 ml⁻¹ (this is taken from the spectrophotometer readout);

DIL= Dilution factor constant = 26.0;

K = Water of hydrolysis constant = 0.9, and

W = Total dry mass of sample (mg) (this is recorded for each sample when weighing).

Note that this dilution ratio can be varied according to the expected starch concentration. The concentration of dry material upto this stage was $0.05\text{g}/(2.5 + 2(50\mu\text{l}))\text{ml}^{-1}$. From this $100\mu\text{l}$ was sub-sampled and analyzed for colour development. Therefore, there is $(2.5 + 2(0.05))/0.1$ times more dry matter in that test-tube before any sub-sampling than that used for the colour development and detection. Consequently, the amount of starch (glucose) that is detected must be multiplied by this factor in the end calculation so that % starch can be calculated on a mass glucose/mass dry matter basis. Hence should the dilution ratio need to be changed, the multiplication factor (DIL) would need to be recalculated.

RESULTS AND DISCUSSION

Fruit counts and thus size distributions on both farms in 1991 and 1992 were normally distributed, however the tail of the 'bell-curves' were larger on the right hand side of the curves where small fruit occurred (Figs. 1 and 2). This was expected as 'Hass' trees have a 'small fruit problem'. Although there were insufficient data for valid statistical analyses because of theft of data, representative yields for individual trees are presented. At Cooling (Wartburg) (Fig. 1) in July 1991, the count with the most fruit was count 18. In November 1991 however, the greatest number of fruit were found for count 14. This implies that the longer fruit are left to hang on the trees, the larger they become due to continual cell division in the mature fruit, albeit at a reduced rate.

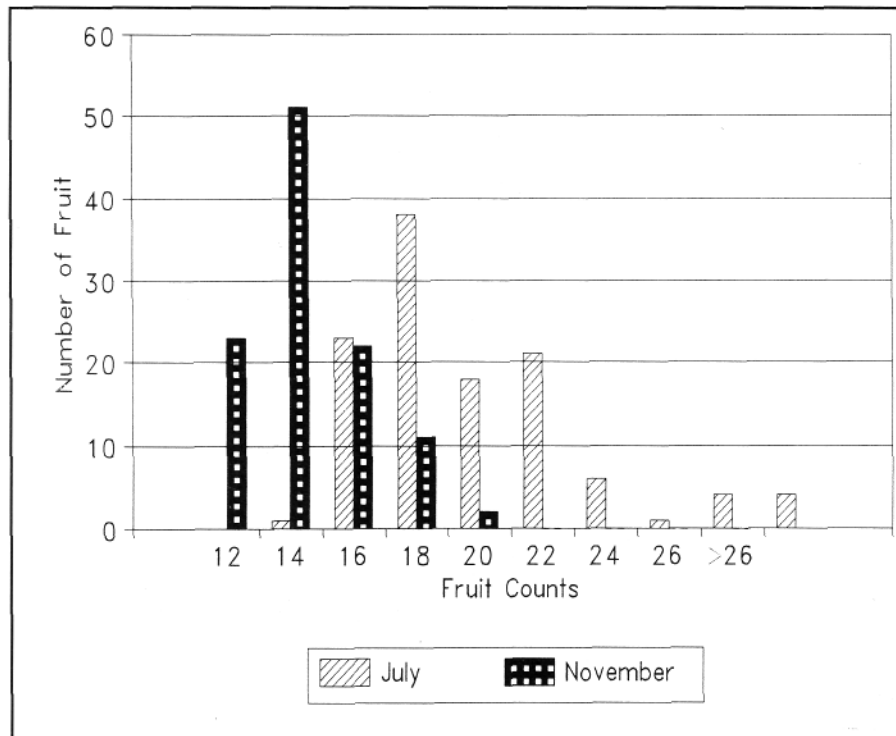


FIG. 1 Number of fruit per count harvested from two trees in July and November 1991 at Cooling (Wartburg).

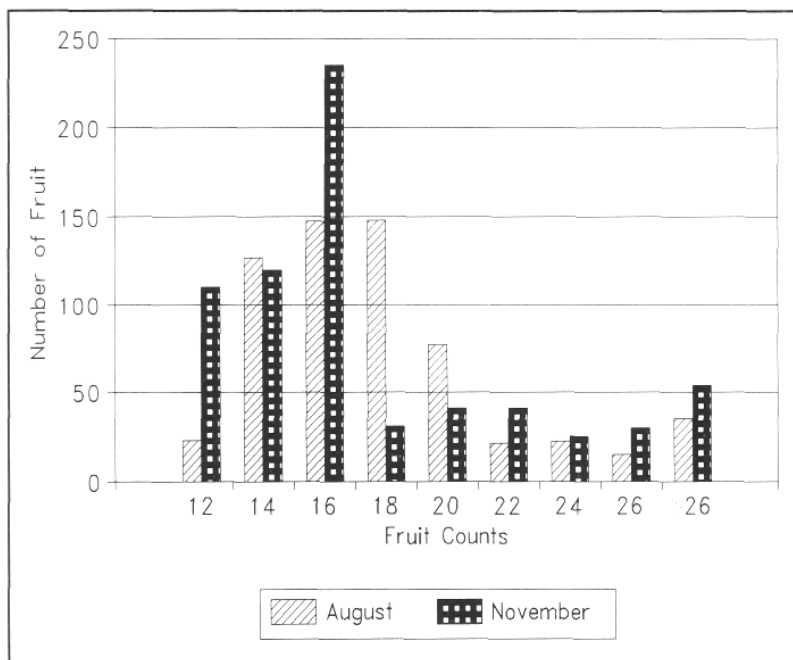


FIG. 2 Number of fruit per count harvested from two trees in August and November 1991 at Everdon (Howick).

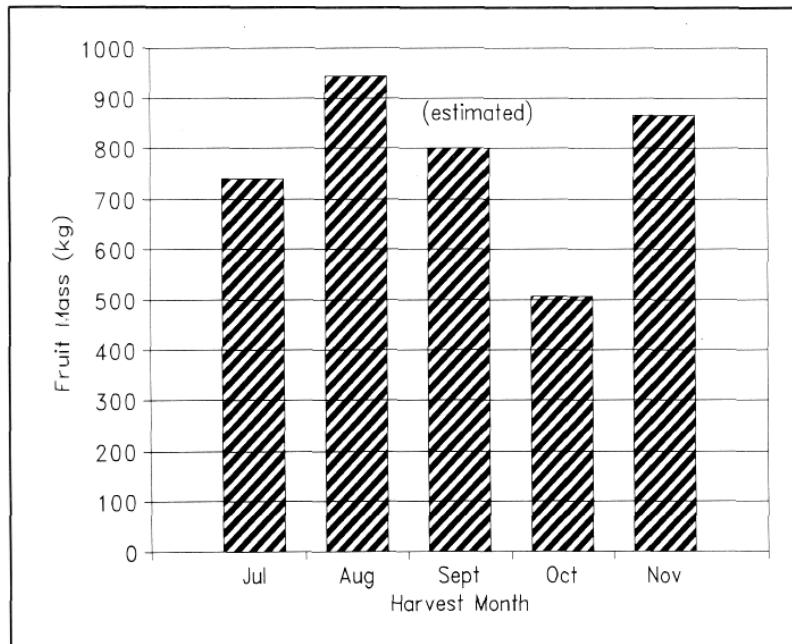


FIG. 3 Cumulative yields for all trees at Everdon (Howick) in 1991.

At Everdon (Howick) a similar trend was observed (Fig.2). Unlike Cooling (Wartburg) however, the normal distribution was centred around count 18 in August and count 16 in November 1991. The greater number of fruit at Everdon (Howick) (± 700 for the two trees) compared to Cooling (Wartburg) (± 300 for the two trees) may be responsible for the smaller increase in fruit size, as limited photoassimilates had to be distributed evenly among many more fruit.

At Everdon (Howick) in 1991 (Fig.3), the August and November harvests yielded about 200 kg more fruit than the July harvest. In contrast, the October harvest yielded about 200 kg less than the July harvest. Unfortunately, the actual data for September were unavailable but the total mass of fruit was estimated at about 800 kg. This figure was obtained by multiplying the approximately 45 lug boxes harvested in September by 18 kg per lug box. In assessment, the data for Everdon (Howick) in 1991 demonstrate clearly that yields were not adversely affected by hanging fruit later than July. Indeed, yields in August, September and November were higher than in July. There were no significant differences in yields for the same trees during 1989 and 1990 (Graham 1991). Consequently, since 1991 was the third consecutive year in which trees at Everdon (Howick) were subjected to delayed harvesting until November, it is safe to assume that the treatment of delayed harvesting had taken effect. Several factors probably contributed to this increase in yield observed later in the season. Firstly, the trees were young, healthy and vigorous, and from visual observations had relatively high leaf: fruit ratios. Secondly, fruit growth was very slow after July with very little dry mass accumulation any increase in yield is accompanied by a large increase in moisture. Thirdly, the energy/water/mineral competition of old fruit is not high when compared to other active sinks. Fourthly, the young, vigorous trees had adequate

reserves to cope with the extra "load". Note that the results would probably have been very different if the trees were any older; lacked vigour; *Phytophthora cinnamomi* infection was not under control, or management was generally poor. However, Whiley *et al.* (1992), working with 'Fuerte' in S.E. Queensland for three consecutive seasons, found that their latest harvest reduced mean yields by about 15%, and induced alternate bearing.

Flowering of trees (Fig. 4) at Everdon (Howick) in both 1991 and 1992 began in late August, peaked in mid-September and was finished by the end of October. A similar trend was seen for trees at Cooling (Wartburg), with however a temporal delay of one month. In 1991 at Everdon (Howick), flowering of all trees was complete in September while in 1992 a few trees reached peak flowering in October. A similar trend was seen at Cooling (Wartburg) except that this occurred one month later. These delays in flowering in 1992 were probably related to the prevailing drought, although some irrigation took place.

In contrast to flowering, the "single" vegetative shoot flush at Everdon (Howick) and Cooling (Wartburg) began simultaneously in mid-October (Fig. 5) but ended in February 1993 at Everdon (Howick) and March 1993 at Cooling (Wartburg). This implies that growth at Everdon (Howick) was less prolonged than at Cooling (Wartburg). Interestingly only one prolonged vegetative shoot flush was observed at both farms. A second shoot flush in summer, which was noted by Whiley *et al.*, (1988), was not observed per se it was part of an overall period of growth. It is possible that firstly, the estimation method employed viz. what percentage of the tree has actively growing shoots at a particular time, failed to identify the flush as actual growth measurements of shoots were not recorded.

The first root flushes were observed in March and April 1991 on Everdon (Howick) and Cooling (Wartburg) respectively (Fig. 6). At Everdon (Howick) the root flush peaked in July 1991 while at Cooling (Wartburg) it plateaued in August 1991. Both root flushes then decreased until December 1991 at Everdon (Howick) and January 1992 at Cooling (Wartburg). In both cases, the subsequent increase in root flushing began one month after the respective shoot flushing was complete. The ensuing rooting flush until March 1992 was short-lived and the subsequent decrease coincided with rapid fruit development and growth. Root flushing at Cooling (Wartburg) decreased from March 1992 until October 1992, while a third root flush began at Everdon (Howick) in July 1992. The start of this root flush coincided with the premature removal of fruit in July 1992 and it appears that storage reserves which were not utilized by the fruit were rechannelled into vegetative flushing.

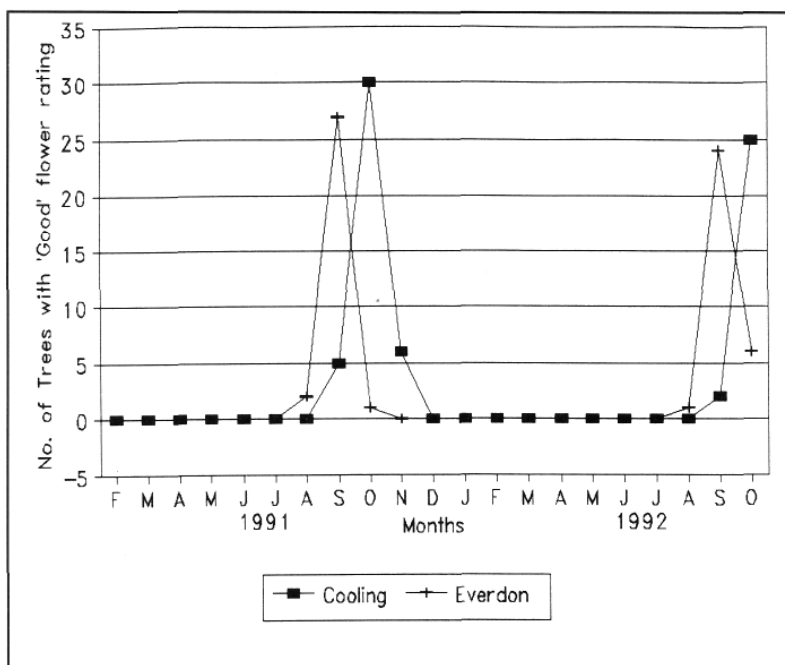


FIG. 4 Flower ratings for trees at Everdon (Howick) and Cooling (Wartburg) for the period February 1991 to October 1992.

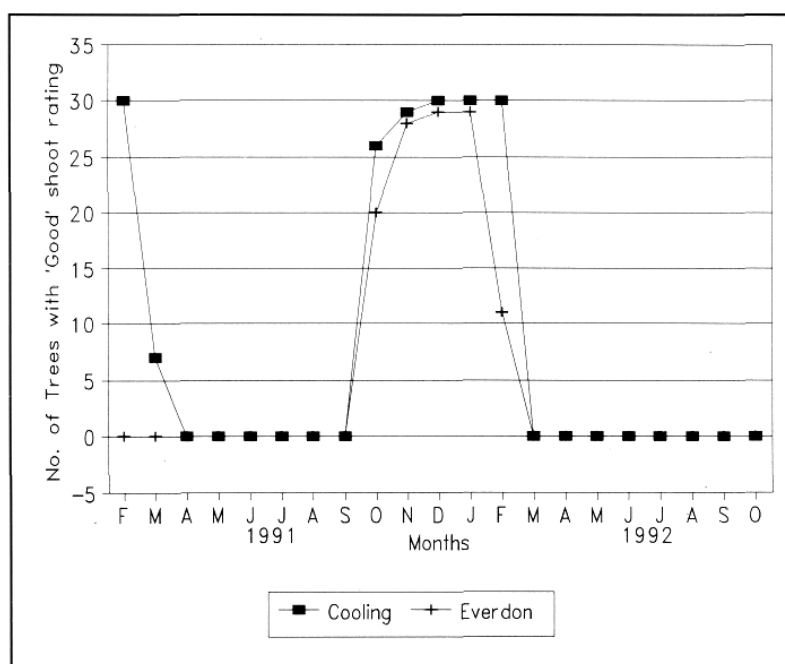


FIG. 5 Shoot flushing for trees at Everdon (Howick) and Cooling (Wartburg) for the period February 1991 to October 1992.

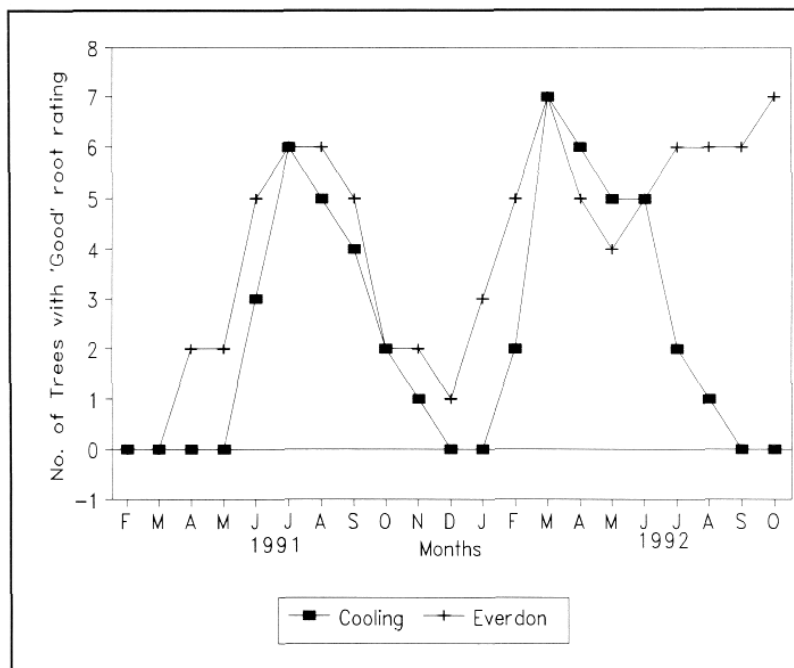


FIG. 6 Root flushing for trees at Everdon (Howick) and Cooling (Wartburg) for the period February 1991 to October 1992.

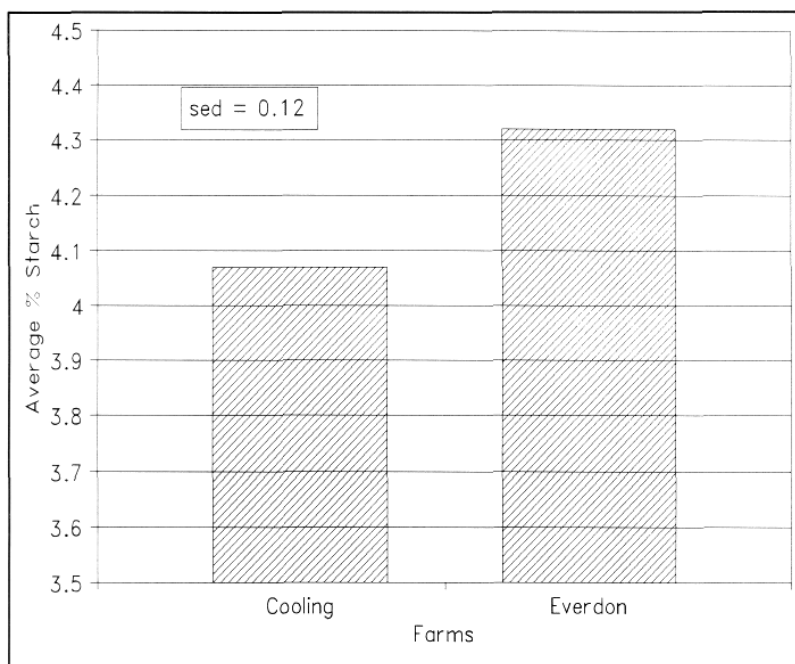


FIG. 7 Mean overall % bark starch at Cooling (Wartburg) and Everdon (Howick) from February 1991 to July 1992.

Mean monthly levels of bark starch, when averaged for the whole year, were higher in trees at Everdon (Howick) than Cooling (Wartburg) for the period February 1991 to July 1992 by about 0.3% (Fig. 7). This was most probably because the trees at Everdon (Howick) were some two years older than the trees at Cooling (Wartburg). In contrast, trees at Cooling (Wartburg) from August to October 1992, at a period in the cycle when starch concentrations are high, had mean starch levels of 0.6% higher than Everdon (Howick) (Fig. 8). The small crop load in 1992 at Cooling (Wartburg), due to early removal of the fruit by hail, is probably responsible for this marked increase in carbohydrate reserves. The relatively high starch levels recorded on both farms during August, September and October in 1992 compared to the same period in 1991 is accountable to the low crop loads.

The harvest interactions were highly significant at the 0.3% confidence interval, over the period February 1991 to July 1992 (Fig. 9). Trees harvested in July and September had the highest (about 4.8%) and lowest (about 4.0%) mean annual starch concentrations (based on monthly samples) respectively. There were however no statistical differences in mean starch levels between trees harvested in August, September, October and November. Mean starch levels of trees harvested in July were higher when compared to the other four harvest dates as less reserve had been allocated to fruit for lipid synthesis. This is supporting evidence that 'Hass' fruit harvested at Cooling (Wartburg) in July may be physiologically immature (Kaiser & Wolstenholme, 1993). In contrast, mean starch levels of trees harvested sequentially in August, September and October in 1992 were not statistically different ($P = 0.259$). This was expected as there were no fruit on the trees after July and carbohydrate reserves were thus unaffected.

The differences in mean monthly starch levels for both farms from February 1991 to October 1992 were highly significant ($P < 0.001$) (Figs. 10 and 11). At Cooling (Wartburg) mean starch levels were lowest at slightly more than 2% in February and slightly less than 2% in March 1991. A similar decrease occurred at Everdon (Howick) from ea. 3.5% in February to just less than 3% in June 1991. These decreases coincided with root flushes which would have been drawing on the carbohydrate reserves of the trees. The mean monthly starch levels then increased from about 2% in March to slightly more than 8% in October 1991 at Cooling (Wartburg) and from just less than 3% in June to just over 7% in September 1991 at Everdon (Howick). Both of these peaks in starch concentrations coincided with the start of flowering on the respective farms. The subsequent decrease in mean monthly starch levels continued until December 1991 and then February 1992 (to just over 3%) at Everdon (Howick) and January 1992 at Cooling (Wartburg) (less than 2%). This decrease is undoubtedly due to an increased carbohydrate demand by rapid fruit growth and the ensuing vegetative shoot flush in summer.

The subsequent slight increase in mean starch concentration to about 2.5% on Cooling (Wartburg) and just more than 4% at Everdon (Howick) in March 1992 coincided with the completion of the summer shoot flush new leaves were presumably becoming net exporters of carbohydrates. This short-lived increase in mean starch concentrations in March 1992 was followed by decreases to about 1.5% at Cooling (Wartburg) and slightly less than 3% at Everdon (Howick) in April 1992. Both of these decreases coincided rapid fruit growth and with root flushes. The root flushes on both farms in

1992 were a month later than in 1991 and this was probably related to the retarded physiological state of the trees, because of the prevailing drought.

As in 1991, mean starch levels increased on both farms from April and peaked at just less than 11% starch in September 1992 at Everdon (Howick) and about 10.5% in October 1992 at Cooling (Wartburg) (Fig. 11). Once again these peaks coincided with the start of flowering. The definite cyclical trend in mean monthly starch levels observed in 1991 on both farms was echoed in 1992. The temporal separation of one month between the cycles on both farms in 1991 was also repeated in 1992.

The month by harvest interaction was highly significant ($P < 0.001$). However, this interaction does not take into account the timing of events between the farms. Consequently, the highly significant harvest by month by farm interaction ($P < 0.001$) which had the same number of degrees of freedom (viz. 68), was graphed for the period February 1991 to July 1992 for Cooling (Wartburg) (Fig. 12) and Everdon (Howick) (Fig. 13). For both of these figures the August and October harvests have been omitted as they were very similar to the September harvests.

The mean monthly starch levels of July harvested trees fluctuated most on both farms, ranging from maxima of 10% to 12% in spring to minima of about 2% in winter (Figs 12 and 13). These spring maxima of 10% to 12% for July harvested trees when compared to 4% to 7% for November harvested trees on both farms were expected, as the early removal of fruit in July facilitates alternative channelling of carbohydrates into storage reserves. The subsequent minima of about 2%, which coincided with the root flushes in April 1992 on Everdon (Howick) and January to April 1992 on Cooling (Wartburg), were lower than the minima observed for any of the other harvest months. It is possible that storage reserves which are accumulated in the July harvested trees may not have been preferentially allocated to the following year's crop as flowering and fruit set in July harvested trees were not noticeably higher than any of the other trees. Instead, the storage reserves may have been allocated to the vegetative shoot and root flushes. If this is the case then roots would benefit from accumulation of reserve carbohydrates, which would indirectly benefit overall tree performance.

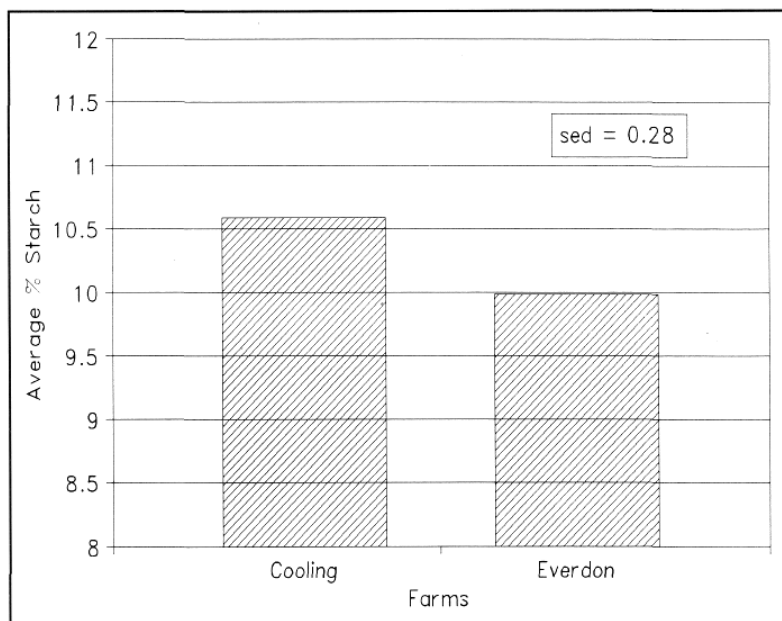


FIG. 8 Mean overall % bark starch at Cooling (Wartburg) and Everdon (Howick) from August 1992 to October 1992.

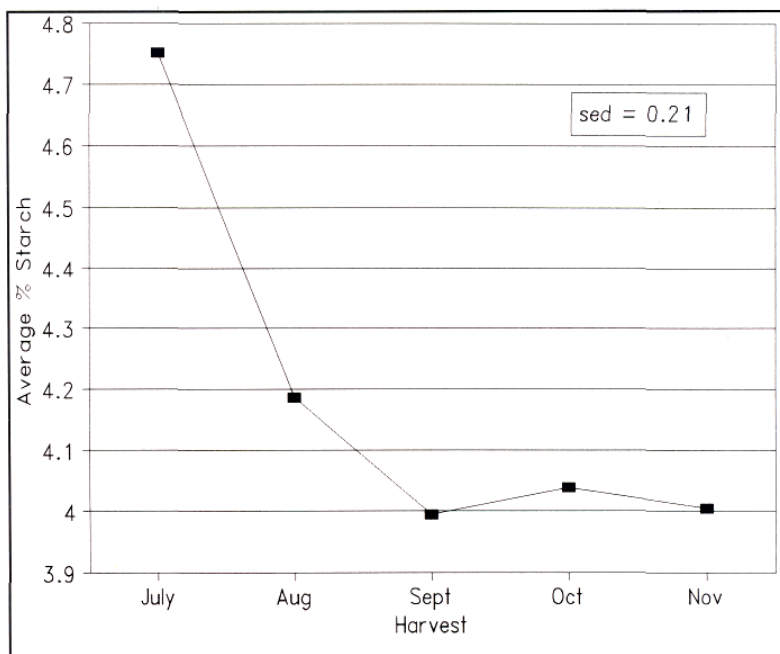


FIG. 9 Annual average bark starch levels for all trees at Everdon (Howick) and Cooling (Wartburg) for the five sequential harvest dates from July to November.

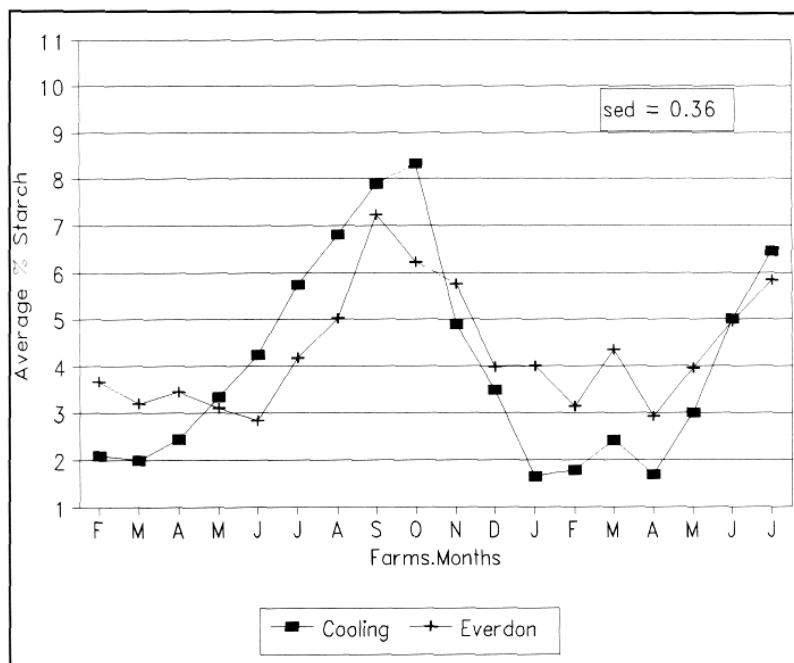


FIG. 10 Mean monthly starch levels for trees at Cooling (Wartburg) and Everdon (Howick) from February 1991 to July 1992.

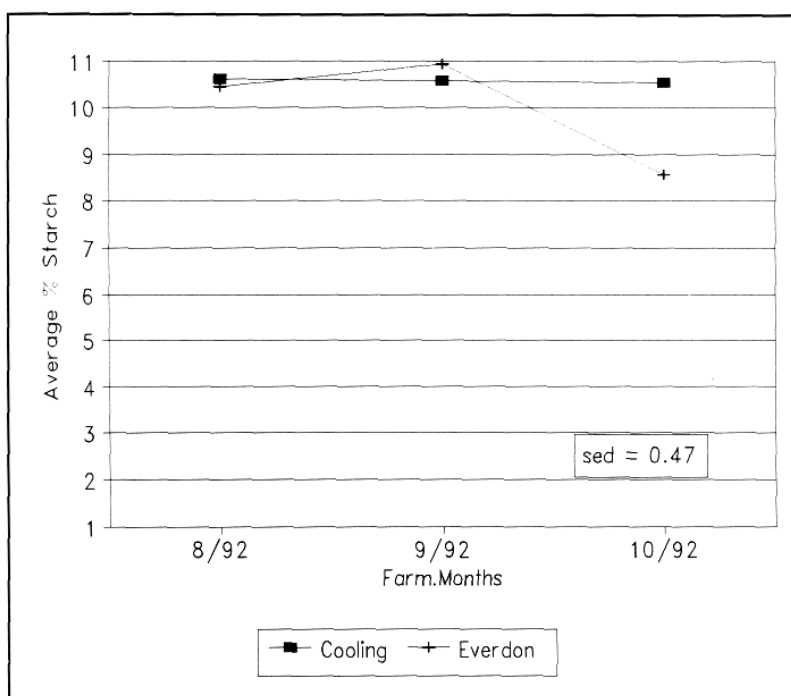


FIG. 11 Mean monthly trunk bark starch levels for trees at Cooling (Wartburg) and Everdon (Howick) from August to October 1992.

CONCLUSIONS

When fruit were left to hang on the trees, fruit size continued to increase. This was expected since it is well documented that mitotic cell division in avocado fruit continues, although slowly, until harvesting (Schroeder, 1953). In fact data for 1991 demonstrated clearly that fruit size increased between July and November, with most fruit in count 18 in July and count 14 in November. Consequently, late hanging of fruit is beneficial where larger fruit are sought. Cumulative yield data for 1991 were higher in August, September and November than in July at Everdon (Howick). Unfortunately, yield data for 1992 are not valid due to the untimely removal of fruit and must be ignored. Thus on the basis of yield data obtained in 1991, total yields in well-managed orchards are not expected to decrease dramatically the longer the fruit are left to hang on the trees. However, Whiley *et al.*, (1992) found that over a three year period, 'Fuerte' trees subjected to on-tree storage resulted in a 15% decrease in yield, and also led to alternate bearing, when fruit were left to hang very late in the season

As far as phenology is concerned, vegetative and reproductive flushes were synchronous between trees harvested in different months on each farm. Perhaps the rating criteria were too generalized, and more frequent actual measurements of shoot extension and root elongation of individual trees would have shown distinctly different growth rates between trees harvested in different months. An undertaking such as this was not possible for this particular study due to time and distance constraints and lack of manpower. A temporal separation of one month was however observed between the phenological events on the two different farms. Flowering and the vegetative flushes began and ended a month earlier at Everdon (Howick) than Cooling (Wartburg). The vegetative shoot flush began in September on both farms in 1991 but ended at Cooling a month after Everdon. Fluctuations in starch concentrations in response to phenological changes and lipid accumulation can best be put into perspective by constructing two phenological cycles for the two farms and superimposing lipid and starch accumulations on them (Figs. 14 and 15).

Annual average trunk bark starch levels were higher in trees harvested in July than those harvested in August, September, October and November. Also, there were no significant differences in the mean starch levels of trees harvested in August, September, October and November. These data suggest that less starch reserves were allocated to fruit on trees harvested in July. The monthly averages of starch levels closely paralleled the key energy related aspects of the trees where starch levels fluctuated with different phenological events. Again the temporal separation in phenological events of one month between farms carried over to fluctuations in starch levels.

Trunk bark starch levels fluctuated the most on trees where fruit were harvested in July. Although they reached the highest levels of about 12% in September, the subsequent drop to about 2% in January was lower than the levels observed in trees harvested after July. In addition flowering, fruit set and more importantly yield in trees harvested in July were not higher than those harvested from August onwards. Apparently, "extra" starch reserves in July harvested trees were channelled preferentially into the vegetative root and shoot flushes and not the following year's crop. Also the fact that starch levels were not the lowest in trees harvested after July may imply that lipids reserves in the fruit are

in fact acting as partial sinks. In any event, four years of data imply that for trees of the age, vigour, health, crop load and general level of management in these cool, mesic areas of Natal on good soils, carbohydrate levels at key stages of the phenological cycle were adequate. Late hanging of fruit did result in depression of reserve carbohydrate levels when such fruit entered a new season coincident with the critical flowering and fruit set period of the following crop. However, the fact that subsequent yields were not significantly depressed indicates that at least with good management in non-stressful environments, "critical" energy levels were not breached or alternatively, healthy leaves were able to cope with carbon demands at critical times.

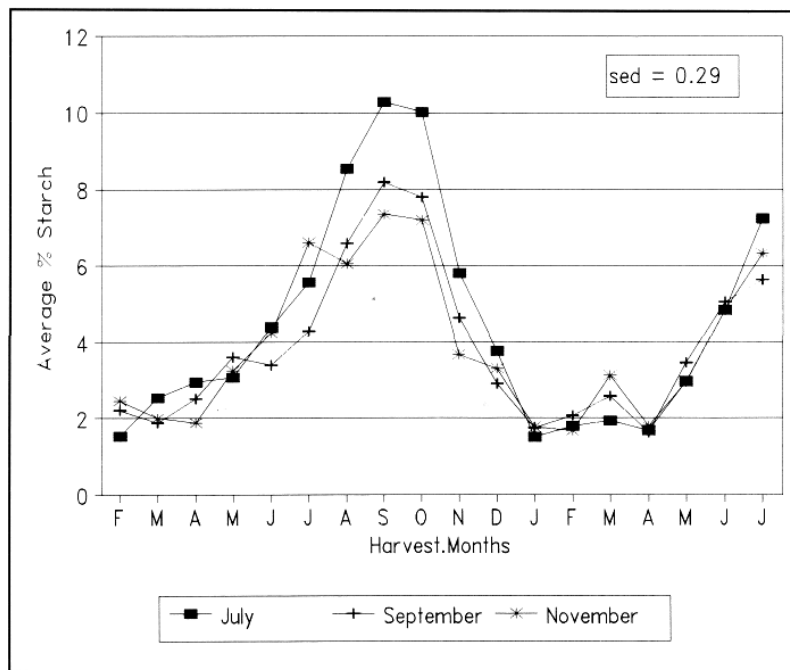


FIG. 12 Mean monthly trunk bark starch levels of July, September and November harvests for Cooling (Wartburg) from February 1991 to July 1992.

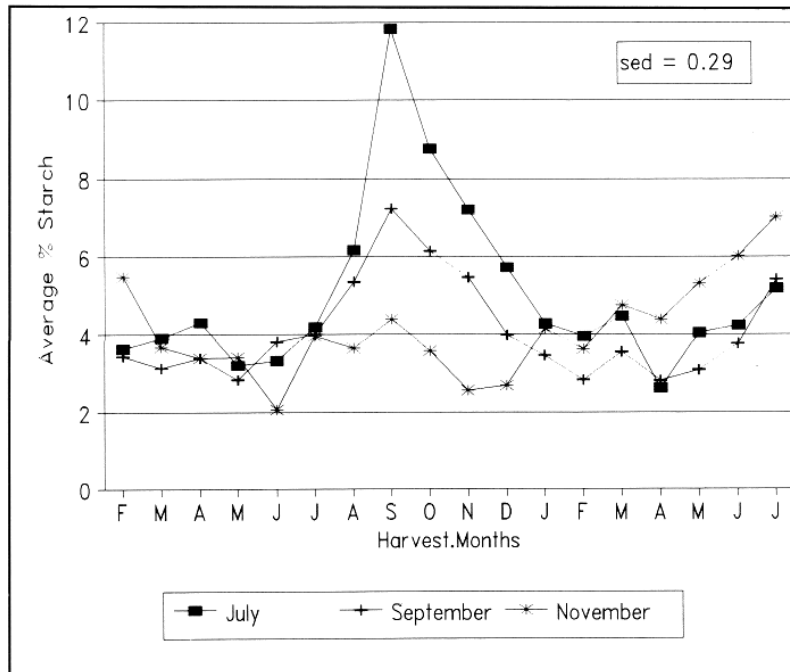


FIG. 13 Mean monthly trunk bark starch levels of July, September and November harvests for Everdon (Howick) from February 1991 to July 1992.

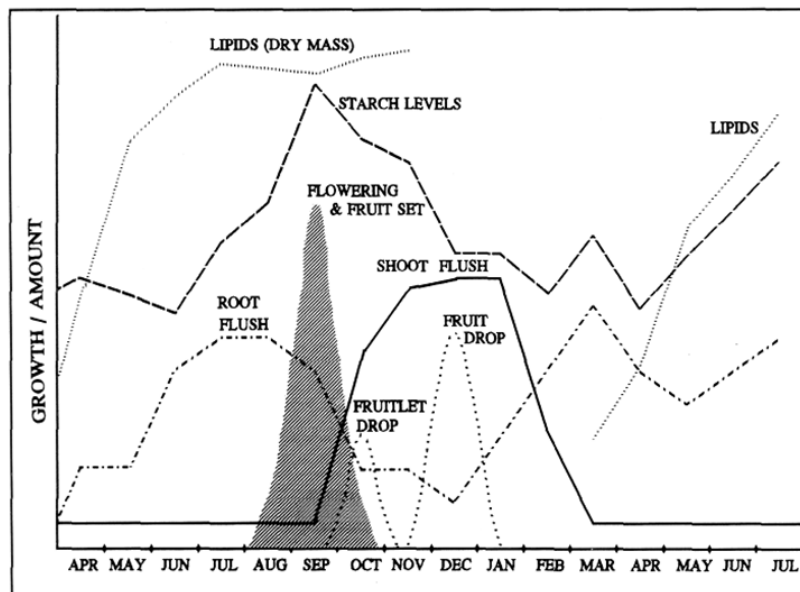


FIG. 14 Total phenological cycle of 'Hass' avocado at Everdon (Howick), 1991 and 1992.

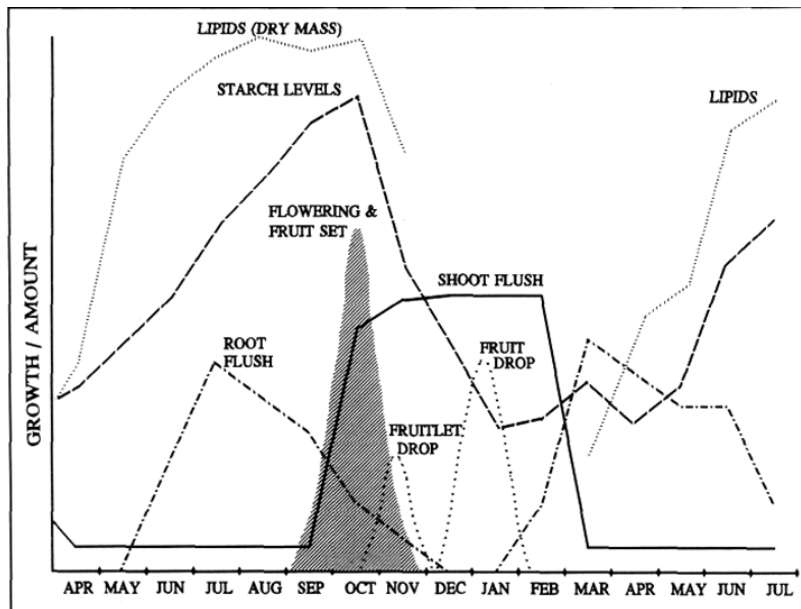


FIG. 15 Total phenological cycle of 'Hass' avocado at Cooling (Wartburg), 1991 and 1992.

Late hanging of 'Hass' avocado fruit was not detrimental to the carbohydrate levels in trees and more particular to yield. This together with the evidence that fruit lipid levels on a dry mass basis plateaued and decreased late in the season (Kaiser & Wolstenholme, 1993), certainly reinforce in addition the desirability of earlier, selective harvest of larger fruits, to reduce any stress factors which may become apparent in trees under less optimum conditions than experienced in this trial. Late hanging of fruit intended for export may be left until September in the cool mesic inland areas of Natal. However, if fruit are exported later than September they will most likely meet with competition from abroad eg. Israeli fruit, and prices may thus be lower. In addition, the specific requirements related to the export market in particular may override the desirability of later harvest (eg. market requirements and shipping schedules). However, for the local market late hanging of at least a portion of the crop will surely make financial sense in current circumstances. An economic modelling exercise is indicated. A further constraint is that late hung fruit would be more subject to other risk factors, eg. disease, hail, drought, wind etc.

Finally, it is pertinent to stress the favourable conditions for the trees (in relative terms) which prevailed during the trial. Trial trees grew in relatively cool, mesic, non-stressful environments and received good intensive management. Under such conditions, contrary to expectation, late hanging was not detrimental to subsequent yield or to certain aspects of fruit quality. On theoretical grounds one can anticipate that there are conditions under which a very different result may have occurred. In particular, it would be unwise to recommend greatly delayed harvest in much warmer and more stressful environments (including the edaphic factor). Also, non-vigorous trees, trees with a high crop load, and trees in which *Phytophthora* root rot is not under control may well be prime candidates for aggravated carbon stress, reduced yield and pronounced alternate

bearing. As always, management expertise and economics will be the deciding factors.

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