

## PHENO-PHYSIOLOGICAL MODELLING IN AVOCADO - AN AID IN RESEARCH PLANNING

Anthony W. Whiley and Jack B. Saranah  
Maroochy Horticultural Research Station Department of Primary Industries  
Queensland, Nambour 4560 Australia

B. Nigel Wolstenholme  
Department of Horticultural Science University of Natal  
Pietermaritzburg 3209 South Africa

### Abstract

A revised and expanded pheno-physiological model has been developed for cv. Hass growing in a cool, humid subtropical climate in south-east Queensland. The model quantifies the seasonal growth activities of reproductive and vegetative components of the tree, details seasonal changes in leaf nitrogen and chlorophyll concentrations, and records changes in the photoassimilation efficiency of leaves from summer through to spring. The pheno-physiological model has assisted in the development of disease prevention strategies and limitations to production have been identified. Studies based on this information have been implemented and successful outcomes achieved. These are discussed in relation to a whole-tree approach to research and development of avocado in subtropical regions.

### 1. Introduction

Plant growth responses are largely precipitated by seasonal environmental changes which either induce or release stress thereby promoting associated changes in physiological processes. Ultimately this leads to a progression of the cropping cycle or a sequence of phenological events which normally occur in an orderly manner. In avocado (*Persea americana* Mill.) tree phenology was first reported in the late 1950's (Chandler 1958; Venning and Lincoln, 1958) with additional contributions to the knowledge base during ensuing years (Kotz6, 1979; Wolstenholme, 1981; Davenport, 1982). However, the first detailed conceptual model was not published until 1988 (Whiley et al., 1988). This model has since been refined with the incorporation of physiological data providing a more in-depth interpretation of tree growth and potential yield limitations. We report on the use of this model as a tool for developing new initiatives in research to enhance production in subtropical climates.

### 2. Materials and Methods

A commercial 'Hass' avocado orchard at Maleny in S.E. Queensland (latitude 26.50S, altitude 520 m) was chosen for the pheno-physiological study. The climate is cool, mesic subtropical with a high mean annual rainfall of 2000 mm in a summer/wet: winter/dry pattern.

During 1988 'Velvick', a Guatemalan race seedling selected in Queensland, was clonally propagated and grafted to 'Hass' scions. In March 1989 five trees were planted in central positions 1 m from windows of a rhizotron facility especially constructed for the study and described by Whiley (1994). At the time of planting, under-tree mini-sprinklers ( $10 \text{ l hr}^{-1}$ ) were installed at each site to supplement natural rainfall. Trees were fertilized according to the schedule for tree age developed for avocados growing in S.E. Queensland (Banks 1992).

Root measurements were made only of the white, unsubsided "feeder" roots. Data were collected at monthly intervals by tracing the outline of white roots visible at the soil-panel interface onto transparent sheets of acetate with a black indelible pen. The information on the acetate sheets was digitized by scanning to an electronic file using a Hewlett Packard ScanJet IIc. Root lengths were determined by computerized image analysis (Sci-Scan Image Analysis System, Delta T, UK). This method gave a total length (m) of visible white root at the soil-panel interface ( $0.58 \text{ m}^2$  vertical window area). Reproductive and vegetative phenology data were collected for four seasons at monthly intervals, or more frequently when necessary, using a modified system of Whiley et al. (1988) described by Whiley (1994).

The determination of nitrogen concentration was made from 15 of the most recently matured summer-flush leaves selected at monthly intervals from May until December 1992. After preparation nitrogen was measured following a Kjeldahl digest.

Photoassimilation studies were carried out from March to December 1992 on five fully expanded sun-exposed leaves on the northern side of each tree.  $\text{CO}_2$  assimilation (A) was measured at monthly intervals with a LICOR LI-6200 portable photosynthesis meter (LICOR, Nebraska, USA). All measurements of A were made at or above light intensities of  $1200 \mu\text{mol quanta m}^{-2} \text{ S}^{-1}$  and between 0830 to 1030 h, a low stress time of day. Chlorophyll concentrations were determined at monthly intervals from five leaves on the northern side of the trees using the technique described by Proctor (1981).

### 3. Results and Discussion

The leaf concentration flux of nitrogen showed significant changes which could be related to critical stages of tree phenology (figure 1). Nitrogen concentration remained relatively stable from April until July, a period of extended quiescence in the canopy of the tree (figure 1a). However, there was a sharp decline during the growth of inflorescences probably due to remobilisation to support this adjacent sink, with recovery during anthesis but declining once more during fruit set and spring shoot growth. The decline in leaf N concomitant with fruit set and shoot growth has similarly been reported in citrus, where it was concluded that young vegetative flushes draw nitrogen from reserves in old leaves (Erner, 1988).

Net  $\text{CO}_2$  assimilation of sunlit summer-flush leaves reached its highest rate in April ( $18.3 \text{ CO}_2 \mu\text{mol m}^{-2} \text{ S}^{-1}$ ) and then slowly declined through to May (figure 1 a). By June there was a rapid decline in A which remained at about  $10 \mu\text{mol CO}_2 \text{ m}^{-2} \text{ S}^{-1}$  through to October. There was a small recovery in A by November followed by a rapid decline as leaves senesced. Except for a lag phase going into winter the pattern of chlorophyll concentrations in leaves substantially mirrored A (figure 1 a).

The autumn/winter decline in A can be attributed to at least four factors: increasing vapour pressure deficits (Schultze, 1986); end product feedback-inhibition due to increasing leaf starch concentrations (Schaffer et al., 1987); low temperature photoinhibition of photosystem II (Smillie and Hetherington, 1983); and reduced leaf chlorophyll and N concentrations (DeJong,

1982; Syvertsen, 1984). It is likely that all of these factors contribute to the depression of A to a greater or lesser degree during winter and spring.

The pheno-physiological model developed for 'Hass' identified seasonal interactions between vegetative (roots and shoots) and reproductive (flowers and fruit) components of the tree (figures 1 b and 1 c). The offset bimodal cycle of root and shoot growth (sink phase) identified in this study was shown to be critical with respect to the timing and distribution of hunk injected phosphonate for Phytophthora root rot control in subtropical climates (Whiley et al., 1995). Injection following the sink:source transition of major flush periods when roots become strong sinks are the most effective times for increasing phosphonate concentrations in roots and treatment is application is based on key phenological events.

With respect to tree productivity one of the most critical periods determining both yield and fruit size occurs immediately following flowering when many fruits are dropped from the tree (figure 1 c). Competition for resources between developing fruit and new shoot growth occurs at a time when A (figure I a) and root growth (figure 1 b) are depressed. Studies by Whiley (1994) have determined that in warm, humid subtropical climates assimilates from current photosynthesis as opposed to stored sources are critical for fruit retention and growth. From this identified deficiency of low A during the critical spring period, research has demonstrated that by increasing leaf N through soil applications of urea immediately prior to flowering in conjunction with mid-bloom foliar applications of paclobutrazol (Whiley et al., 1990), significant increases in 'Hass' yield are obtained. The replacement of leaf nitrogen and the suppression of new shoot growth (by paclobutrazol) results in higher A rates in the over- wintered canopy presumably increasing the carbon supply to developing fruits.

#### 4. Conclusions

The development of pheno-physiological models has assisted in interpreting tree growth providing a greater understanding of temporal relationships between the components of the tree with relation to growth and their physiological status. This has been used to advantage in developing strategies to control Phytophthora root rot and to improve fruit set, retention and yield. However, despite this considerable improvement in our knowledge, sustainable yield remains lower than the potential target of about 32 t ha<sup>-1</sup> estimated for avocados by Wolstenholme (1986). It is likely that we are reaching the genetic limits of current cultivars and the next step forward will only occur with improved rootstocks and varieties.

#### References

- Banks, A., 1992. Growing avocados in Queensland. Department of Primary Industries, Brisbane. pp. 1-36.
- Chandler, W.H., 1958. The avocado. In: Evergreen orchards. Lea and Febiger, Philadelphia. pp. 205-228.
- Davenport, T.L., 1982. Avocado growth and development. Proc. Fla State Hort. Soc. 95: 92-96.
- DeJong, T.M., 1982. Leaf nitrogen content and CO<sub>2</sub> assimilation capacity in peach. J. Amer. Soc. Hort. Sci. 107: 955-959.

- Emer, Y., 1988. Citrus fruit set: carbohydrate, hormone, and leaf mineral relationships. In: Manipulation of fruiting. C.J. Wright (ed.). Butterworths, London. Pp. 232-233.
- Proctor, J.T.A., 1981. Stomatal conductance changes in leaves of McIntosh apple trees before and after fruit removal. *Can. J. Bot* 59: 50-53.
- Schaffer, B., Ramos, L., and Lara, S.P., 1987. Effect of fruit removal on net gas exchange of avocado leaves. *HortScience* 22: 925-927.
- Schultz, E.D., 1986. Carbon dioxide and water vapour exchange in response to drought in the atmosphere and in the soil. *Annu. Rev. Plant Physiol.* 37: 247-274.
- Smillie, R.M., and Hetherington, S.E., 1983. Stress tolerance and stress-induced injury in crop plants measured by chlorophyll fluorescence in vivo. *Plant Physiol.* 72: 1043- 1050.
- Syvertsen, J.P., 1984. Light acclimation in citrus leaves. 11. CO<sub>2</sub> assimilation and light, water, and nitrogen use efficiency. *J. Amer. Soc. Hort. Sci.* 109: 812-817.
- Venning, F.D., and Lincoln, F.B., 1958. Development morphology of the vegetative axis of avocado (*Persea americana* L.) and its significance to spacing, pruning practices, and yields of the grove. *Proc. Fla. State Hort. Soc.* 71: 350-356.
- Whiley, A.W., 1994. Ecophysiological studies and tree manipulation for maximisation of yield potential in avocado (*Persea americana* Mill.). Unpublished PhD Thesis, Dept. Hort. Sci., Univ. Natal, Pietermaritzburg.
- Whiley, A.W., Hargreaves, P.A., Pegg, K.G., Doogan, V.J., Ruddle, L.J., Saranah, J.B., and Langdon, P.W., 1995. Changing sink strengths influence translocation of phosphonate in avocado (*Persea americana* Mill.) trees. *Aust. J. Agri. Res.* 46: 1079- 1090.
- Whiley, A.W., Saranah, J.B., Cull, B.W., and Pegg, K.G., 1988. Manage avocado tree growth cycles for productivity gains. *Queensland Agric. J.* 114: 29-36.
- Wolstenholme, B.N., 1981. Root, shoot or fruit. *S. Afr. Avocado Growers' Assoc. Yearb.* 4: 27-29.
- Wolstenholme, B.N., 1986. Energy costs of fruiting as a yield-limiting factor with special reference to avocado. *Acta Hort.* 175: 121-126.

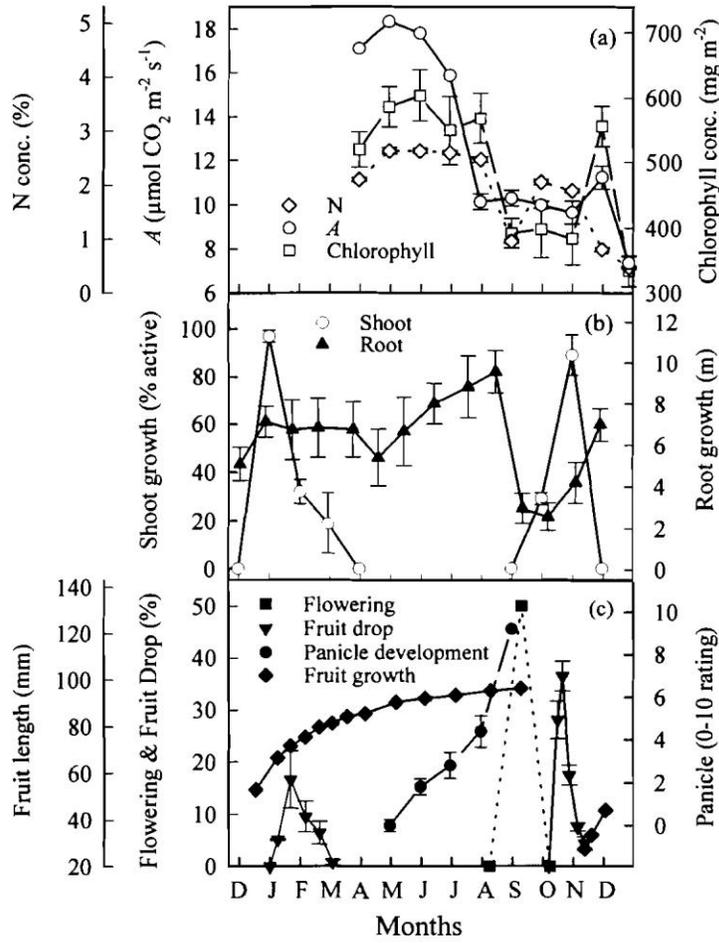


Figure 1. Pheno-physiological model for cv. Hass on cloned 'Velvick' rootstock growing at Maleny, S.E. Queensland where: (a) is the seasonal change in leaf nitrogen (N) and chlorophyll concentrations and CO<sub>2</sub> assimilation (A); (b) is the seasonal relationship between shoot and root growth; and (c) is the relationship between floral development and fruiting. Data points are mean values from five trees  $\pm$  vertical SE bars which are obscured by symbols at some points. Redrawn from Whiley (1994).