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Sink Demand for Starch Reserves in Avocado Trees

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ABSTRACT

Fruit and vegetative growth, along with the normal development of the permanent structures of the tree, require energy and carbon building blocks, The role of starch reserves in supplementing the daily photosynthate production is of vital importance. Low starch reserves at the beginning of a new reproductive season, facilitate an off-year which is often followed by a big yield with small fruit the following season. Although the starch reserve available in the plant is not the only factor determining on/off-years, it plays a major role in many plant processes. For the producer it is important to promote the build up of reserves and to avoid any unnecessary utilization of these reserves. For the purpose of this paper the carbohydrate demand and storage capacity of six-year-old Hass avocado trees will be dealt with for the period immediately after harvest of an off-year to immediately after harvest of the subsequent on-year. In addition, the effect of fruit load on the accumulation and utilization of starch under induced on and off-year situations will be discussed. The results illustrate that the bulk of tree carbohydrate reserves are found in the roots and wood. Fruit thinning seems to be necessary and it will be necessary to determine the optimum fruit load a tree can handle when taking into account the cultivar, locality, soil conditions, tree age and tree size.

Additional index words: carbohydrates, reserves, fruit thinning, Persea Americana.

INTRODUCTION

The energy required by the avocado tree at specific times to produce the necessary foliage for future photosynthate demand, and flowers to encourage optimal pollination as well as sustaining the growth and development of a satisfactory yield of quality fruit, exceeds the daily maximum photosynthesis rate of the tree. For this reason the build-up of carbohydrate reserves in the tree tissues during the interim periods are crucial to its productivity. The only way to increase the photosynthesis rate of the tree is to ensure that there are sufficient clean, healthy, insect free leaves exposed to the required light intensity and that condition such as sufficient water, temperature and humidity, very little wind and no pollution for the tree are optimal. A strong sink also promotes photosynthesis (Geiger, 1976). Some of these factors, we however, have little or no control over. If we cannot increase the photosynthesis rate significantly, then we must ensure the maximum build-up of reserves in the tree. In theory, thicker stems and branches as well as an extensive root system will provide more storage room for carbohydrates and this effect is sometimes evident in trees grown under dry land conditions. Although alternate bearing is influenced by environmental and endogenous factors (Monselise & Goldschmidt, 1982), the carbohydrate status of the plant must be optimal throughout the year before these factors can be investigated. In several cases, low carbohydrate levels actually influence these factors which cause alternate bearing. Various studies are at present underway to determine the build-up, canalisation and application of reserves. For the purpose of this paper, the carbohydrate demand and storage capacity, as well as the effect of fruit thinning on these carbohydrate reserves will be dealt with.

MATERIALSAND METHODS

The first trial was conducted at the ITSC in Nelspruit. Twelve six-year-old Hass avocado trees, at the beginning of an on-year cycle, were selected on the basis of tree volume and stem circumference. Three trees were totally excavated at four different times of the year. That is in July 1995, one month after harvest with bud and flower development, in October with young fruit development, together with root and spring flushes, in February at the start of rapid fruit development and in June 1996 at harvest. The trees were destructively sampled and divided into different plant parts i.e. roots, bark, wood, shoots, leaves (old and new) and fruit. Samples of the different plant parts were also taken from five trees with a good yield (on-year) and from five trees bearing little or no fruit (off-year). All the samples were dried and starch analyses were done according to a modified AOAC method. The concentrations as well as the absolute quantities of starch were determined so that calculations could be made with regard to the relative contribution of each separate part of the tree.

In a second trial, nine six-year-old Hass avocado trees in an on-year were selected. They were induced into on and off-year bearing cycles. In November 1995 all the fruit of three trees were removed, on three trees 50% of the fruit were thinned out by hand and three trees were left as controls. Samples of the different plant parts were taken at different physiological phases and were analysed for starch concentration.

RESULTS AND DISCUSSION

In figure 1 the total starch content for six-year-old Hass avocado trees is shown at four stages during the year. All the trees used in this trial had very low yields or no fruit at all in 1995 but had an average yield of 35kg per tree in 1996. From the graph, and as mentioned by Oliveira and Priestley (1988) and Whiley and Wolstenholme (1990), the greatest build-up of starch occurs in the roots, wood and to a lesser extent, in the shoots. These parts represent the largest sinks for carbohydrate reserves which are required during the fruit season. The fruit is a strong sink for carbohydrate and overshadows all other parts during their development until harvest. On average about 14kg of starch was built up within the plant between July and October when the trees were in full bloom. Eight kilogram was stored in the roots and 3,5kg in the wood. The total amount of 14kg declined sharply to 7,5kg starch remaining in February at the start of rapid fruit development. During this period a lot of energy is required for the October/November root flush as well as for the spring flush after the second fruit drop phase. Some of the carbohydrate is also transformed to energy for the active mitosis process which is taking place in the young developing fruit. At harvest only 8kg of starch is left in the plant.

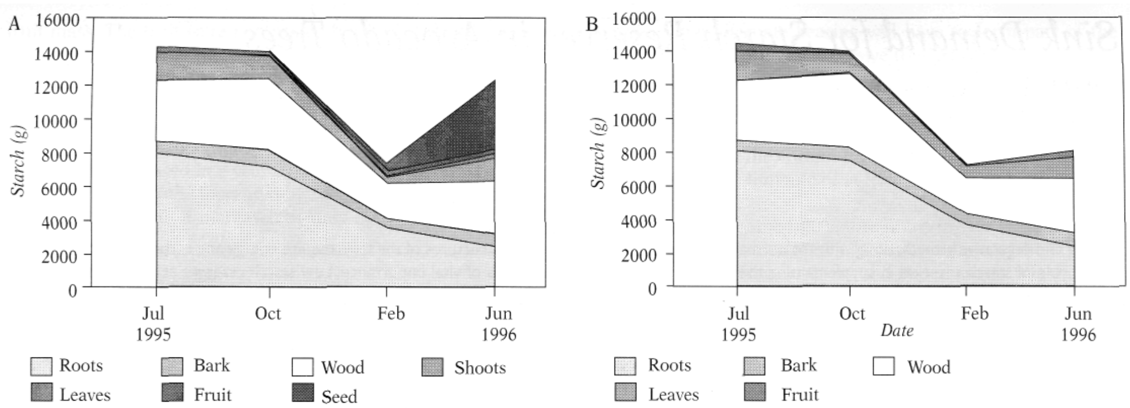

Figure 1
Total starch accumulation and utilization for six-year-old Hass avocado trees.
(A) - with fruit contribution and (B) – without showing fruit contribution

In figure 2A the total amount of starch in trees in an on-year with an average yield of 72kg fruit per tree is shown. The amount of oil present in the fruit at harvest is converted to the amount of starch needed to produce the oil in order to show the actual energy requirement. All these trees were also in an off-year at harvest in 1995. From the graph about 12,5kg of starch is built up at the beginning of the new reproductive phase. It further increases to 14kg in October 1995 in spite of the flower bud and flower development during this period. A sharp drop in the total starch content follows, leaving the plant with 8kg of starch at the beginning of February 1996.

After February, the total starch content of the tree (excluding the fruit) drops further to only 6kg in June 1996. Ten kilogram of the 16kg starch is found in the fruit. These trees produced an average of 72kg fruit per tree in 1996 and only 6kg starch was left at the beginning of the new reproductive phase. As all these trees are in an off-year cycle in 1997, the 6kg starch reserves were not enough for initiating satisfactory yields for the following harvest season. Monselise and Goldschmidt (1982) stated that heavy crops produced during the on-year, is the most universally recognised cause of alternation and that starch levels in an off-year are much higher than in an on-year. This is also demonstrated by the total starch content for five trees in an off-year (figure 2B). In this case, all the trees produced an average of 54kg fruit per tree at harvest in 1995 and started with an average of 6kg starch reserves at the beginning of the new reproductive season. Rapid starch accumulation occurs in all plant parts of the tree except the leaves and it increased from 6kg starch per tree to 14kg starch in October 1995. Although the amount of starch for on and off-year trees were exactly the same for October (figures 2A and 2B), little or no fruit set and fruit development had occurred in the off-year trees.

This confirms what was found by Davie and van der Walt (1994) that the time when the plant determines whether it will move into an on or off-year season, is long before the fruit development stage in October. It may be just before or just after harvest. What is of great importance is the fact that after February there is an accumulation of starch reserves in almost all the plant parts and at harvest in 1996 about 11kg starch reserves were available for the next reproductive season. All these trees are in an on-year in 1997 with average fruit counts of 400 fruit per tree.

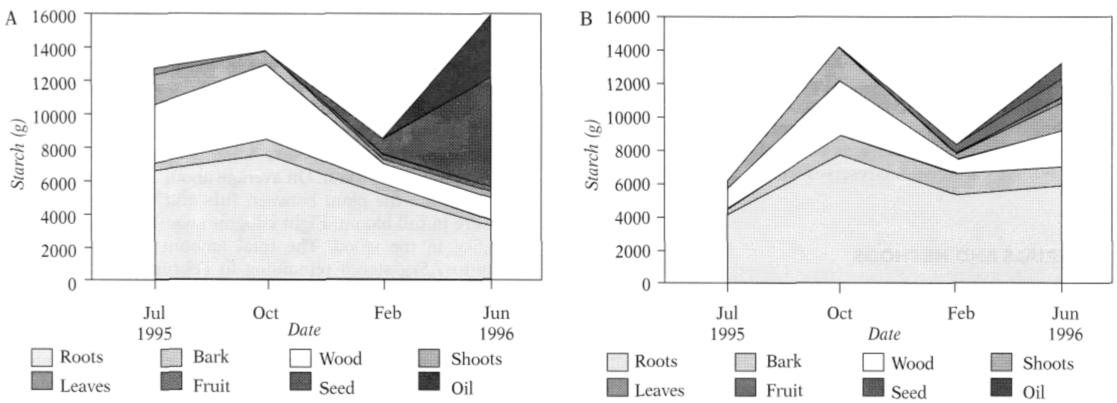

Figure 2
Total starch (carbohydrate) accumulation and utilization for six-year-old Hass avocado trees in (A) an on year and (B) in an off year

As 65% of the starches (figure 3) of plants in an on-year are finally channelled to the fruit, fruit thinning may be the answer for starch conservation. The aim is to have trees in an orchard regularly bearing an optimum number of quality fruit. In figures 4A and 4B the on and off-year cycle is also quite clearly demonstrated in the starch concentration of the roots and wood respectively. Where no fruit is removed from the tree, the starch concentration in the wood (figure 4B) drops from 125mg/g dry matter (DM) in November 1995 to 8mg/g DM in February 1996. After harvest the trees were in an off year and the concentration increased to 150mg/g DM and then stayed high with 110mg/g DM in February 1997. Where all the fruit were removed from the trees in November 1995, the starch concentration dropped from 120mg/g DM starch to 60mg/g DM and this was much higher in contrast with trees where no fruit were removed (8mg/g DM). The starch concentration of the trees where all fruit were removed increased from 60mg/g DM starch in February 1996 to 135mg/g DM in August. The trees are however in an on-year with a heavy fruit load for 1997 and the starch concentration dropped sharply from August 1996 to February 1997 (to 9mg/g DM). Here again the trees with low yields have a much higher starch concentration of 130mg/g DM in contrast with the 9mg/g DM for trees with high yields. Trees where only 50% of the fruit were removed in November 1995 were again in an on-year after harvest in 1996. Although they yielded about 100 fruit per tree the following season, the starch concentrations in the wood of these trees were still high (79mg/g DM). The same on/off-year situation was found in the starch concentration of the roots of the trees (figure 4A).

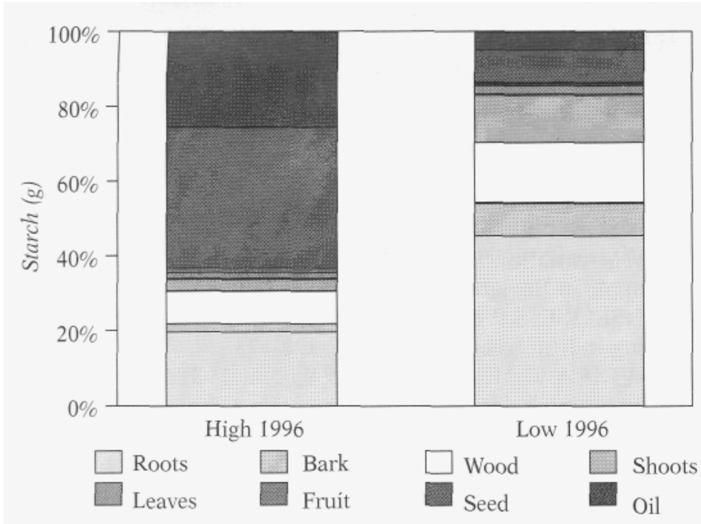

Figure 3
Distribution of starch in high and low yielding trees at harvest (1996)

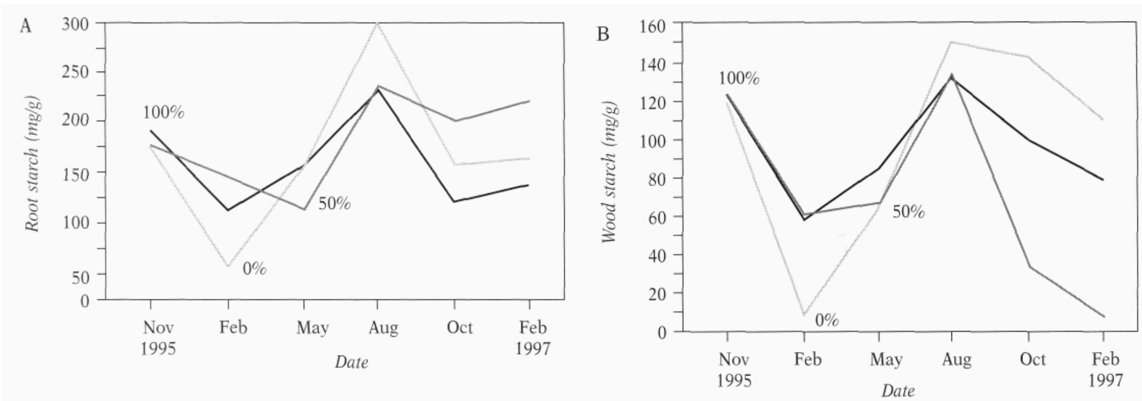

Figure 4
Effect of fruit thinning (Nov. 1995) on root (A) and wood (B) starch concentrations for six-year-old Hass avocado trees

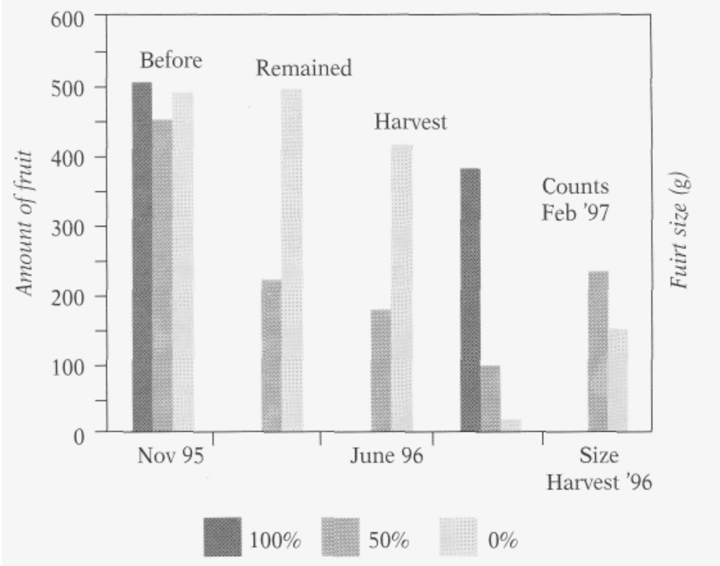

Figure 5
Fruit counts for six-year-old Hass avocado trees before and after fruit thinning, at harvest 1996 and fruit counts for February 1997. Fruit size at harvest 1996 is shown in the last column

In figure 5 the total fruit counts at harvest during 1996 were what was expected but the average fruit size of fruit from trees where no fruit were removed in November 1995 was much smaller (155g) than trees where 50% of the fruit were removed (240g). The fruit counts for 1997 are very important. Trees where no fruit were removed in November 1995, had a big yield at harvest in 1996 but had little or no fruit in February 1997. Where 50% fruit were removed, the trees were again in an on-year although we expected a better yield due to the good rains during the 1996 season. The trees where all the fruit were removed in November 1995 had no fruit at harvest 1996 but are again in an on-year with an average of 370 fruit per tree when counted in February 1997. For this reason there must be an optimum percentage for fruit thinning between 0% and 100% to ensure trees providing regular yields of quality fruit of the correct size. As it is stated, by Jackson and Hamer (1980), the human ability to regulate cropping by fruit thinning, pruning, breeding, pest control, hormonal treatments and better control of environment can minimize the effects of environmental triggers of alternation. Starch reserves must therefore be managed optimally by all these factors to ensure good yields year after year.

CONCLUSIONS

- The bulk of tree carbohydrate reserves are found in the roots and the wood.
- Fruit loads of the current year have a great effect on the carbohydrate reserves for the following year.
- Low carbohydrates at harvest are correlated with the subsequent off-year which in

turn results in an on-year with small fruit the following season.

• Further research is necessary to establish the most efficient method of fruit thinning (hand thinning or pruning) and to determine the optimum fruit load a tree can handle.

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