'HASS' AVOCADO TREE PHENOLOGY IN 2004 FOR THE WESTERN BAY OF PLENTY.

J. Dixon, T.A. Elmsly and D.B. Smith
Avocado Industry Council Ltd, P.O. Box 13267, Tauranga 3110
Corresponding author: jonathandixon@nzavocado.co.nz

ABSTRACT

Understanding the growth cycle of avocado trees is very important in order to plan orchard management activities for the most effect. Determining changes from year to year in the timing of the appearance of flowers and shoots by monitoring a small number of trees can assist a grower to determine the best actions to correct an imbalance in growth. Careful observation of the tree growth cycle over several years will also help to establish the validity of many assumptions that are used to describe how 'Hass' avocado trees grow in New Zealand. With a better understanding of tree phenology there is the potential to change the timing of some management activities to improve yield. Well managed young trees on two orchards in the Western Bay of Plenty were selected to be monitored over the course of several years to establish the variation in phenological events each year. This report describes the first year of the 'Hass' avocado phenology monitoring project. The growth pattern of shoots, flowering and fruit set were similar on both orchards. There were two distinct periods of shoot growth, the first spring initiated flush starting in October and finishing at the end of November, the second summer initiated flush started mid-January and finished in mid-April. Flowering started a short time earlier than the spring initiated flush. Flowering lasted for about 4 to 5 weeks on each orchard. Fruit numbers reached a peak about 1 month after the peak of flowering. Root flushes occurred at times when the shoot growth was low. There was a clear pattern of starch accumulation and loss over the course of the year that could be correlated with the onset of flowering. The starch content of main limbs was at maximum just before the beginning of flowering and minimum about June. The results presented in this study form the baseline against which future year's changes in phenology will be measured.

Keywords: *tree growth cycles, flowering, roots, shoots, starch, weather*

INTRODUCTION

Phenology is a technical term used to describe the growth cycles of shoots, roots and flowers of plants. Understanding the growth cycle of avocado trees is very important in order to plan orchard management activities. For example, having a detailed description of the phenology of an avocado tree allows a grower to know when the best time is to apply fertiliser to support the growth and development of shoots. The general pattern of shoot and root growth has been well established in a number of studies (Arpaia *et al*., 1996; Whiley and Saranah, 1995; Graham and Wolstenholme, 1991). The general phenology of 'Hass' avocados grown in the Western Bay of Plenty was established some 10 years ago (Thorp *et al.*, 1995) and was determined to be similar to the growth patterns of avocados in other countries. Therefore, a project looking at aspects of avocado phenology in the Western Bay of Plenty is not required to define the phenological cycle for New Zealand conditions.

Having detailed descriptions of phenological events and establishing the variations in the general pattern of growth and development each year could greatly assist establishing best practice for regular cropping. Changes from year to year in the timing of the appearance of flowers and shoots can be captured by monitoring a small number of trees over a number of years. This may allow the effect of changes in the timing and strength of flowering on yield to be determined. Of equal importance is developing tools that will allow important aspects of the tree growth cycle to be measured. These tools can then be used to determine if the phenological events are occurring more strongly or weakly than may be desired. Subsequently a grower can take action to correct an imbalance in growth.

For New Zealand avocado growers to achieve consistent avocado crops an important skill will be to detect perturbations of the tree growth cycle with sufficient lead time to undertake management activities that will drive the desired outcomes from the tree. As an example, what are the consequences in future years of leaving a heavy avocado crop to be harvested late in the harvest season on future flowering and shoot growth? Research projects in South Africa (Graham and Wolstenholme, 1991) and in Australia (Whiley *et al.,*1996) would suggest late hanging of fruit alters the timing of flowering, growth flushes and the amount of starch in the tree. Careful observation over the course of several years will also allow testing of many assumptions and theories that are considered to describe how 'Hass' avocado trees grow in New Zealand. The potential therefore exists to change the timing of some management activities to improve the yield potential of the trees.

As a first step towards formulating an hypothesis of how to manage avocado phenology to achieve regular crops a detailed and accurate description of phenological events building on previous observations (Thorp *et al.* 1995) is required. Well managed young trees on two orchards in the Western Bay of Plenty were selected to be monitored over the course of several years to establish the variation in phenological events each year and to correlate these events with each other and internal tree factors and orchard factors. This report describes the first year of a 'Hass' avocado phenology monitoring project that serves as the baseline against which the tree growth cycle will be compared in other years.

MATERIALS AND METHODS

Orchards

Five trees similar in size, shape and age from each of two orchards were selected to be regularly measured throughout the year. Orchard 1 is located in Te Puna and was regularly irrigated. Orchard 2 is located in Tauranga and was not irrigated. The trees in Orchard 1 had several large (15m+) Zutano trees within 30m while the trees in Orchard 2 had no pollinizer trees within several hundred meters. The soil type for each orchard was similar as a volcanic ash with high organic matter content of 12% and 7.4%. The trees were 5 years old at the time the phenological measurements started. Both orchards were fertilised and kept free from pests and diseases according to typical industry practice with minor adjustments in the amount of minerals required determined by leaf and soil tests conducted in April/May of each year.

Shoot growth

Four branches per tree, one each on the North, West, South, East aspects, 20 branches per orchard, were selected for measurement of shoot growth. Branches were selected at 1.5m to 2m height. The length of the new growth was measured from the bud ring to the shoot tip to the nearest mm. The length of the flower panicle was measured separately from the vegetative shoot. The total shoot length of the flower and vegetative shoot is reported here. The shoot length was measured about every 2 weeks during the year. For each spring initiated shoot that did not grow again in the summer/autumn period an adjacent shoot on the same aspect was selected and measured to indicate the amount of summer/autumn growth.

Root growth

The appearance of new roots at the soil mulch interface was measured as changes in total root length in a 0.5m x 0.5m square (0.25m^2) quadrant pegged into the ground inside the drip line. There were 2 quadrants per tree, one each on the north and south facing aspects of the tree. A digital photo of each quadrant was taken every two weeks. The length of roots was measured off the photographs to the nearest mm, after correction for the width of the quadrant to normalise the root length measurements from one photograph to another.

Flowering

On each tree two indeterminate flowering branches and two determinate flowering branches were selected for counting open flowers and the number of newly set fruit. These branches were different to the branches used for shoot growth measurements. The development of flower buds from bud break until the end of flower opening was rated on a scale of 1 to 10 (the scale is described in the photos below). Just prior to flower opening (stage 5 to 6), all of the flower buds were counted. Once the first flower had opened the number of open flowers and any newly set fruit were counted on the selected flowering branches every three to four days. Flowers and fruit were not counted on weekends. The gender of the flowers was not recorded. A newly emerged fruit was counted once the new fruit was clearly visible through the sepals, at about 3 to 4 mm in diameter.

Fruit set and drop

To follow the pattern of fruit set and to determine the timing of the fruit drop the numbers of fruit on the same branches as the flower counts were used. The numbers of fruit were counted every three to four days until the fruit numbers remained the same for three consecutive counts.

Starch analysis

Each tree was sampled for trunk starch content using a cordless drill equipped with an 8 mm bit for drilling wood. The bark was removed and discarded; wood shavings were collected from a hole up to 25 mm deep from each of three main limbs within 0.5 m of the main trunk. Wood samples for starch analysis were collected once a month. The wood shavings were stored in sealed polyethylene bags at -18°C before drying at 55°C and ground to a fine powder for analysis of starch according to the total starch assay Megazyme AACC method 76.13 (Megazyme International Ireland Limited) as described by McCleary *et al*. (1997).

Weather

The shade air temperature within the canopy of one tree in each orchard and the soil temperature at 100mm depth for one tree were recorded using temperature microloggers (HortPlus, Cambridge, New Zealand) The microloggers were set to record the temperature once every 30 minutes. The microloggers within the trees were placed within a Stevenson's screen while the loggers in the soil were buried in a plastic bag sealed to prevent exposure to water. The soil moisture matrix potential under one tree on each orchard was measured each time the orchard was visited at 30cm and 60cm using Irrometer tensiometers within the drip line under the canopy and under the mulch layer under the tree. Rainfall outside of the trees was measured using a rain gauge (Nylex Rain Gauge, 150mm capacity) and recorded each time the orchard was visited.

Flower development stages

Stage 1 – bud break

Stage 2 – 10% expansion of cauliflower

Stage 3 – 50% expansion of cauliflower

Stage 4 – 75% expansion of the cauliflower (copper residue is visible on the leaf)

Stage 5 – 100% expansion of cauliflower

Stage 6 – First flower open

Stage 7 – 25% of flowers have opened

Stage 8 – 50% of flowers have opened

Stage 10 – 100% of flowers have opened

RESULTS

Shoot growth

Indeterminate flowering shoots

Early stages of spring flush – note the open flowers and newly emergent shoots

Early spring flush – note the new vegetative bud emerging underneath the centre shoot

Later development of spring flush – note the extension of the flower portion of the new shoot

Indeterminate shoot – November at the end of flower opening

Indeterminate shoot – note the elongated shoot

Indeterminate shoot – mid December

Indeterminate shoot – note the very long extension of the flower before the vegetative growth started

Spring flush in early January – note the first leaves are nearly fully expanded

Determinate flowering shoots

Determinate shoot before the flower stalks abscise

Determinate shoot – note this may develop vegetative shoots once flowering has finished

Determinate shoot after the December drop note no vegetative growth at all

Determinate flowering shoot – note the healthy over wintered leaves

Roots

Feeder roots under the mulch and in the 'A' horizon

Phenological cycle

The growth pattern of shoots, flowering and fruit set were similar on both orchards (Figure 1). There were two distinct periods of shoot growth, the first spring initiated flush starting in October and finishing at the end of November, the second summer initiated flush started mid-January and finished in mid-April. Although there were two main periods of shoot growth some shoot growth occurred on at least one aspect of the tree from the beginning of October to the beginning of May. There was very little shoot growth from May until October. The aspect of the tree where the flowering branches were located also influence when flowering and shoot growth occurred with the earliest flowering and shoot growth on the north facing aspect and the latest flowering and shoot growth on the south and east facing aspects (Table 1). Flower opening times were not affected by shoot type but the determinate flowering shoot type had vegetative growth about 2 months after the indeterminate flowering shoots (Table 1).

Flowering started after the shoot flush was about 1 month old for Orchard 1. For Orchard 2 flowering and shoot growth occurred at the same time as the spring initiated flush. Flowering lasted for about 4 to 5 weeks on each orchard. The development of flower buds was similar between orchards with bud break occurring near the end of September. Flower

Table 1. Typical date of first open flower (flower development stage 6) and date of first emergent shoots of 'Hass' avocado trees in the Western Bay of Plenty

Date of first flower opening				
Shoot type	**Indeterminate**	**Determinate**	**Indeterminate**	**Determinate**
Orchard	**1**	**1**	**2**	**2**
Aspect				
North	22/10/2004	22/10/2004	31/10/2004	Not Obs.
East	23/10/2004	5/11/2004	28/10/2004	Not Obs.
South	6/11/2004	Not Obs.[1]	5/11/2004	Not Obs.
West	31/10/2004	29/10/2004	3/11/2004	22/10/2004

Date of emergence of vegetative shoot				
Shoot type	**Indeterminate**	**Determinate**	**Indeterminate**	**Determinate**
Orchard	**1**	**1**	**2**	**2**
Aspect				
North	6/10/2004	10/12/2004	18/10/2004	22/10/2004
East	19/10/2004	16/12/2004	5/11/2004	21/10/2004
South	18/10/2004	Not Obs.	25/10/2004	22/10/2004
West	16/10/2004	10/12/2004	26/10/2004	Not Obs.

[1]*Not observed.*

bud growth was rapid with the first flowers open on 4 November and the last flowers closing on 16 December. Fruit numbers reached a peak about 1 month after the peak of flowering after which they fell rapidly until the end of December. The fruit set on both orchards was heavy indicating that the trees were in an 'on' year.

There was more root growth in Orchard 1 than in Orchard 2. For Orchard 1 some root growth occurred in mid-September, in November at the same time as flowering and shoot flush, in December and in March. For Orchard 2 there was root growth in December and again in April and June/July.

From these observations in the month of November for the trees in the two orchards underwent all the major growth events that can occur on avocado trees, shoot growth, flowering, initial fruit set and root growth.

Weather

The shade air temperature and soil temperature pattern over the year were, in general, similar for each orchard (Figure 2). Frosts as indicated by air temperatures below or near 0ºC were common from July (winter) until the beginning of October. In October the minimum daily air temperature warmed by about 5ºC until January where the daily minimum temperature again increased to be in the range of 10ºC to 15ºC. Daily maximum air temperatures ranged from 15ºC to over 20ºC when the flowers were opening then increased the reach daily maximum temperatures at about 25ºC in mid-February. Rain was relatively evenly distributed from July until April with high amounts of rain in April and June. The soil moisture matrix potential of Orchard 1 was below -20kPa over the year. Orchard 2 soil matrix potential increased to about -90 kPa in March and reached -70 kPa in May despite over 150mm of rain. Soil temperatures increased from about 10ºC at the beginning of October and reached a peak at about 20ºC in mid-February before declining back to about 10ºC in June.

Starch

There was a clear pattern of starch accumulation and loss over the course of the year that could be

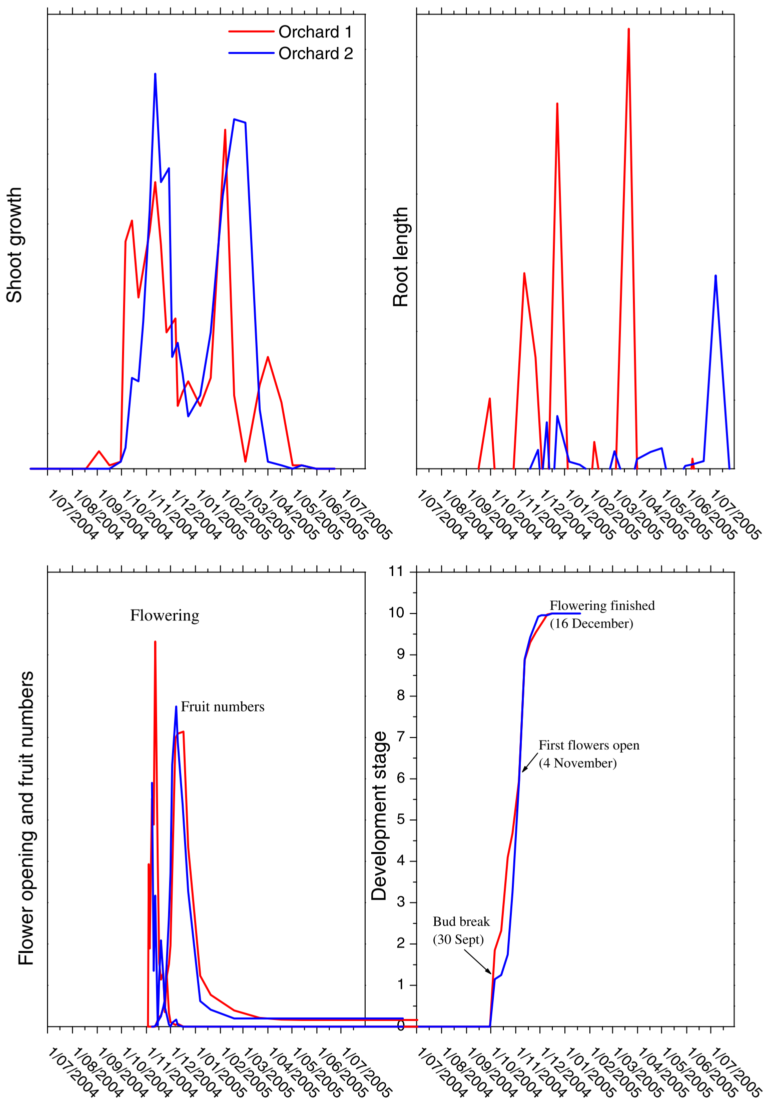

Figure 1. Shoot growth, root growth, flowering and fruit set and development of flower buds of Hass avocado trees in the Western Bay of Plenty.

correlated with the onset of flowering (Figure 3). The starch content of main limbs was at maximum just before the beginning of flowering and minimum about June (Figure 3). The maximum starch content in the main limbs was about 5% for Orchard 1 and about 7% for Orchard 2 but the minimum starch content in main limbs was about 1% for Orchard 1 and about 2% for Orchard 2.

DISCUSSION

The main patterns of growth were: for the spring shoot flush to begin at about the same time as the trees were flowering and continue over the December fruit drop period. There was another shoot flush that peaked about 3 to 4 months after the peak of the spring flush. When there was little shoot growth there were root flushes. Vegetative growth ceased over the winter period. This pattern of vegetative growth is similar to that reported in South Africa (Graham and Wolstenholme, 1991). However, there was a difference in the timing of flowering and root flushes where flowering in South Africa was well in advance of the first spring flush and root flushes occurred at the same time as the shoot flushes. Flowering was also recorded as

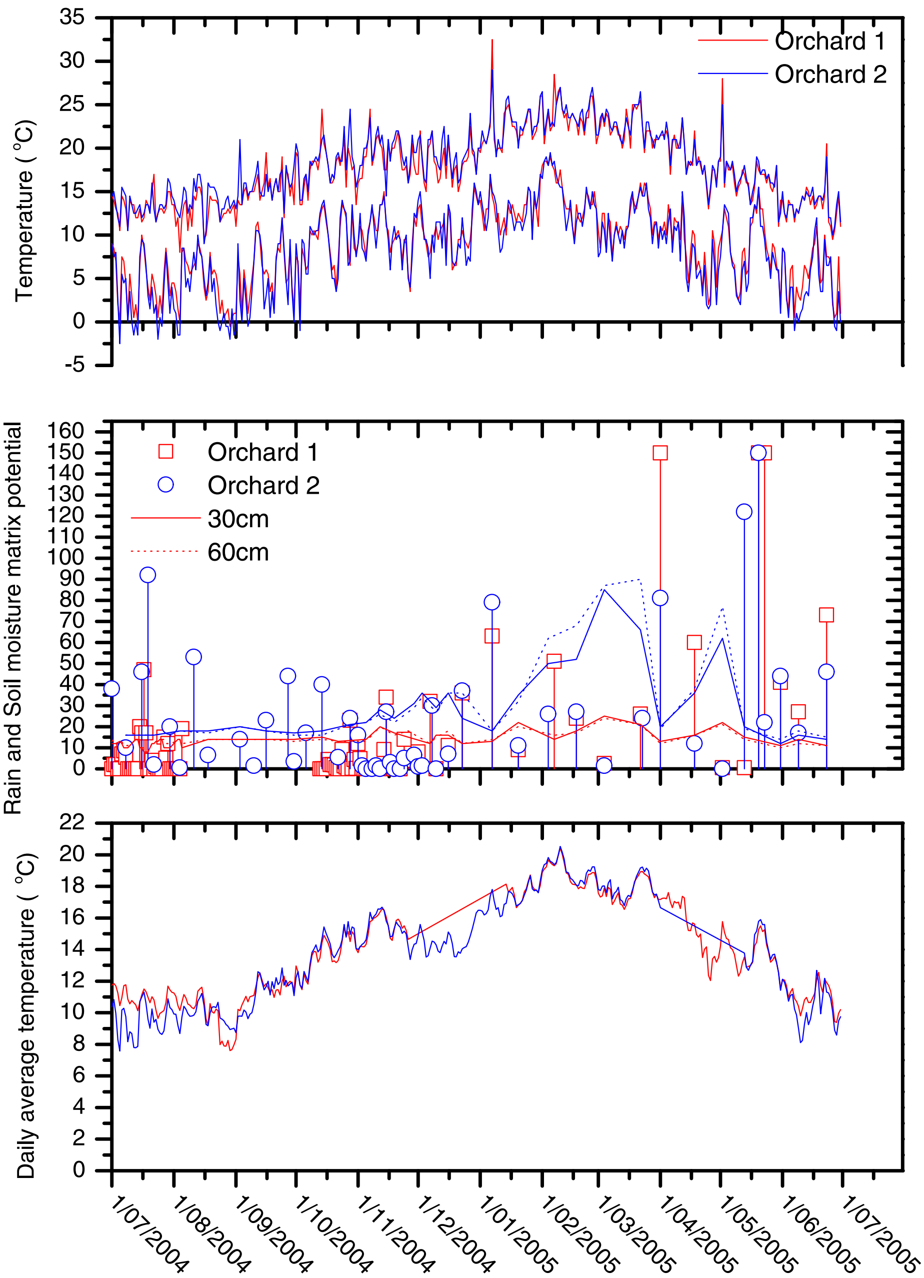

Figure 2. Daily maximum and minimum temperatures, average soil temperature at 100mm depth, rainfall and soil moisture matrix potential.

being in advance of the spring growth flush in Queensland, Australia (Whiley and Saranah, 1995). In California the spring flush and flowering appear to follow a similar pattern to that reported here (Arpaia *et al.,* 1996; Liu *et al.*, 1999). Root growth in California and Queensland, however, continued over most of the year in contrast to the flushes of root growth observed here. Root growth followed shoot growth and appeared to occur at periods when the shoot growth was low. This contrasts to that found by Thorp *et al.* (1995) where root growth occurred at the same time as shoot growth.

The starch cycle reported here was similar in South Africa, Australia (Scholefield *et al.* 1985) and California (Arpaia *et al.*, 2000) to that reported here with a peak in starch concentration at the beginning of flowering after which the starch declined to a minimum point in February before accumulating

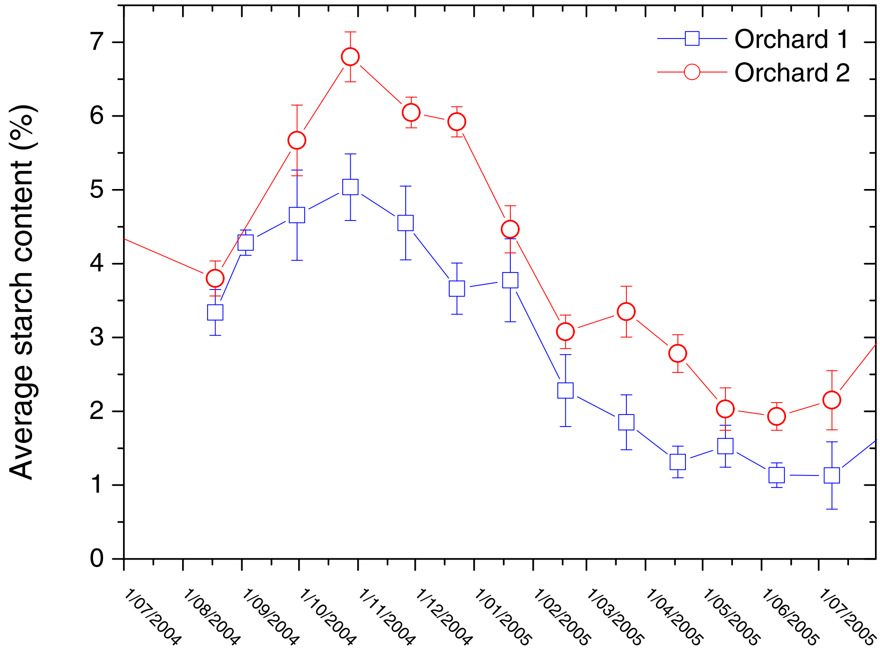

Figure 3. Starch content in the main limbs of Hass avocado trees.

over the autumn and winter until flowering (Graham and Wolstenholme, 1991). In both South Africa and Australia the trees flowered in winter in contrast to the spring flowering in New Zealand.

CONCLUSIONS

The pattern of shoot growth, root growth and flowering in 2004 for the sites used in this study was one period of flowering with a flush of shoot growth, a flush of shoot growth and several flushes of root growth between shoot flushes. Full bloom was in the first week of November, the shoot flushes in October/November and February/March. Fruit drop occurred one month after full bloom. There was no growth in shoots or roots recorded over winter. There was a well defined cyclical pattern of starch accumulation and decline with maximum starch just before the start of flowering and minimum starch in June.

ACKNOWLEDGEMENTS

The AIC wishes to thank Alex and Colleen Barker, Colin Jenkins and Steve Bryant and the Ngai Tukairangi Trust for the use of their trees in this study.

REFERENCES

Arpaia, M.L., Robinson, P.W., Liu, X., Mickelbart, M.V. and Witney, G.W. (1996). Development of a phenological model for California 'Hass' avocado. *1996 Avocado Research Symposium* pp. 7-11.

Arpaia, M.L., Robinson, P., Mickelbart, M., Stottlemyer, D., Manor, W., Fokt, E., Madore, M. and Heath, R. (2000). Enhancement of avocado productivity. II. Tree phenology, carbohydrate cycling and canopy management. *2000 Avocado Research Symposium* pp. 17-22.

Graham, A.D.N. and Wolstenholme, B.N. (1991). Preliminary results on the influence of late hanging of Hass avocados (*Persea americana* Mill.) on tree performance. *South African Avocado Growers' Association Yearbook* **14**: 27-37.

Lui, X., Robinson, P.W., Madore, M.A., Witney, G.W. and Arpaia, M.L. (1999). 'Hass' avocado carbohydrate fluctuations. I. Growth and phenology. *Journal of the American Society of Horticultural Science* **124:** 671-675.

McCleary, B.V., Gibson, T.S. and Mugford, D.C. (1997). Measurement of total starch in cereal products by amyloglucosidase - -amylase method: Collaborative study. *Journal of the Association of Official Analytical Chemistry* **80**: 571-579.

Scholefield, P.B., Sedgely, M. and Alexander, D.McE. (1985). Carbohydrate cycling in relation to shoot growth, floral initiation and development and yield in the avocado. *Scientia Horticulturae* **25**: 99-100.

Thorp, T.G., Anderson, P. and Camilleri, M. (1995). Avocado tree growth cycles – a quantitative model. *Proceedings of the World Avocado Congress III* pp. 76-79.

Whiley, A.W. and Saranah, J.B. (1995). Pheno-physiological modelling in avocado – an aid in research planning. *Proceedings of the World Avocado Congress III* pp. 71-75.

Whiley, A.W., Rasmussen, T.S., Saranah, J.B and Wolstenholme, B.N. (1996). Delayed harvest effects on yield, fruit size and starch cycling in avocado (*Persea Americana* Mill.) in two subtropical environments. II. The late maturing cv. 'Hass'. *Scientia Horticulturae* **66**: 35-49.

