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Prospects for vegetative-reproductive growth manipulation in avocado trees

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ABSTRACT

Vegetative-reproductive competition at critical periods, especially during fruit set, needs to be under grower control to maximise fruit yield and quality. This paper discusses how N nutrition and chemical manipulation in particular can be used to achieve these goals. In the longer term, the prospects for new semi-dwarfed cultivars are evaluated.

UITTREKSEL

Kompetisie tussen vegetatiewe en reproduktiewe groei, veral gedurende die kritiese vrugset periode, moet onder die kweker se beheer wees om vrugopbrengs en kwaliteit te verhoog. Hierdie referaat bespreek veral die rol van stikstof en chemiese groei-reguleerders. Vir die langtermyn, is die vooruitsigte vir semi-gedwergde kultivars en onderstokke bespreek.

INTRODUCTION

Vegetative growth of a tree crop consists of various components, which for the purposes of this paper consist of the leaves and young (green) shoots (capable of photosynthesis); the aerial structural framework of branches and trunk; and the below-ground root system. Green, chlorophyll-containing tissues, primarily leaves, constitute the photosynthetic "factory" of the tree upon which all other growth depends. Surplus carbohydrate energy not immediately required, is stored in various plant parts, usually mainly in the trunk and larger branches, but also in the roots in crops such as the pecan, tea and apple. The main storage reserves are typically in the form of starch.

Reproductive growth consist of flowers and fruits, and in avocado the fruits are of course the economic end product. The commercial grower is in the first instance interested in maximising the mass of fruit harvested per unit area, usually per hectare. Thus yield per ha is of vital importance, especially **average** yield over a period of years. However, economic factors are also crucial in the current inflationary climate. Hence the grower needs to maximise **net return** per ha, which implies that maximisation of yield must reflect economic constraints. This must furthermore be done without jeopardising fruit quality, especially when markets are thousands of km distant.

VEGETATIVE-REPRODUCTIVE COMPETITION

Vegetative and reproductive growths compete for the photosynthetic products of the leaf factory. A certain, moderate amount of leaf growth is naturally essential. Excessive growth of leaves and woody, structural tissues is however wasteful of scarce resources of energy, proteins, minerals, water, etc. Most of the yield improvement in modern annual crops has in fact been achieved by changing the allocation of photosynthate and other resources away from woody towards fruits and seeds (Loomis, 1983; Patrick, 1988).

Tree crops differ from annuals in that they are usually relatively poorly selected, especially for yield. Their evolutionary background also imposes constraints, and this certainly applies to the avocado with its high-altitude tropical rainforest origin (Wolstenholme, 1985; 1988). Breeding and selection have already achieved much in reducing vegetative dominance in avocado, but only represent a modest start.

Source — sink competition

In plant physiology, "sources" are net contributors or exporters of photo-assimilate and are therefore green leaves (overwhelmingly), green shoots and green fruits (Blanke & Lenz, 1989). "Sinks" are net importers of resources, produced by the sources and constitute in particular actively growing tissues. Sink strength is the term applied to a sink's ability to attract metabolites from sources, in competition with the other sinks, and varies with the organ involved, and with time (eg Hale & Weaver, 1962).

In general, fruiting has a strong effect on assimilate partitioning and tends to antagonise vegetative and especially root growth. The order of priority among sinks is usually: seeds > fleshy fruit parts = shoot apices and leaves > cambium > roots > storage (Cannell, 1985). In practice, assimilate demand by each tree component depends on its current metabolic rate (sink activity) and size, and is mediated by plant hormones (Landsberg, 1988). Oil-strong fruits such as avocado (Wolstenholme, 1985) and macadamia nut (Stephenson *et al*, 1989) make heavy demands on carbohydrate energy sources.

Timing of competition

The phonological growth cycle model in avocado (Whiley *et al,* 1988) provides a general visual representation of the constantly changing competition between sources and sinks in a bearing tree. Tree crops have evolved various ways or growth strategies to minimise direct competition. Vegetative growth and reproductive growth are partially separated both in time (flushing) and spatially (Browning, 1985). Nevertheless there are certain critical phases where competition is fierce, and where "make or break" situations arise. In avocado, these are during early fruit set (August to November, depending on the area), and to a lesser extent in midsummer.

The critical fruit set and second flush periods

In avocado, the flowering panicle, although superficially appearing to be terminally situated, is actually sub-terminal, i.e. is subtended by a vegetative bud capable of growing out. If the tree is excessively vigorous, this indeterminate shoot is likely to compete vigorously with setting fruits, resulting in heavy fruit drop. It also reduces the movement of calcium into fruitlets during the critical first six to eight weeks (Witney *et al,* 1986; Cutting & Bower, 1989a), thereby pre-disposing the fruits to physiological disorders (Bower & Cutting, 1988). Vegetative-reproductive competition at this time is therefore a key determinant of yield (especially in vigorous cultivars such as Fuerte and Sharwil) and of fruit quality.

During seasons of heavy fruit set, avocado trees have a last opportunity to adjust crop load during the second shoot flush in mid-summer (mid-December to early February, depending on climate). Stressful conditions at this time have led to losses of over 400 fruits per tree which had attained 10 to 40% of their final mass (Wolstenholme *et al,* 1990).

MANIPULATION OF THE VEGETATIVE-REPRODUCTIVE BALANCE

According to Browning (1985) the most fundamental step the horticulturist can take to improve fruit set in tree crops is to reduce vegetative vigour. This applies to deciduous fruits (Williams, 1988) but even more so to large sub-terminally and terminally fruiting trees like the avocado. As stated by Forshey & Elfving (1989) the ultimate objective of all pomological practices is really the manipulation of the vegetative growth-fruiting relationship. Efficient management aims to maximise fruit production concurrent with minimising unproductive wood growth. Simply put, we are in the business of fruit production rather than timber production. What can we do to manage avocado trees?

Managed N Nutrition

Nitrogen, of all the essential elements, is the key manipulator. Too much N encourages too much vegetative growth at the wrong time, and thereby can reduce yield as well as fruit quality. Management of the N status of the tree is one of the most powerful tools at the grower's disposal. The general experience in the warm subtropical summer-rainfall climates of South Africa and Australia is that we must deemphasise N. This is more so in good, deep, organic matter — rich soils where mineralisation can release large amounts of "free" N each season. By keeping N under control, we will have smaller, less woody, more fruitful trees with higher fruit Ca content.

However, there is no easy formula, and the grower needs to be both knowledgeable, and have the ability to "read" the trees for crop load, and to relate this to leaf analysis and to the season. Fuerte and Sharwil are much thicker cultivars to handle than Hass, Ryan or Pinkerton. They are potentially very vigorous cultivars (if *Phytophthora* is not a problem) which can easily get out of control. In other words, their vegetative-reproductive balance is more critical and more on a knife edge. This is especially true in climates not conducive to good fruit set, i.e. in cooler areas for these "B-flowering type" cultivars. If temperatures are too cool at fruit set, we can end up with a subsequent growth explosion, consequent on low fruit set.

Leaf N levels

Leaf analysis gives the grower an estimate of the N status of his orchard every year. In South Africa, leaf samples are normally taken from March onwards from predominantly spring-flush leaves of non-fruiting shoots although this is not specified (Langenegger & Koen, 1979). We believe that a strong summer flush will complicate leaf selection, ideally, leaves should be tagged in spring to ensure selection of the right leaves for analysis. We also believe that since N is such a key element, there is scope for more research on standardising for leaf type and age (fruiting vs non-fruiting; spring vs summer flush), and cultivar.

In Queensland, leaf analysis is for mature leaves of the **summer** flush, sampled in May (Piccone & Whiley, 1986). Research has shown that this provides for the period when the N flux in the leaves is lowest, i.e. most stable. The summer period is too variable for reliable leave analysis, and the period of flower panicle development is too late.

Experience in California, South Africa and Australia supports the contention that leaf N in Fuerte must not exceed 2% in bearing trees sampled in autumn. This applies particularly in the warm, moist subtropics with deep soils high in organic matter. The ideal for such vigorous cultivars is probably 1,6 — 1,8% in bearing trees. Trees with lower levels must naturally receive more N fertiliser.

Hass needs higher leaf N for high productivity. Optimum leaf levels in South Africa have been given as 1,9 — 2,2% (Partridge, 1989). In S.E. Queensland, leaf levels as high as 2,5 — 2,7% in Hass and Wurtz have not reduced yield, and in fact are needed to maintain the correct leaf: fruit ratio as trees lose vigour due to heavy cropping. These cultivars have a different growth habit, and do not easily over-respond to N.

Timing of N fertilisation

With respect to timing, it would seem to make sense to direct N fertilisation (if required) at the **summer** growth flush rather than the spring growth flush. Timing of N fertilisation in this way will allow for a better summer flush which is less likely to throw fruits off the tree, as long as irrigation is properly managed to reduce stress at this time. The new leaves formed in January will be younger, photosynthetically more efficient, and better able to support the high **energy** demands of the rapidly growing fruits at this time. This should help to reduce "carbohydrate stress" in autumn, which is often accompanied by severe manifestations of *Phytophthora* root rot. Lastly, it has been shown that *Phytophthora* infection of roots reduces the N content (and that of several other elements) in avocado leaves (Whiley *et al,* 1987). Excessive N levels are therefore more likely to be a problem in trees free of or recovering from root rot.

Physical Manipulation

Physical manipulation can take the form of bending, tying, training, girdling or scoring.

Branch orientation training, and more specifically the bending of branches away from the vertical, has been widely used in deciduous fruit trees to decrease shoot vigour and increase flowering, fruiting and yield (Forshey & Elfving, 1989). Exploratory trials at Westfalia Estate, Duivelskloof (S. Köhne, pers comm) were not successful, as excessive axillary bud growth was stimulated, making the trees more vegetative.

Girdling, cincturing or scoring are ancient horticultural techniques to help regulate vegetative growth and productivity in deciduous trees such as apples (Greene & Lord, 1983). Girdling in avocados is controversial, but has been reported to increase yield in Israel (Lahav *et al,* 1971) and Australia (Trochoulias & O'Neill, 1976). There is certainly scope to examine this practice locally, but only on excessively vigorous cultivars or trees which are free of *Phytophthora.*

Pruning

This technique is also widely used in deciduous fruit trees to regulate the vegetative-reproductive balance.

Shoot pruning is done to selectively invigorate remaining shoots in over-cropping trees, and therefore reduces fruiting by shifting resources towards vegetative growth. It is therefore, in the classical sense, not a technique to apply to overly vigorous avocado trees, eg when crowding starts in densely spaced orchards, unless measures are taken to cope with the consequent explosion of growth and loss of fruiting. There may nevertheless be scope for research on special pruning techniques aimed at reducing tree vigour and stimulating complexity (G Jacobs & J G M Cutting, pers comm).

Root pruning, on the other hand, has been used to dwarf fruit trees. Geisler & Ferree (1984) reviewed responses in apple trees. We are aware of no research in avocado trees, and are hesitant to recommend this practice due to the over-riding importance of *Phytophthora* root rot.

Shoot tipping was shown by Biran (1979) in Israel to temporarily reduce growth of strongly competitive spring shoots arising from indeterminate avocado flower panicles, with beneficial effects on yield. This work has been continued locally by Cutting & Bower (1989), and may be practical on young trees starting bearing. However, results to date have not been conclusive, possibly because the whole new shoot has been broken out. We believe that **tipping** the spring flush shoot after three or four new leaves have formed would give a much better response.

Chemical manipulation

Chemical growth retardants, especially triazole compounds, can dramatically reduce shoot growth. In avocado, most research has been conducted on paclobutrazol (Cultar®) (Köhne & Kremer-Köhne, 1987; Köhne, 1988; Symons *et al,* 1988; Wolstenholme *et al*, 1990; Adato, pers comm). In discussing prospects we need to distinguish between foliar sprays and soil drenches, which have different objectives.

Foliar sprays

The objective here is quite simply to apply a chemical growth check to excessively vigorous spring (or summer) growth flushes, to temporarily increase the sink strength of fruitlets / fruits and thereby increase yield.

Increased yields from treated branches have been reported (Köhne & Kremer-Köhne, 1987). There are reports from Adato's work in Israel that relatively high concentrations of up to 3,2% Cultar® increased yields of low-bearing Fuerte. Wolstenholme *et al* (1990) significantly increased initial fruit set in vigorous Fuerte and Hass in Queensland at concentrations of 2 500 and 5 000 mgℓ^{-1} paclobutrazol, but in the first season this was negated by heavy summer fruit drop. In a continuation of this work, Whiley *et al* (unpublished data) have found that over a period of two years, concentrations down to as low as 625 mgℓ^{-1} statistically increased yields. Work in Natal appears to have been less successful in increasing yield, but these trees were less vigorous. A complication of this type of research is tree-to-tree variability, which could possibly only be overcome by having at least ten trees per replication, and a minimum of two years' data.

A welcome additional benefit arising from the Queensland research has been a definite increase in average fruit size in Hass, due presumably to altered assimilate partitioning to fruitlets. However, higher concentrations than 625 mgℓ^{-1}, eg 1 250 and 2 500 mgℓ^{-1} seem to be necessary for this — i.e. we need a more dramatic growth check to bring about the required assimilate re-distribution (Whiley, *et al,* unpublished data).

Whiley has also noted that a 1 250 mgℓ^{-1} foliar paclobutrazol spray applied at 50% flower opening significantly increased fruit Ca content in the first eight weeks in both Fuerte and Hass in Queensland and South Africa. Cutting & Bower (1986b) have produced evidence that avocado flowers and fruitlets are poor exporters of the auxin IAA, in comparison with the associated growing vegetative shoots, and that correspondingly the rapidly-transpiring shoots import more Ca. The postulated interrelationship between IAA export and Ca import (Banuelos *et al,* 1987) in tomatoes may therefore also hold for avocado. Again, reduction of spring flush vigour will benefit Ca allocation into fruits.

Soil drench applications of paclobutrazol have a different objective, viz to control overall tree size in young, vigorously growing trees in high density orchards. In this way the first tree removal (tree thinning) may be delayed by a year or more. We have not researched this application, which is registered in South Africa. We believe however that it must be used carefully, and only if all other management limiting factors have been eliminated. It would be absolutely pointless, for eg to use paclobutrazol in non-vigorous orchards, including those with a *Phytophthora* problem. Why attempt, at some expense, to control vigour when there is little vigour to be controlled?

Our experience on older trees which have been heavily pruned or staghorned to reduce orchard crowding is that soil applications of paclobutrazol are likely to be uneconomic. Certainly this is so in the mild, mesic environments and on the high organic matter rainforest soils of SE Queensland. Here even ridiculously high dosages failed to "hold" the inherent vigorous regrowth after pruning.

Paclobutrazol use — proceed with caution

At this stage of research we advise growers to proceed with caution when considering using either foliar or soil applications of paclobutrazol. This chemical is not a panacea and will certainly not substitute for below-par orchard management. Objectives must be kept firmly in mind, and these differ for foliar applications (yield increase; larger fruit size in small-fruited cultivars: higher fruit Ca content) and soil drenches (overall reduced tree vigour: high density plantings). Lastly, paclobutrazol must not be used unless there is a problem with **vigorous,** healthy trees, with well managed N levels.

Paclobutrazol does have a role to play, but it takes knowledge and ability to use it successfully. Perhaps only 5 to 10% of growers have this level of expertise. In the final analysis, economics will dictate. With a relatively expensive chemical, benefits must be pronounced to justify use.

Rootstocks

There is a conception that dwarfing rootstocks are the ultimate tool in controlling tree vigour, and Mexican selections (Sanchez Colin & Barrientos-Priego, 1987) have recently been imported. While such research is necessary, we again wish to urge caution. Even with deciduous fruit trees in the W Cape, the vegetative-reproductive balance is controlled more by training and pruning than by dwarfing rootstocks.

Certainly there is increasing evidence that very vigorous avocado rootstocks such as Martin Grande (the G 775 series) may reduce precocity and result in excessively large trees. This rootstock was selected for favourable pathological attributes (tolerance to *Phytophthora),* and was unfortunately not adequately tested for horticultural attributes. However, the moderately vigorous Duke rootstock is producing reasonably vigorous and precocious trees, which have been successfully adapted to many situations if correctly managed.

The point at issue is to what extent the avocado tree has to grow in order to develop sufficient photosynthetically efficient foliage (Whiley, 1990) to cope with an energetically expensive and heavy crop load. A truly dwarfing rootstock (eg producing trees one-quarter to one-third of "standard" size) may not allow regular and efficient fruiting, and would furthermore put considerable strain on the cost of establishment. Many growers baulk at planting 200 to 400 trees per ha, let alone double this number. Perhaps a semi-standard tree size (75% of standard) or semi-dwarfing (50% of standard) will prove to be viable. This, of course would have to be combined with *Phytophthora* tolerance — a tall order unless genetic engineering techniques are used.

Precocious, semi-dwarf scion cultivars

Breeding and selection programmes for highly precocious and fruitful scion cultivars are of high priority for avocado. The first-generation standard of excellence was the vigorous but often unfruitful Fuerte. This is now being replaced by the second-generation Hass, less vigorous and a more reliable bearer. There have been several contenders for the third generation cultivar, more precocious and semi-dwarfed and hopefully higher-yielding than Hass. But will Pinkerton or Gwen make the grade, especially in the warm moist subtropics? There is a long way to go before we have trees with the production efficiency of a modern apple cultivar. Such cultivars will also have to meet stringent quality criteria.

CONCLUSIONS

In this paper we have attempted to update the state of our knowledge on a key aspect of avocado orchard management in healthy orchards, viz the control of vegetative vigour at certain critical periods. We conclude that research has given us many pointers which can be intelligently applied in the orchard situation. However, we emphasise that there is still much to be done, and call for your continued support of research efforts.

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