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Chemical manipulation as part of a management programme for improved fruit yield and quality in avocado orchards

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ABSTRACT

Chemical manipulation of avocado trees was recently incorporated into the avocado manipulation programme at the ITSC. The current paper examines the effects of three growth inhibitors on fruit yield and size. The work shows that applications to the spring flush have a better effect on yield than applications to the flowers. The trial also indicates that Cycocel provides better yields and fruit size than Sunny and Cultar. This chemical thus shows promise as an economical growth inhibitor in avocados.

The current paper also examines the role of calcium sprays in improving fruit quality. It was shown that calcium sprays can reduce the incidence of both grey pulp and vascular browning in cold stored avocado fruit.

Furthermore, the role of two synthetic auxins in fruit development was examined. It was shown that NAA applied at flowering has a fruit thinning effect, while 2,4-D increases fruit retention and provides better yields relative to control trees.

INTRODUCTION

Many of the problems currently facing the South African avocado industry can be addressed by means of an efficient orchard management programme. Such a programme includes correct planting distances, appropriate fertilisation and irrigation practices and physical manipulation of the trees in the orchard amongst others (Stassen and Davie, 1996a; Stassen and Davie, 1996b; Stassen *et al*., 1997). All of the above have been researched at the ITSC for a number of years. Recently, chemical manipulation was added to this programme and this topic will be the focus of the current paper.

The chemical manipulation programme is presently addressing the problems of orchard encroachment, poor fruit set and retention, small fruit size and inferior post-harvest quality all of which have been listed as critical areas of research by SAAGA in the last two seasons. In order to facilitate this discussion, the chemicals used in these trials have been divided into three broad categories as follows:

- Growth inhibitors

- Calcium-containing products
- Auxins

While this paper will deal exclusively with the chemical manipulation programme, it must constantly be remembered that these products are always used in conjunction with other management practices and form a small part of a holistic management programme.

GROWTH INHIBITORS

The avocado (*Persea Americana* Mill.) is a sub-story rainforest species (Whiley and Schaffer, 1994) and, as is typical for such trees, is capable of extremely rapid vegetative growth. It is this rapid growth which leads to many of the problems experienced in the avocado industry.

The first problem arising from this prolific growth is orchard encroachment. In areas with high potential soils, trees planted at standard densities fill their allotted space in the orchard within 5 years (Köhne, 1988). This makes it difficult to harvest and carry out other orchard operations, resulting in increased labour costs. Considerable research has been carried out by the ITSC in recent years in order to control encroachment and tree vigour by means of pruning (Stassen *et al,* 1995; Snijder and Stassen, 1997). The techniques developed by these authors have achieved good control of tree growth and are currently being widely applied in the avocado industry. However, while pruning removes unwanted growth and helps to shape trees, it also stimulates regrowth. It is vital that this regrowth be controlled. This is where growth inhibitors can play an important role. By inhibiting gibberelin synthesis, and thus reducing shoot length (Sachs and Hackett, 1972), these compounds can lead to an overall reduction in vegetative growth. They also have other effects, such as increased flowering and fruit yield. These effects were summarised by Renter & Stassen (1997).

The second group of problems arising from excessive growth in the avocado tree involves the effects on fruit yield. The vegetative growth in avocados occurs as a series of flushes, the first of which takes place shortly after fruit set. This flush is a strong sink for water, minerals and photoassimilates and only loses its sink strength after about 40 days of growth (Whiley and Schaffer, 1994). During this period, the developing fruit is deprived of nutrients and a large drop of newly set fruit often occurs. A second vegetative flush in the summer has a similar effect, with up to 60% of the remaining fruit dropping (Wolstenholme *et al*., 1990). This competition between vegetative and fruit growth may also contribute to the problem of small fruit size in certain cultivars. Furthermore, it is not inconceivable that this competition deprives the developing fruit of certain minerals which are required for proper cell development. One consequence of poor cellular development is that fruit will exhibit substandard post-harvest quality particularly under conditions of cold storage. The second area in which growth inhibitors can be of benefit is that of fruit growth and development. By reducing vegetative growth, these compounds reduce the sink strength of the flushes and thus decrease competition between vegetative and reproductive growth. This should lead to improved fruit set and retention, as well as increases in fruit size.

The aim of this trial was to examine the effects of three growth inhibitors on vegetative and fruit growth in Hass avocados. Two of these compounds (Sunny and Cultar) are currently registered for use in avocados, while the third (Cycocel) is widely used in the deciduous industry. Cultar and Sunny have received considerable attention in the avocado industry, and the trials carried out with these chemicals indicate that growth inhibitors have a definite role to play in improving crop yields. Cycocel was introduced into the trial because of its success in the deciduous industry, and because its extensive market in this industry makes it an economic alternative to the growth inhibitors currently used in the tropical crops. A comparison of the costs of these growth inhibitors was made by Renter and Stassen (1997).

Methods and Materials

The trial was conducted at Koeltehof farm in a six year old Hass orchard planted at 6m x 6m. Each treatment was carried out on 36 trees divided into blocks of six trees. The blocks were randomly situated in the orchard and separated by guard rows. The treatments and timing of applications are as follows:

1.	Sunny	1%	full late flower
2.	Sunny	1%	spring flush
3.	Cultar	0.4%	full late flower
4.	Cultar	0.4%	spring flush
5.	Cycocel	2000 ppm	spring flush
6.	UP-50	2%	full late flower
7.	Control		

In all treatments, Nu-Film was used as a wetter and trees were sprayed to run-off.

In order to quantify the effect on vegetative growth, flush lengths and tree drip areas were measured before and after the spring flush. Fruit set was established at the time of the spring flush. At fruit maturity, tree yields were established by means of total fruit counts as well as total weight per tree. Fruit weight distributions were measured by selecting six trees per treatment and weighing the individual fruits on those trees.

Results and Discussion

All data regarding fruit set and the effect on vegetative growth was published in the 1997 SAAGA yearbook (Renter and Stassen, 1997). The current discussion will deal with the effect of growth inhibitors on fruit size and tree yields. The yield data for the current trial indicates several important trends. The first of these is the effect of the growth inhibitors on tree yields. As shown in Figure 1, none of the treatments gave a significantly higher yield than the controls, although Cultar applied to the spring flush gave slightly larger yield. However, Sunny applied at flowering reduced the yield significantly and when applied to the spring flush also gave a lower yield. This was unexpected as it is inconsistent with data supplied by the manufacturer of Sunny. The drop in yield can probably be explained by the fact that the Sunny in this trial was applied without the recommended adjuvant (UP-50). This hypothesis is supported by the fact that UP-50 alone improves fruit set (Fig. 1).

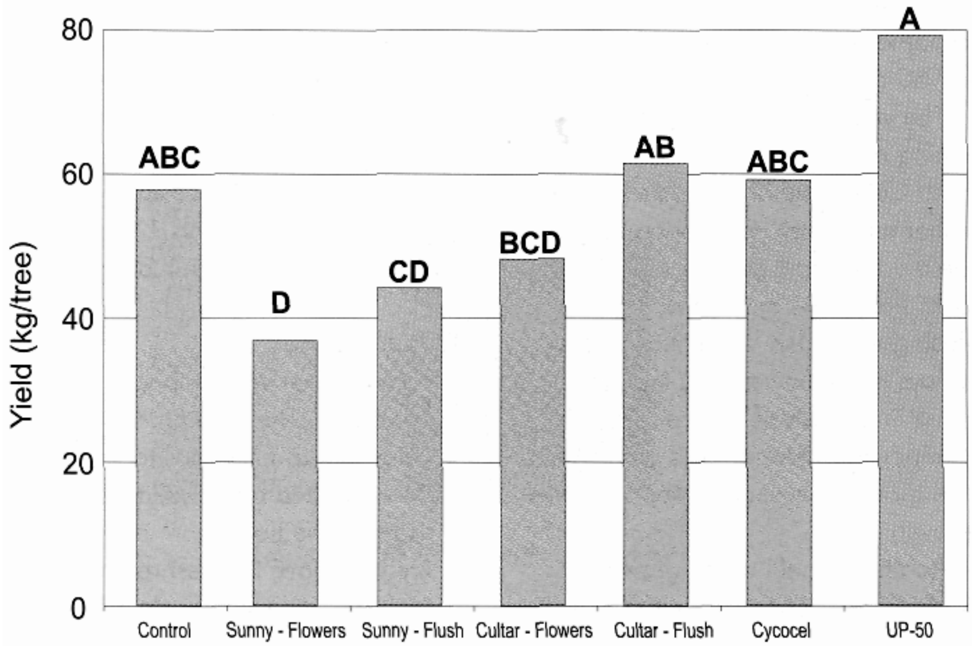

Figure 1: Effect of growth inhibitors on fruit yield in Hass

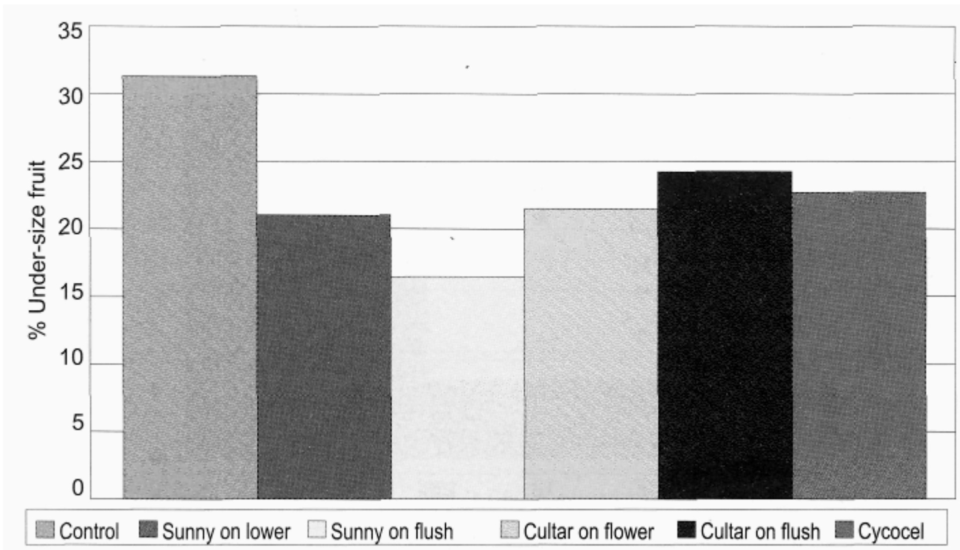

Figure 2: Effect of growth inhibitors on the number of under-size fruit

The yield data also shows that timing of application is important. Both Cultar and Sunny were applied at either full flower or at spring flush. The yield data shows that for both chemicals, the sprays applied at the spring flush gave higher yields than the sprays at full flower. This indicates that direct inhibition of flushes reduces competition between fruit and vegetative growth, allowing better fruit growth.

Another benefit of the growth inhibitor applications is a reduction in the number of undersized fruit. As shown in Figure 2, 31% of all fruit from control trees was undersized. In contrast all growth inhibitors reduced this percentage, with Sunny applied to the spring flush having the best effect (approximately 17% of all fruit in this treatment were undersized).

Figure 3 shows the effect of the growth inhibitors on fruit size distributions. In this figure, only the treatments applied to the spring flush are compared. The control trees produced the bulk of their fruit in the 16 and 18 count categories, with smaller numbers of fruit in the 14, 20 and 22 count categories. Cultar provided an overall increase in the number of cartons per tree but the increase occurred primarily in the smaller fruit categories (count 18 and 20). Sunny performed consistently with the manufacturer's claims by reducing the number of small fruit and increasing the number of large fruit. As shown in Figure 3, Cycocel produced the best results in this trial. It increased the number of fruit in counts 14 and 12 and even gave some fruit at count 10.

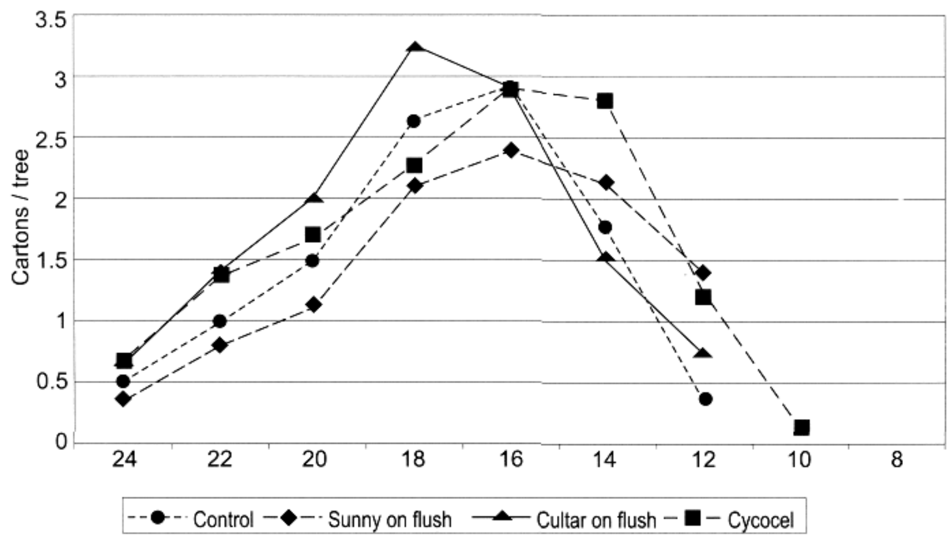

Figure 3: The effect of growth inhibitors on fruit size in Hass

To summarise:

1. Timing of growth inhibitor sprays is important. The current trial indicates that applications to the spring flush result in better yields than those to the flowers.
2. Cycocel gave the best results in this trial. It gave a similar yield to the control trees, while reducing the number of small fruit and increasing the number of larger fruit. While Sunny also increased the ratio of large to small fruit, it showed a significant decline in yield. Cultar improved the overall yield somewhat, but most of the increase occurred in smaller fruit categories (although these fruit were still large enough to be shipped as export fruit). This data is particularly significant when one considers that Cycocel is the most economical of the three growth inhibitors used.

CALCIUM-CONTAINING PRODUCTS

It has been known since the mid 1800's that a wide range of internal fruit and vegetable disorders are of a physiological nature, but it was only in the 1930's and 1940's that these were directly associated with low calcium levels (Shear, 1975). Since then, low calcium levels have been positively linked with disorders such as bitter pit, cork spot, internal breakdown and lenticel breakdown in apples; blossom-end rot in tomatoes and peppers; blackheart in celery; internal browning in Brussels sprouts and cracking in cherries and prunes - as summed up in a review of this topic by Shear (1975).

While most of the work on calcium related internal disorders has been carried out in deciduous crops, a considerable body of work has shown a correlation between low calcium levels and internal breakdown in mango fruit (Young & Miner, 1961 ; Singh *et al*., 1993; Hermoso *et al*., 1996). Furthermore, a number of authors have investigated the relationship between low calcium levels and internal disorders in avocado fruit — particularly those disorders related to chilling injury in stored fruit. This work (reviewed by Bower and Cutting, 1988) indicates that low calcium levels may play a role in the internal disorders seen in avocados. A survey of a large number of avocado orchards throughout New Zealand showed a strong correlation between low calcium and a high incidence of post-harvest vascular browning and flesh browning. This same survey showed that late-harvested fruit had lower calcium levels and more internal disorders (Thorp *et al.*, 1997). Cutting *et al.* (1992) also established a relationship between late harvesting, low calcium and poor post-harvest quality. These relationships between calcium and fruit quality also hold within individual fruits. Chaplin & Scott (1989) showed that internal disorders start in the distal end of individual avocado fruits and that calcium levels are lowest in this part of the fruit.

A number of researchers have shown that post-harvest calcium applications in avocados, which give higher fruit calcium levels, result in lower respiration and ethylene production rates. These treatments also give better fruit quality and longer ripening times (Tingwa & Young, 1974; Wills & Tirmazi, 1982; Eaks, 1985). Furthermore, van Rensburg and Engelbrecht (1985) have shown that post-harvest calcium applications decrease the levels of the components responsible for flesh browning.

To date, very little work has been done on pre-harvest spray applications of calcium in avocados. However, work in other crops suggests that the use of standard $CaCl_2$ and $CaNO_3$ sprays can improve postharvest fruit quality. However, both of these materials have certain problems - particularly phytotoxicity at higher rates (Wooldridge & Joubert, 1997). A range of new organically chelated calcium products have recently become available which are reported to give excellent uptake and minimal phytotoxicity. This trial was set up to examine the effect of one such product Calcimax on post-harvest quality in avocados.

Methods and Materials

The trial was carried out at Burgers - hall Experimental Station on 2 year old Edranol trees. Treatments were:

1. Control
2. 0.5% Calcimax spray (± 3 weeks after fruit set)

3. 1% Calcimax spray (± 3 weeks after fruit set)

Each treatment comprised 11 single-tree replicates randomly situated in the orchard.

In both trials fruit was harvested at maturity, stored at 6°C for 21 days, ripened at room temperature for 7 days and analysed for internal and external disorders. Individual fruit weight and size was measured, as was tree yield. Fruit mineral contents were also determined.

Results and Discussion

The fruit mineral analyses indicate that both of the Calcimax treatments resulted in a slightly increased fruit calcium level (Fig. 4). However, statistical analysis of the data shows that this increase was not significant. Despite this lack of significance, there were still differences between treatments in the extent of internal disorders following three weeks of cold storage. As Figure 5 indicates, grey pulp was reduced by 17% in fruit receiving 0.5% Calcimax sprays and by 27% in fruit receiving a single 1% Calcimax spray. Furthermore, the incidence of vascular browning was reduced by 19% and 20% respectively for the 0.5% and 1% sprays (Fig. 6). This is in contrast to the situation reported by Veldsman (1983) who obtained no improvement in avocado fruit quality with as many as six sprays of $CaNO_3$. It would appear that Calcimax allows for more efficient calcium uptake than the more traditional calcium nitrate. This is in agreement with data obtained using Calcimax in other crops. Wooldridge and Joubert (1997) found that this product is highly efficient in improving internal quality in apples and also provides a reduction in internal breakdown in plums. At this time there is no explanation for the lack of significant differences in calcium levels between control and treated fruit.

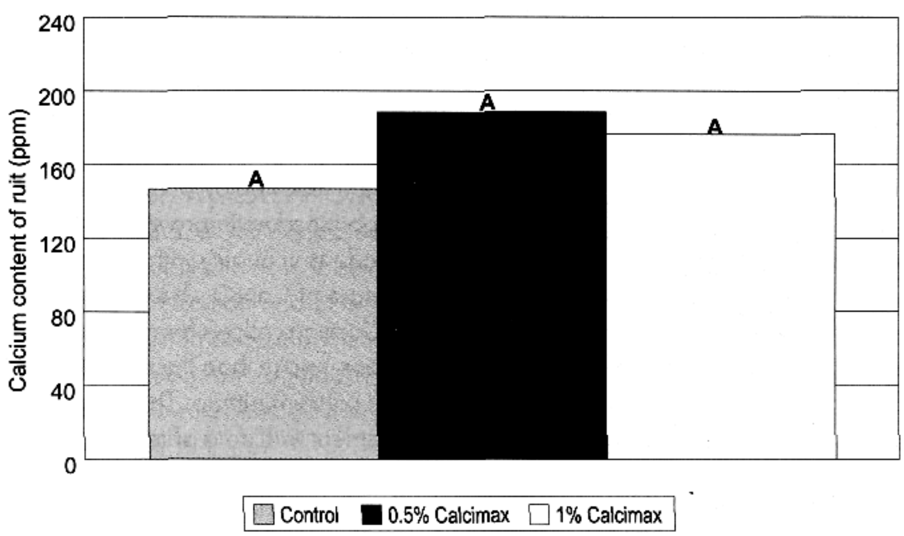

Figure 4: Calcium content of Edranol fruit treated with Calcimax

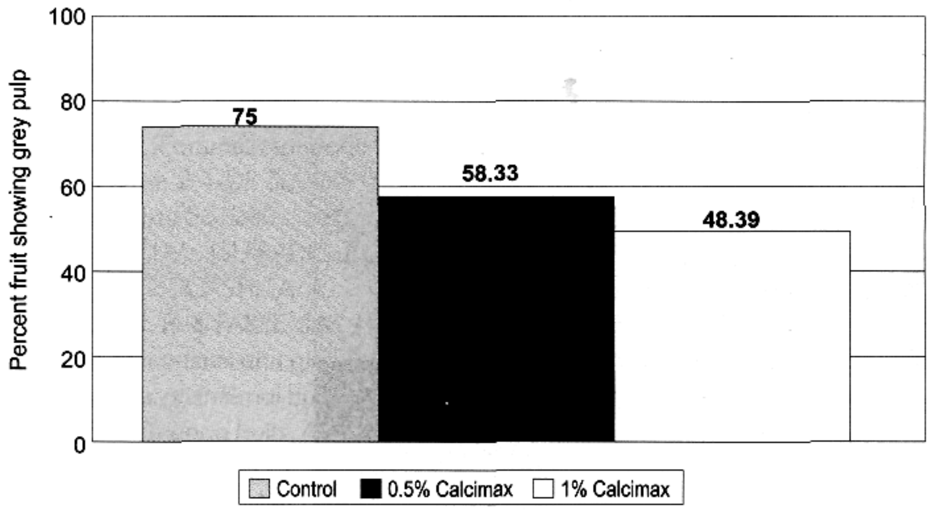

Figure 5: ***The effect of calcimax treatments on the incidence of grey pulp in Edranol fruit***

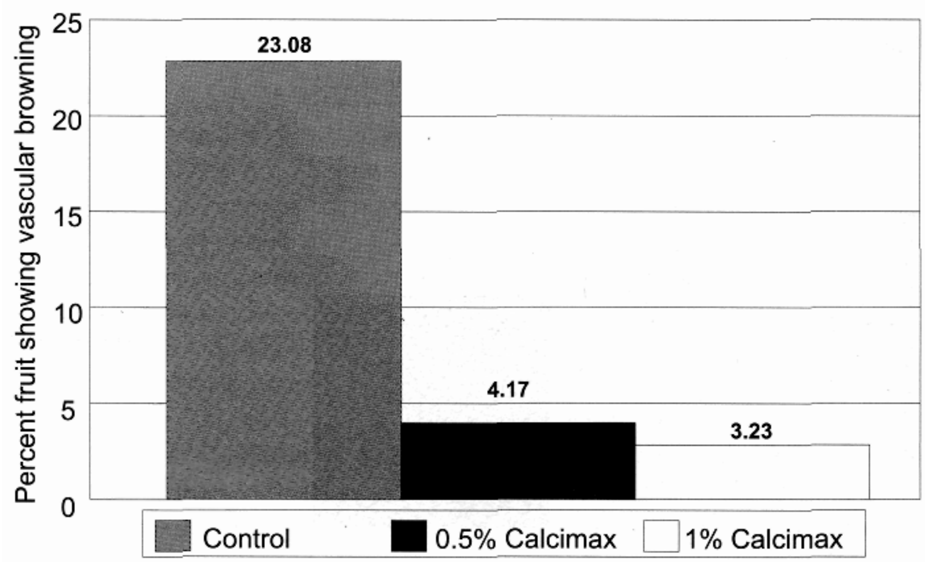

Figure 6: ***The effect of calcimax treatments on the occurrence of vascular browning in Edranol fruit***

AUXINS

Auxins play a role in a host of plant functions, several of which could be beneficial to the avocado industry. The first role of importance is the ability of auxins to improve fruit sink strength - particularly the ability to attract calcium to the developing fruit. As already discussed, calcium plays an important role in fruit quality. Cutting and Bower (1989, 1990) have shown that auxin export from plant organs correlates with calcium import. Increased auxin export generally results in increased calcium uptake. Auxin also delays fruit ripening (Tingwa & Young, 1975).

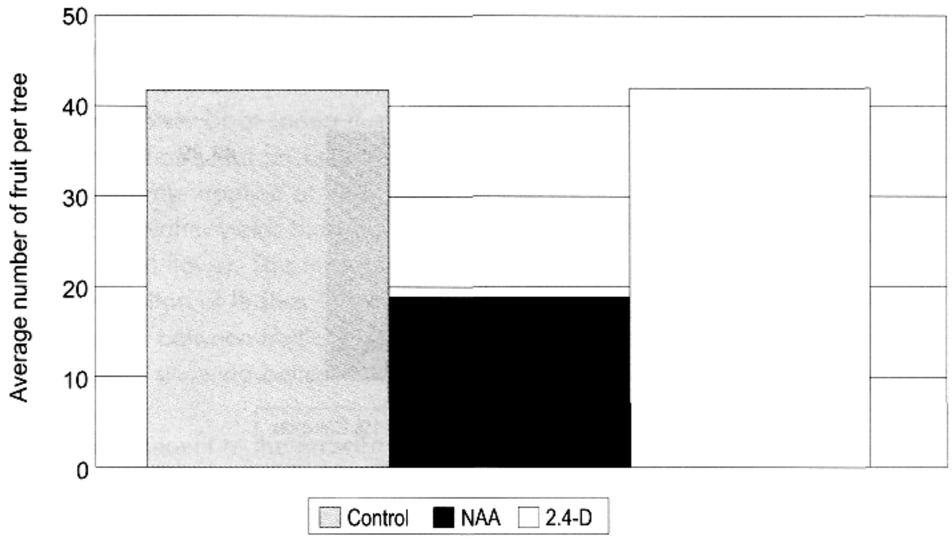

Figure 7: ***Initial fruit set in auxin-treated Ryans***

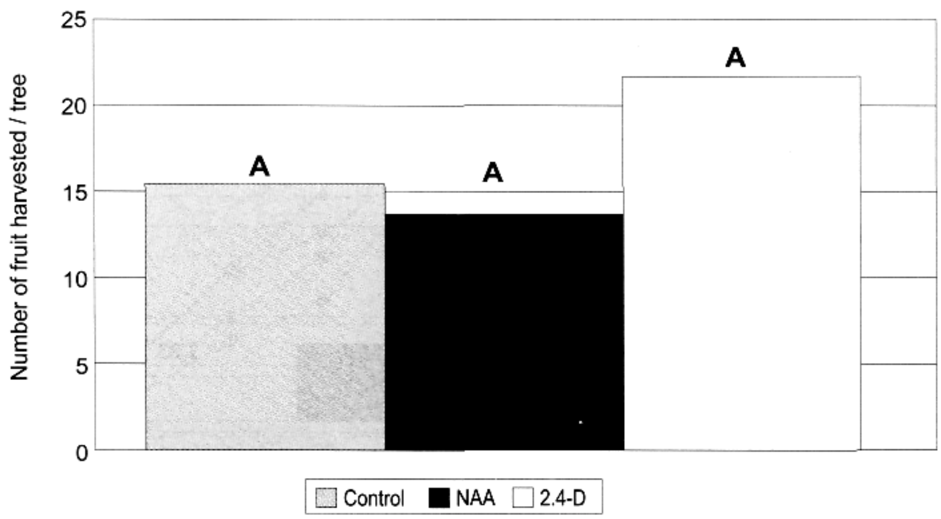

Figure 8: ***The effect of auxins on fruit yield in Ryan***

In addition to playing a role in sink strength, auxin also plays a role in fruit setting and retention, as well as fruit size. The auxin 2,4,5-TP has been shown to increase fruit set in litchi (Stern *et al*., 1997), while the synthetic auxin 2,4-DP has been shown to increase fruit size by 19% in mandarins (El-Otmani *et al*., 1993) and 14% in apricots (Agusti *et al*., 1994).

The current trial set out to establish the effect of two synthetic auxins on fruit set, retention and size in avocados.

Methods and Materials

This trial was carried out at Burgers - hall Research Station. It was conducted in 2 year old Ryan avocados at full flower, using NAA (100 ppm) and 2,4-D (100 ppm). Each auxin was applied as a full cover spray to seven randomly selected single tree replicates, with a further seven trees serving as controls.

After fruit set, fruit was counted and the trees were then thinned to 30 fruit. At fruit maturity, individual fruit sizes were measured and the number of fruit per tree was recorded.

Results and Discussion

This preliminary trial was relatively small, but yielded some interesting data. The initial fruit set data (Fig. 7) indicates that while 2,4-D had no effect on fruit set, NAA had a fruit thinning effect. This may be useful in some cultivars where fruit set is excessive, but if the object is to improve set then NAA is not the auxin of choice. Perhaps the most important data to come out of this trial is the effect of 2,4-D on fruit retention. As mentioned, these trees were thinned to 30 fruit per tree after fruit set. Figure 8 shows that the control trees dropped fruit throughout the season and yielded approximately 15 fruit per tree at harvest giving only a 50% fruit retention rate. In contrast, the trees treated with 2,4-D yielded 22 fruit per tree a 73% retention rate. The treated trees thus yielded 46% more fruit than the controls. While not much information is available on the effect of auxins in avocados, this data indicates an important role for these compounds in avocado production. The ability of 2,4-D to increase fruit retention is particularly significant when one considers that South African avocado trees generally experience two to three periods of considerable fruit fall during the growing season. At this stage it is not known whether these auxins will affect avocado fruit size. The single application used in this trial yielded no effect on fruit size for either of the two auxins investigated.

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