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The effect of pre- and postharvest calcium applications on the postharvest quality of Pinkerton avocados

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ABSTRACT

One of the problems facing South African avocado producers is that of poor postharvest quality in avocado fruit. This is extremely evident in fruit which has been stored at low temperatures and is particularly acute in the Pinkerton cultivar. Research in avocados, as well as other crops, has shown that internal fruit disorders are directly related to low fruit calcium levels. Despite a large amount of evidence for this relationship, little has been done to address this problem in avocados. In order to rectify this situation, a trial was set up to establish the effects of both preharvest and postharvest calcium applications on the quality of Pinkerton avocados. What distinguishes this trial from similar work in the past is the use of new calcium products formulated specifically for maximum uptake and translocation, with a minimum of phytotoxicity.

The series of trials carried out this season indicates that a number of benefits are to be derived from calcium applications. These include firmer fruit, a reduction in both external and internal physiological disorders and a decline in certain pathological disorders. However, the work also indicates that other factors play a role in fruit quality and that these factors may override the advantages derived from calcium applications. One such factor is fruit maturity. The work indicated that preharvest applications are more effective early on in the development of the fruit rather than just before harvest. It was also seen that postharvest calcium applications can provide a means for improving fruit quality. While there is still considerable work to be done in this field, it has been shown that calcium applications provide a practical and effective means of improving avocado quality.

INTRODUCTION

The Pinkerton cultivar is one of contrasting properties. On the one hand, it has a naturally compact growth which allows for higher density plantings and for easy maintenance in normal plantings. It has good fruit size and gives average yields of around 20 t/ha compared to an industry average of 8 -12 t/ha in other cultivars. On the other hand, it has an extended flowering period which results in a crop containing fruit with a variety of maturity stages. It also has a considerable problem with postharvest disorders. These problems may well be related.

The primary disorder occurring in postharvest fruit is a discoloration of the mesocarp, referred to as grey pulp. This condition is aggravated by cold storage — a necessary requirement for fruit destined for the export market. This condition is not unique to avocados — discoloration and internal breakdown of fruit flesh has been recorded for a wide variety of both tropical and subtropical, as well as deciduous fruits. There are a number of factors that play a role in fruit quality but a review of the literature indicates that, in many instances, nutrient deficiencies are a major culprit.

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, watermelons 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). These are just a few of the 35 or so disorders listed in this review.

Calcium has a number of vital roles in plant tissues, but for the purpose of this discussion two of these roles are of particular interest:

1. Calcium increases membrane stability

2. Calcium increases cell wall strength (Poovaiah *et al.,* 1988).

As pointed out by Kirkby and Pilbeam (1984), tissues high in calcium have stronger cell walls, are firmer and resist infection more readily. These authors also point out that lack of adequate calcium leads to browning of tissues. This can occur for two reasons. Firstly, membranes in such tissues become less stable, allowing vacuolar substrates — specifically ortho-dioxy-phenols — to leak into other compartments where they undergo catalytic oxidation (via polypheno oxidase) and polymerisation, to form the polyphenols which give these tissues their typical brown appearance (van Rensburg & Engelbrecht, 1986; Bangerth *et al.,* 1972). At the same time, calcium may act to chelate phenolics and prevent their oxidation (DeKock *et al.,* 1975 as quoted in Kirkby & Pilbeam, 1984).

Most of the above-mentioned work on calcium related internal disorders has been carried out in deciduous crops. However, the tropical and subtropical crops are receiving more attention, with a considerable amount of literature being available — particularly for mangoes. This work has shown a definite correlation between low calcium levels and internal breakdown in mango fruit (Young & Miner, 1961; Singh *et al.,* 1993; Hermoso *et al.,* 1996). A number of authors have also 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 & Cutting, 1988) indicates that low calcium levels may play a role in the internal disorders seen in avocados. A comprehensive survey of avocado orchards in New Zealand has shown a strong correlation between low calcium and a high incidence of postharvest 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) have also established a relationship between late harvesting, low calcium and poor postharvest quality in South African fruit. These relationships between calcium and fruit quality also hold for individual fruits — Chaplin and Scott (1980) showed that internal disorders generally start in the distal end of individual avocado fruits where calcium levels are at their lowest.

It must be noted that the availability of calcium in soils is seldom a limiting factor — most soils contain sufficient calcium to meet the plant's nutritional requirements. The problem of calcium deficiency is more often due to poor distribution of calcium in plants once uptake has occurred (Bangerth, 1979; Kirkby, 1979). This is the reason why deficiency symptoms can occur even in plants growing on calcium-rich soils. It is also the reason why plants with good leaf calcium levels can exhibit fruit deficiency disorders (Bangerth, 1979). It must also be remembered that calcium is transported primarily via the xylem (Bangerth, 1979). Thus, rapidly transpiring organs — such as leaves — have greater access to calcium from the roots than organs such as fruit (Kirkby & Pilbeam, 1984). This preferential transport via the xylem also means that redistribution of calcium from leaves to other organs is relatively low, since transport out of plant organs is primarily via the phloem.

While the role of calcium in fruit quality and senescence is now well established, correcting the disorders that occur as a result of calcium deficiency is not straightforward. In fact, calcium nutrition has been described as the most complex problem in fruit nutrition (Faust, 1979). This is due to the fact that absolute calcium values are not as important as the balance between calcium and other minerals — including N, B, Mg, K, Zn and P. Furthermore, factors such as light levels, pruning, fruit size, crop load and auxin levels affect calcium nutrition (Ferguson, 1984; Monselise & Goren, 1987).

A number of researchers have shown that postharvest 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 postharvest calcium applications decrease the levels of the components responsible for flesh browning. Many of these trials have made use of postharvest calcium applications, whereby fruit is vacuum infiltrated with various calcium salts — a procedure which is not practical on a commercial scale.

An alternative to postharvest infiltration is to apply calcium as foliar sprays in the orchard. To date, very little work has been done on preharvest spray applications of calcium in avocados. 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). Where this approach has been tried in avocados, it met with little success (Veldman, 1983). Part of the reason for these poor results is that calcium salts are not readily taken up, and that once in the leaves not much transport towards the fruit occurs.

A possible solution to this problem is the availability of a range of new organically complexed calcium products. These products have been formulated to give excellent uptake and minimal phytotoxicity. A further advantage is that the organic compounds to which the calcium is attached are readily transported within plant tissues — along with the attached calcium. One of these products (Calcimax), tested in apples and plums (Wooldridge & Joubert, 1997) significantly improved postharvest quality in both of these crops. Another product, tested as a postharvest application in melons, increased the shelf life of these fruits from 10 to 24 days (Lester & Grusak, 1999).

The current trial was set up to examine the effects of several of these new products on the postharvest quality of Pinkerton avocados, and to compare preharvest and postharvest applications of the products.

MATERIALS AND METHODS

Preharvest applications

This trial was carried out at three sites:

A. Weirich farm, Kiepersol

B. ITSC orchard, Nelspruit

C. HL Hall and Sons, Nelspruit

Unfortunately, hail destroyed the trial at Hall's and therefore produced no data.

A. KIEPERSOL TRIAL

Treatments were as follows:

1. Control
2. Calcium Dextrolac 2L/ha
3. Calcimax 0.5%
4. Basfoliar Calcium 4.5L/ha
5. Caltrac 4L/ha

Application rates were approximately 1000L/ha of spray solution. Wetter was used (Nu Film) at 15ml/100L each treatment was subdivided into three further treatments:

1. Early season sprays (3 x sprays)
2. Preharvest spray (1 x spray)
3. Early season + preharvest sprays (total 4 x sprays)

Early season sprays were applied at full flower, fruit set and 2 weeks after set. Preharvest sprays were applied two weeks before harvest. After harvest, fruit were washed, waxed and stored at 6°C for 21 days. They were then ripened at room temperature and evaluated.

B. NELSPRUIT TRIAL

Treatments were:

1. Control

2. Caltrac 4L/ha
3. Calcimax 1%
4. Calcium Metalosate 4L/ha

In total, three applications were made at a rate of 1000 L/ha with Nu Film added at 15ml/100L. Applications were:

1. At flowering
2. At fruit set
3. Four weeks after fruit set.

At harvest, fruit were picked according to age. One set was picked at a moisture content of 72 - 74% and the other at 75 - 78%. Fruit was washed, waxed and stored at 6°C for 21 days. They were then ripened at room temperature and evaluated.

Postharvest applications

This trial was set up using Pinkerton fruit from the Weirich estate, Kiepersol. Treatments were incorporated into the standard postharvest protocols as follows:

1. Wash in HTH bath
2. Rinse in water
3. Imbibe for 10 minutes in calcium treatment
4. Allow to air dry
5. Wax fruit
6. Store at 6°C for 21 days
7. Ripen at room temperature and evaluate

Treatment solutions were as follows:

1. Control - water
2. Calcimax – 25ml in 10L
3. Stopit-25 ml in 10L
4. Ca Metalosate - 50ml in 10L
5. Ca Dextrolac-50ml in 10L
6. Basfoliar Ca - 15.57ml in 10L All of the above equate to 0.25g Ca/L.

RESULTS AND DISCUSSION

Preharvest applications

A. KIEPERSOL TRIAL

Before discussing specific data for this trial, it must be noted that all of the data sets here showed considerable variation. It would appear that some factor other than calcium had an affect on fruit quality in this trial. Work done by Kruger *et al.,* (in press) in these orchards indicates that fruit maturity was the primary factor affecting fruit quality, with calcium status playing a secondary role. The data indicates that application timing had a significant effect, with early season sprays always giving better fruit quality than late season sprays. Figure 1 shows that early season calcium applications (both alone and combined with late applications) give a lower incidence of grey pulp in stored fruit.

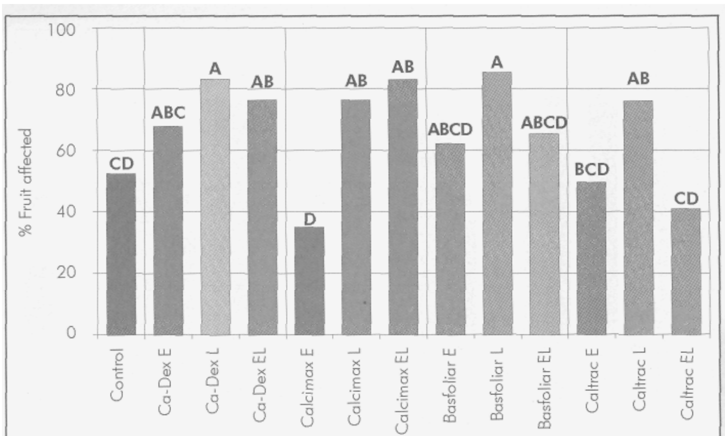

Figure 1 ***The incidence of grey pulp in Pinkerton fruit following foliar calcium applications***

While there were no statistically significant differences, early Calcimax applications almost halved the incidence of grey pulp. Figure 2 indicates that early season applications also reduce the seventy of grey pulp within individual fruits.

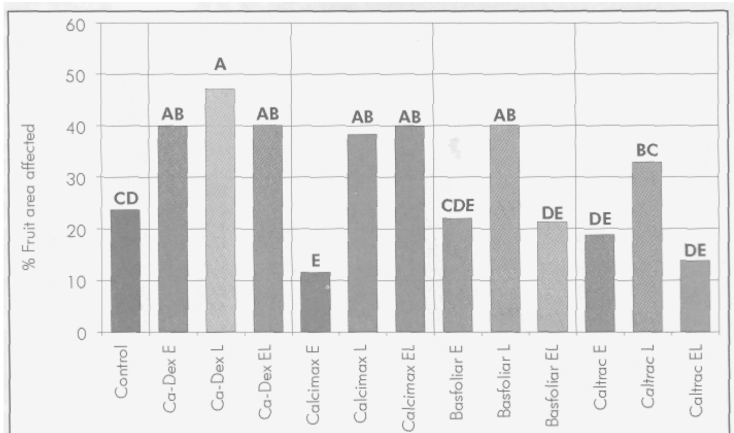

***Figure 2** Effect of Calcium sprays on the severity of grey pulp in Pinkerton fruit*

In the case of the Calcimax application, this reduction was statistically significant. A rather unexpected result in this trial was a reduction in the severity of anthracnose where calcium applications were made (Fig. 3).

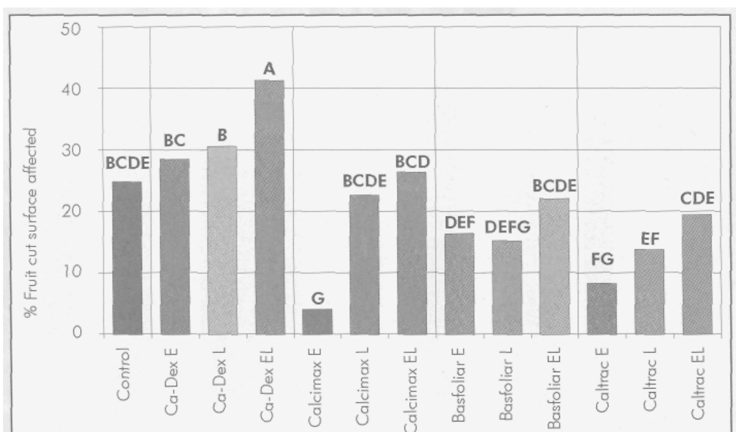

***Figure 3** The effect of calcium sprays on the severity of anthracnose in Pinkerton fruit*

It was noted that early season applications of Calcimax and Caltrac significantly reduced the severity of anthracnose. In addition to grey pulp, another physiological disorder encountered in cold-stored avocados is black cold injury. Figure 4 shows that eight of the twelve calcium applications tested in this trial totally eliminate this disorder.

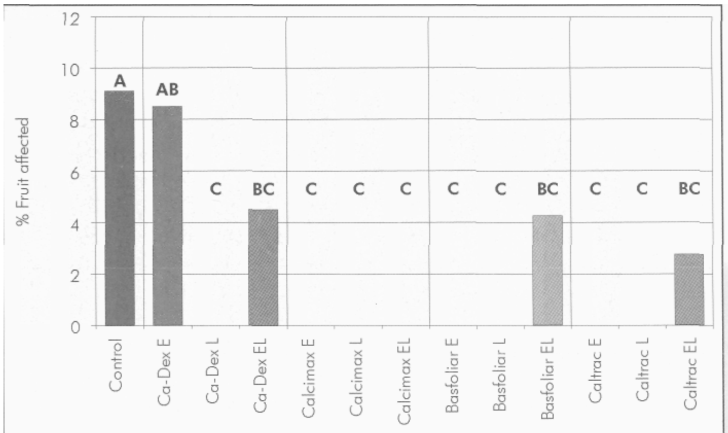

Figure 4 ***The effect of calcium sprays on the incidence of external cold injury in Pinkerton fruit***

Compared to the 9% incidence in the control fruit, this is a significant result. The results show that in most cases, combined applications are less successful than either early or late applications.

B. NELSPRUIT TRIAL

In this trial mature fruit was separated from less mature fruit prior to evaluation. This was done in order to establish whether fruit maturity interacts with calcium status to determine fruit quality. It was clearly shown that younger fruit tend to have better internal quality than older fruit. Figure 5 shows that younger fruit in every treatment had a lower incidence of grey pulp than older fruit. However, only the Calcimax application to young fruit gave better quality than the controls.

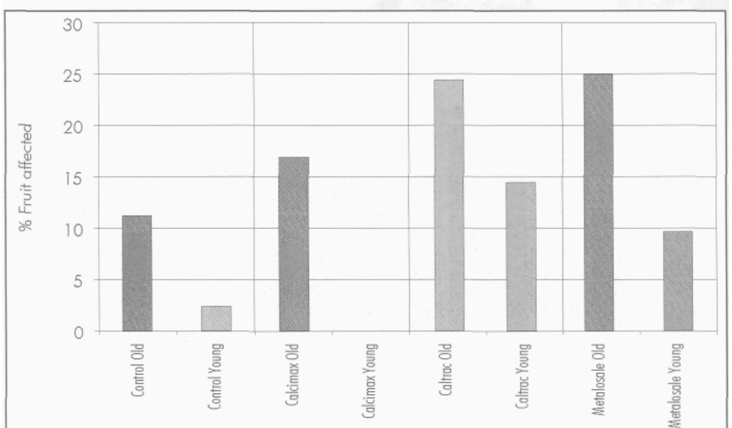

Figure 5 ***The effect of calcium sprays and fruit age on the incidence of grey pulp in Pinkerton***

Figure 6 shows that some calcium applications can also have an effect on fruit ripening.

It can be seen that several treatments gave fruit that were firmer than control fruit. However, this improvement was only statistically significant in the case of Calcimax applications to younger fruit.

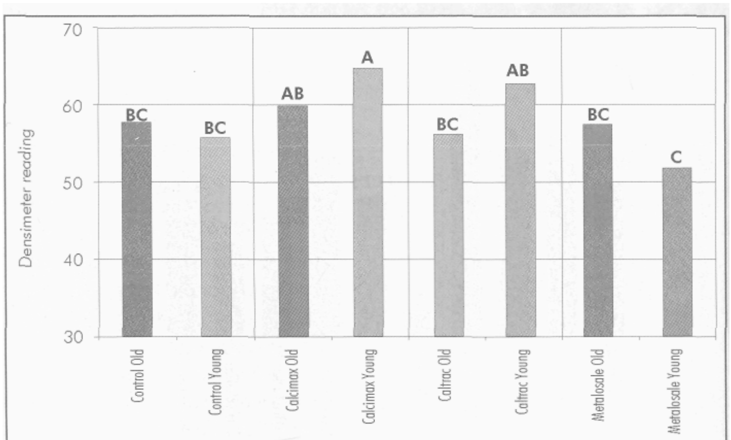

Figure 6 ***The effect of calcium sprays and fruit age on fruit firmness in Pinkerton avacados***

The above data indicates that while preharvest calcium applications can improve fruit quality, other factors also play a role. It was shown that fruit maturity has a definite effect, and that allowing fruit to become over-mature may well cancel any benefits derived from calcium applications. However, where fruit is harvested at the correct maturity, calcium confers a number of benefits. The first of these is an increase in fruit firmness relative to controls. This leads to benefits such as slower ripening and increased shelf life. This is in agreement with the findings of Bangerth (1979) who concluded that calcium confers increased firmness, reduced respiration, delayed ripening, extended storage life and a reduction in storage rot.

The data in this trial also agrees with the findings of Bangerth (1979) in that a considerable reduction in rot due to anthracnose was found. This is also in agreement with Kirkby and Pilbeam (1984), who pointed out that tissues high in calcium have stronger cell walls, are firmer and resist infection more readily.

Another benefit arising from calcium applications was an improvement in internal quality, with Calcimax giving reductions in both the occurrence and severity of grey pulp. These results contrast with those of Veldman (1983) who obtained no improvement in avocado fruit quality with as many as six sprays of $CaNO_3$. However, this can be attributed to the difference in calcium source. Where Calcimax has been used in apples (Wooldridge & Joubert, 1997), considerable improvements in both shelf life and fruit quality have been derived — much more so than the benefits derived from $CaNO_3$ and $CaCl_2$. This indicates that chelated calcium products are more effective than $CaNO_3$, probably due to more efficient uptake and translocation of the product. Another advantage to using chelated products is their safety — even high application rates — up to 4 times the recommended rate — give no phytotoxicity (pers. com., K. Stoll). This is in direct contrast to the phytotoxicity experienced with high rates of $CaNO_3$ and $CaCl_2$.

Postharvest applications

The postharvest trial indicated a definite role for calcium in postharvest quality. In fact, these postharvest applications in general gave better results than the preharvest applications. Figure 7 show that all of the products tested gave firmer fruit than the controls after 21 days of cold storage.

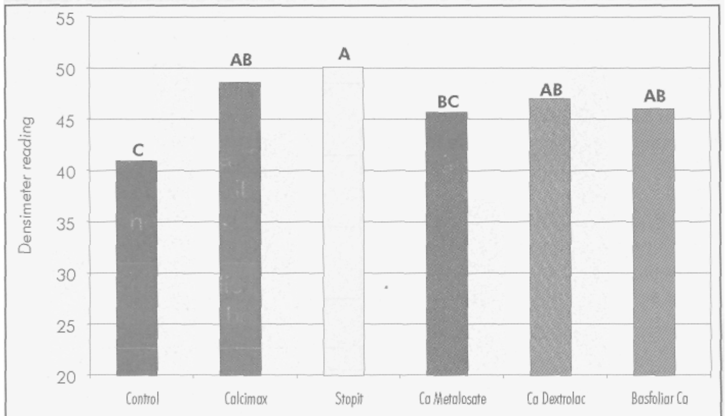

Figure7 ***The effect of post-harvest calcium dips on the firmness of Pinkerton fruit***

Four of these five treatments were statistically significantly better than the controls. In addition to this, all treatments reduced the incidence of grey pulp by more than 50% (Fig. 8).

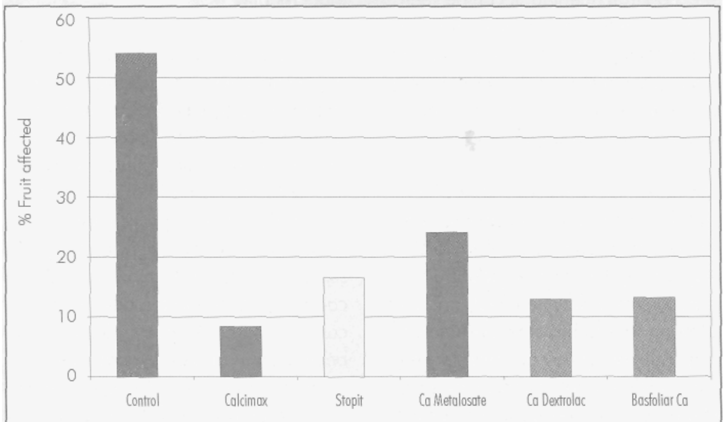

Figure 8 ***The effect of post-harvest calcium dips on the incidence of grey pulp in Pinkerton fruit***

The best treatment (Calcimax) reduced the incidence from 52% to just 8%. Furthermore, several of the products reduced the incidence of lenticel damage (Fig. 9) and anthracnose infection (Fig. 10). Again, it seems that calcium has a role in strengthening cell walls and this helps to prevent infection.

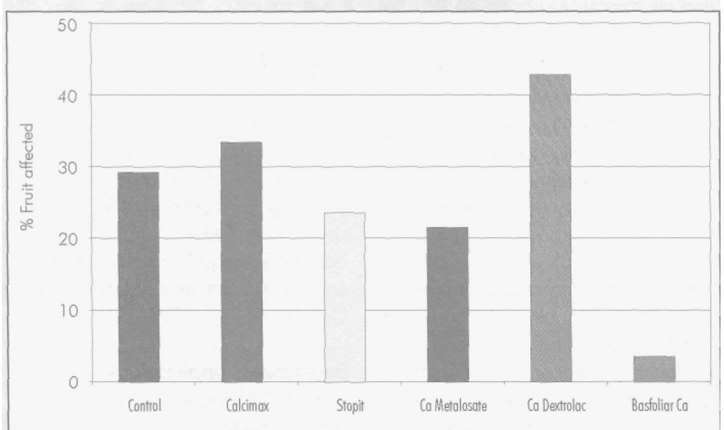

Figure 9 The effect of post-harvest calcium dips on the incidence of lenticel damage in Pinkerton

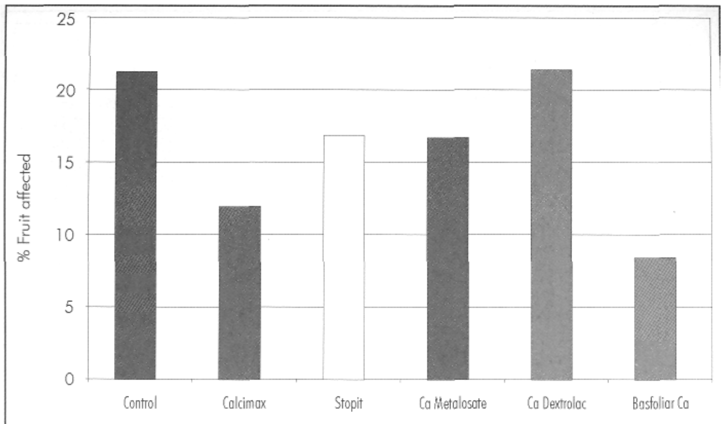

Figure 10 The effect of postharvest calcium dips on the incidence of anthracnose in Pinkerton

This result is in agreement with the work carried out by Tingwa and Young (1974) and Wills and Tirmazi (1982). In both cases, these workers showed that calcium applications give better quality and longer ripening times in avocados. The difference between this trial and previous postharvest trials is the ease of application. In the past, postharvest calcium applications involved either long incubation times or vacuum infiltration of fruit. The current trial attempted to move away from such protocols as they are not practically applicable in commercial packhouses. In this regard the complexed calcium products are much more versatile — they allow good uptake in relatively short periods of time. This is confirmed by the findings of Lester and Grusak (1999), who used Calcium Metalosate for postharvest treatments of melons. These authors found that postharvest dips extended the shelf life of melons from 10 days to 24 days. Such increases in shelf life allow more time for the shipping of fruit to export markets, as well as more time for the marketing of fruit once it reaches its destination.

Thus there is definitely a role for both preharvest and postharvest calcium applications in the avocado industry. However, there are still a number of problems to be solved.

One such problem is the large volume of fruit handled by the packhouses, and the practical implications of these volumes receiving postharvest treatments. It is hoped that these problems can be addressed in the forthcoming season.

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