

CARBOHYDRATE AND OTHER STUDIES ON ALTERNATE BEARING FUERTE AND HASS AVOCADO TREES

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ABSTRACT

Studies were conducted during 1992 on avocado trees with a five year individual record of regular alternate (biennial) bearing. Photosynthesis measurements did not reflect significant differences in the "on" and "off" trees but very significant differences were found in the starch content of root, phloem, and xylem samples. Sugar values (sucrose, glucose and fructose) in the same material did not show significant differences between "on" and "off" trees but chlorophyll determinations revealed a shift in the chlorophyll a to b ratio. The "off" trees had a very much higher mean starch content than the "on" trees in May and July. It can be concluded that carbohydrates play a central role in alternate bearing and is a probable mechanism in perpetuating the cycle.

INTRODUCTION

Alternate bearing is one of the most serious problems in deciduous and evergreen trees (Monselise & Goldschmidt, 1982). It is somehow inherent to the nature of perennial plants (Couranjou, 1989).

Alternate or biennial bearing is characterised by the production of a heavy crop one year followed by little or no crop the next year. The main disadvantage is a few large fruit one year alternating with a mass of marbles (Jonkers, 1979; Gallasch, 1974). Furthermore the quality of the fruits in the "on" year can be unsatisfactory and the depletion of tree carbohydrate reserves as a consequence of the vigorous growth and fruit production in the "on" year can in some cases cause the collapse of trees (Monselise & Goldschmidt, 1982).

Accurate yield predictions are of value to the producer and the market but of greater importance is the production of fruit of consistently good quality. The initial trigger for the start of an alternating (biennial) cycle may be an external factor such as frost, lack of pollination and drought which may eliminate one year's crop (Jonkers, 1979; Lavee, 1989; Monselise & Goldschmidt, 1981; Monselise & Goldschmidt, 1982). Once this cycle has started it usually amplifies annually and is self-perpetuating.

Monselise & Goldschmidt (1982) felt two situations that may cause biennial bearing were:

a) An "off" year caused by a lack of flowers, lack of fruit set, or excessive flower or fruit

drop.

- b) An "on" year with a large amount of flowers and limited fruit drop and thus a large crop set.

Lavee (1989) suggested that the signal for low or high fruit set is probably hormonal, diffusing from the fruits and leaves and is a signal for, and a result of, the level of flower and bud differentiation and fruit set. Two probable mechanisms for the control of flowering and fruit set were referred to by Bower *et al.*, (1990), namely energy reserves and endogenous plant growth regulators.

Energy reserves

Flowering, fruit set and fruit growths utilize large amounts of carbohydrates. The following hypothesis was proposed: a carbohydrate deficit limits flowering, fruit set and fruit growth and thus is the cause of alternate bearing (Jones *et al.*, 1974; Garcia-Luis *et al.*, 1988).

Plant growth regulators

There is much evidence for the role that plant growth regulators play in controlling flowering. Jackson & Sweet (1972) stated that maturing fruit produce endogenous plant growth regulators and these change the hormonal balance and probably control flower initiation. Hoad (1984) suggested that a change in the endogenous hormone levels may be more important than differences in carbohydrate levels in the control of flowering. Ebert & Bangerth (1981), Garcia-Luis *et al.*, (1988) and Jonkers (1979) all stated that gibberellic acid produced in the seeds of fruit inhibits flower induction and this has led to the hypothesis that biennial bearing cultivars produce more gibberellins than regular bearing cultivars. It is however possible that plant hormones and reduced energy reserve factors combine to depress flower formation.

The above observations prompted the present research which has two aims.

1. To determine the role of carbohydrates, photosynthesis and chlorophyll in the control of flowering and fruit set.
2. To determine the recovery rates for "on" trees with depleted carbohydrate reserves after a heavy crop load and compare it with the "off" (E) trees that had a low yield resulting in a lower carbohydrate demand.

MATERIALS AND METHODS

Westfalia Estate provided the sample trees for which the individual annual fruit yield records were known. This data was recorded over a period of 5 years starting in 1987. The trees are graded A,B,C,D, and E according to yield with an A if the yield was heavy and E if the yield was low. Some of the trees showed a constant "on" and "off" bearing pattern (AEAEA and EAEAE) while a few were consistently good or poor bearers.

Hass and Fuerte trees with individual records were used in this study. Samples have

thus far been taken at three different stages during the growth cycle of these trees i.e. in May, July and November of 1992. These included carbohydrate samples of the roots, leaves, phloem and xylem and were taken in order to determine the differences in the carbohydrate levels of the "on" (A) trees and the "off" (E) trees. Starch and sugars were initially determined but as the study was more concerned with reserve non-structural carbohydrates only starch was determined in the later studies.

Photosynthesis measurements were taken with the Li-Cor IRGA. After the first set of photosynthesis measurements no correlation could be found between the A and E trees as the variation were extensive. The photosynthesis measurements were therefore discontinued. The chlorophyll content of leaves for A and E trees were however determined.

RESULTS AND DISCUSSION

The results clearly indicate that there were very significant differences in starch content between trees with a large crop (A) and trees with a small crop (E) at harvesting time. In Figs. 2a and 2b it is shown that the heavy fruit load depleted the carbohydrate reserves of the A trees in May, while the E trees had recovered as a result of low carbohydrate demand. The E trees which will probably be A trees the following season confirm the empirical starch curve data of Whiley & Wolstenholme (1990) (Fig. 1).

In Figs. 2a and 2b the mean starch content for the A and the E trees that were sampled is shown against time and it is clear that the E trees had a much higher mean starch content than the A trees during May. In the case of the E trees it was found that the small crop did not deplete the carbohydrate reserves of the trees and thus fruit would set for an "on" year. During July the A trees had recovered to the same level that the E trees were in May and increased still further in November. The E trees however, reached a maximum starch level in July and showed a sharp decline in the reserve carbohydrate content in November. The carbohydrate reserves were being used in fruit set and growth and the E trees would probably all be A trees in the forthcoming season.

The sugar levels, glucose, fructose and sucrose shown in Fig. 3 fluctuated greatly and no correlation could be found between sugar and yield for the E and A trees. This is due to the fact that sugars are not reserve carbohydrates but vary with photosynthesis rate and respiration.

From this study it could be concluded that drastically reduced levels of reserve carbohydrate limited fruit set. With respect to the recovery rate of the A trees it was apparent that at a critical stage insufficient carbohydrates were present to ensure a good fruit set. Carbohydrate levels therefore play a central role in alternate bearing and are probably responsible for perpetuating the cycle.

It is possible that gibberellic acid produced in excess by the endocarp of fruits in an "on" year could limit flowering and fruit set. This hormone gives rise to parthenocarpic fruit that abscises early. Endogenous plant growth regulators and specifically gibberellic acid levels will be investigated in 1993.

Photosynthesis activity is influenced significantly by the time, relative humidity, light intensity, temperature, wind, leaf position and age of the leaves. Because of this

variation further measurements have been discontinued.

In Fig. 4 leaf chlorophyll levels are shown and although no differences could be found in total chlorophyll concentration in the leaves of the A and E trees there was however an interesting phenomenon observed in May. The ratio of chlorophyll a (C_a) to chlorophyll b (C_b) of the A trees tended toward 1:1, while that of the E trees approximated 3:1. In normal plant growth the approximate ratio of $C_a:C_b$ is usually in the order of 3:1. In July however, the leaves of the A and the E trees all showed an approximate ratio of 3:1. A possible explanation for the elevated chlorophyll b content of the A trees in May is that the trees were in such a poor condition that only small amounts of new chlorophyll a were being produced. Chlorophyll a is the more unstable form and would decrease, while the more stable chlorophyll b would accumulate.

A factor which may possibly have accentuated the increase in C_b lies with the method of determining chlorophyll as the extraction procedure for chlorophyll used acetone and this dissolved primarily the older chlorophyll. Hexane will now also be used as a solvent as hexane dissolves more of the newly formed chlorophyll. The results of the two methods of determination will then be compared.

The knowledge gained in this study will be used to manipulate avocado tree production in such a way as to reduce the amplitude of the oscillating pattern of fruit yield in alternate bearing trees. It should also provide valuable information which may be applied to the study of the small fruit problem in Hass.

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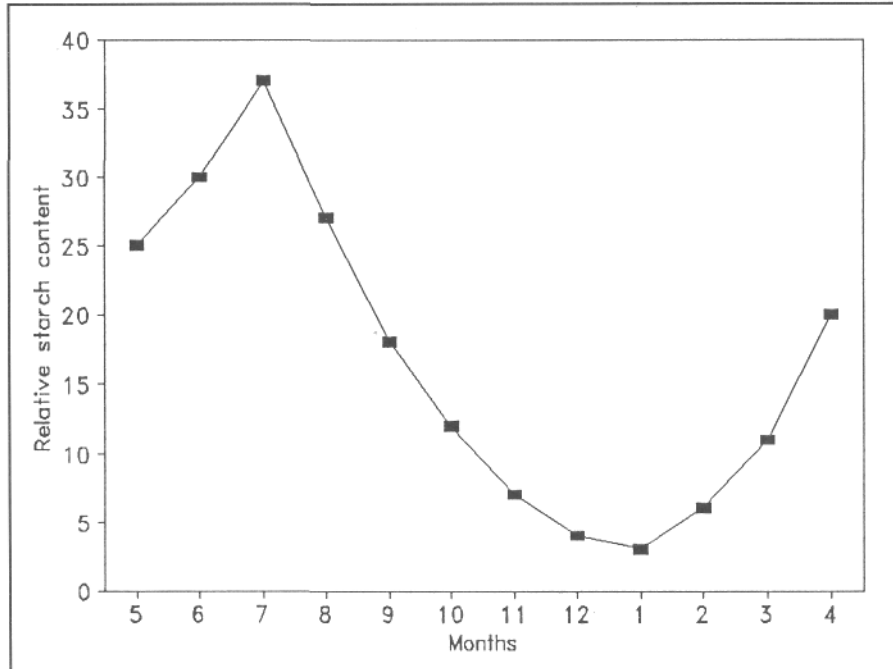


FIG. 1 The empirical starch curve of Whiley & Wolstenholme (1990),.

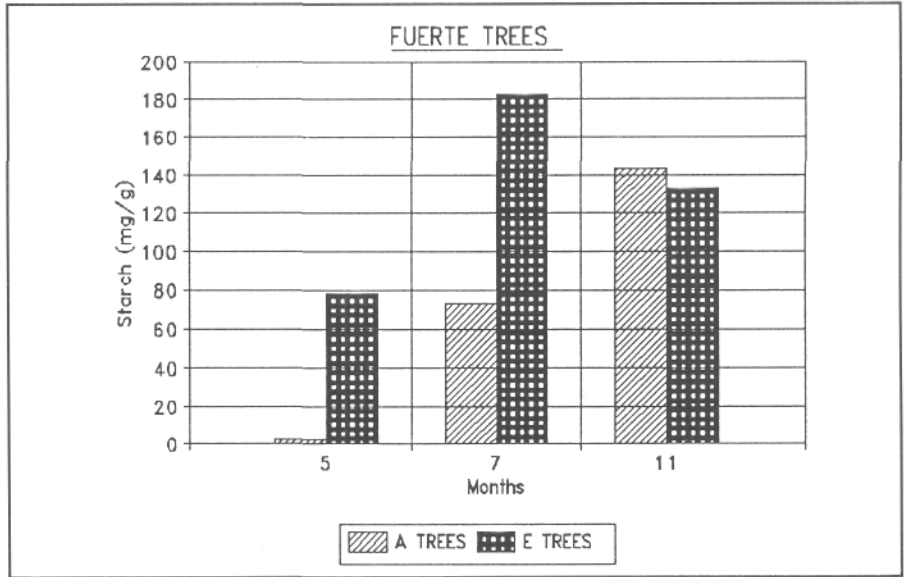


FIG. 2(a) Mean starch content of Fuerte avocado trees at various sampling time

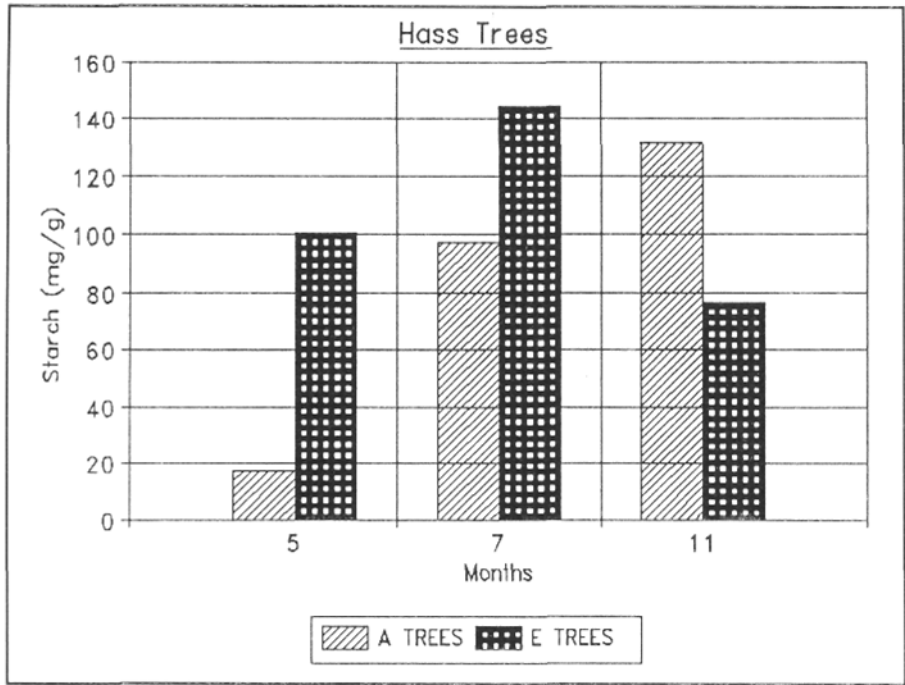


FIG. 2(b) Mean starch content of Hass avocado trees at various sampling times

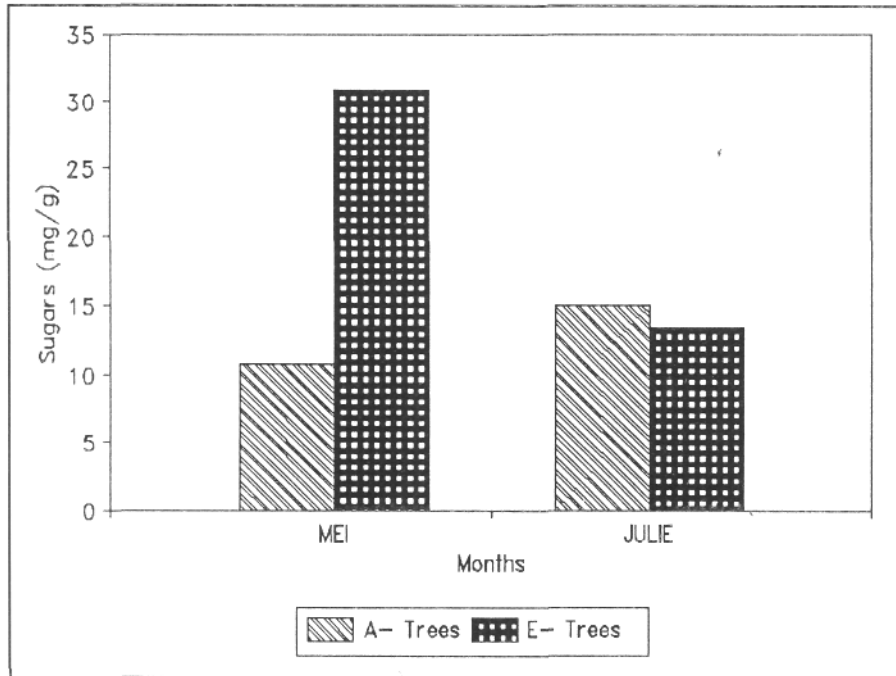


FIG. 3 Mean sugar levels (glucose, fructose and sucrose) in two avocado cultivars

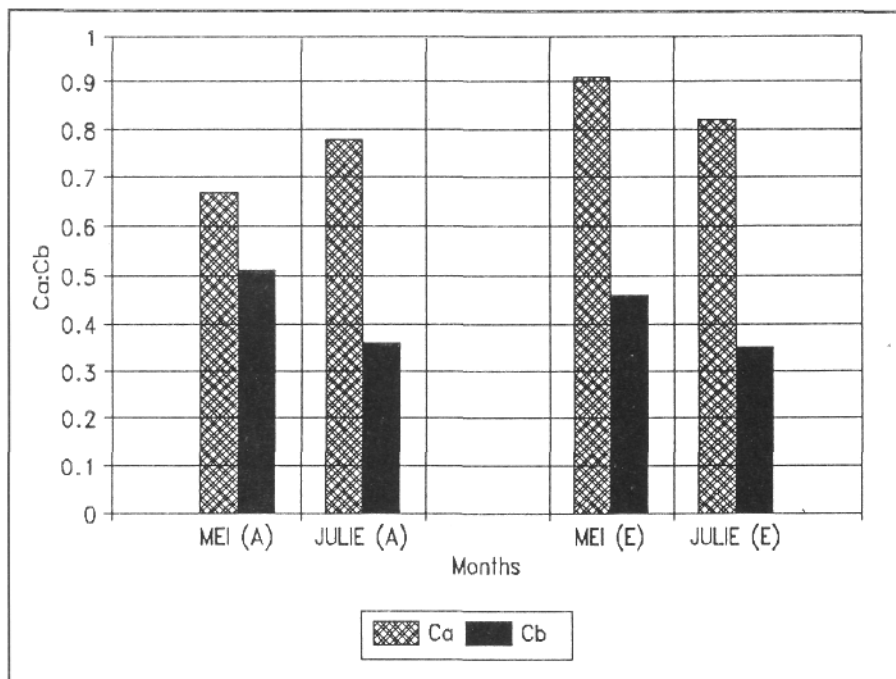


FIG. 4 Ratio of chlorophyll a to chlorophyll b of two different avocado cultivars during the growing season.

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