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SOIL BORON APPLICATION FOR THE ALLEVIATION OF BORON DEFICIENCY OF AVOCADO (*Persea americana* Mill.) IN THE KWAZULU-NATAL MIDLANDS

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SUMMARY

Studies indicated tentatively that foliar applications were ineffective and falsely inflated annual boron analysis results. In spite of sprays, mean leaf boron concentrations varied from 28 - 33 mg·kg^{-1}, which is considered to be deficient. Soil B analyses from four growing areas in KwaZulu-Natal, revealed deficient levels of B, all showing concentrations of less than 1 mg·kg^{-1}. Field trials experimented with soil boron (in the form of Borax) application rates in the range of 5 to 60 g·m^{-2}·year^{-1} 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 fruit numbers. Glasshouse trials showed that 'Edranol' rootstock was 40% more efficient at boron uptake than the widely used 'Duke 7' rootstock.

KEY WORDS: Boron deficiency, fertilisation, nutriment content, foliar spraying.
ABBREVIATIONS: B=Boron; C.E.R.U= Controlled environment research unit; ICP-AES= Inductively coupled plasma atomic emission spectroscopy.

INTRODUCTION

The 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 within the adequate range, i.e. 50 mg·kg^{-1} 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 (Jaganath and Lovatt, 1995; Robbertse *et al*., 1992)

Deficiency symptoms have only recently been identified in Australia, and are until very recently remained unrecognised 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 downward 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 localised necrosis.

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

Research has been undertaken at the University of Natal since 1995, evaluating orchard B status, as well as determining the merit of soil B application, while minimising risk of toxicity.

MATERIALS AND METHODS

Orchard surveys

Farm leaf analysis 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 (Wear, 1965).

Field trials

Trials were initiated at Cooling Estate (30^{o}40'E and 29^{o}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' rootstock planted in 1987. These trees showed chronic B deficiency symptoms when the trial was initiated. Boron was applied in the form of Borax (11% B) at 6 rates; 0, 5, 10, 20, 40 and 60 g Borax per $m^{-2}\cdot year^{-1}$ of canopy area, split into three equal applications, in October, February and April.

This trial was repeated in younger 'Hass' on clonal 'Duke 7' rootstock trees established in 1992. This trial site was gently sloping (< 5%) and trees showed excellent uniformity. Trees showed no severe deficiency symptoms and leaf analysis in 1994 showed B concentration of 25 $mg\cdot kg^{-1}$.

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 soil moisture tension exceeded below -40 kPa.

Data collection spanned from March 1995 to February 1997. No harvest was measured in 1995. Monthly leaf samples were taken before 07h00 (while still wet), and 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) = ≤170 g; count 22 = 171 to 190 g; count 20 = 191 to 210 g; count 18 = 211 to 235 g; count 16 = 236 to 265 g; count 14 = 266 to 305 g; count 12 = 306 to 365 g.

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 were obtained from Westfalia Nursery, Duiwelskloof after the first flush following grafting had matured. Plants were transplanted into 8 liter 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 8 g Borax m^{-2} pot area) applied to two physically and chemically contrasting soils. The final treatment was 8 g Borax m^{-2} applied in combination with 40 g lime and 40 g gypsum per pot and aimed at determining the calcium/boron relationship. Lime was mixed into the profile, and 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 $7^{o}C$ by a 2 kW fan heater in cold weather and between $18^{o}C$ (night) and $28^{o}C$ (day) by fans and evaporative cooling through a wet wall.

Pots were raised on bricks to minimise 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 minimise chance of infection. Plants were individually irrigated by hand on a daily basis so that leaching would be minimised.

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

RESULTS AND DISCUSSION

Orchard survey

The survey of farm record annual leaf analyses indicated that the mean leaf B concentrations varied in the range 28 to 33 $mg{\cdot}kg^{-1}$ (Figure 1). Annual mean leaf B concentration fluctuated from 22 to 54 $mg{\cdot}kg^{-1}$ (Figure 2). Annual fluctuations were alternately high and low for Cooling and St. Paul and Cooling Estates. Baynesfield Estate showed a steady decline over 4 seasons decreasing from 44 $mg{\cdot}kg^{-1}$ in 1993 to 22 $mg{\cdot}kg^{-1}$ 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 unquantified. Real B concentrations can be expected to be somewhat lower. Visits to all estates revealed visual symptoms in most orchards. This suggested that real leaf B concentration was considerably lower than was indicated in annual leaf analyses. Whiley *et al.* (1996) indicated that deficiency symptoms only developed when leaf concentrations fell below 25 mg·kg^{-1}, since it is unlikely that symptoms noticed would have occurred at the noted leaf B concentrations. Real leaf concentrations must therefore be significantly lower. These results suggest that the current method of foliar application cannot be considered effective in KwaZulu-Natal.

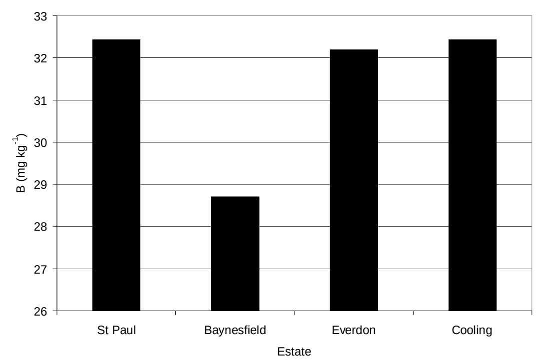

Figure 1. Average leaf boron concentration for 4 KwaZulu-Natal avocado orchards.

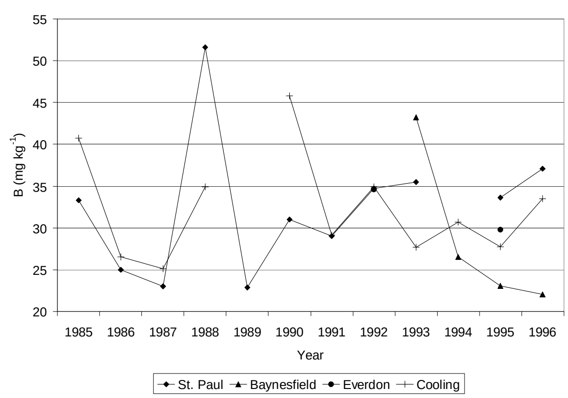

Figure 2. Annual average leaf boron concentration in 4 KwaZulu-Natal avocado orchards.

Orchard trials

All soil applications raised leaf B concentrations higher than those of the control (Figures 3 and 4). The 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 (Figure 3), and between April and May for the younger trees (Figure 4). This was the time during which developing flushes were maturing and fruit growing. It appears soil B applications are able to cater for the tree's heavy demands for B during this time.

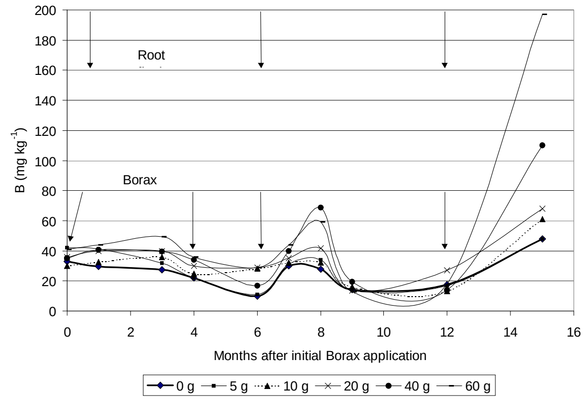

Figure 3. Effect of soil boron application on leaf B concentration of mature 'Hass' trees. Rates are g borax m^{-2}·year^{-1} of canopy area, divided into three applications in October, February and April.

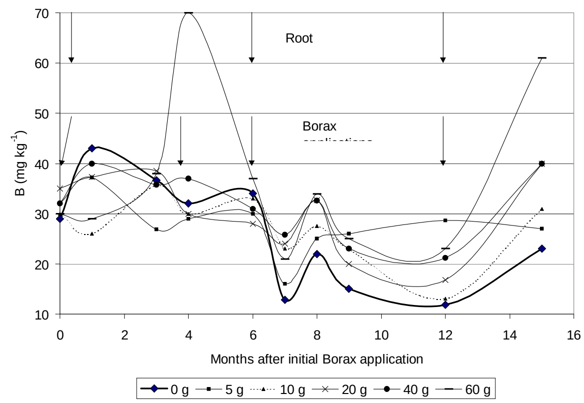

Figure 4. Effect of soil boron application on leaf B concentration of young 'Hass' trees. Rates are g borax m^{-2}·year^{-1} of canopy area, divided into three applications in October, February and April.

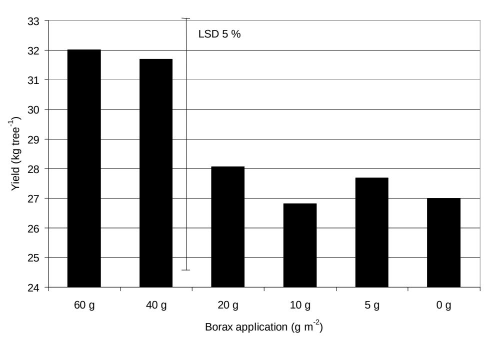

Figure 5. Effect of soil boron application on tree yield in young 'Hass' trees. Application rates are g borax m^{-2}·year^{-1} of canopy soil area, divided into three applications.

Boron toxicity was initially suspected during October 1996 in the 60 g·m^{-2}·year^{-1} treatment and was confirmed when severe toxicity symptoms appeared in both 40 and 60 g·m^{-2}·year^{-1} in January 1997, 15 months after initial application. Symptoms appearing as marginal interveinal necrotic areas were initially visible at the leaf apex, moving progressively towards the petiole end. Leaf B concentration showed cyclical variation throughout the year (Figures 3 and 4). Highest leaf concentrations occurring during June 1996 and January 1997 indicated that times of greatest uptake were November to February followed by April to June.

Soil B applications should be made so as to optimise B supply during peak uptake periods mentioned. Applications should preferably be made 3 to 4 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 can be injected into irrigation water during peak uptake periods. Timing of application becomes less important once soil and plant B reserves have increased to within the adequate range.

Results suggest that initially a moderate application rate (10 to 15 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 appear to be at a peak during this interval in KwaZulu-Natal.

Fruit yield per tree (Figure 5) increased in young B treated trees. Effect of B on average fruit size in young trees (Figure 6) was less clear. 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 of larger fruit sizes while control trees showed increased production of smaller counts. No differences in total fruit number per tree were noticed; hence increase in yield can be attributed to increased fruit size.

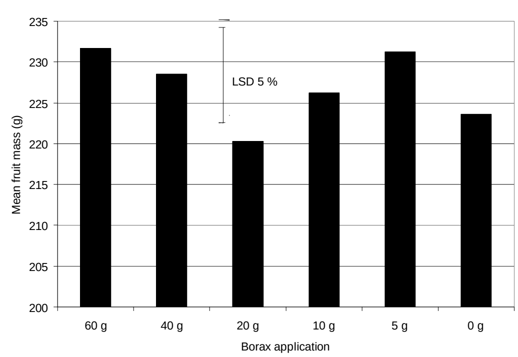

Figure 6. Effect of soil boron application on mean fruit mass in young 'Hass' trees. Application rates are g borax m^{-2}·year^{-2} of canopy soil area divided into three applications.

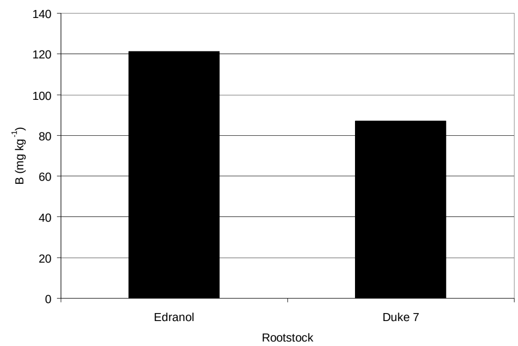

Figure 7. Effect of soil boron application on leaf B concentration of young plants growing on Duke 7 and Edranol rootstock. Application rates are g borax m^{-2} pot surface area applied after planting. Ca indicates application of 40 g calcitic lime and 40 g gypsum per replication.

Glasshouse trial

'Edranol' rootstock proved to be 40% more efficient ($P \leq 0.01$) at B uptake than 'Duke 7' rootstock with 2 different soils in the range of 0 to 12 g Borax m^{-2} pot surface area (Figure 6). 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' rootstock (Mexican origin). Toxicity symptoms appeared at leaf B concentrations of over 100 $mg{\cdot}kg^{-1}$ and defoliation and subsequent death began above 150 $mg{\cdot}kg^{-1}$.

Limed treatments were significant in 'Edranol' rootstock ($P \leq 0.05$) where liming decreased B concentration by 167 and 63 $mg{\cdot}kg^{-1}$ (± 20.9) for soils 1 and 2 respectively. Results indicate that B uptake in 'Edranol' rootstock is more sensitive to liming than 'Duke 7' rootstock.

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 $mg{\cdot}kg^{-1}$). Leaf analysis shows that the 'norm' of 40 to 60 $mg{\cdot}kg^{-1}$ 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 has a relatively high tolerance of soil B concentrations. Field trials indicate that uptake is slow particularly after initial applications, but have a longer lasting effect than foliar applications.

Glasshouse trials indicate that toxicity occurs easily in younger trees. 'Edranol' rootstock is more efficient at B uptake; however, since differences in leaf B concentration between the 2 rootstocks were marginal in control trees, B deficiency in South Africa is probably as a result of extremely low soil B reserves. Results indicate that toxicity is likely to occur at lower application rates in 'Edranol' rootstock than for 'Duke 7' rootstock.

CONCLUSIONS

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

Finally, it must be emphasised that although this trial used applications of up to 60 $g \cdot m^{-2} \cdot year^{-1}$, these were experimental in nature and should not be used commercially. Highest commercial dose would be 15 $g \cdot m^{-2} \cdot year^{-1}$ (applied as 3 split applications) and consultation with an experienced horticulturist is crucial.

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