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Soil Boron Application for Control of Boron Deficiency in the Avocado in the Kwa-Zulu-Natal Midlands

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ABSTRACT

Studies indicated tentatively that foliar boron applications were ineffective and falsely inflated annual boron analysis results. In spite of sprays, mean leaf boron concentrations varied from 28-33 mg/kg. Soil analyses from four growing areas in KwaZulu-Natal, reveled deficient levels of B, all showing concentrations of less than 1 mg/kg. Glasshouse trials showed that Edranol was 40% more efficient at boron uptake than the widely used Duke 7 rootstock. Field trials, experiments with soil boron (in the form of Borax) application rates in the range of 5-60 g/m^2/year showed all treatments successfully raised leaf boron concentration, highest application rates causing toxicity 15 months after initial application. Successful treatments in younger trees resulted in a 4% increase in mean fruit mass, and a consequent 10% increase in yield with no significant difference in

INTRODUCTION

South African avocado industry has relied solely on foliar B application to suffice the avocado's B requirement. Soil applications have been avoided since margins between deficiency and toxicity were regarded as narrow. Recently, it has been shown that the avocado is remarkably tolerant to soil B applications. This has enabled successful soil B application in Australia and New Zealand over the past 10 years. Soil B applications have been shown to be successful in raising leaf B concentrations to the adequate range, i.e. 50 mg/kg without causing toxicity. Such applications are used for their longer lasting effect than foliar applications, since B is poorly phloem translocated. Foliar sprays appear to have an effect limited to the leaves and do not reach roots and developing fruit where requirement for B is crucial. Structure of the avocado leaf should also be considered, foliar sprays are only effective on young leaves since older leaves develop a thick waxy cuticle, impeding uptake of foliar applied B. Foliar sprays are however useful for pollination purposes, and sprays preceding flowering are beneficial.

Deficiency symptoms have only recently been identified in Australia, and have until very recently remained unrecognized in South Africa. Smith *et al* (1995) identified deficiency symptoms as:

•marginal necrosis of younger leaves

•crimped (corrugated) and bumpy regions between veins of younger leaves

•shot holes in younger leaves

•loss of apical dominance, often resulting in multiple shoot production

•prostrate or downwards growth of branches

•swelling of stem nodal regions (chronic symptom)

•splitting of the midrib on the under side of younger leaves

•uneven lamina development of younger leaves cell expansion stopped on one side of leaf followed by localized necrosis

Many of these are typical of avocado in South Africa. Importance of these symptoms was noted by Wolstenholme (1995) after a visit to Australia. Seedling Guatemalan rootstock, widely used in Australia, have been shown to be more effective at B translocation than South Africa's popular Duke 7 (Whiley *et al.,* 1996), perhaps explaining part of the local B problem.

Research has been undertaken at the University of Natal over the past 2 growing seasons, evaluating orchard B status, as well as determining merit of soil B application, while minimizing risk of toxicity.

MATERIALS AND METHODS

Orchard surveys

Farm records for Baynesfield, Cooling, Everdon and St. Paul Estates were used to evaluate orchard B status. Eight soil samples from each estate were submitted to Noordwes Laboratories for analysis of B using the hot water extraction method (Macvicar, 1965).

Figure 3 : Boron toxicity symptoms in avocado

Field trials

Trials were initiated at Cooling Estate (30°40'E and 29°27'S) situated at Bruyns Hill near Wartburg. Cooling, situated on the plateau overlooking the Umgeni Valley, has a mean elevation of 950 m above sea level. Inanda soil form predominates, with ca. 35% clay, derived from table mountain sandstone, with excellent physical properties and great depth.

Two trial sites were established. The first site involved Hass on clonal Duke 7 planted in 1987. These trees showed chronic B deficiency symptoms when the trial was initiated. Treatments were applied in rows to minimize effect of leaching from trees treated with highest application rates. Boron was applied in the form of Borax (11%B) at 6 rates: 0, 5, 10, 20, 40 and 60 g Borax/m^2 canopy area/year, spit into 3 equal applications, applied in October, February and April. Although the site had a gradient of less than 1%, the highest treatment was located on the lowest lying area to minimize the risk of leaching, contamination and potential death of adjacent rows.

This trial was repeated in younger Hass on clonal Duke 7 trees established in 1992. This trial site was gently sloping (<5%) and trees showed excellent uniformity particularly in terms of flowering and fruit set. Trees showed no severe deficiency symptoms and leaf analysis in 1994 showed B concentration of 25 mg/kg.

No foliar B sprays were applied to any experimental or adjacent trees (to prevent drift) for the duration of the trial. Irrigation was based on tensiometer readings and was applied through 2 microjets per tree, when pressure dropped below -40 kPa.

Data collection spanned from March 1995 to February 1997. No harvest was measured in 1996. Monthly leaf samples were taken before 07h00 (while still wet), wiped with a cloth to remove any spray residue, before placing in a paper packet. Pooled leaf samples were taken for treatments on a monthly basis. Fruit were harvested in July. Fruit size was measured gravimetrically and fruit size distributions were recorded according to the following weight classes: count 24 and smaller (oil factory or reject) =170g; count 22 = 171 to 190g; count 20 = 191 to 210g; count 18 = 211 to 235g; count 16 = 236 to 265g; count 14 = 266 to 305g; count 12 = 306 to 365g.

Leaf samples were dried and ashed and prepared for ICP-AES analysis using the method described by Verbeek (1984). Analysis was performed at on a Varian radial ICP-AES at Umgeni Water Analytical Services Laboratory, Pietermaritzburg.

Glasshouse Trials

Fifty Hass plants with clonal Duke 7 rootstock obtained from Westfalia Nursery, Duivelskloof, after the first flush following grafting, had matured. Plants were transplanted into 8 litre white plastic containers containing Inanda soil forms from the Winterskloof area (Soil 1), or Cooling Estate, Bruyns Hill (Soil 2). The former site was selected because trees in this area showed chronic deficiency symptoms, in addition to its sandy nature which one would expect to produce toxicity symptoms under relatively low application rates. Before transplanting, special care was taken to remove pinebark growing media from the roots as this would contaminate the soil with additional boron. The experiment was designed as a 4 x 2 factorial, with 4 levels of B (2, 4 and 8g Borax /m^2 pot area) applied to two physically and chemically contrasting soils. The final treatment was 8g Borax/m^2 applied in combination with 40g lime and 40g gypsum per pot and aimed at determining the calcium/boron relationship. Lime was mixed into the profile to a depth of 30 cm, while gypsum was applied to the soil surface. The experiment was repeated using Hass grafted on Edranol rootstock which were received in May 1996. The entire experiment was arranged as a completely randomised block design in the C.E.R.U. at the University of Natal, Pietermaritzburg. Growing conditions were affected by an unusually warm autumn, extremely cold winter and a prematurely hot spring. Conditions however were maintained when possible above 7°C by a 2 kW fan heater in cold weather and between 18°C (night) and 28°C (day) by fans and evaporative cooling through a wet wall.

Pots were raised on bricks to minimize risk of *Phytophthora cinnamomi* infection. In addition, white pots were specifically used since these would raise soil temperatures to the least degree, a further preventative measure to minimize chance of infection. Plants were individually irrigated by hand on a daily basis so that leaching would be minimized.

Following harvest, leaf samples were analysed for B using methods described above.

RESULTS AND DISCUSSION

Orchard surveys

The survey indicated that mean leaf B concentrations varied in the range 28-33 mg/kg (figure 1).

Annual mean leaf B concentration fluctuated from 22-54 mg/kg (figure 2).

Annual fluctuations were alternately high and low for Cooling and St. Paul and Everdon Estates. Baynesfield Estate showed a steady decline over 4 seasons decreasing from 44 mg/kg in 1993 to 22 mg/kg in 1996. Fluctuations were possibly caused by contamination of leaf analyses by foliar B sprays, therefore values can only be considered as apparent B concentration since the degree of contamination remains unqualified. Real B concentrations can be expected to be somewhat lower. Visits to all estates indicated that visual symptoms of all orchards signified lower leaf B concentration than indicated in leaf analysis. Whiley *et al.* (1996), indicated that deficiency symptoms only developed when leaf concentrations fell below 25 mg/kg. Hence, it is unlikely that symptoms noticed would have occurred at apparent leaf B concentrations. Real leaf B concentrations must therefore be significantly lower. Current method of foliar application cannot be considered effective in KwaZulu-Natal.

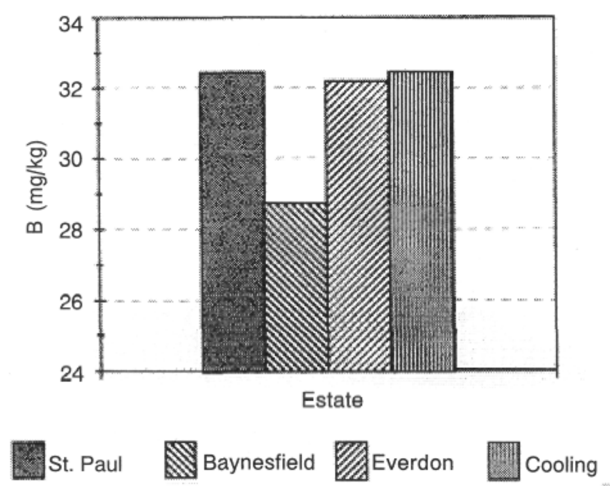

Figure 1. Average long term leaf boron concentration from four KwaZulu-Natal orchards

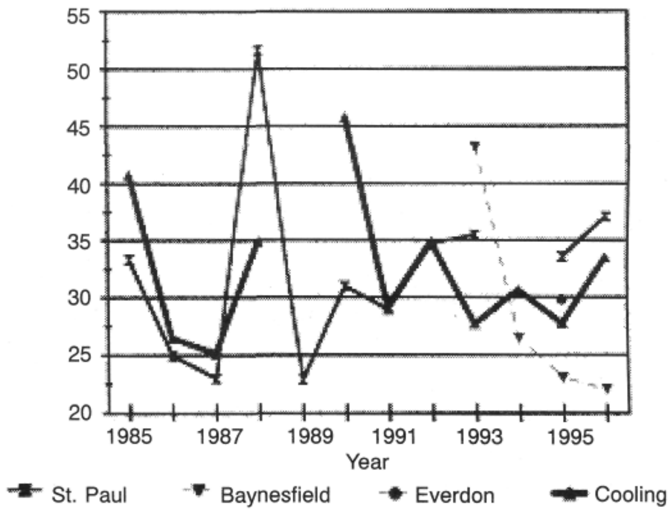

Figure 2. Annual average leaf boron concentration in four KwaZulu-Natal Orchards

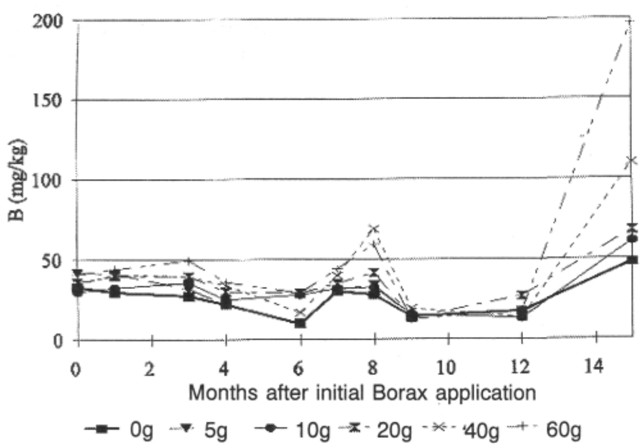

Figure 4. Effect of soil boron application on leaf concentration in older trees at Cooling Estate

Orchard trials

Toxicities were initially suspected during October 1996 in the 60 g/m^2/year treatment and were confirmed when severe toxicity appeared in both 40 and 60 g/m^2/year in January 1997 (figure 3), 15 months after initial application. Symptoms appearing as marginal interveinal necrotic areas were initially visible at the leaf apex, moving progressively towards the stem end. Leaf B concentration showed cyclical variation throughout the year (figures 4 & 5). Highest leaf concentrations, occurring during January 1997 and June 1996, indicated that times of greatest uptake were November to February followed by April to June. All soil applications raised leaf B concentrations higher than those of the control. Amount of B measured in leaf tissue was proportional to the application rate. Although leaf B concentrations were initially in the same range bordering on deficiency, final concentrations were different. Furthermore, it should be noted that control leaves showed the greatest decrease in leaf B concentration between February and April 1996 for older trees, and between April and May for younger trees. This was the time during which developing flushes were maturing and fruit growing. It appears soil B applications are able to cater for the trees' heavy demands for B during this time.

Soil B applications should be made so as to optimise B supply during peak uptake periods mentioned. Applications should preferably be made 4 to 6 weeks before these periods to enable surface applications to dissolve with rainfall or irrigation. Since the peak uptake period from April to June occurs during autumn to winter, application during February would be preferable since rainfall is far more efficient at dissolving applied Borax across the entire drip line area than is irrigation. Where B is applied through the irrigation system, B application can be injected into irrigation water during peak uptake periods. Timing of application becomes less important once soil B reserves have increased to the adequate range.

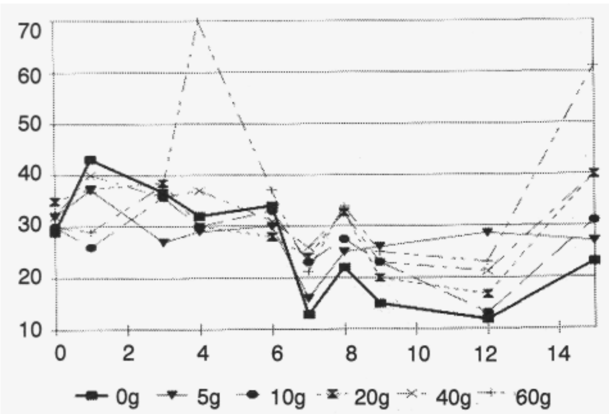

Figure 5. Effect of soil boron application on leaf concentration in younger trees at Cooling Estate

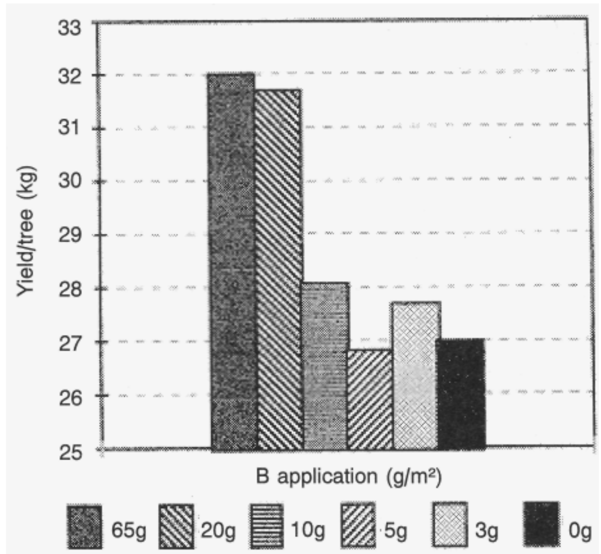

Figure 6. Effect of soil boron concentration on tree yield of young trees at Cooling Estate

Results suggest that initially a moderate application rate (10-20 g/m^2) would ameliorate deficiency within a shorter period, however would only be necessary for the first year, where after a low maintenance dose (5 g/m^2) could be applied. Leaf and soil analyses should be used as a tool to determine application rate. Sampling during February would also be advisable should toxicity be suspected, since leaf B concentrations are at a peak during this interval.

Fruit yield and average fruit size were increased in young B treated trees. Older, more deficient trees showed high yield variability, and differences in yield were inconclusive. Fruit yield was undoubtedly affected by many entangled factors. In addition, effect of B application on these trees would require a longer period to take effect than would younger trees. In the young trees fruit counts showed increased mass in larger fruit sizes while control trees showed increased production in smaller counts. No differences in total fruit number per tree were noticed; hence increase in yield can be attributed to increased fruit size. Commercial value of increased fruit size rather than increased fruit number is very important.

Glasshouse trial

Edranol proved to be 40% more efficient ($p = 0.01$) at B uptake than Duke 7 (figure 6) over 2 different soils (table 1). This finding is in agreement with that of Whiley (1996), where Velvick (also of Guatemalan origin) was found to be 30% more efficient at B uptake than Duke 7 (Mexican origin). Toxicity symptoms appeared at leaf B concentrations of over 100 mg/kg and defoliation and subsequent death began above 150 mg/kg.

Limed treatments were significant in Edranol ($p < 0.05$) where liming decreased B concentration by 167 and 63 mg/kg (± 20.9) for soils 1 and 2 respectively. Results indicate that B uptake in Edranol is more sensitive to liming than Duke 7.

Results have shown that B deficiency is a major problem in orchards in KwaZulu-Natal for numerous reasons. Soil B concentrations are extremely low (< 1 mg/kg). Leaf analysis shows that the norm' of 40-60 mg/kg is seldom reached by using foliar sprays. In addition, the degree to which foliar sprays falsely inflate leaf B concentration remains to be quantified, however severe nature and frequency of deficiency symptoms in the field seems to indicate that leaf B levels are considerably lower than indicated. Furthermore, it appears that while soils are deficient in B, the avocado has a relatively high B requirement. Moreover, the avocado appears to show limited capacity for B uptake, hence have a high tolerance of soil B concentrations. Field trials indicate that uptake is slow particularly after initial applications, but have a longer lasting effect. Tree response in terms of increased fruit size shows the shortfall of B required for growth processes.

Table 1: Effect of rootstock, soiltype, boron application and calcium application on leaf boron concentration

Rootstock	Duke		Edranol	
Soil	Soil 1	Soil 2	Soil 1	Soil 2
0g	17.8	40.7	36.2	29.4
4g	36.6	55.6	62.8	61.7
8g	83.4	99,7	252.3	144.9
12g	165.5	215.0	275.8	181.9
8g+Ca	56.2	87.7	84.7	81.9

Glasshouse trials indicate that toxicity occurs easily in younger trees. Edranol is more efficient at B uptake; however, since differences between the 2 rootstocks are marginal in control trees, it indicates that B shortfall rather than uptake and translocation (i.e. a rootstock factor) is the limiting factor under South African conditions. Therefore, it should be noted that the South African avocado will take longer to respond to B applications since it is based on Duke 7 rootstock, however, the capacity for uptake is present. It follows that toxicity would occur at lower applications in Edranol than in Duke 7, and this in itself allows a greater margin of error and this is to the South African Growers' advantage.

CONCLUSIONS

It can be concluded that B deficiency is widespread in avocado orchards of KwaZulu-Natal, since current methods of foliar applications are not meeting the tree's requirements. Rather, indications are that leaf analysis are falsely inflated and not providing a true indication of orchard B status.

Finally, it must be emphasised that although this trial used applications of up to 60 g/m^2/year, these are experimental in nature and should not be used commercially. Highest commercial dose would be 15 g/m^2/year (applied as 3 split applications), however, consultation with an experienced horticulturalist is crucial.

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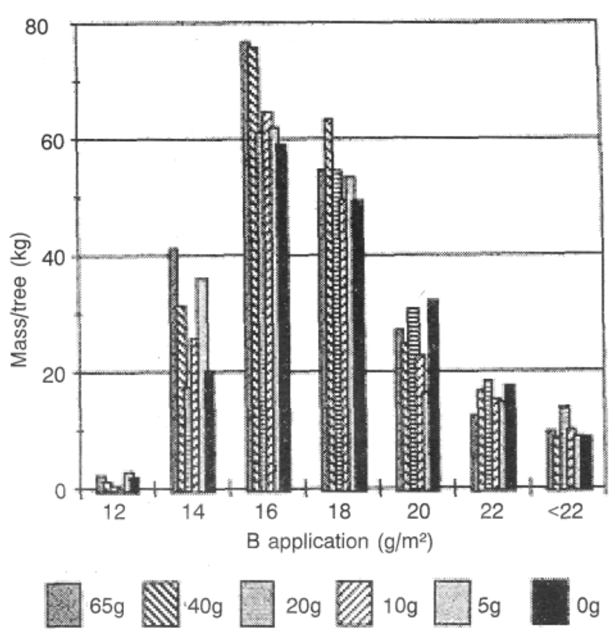

Figure 7. Fruit mass distribution per count for treatments 0-65gm applications in young trees at Cooling Estate

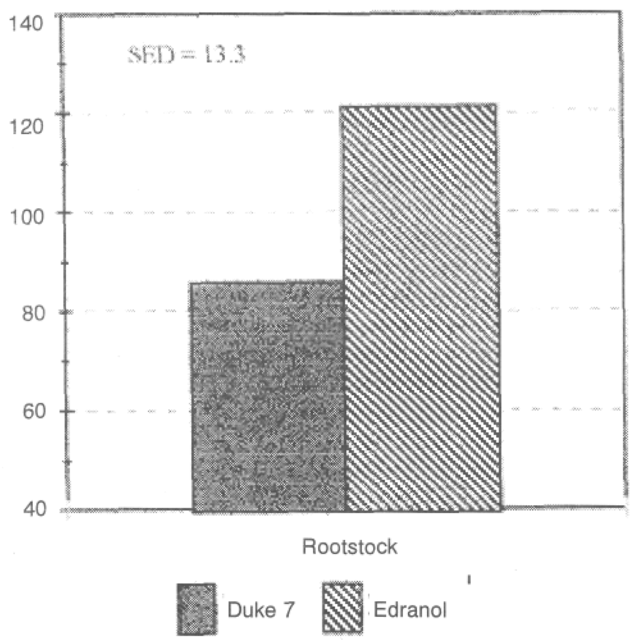

Figure 8. Effect of rootstock on leaf boron concentration

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