THE IMPACT OF FOLIAR APPLICATIONS OF NITROGEN AND BORON ON 'HASS' AVOCADO FRUIT SET IN 2004.

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ABSTRACT

Boron is an essential trace element and nitrogen is an essential macro element for avocado trees with an important role in flowering and fruit set. Foliar applied boron in South Africa and California has increased the boron content of flowers which has been correlated with increased fruit set. Increasing the boron content of inflorescences did not have a consistent effect on increasing yield in Florida and Spain. Foliar applied nitrogen has been reported to increase yield in Fuerte avocado trees and in Israel urea applied to leaves has increased the nitrogen content of the flowers. Application of foliar boron at the early stages of the expanding flower panicles is a common practice in New Zealand thought to enhance fruit set but has not been evaluated for its effect on fruit set. The inconsistent effects of foliar applied boron and nitrogen found in other countries implies that fruit set may not always be enhanced. A study was conducted to determine if applying foliar boron as Solubor®, nitrogen as low biuret urea and boron and nitrogen in combination on ‘Hass’ avocados increased fruit set on two orchards. Boron content of inflorescences was increased by up to 2 fold compared to control inflorescences. Nitrogen application did not increase flower nitrogen content or flower boron concentration. A combination spray of nitrogen and boron generally increased the boron content of inflorescences. There was no effect of treatment on the concentration of the other minerals analysed. The optimum boron concentration in the inflorescence for maximum fruit number was between 50 to 65 ppm. Inflorescences with boron concentrations above or below 50 to 65 ppm did not differ in their fruit counts. Fruit numbers were increased by 30% to 60% at the optimum boron content compared to the control. There were greater differences in fruit numbers between orchards with Orchard 2 having 2 to 3 times more fruit than Orchard 1 at similar flower boron concentration. This indicates the boron and/or nitrogen in inflorescences alone does not limit fruit set of New Zealand 'Hass' avocado trees. This suggested that applying foliar boron and/or nitrogen to inflorescences was not overcoming a factor that was limiting fruit set and that there are unknown tree factors limiting fruit set. Additionally, applying foliar boron as a blanket spray to avocado trees cannot be guaranteed to ensure that the optimum boron concentration is not exceeded. Therefore increasing the boron content of ‘Hass’ avocado flowers could be having a small impact on increasing fruit set.

Keywords: *minerals, flowers*

INTRODUCTION

Boron is an essential trace element for avocado trees (Whiley *et al.*, 1996) playing an important role in flowering, fruit set and fruit development (Lahav and Whiley, 2002). Avocado pollen germination, pollen tube growth and fertilisation of the ovule have all been shown to be enhanced following application of foliar boron to flowers (Jaganath and Lovatt, 1995). Foliar applied boron in the form disodium octaborate tetrahydrate (commercially available as Solubor®) to mature 'Hass' avocado leaves and flowers in South Africa significantly increased boron content in inflorescences and was correlated with an increase in fruit set (Robbertse *et al.*, 1992). 'Hass' avocado trees on 'Duke 7' rootstocks in California when treated with foliar sprays of Solubor® at the cauliflower stage of flower bud development had increased cumulative yield over three years by 25% and 23%, respectively (Jaganath and Lovatt, 1995). Foliar applications of Solubor® applied to the West Indian cultivars 'Booth

7' and 'Lula' in Florida increased inflorescence boron concentrations from 1.5 to 12.1% higher than that in leaves (Li *et al*., 1997). The effect of increased boron in inflorescences on yield depends on cultivar and application rate as the yield of 'Booth 7' trees was increased when Solubor® was applied at 1.1 kg per hectare but was not increased when Solubor® was applied at 2.2 kg per hectare (Li *et al*., 1997). By contrast the yield of 'Lula' avocado trees was not affected by the application of Solubor® (Li *et al*., 1997). This suggests that there is an optimum rate of Solubor® application depending on the cultivar being treated and may explain why the yield of 'Hass' avocado trees treated with 2.35 kg Solubor® when the flowers were at the cauliflower stage in Spain was not affected despite increased leaf boron concentration (Torres *et al*., 2002).

Nitrogen is also an essential macro element for avocados (Lahav and Whiley, 2002) and foliar applications of nitrogen have been investigated as potential treatments to enhance fruit set in avocados (Jaganath and Lovatt, 1995; Lovatt, 1999). The premise of using foliar applications of nitrogen as low biuret urea (46% elemental nitrogen) is based on research that has shown foliar applied nitrogen has increased the yield of 'Fuerte' avocado trees (Abou Aziz *et al*., 1975). Further research has also demonstrated that 'Fuerte' avocado leaves dipped in solutions of urea at concentrations up to 8% absorbed between 65-85% of the available nitrogen after 2 to 5 days (Klein and Zilkah, 1986). The nitrogen absorbed by the leaves appears to be translocated to the inflorescences with the percentage of nitrogen in the flowers proportional to the amount applied to the leaves (Zilkah *et al*., 1987). Urea treated leaves irrespective of proximity to the inflorescences were equally effective in increasing the nitrogen content of inflorescences suggesting that urea applications do not need to be targeted to the inflorescences (Zilkah *et al*., 1987). The application of urea also increases the number of lateral inflorescences down a branch extending the flowering period (Zilkah *et al*., 1987). However, there were phytotoxic symptoms to leaves caused by urea applications above a concentration of 4% (Klein and Zilkah, 1986; Zilkah *et al*., 1987). In addition, 'Fuerte' avocado flowers have been reported to be damaged at urea concentrations above 0.5-1% (Klein and Zilkah, 1986).

In New Zealand, applying Solubor® to enhance fruit set is a common recommendation and is based on practices recommended in South Africa and elsewhere. Foliar application of 1% low biuret urea is also advocated and Solubor® is usually applied in combination with the low biuret urea up to three times over flowering. These times are: at the initial cauliflower stage, 15% expanded but unopened flower buds and when about 30-50% expanded with spring vegetative flush. From 2003 the amounts of elemental boron being recommended are 940.5 g per hectare (three lots of 313.5 g, 100g Solubor® in 100 L, sprayed to runoff at 1500 L per hectare) and 20.7 kg elemental nitrogen (three lots of 1% low biuret urea at 15 kg per 1500 L) compared to the recommendation before 2003 of 15 g elemental boron per hectare (three lots of 5 g, 1 kg Fetrilon Combi 2 in 1500L per hectare) and 15.6 kg elemental nitrogen (three lots of 0.75% low biuret urea at 11.25 kg per 1500 L). These rates of Solubor® and low biuret urea application are a 60 fold increase in the amount of elemental boron being applied than previously recommended during flowering. To the authors knowledge the application of Solubor® or low biuret urea has not been evaluated for its effect on fruit set of New Zealand 'Hass' avocado trees.

In a study conducted on commercial 'Hass' avocado trees in California foliar applications of Solubor® or low biuret urea as an individual spray during the cauliflower stage of development significantly increased the number of pollen tubes that reached the ovule, increased ovule viability and cumulative yield over untreated trees (Lovatt, 1999). When a combined foliar application of boron plus low biuret urea was used there was no effect on yield despite increased numbers of pollen tubes reaching the ovule and increased ovule viability (Jaganath and Lovatt, 1995; Lovatt, 1999). The conclusion from this research was that to be effective foliar applications of boron or low biuret urea must be directly to the inflorescences and that combining boron and nitrogen foliar applications is not beneficial in improving yield (Lovatt, 1999). Such results argue that the current practice of applying boron and nitrogen in combination at flowering may not be enhancing fruit set. A study was conducted to determine if applying nitrogen or boron as individual foliar sprays and a combination spray of boron and nitrogen during flowering is beneficial to fruit set of New Zealand 'Hass' avocado trees.

MATERIALS AND METHODS

Avocado trees cultivar 'Hass' on seedling 'Zutano' rootstock were selected in two commercial orchards in the Bay of Plenty region (37°S, 176°E) for foliar applications of 1% low biuret urea (46% nitrogen, <0.2% biuret content) or disodum octaborate tetrahydrate (Solubor® 20.9% w/w boron) dissolved in water at a rate of 100 g per 100 L water. The trees used in Orchard 1 were 7 years old and between 5 to 6 meters height and breadth, fertilised according to accepted industry norms but were not irrigated and had no pollenizer trees planted within the orchard block. The trees used in Orchard 2 were similar in age, shape and size to those in Orchard 1 but were irrigated every 4 days and had very large (15m+ height) Zutano pollenizer trees within 20m. Both orchards used managed bees for pollination. In each orchard 8 trees similar in size and shape were selected for treatment. Sixteen similar branches on each tree were selected at random to be treated with one of four treatments:

1) Control: not sprayed
2) Nitrogen only: 1% low biuret urea
3) Boron only: Solubor® at a rate of 100g per 100 L
4) Nitrogen and Boron (N+B): a combination spray of 1% low biuret urea and Solubor® at 100g per 100 L.

The foliar applied fertiliser was applied to run-off and care was taken to spray only the branch being treated to avoid cross-contamination of treatments. Both leaves and developing inflorescences were sprayed. Each tree therefore had all four treatments applied. As 4 branches per treatment on 8 trees in each orchard were treated the experiment was effectively repeated 8 times in each orchard.

For Orchard 1 treatments were applied on the 28/10/2004 when the flower buds were at 15-20% expansion. For Orchard 2 treatments were applied on 28/10/2004 when the flower buds were at 15% expansion. Flowering was more advanced on Orchard 2 than Orchard 1 but was still within the accepted treatment window. All of the inflorescences on one branch per treatment from each tree were selected for mineral analysis 8 days after treatment. As the mass of inflorescences from one branch was an insufficient quantity of fresh material for mineral analysis the inflorescences from two adjacent trees were combined for analysis by Hill Laboratories, a commercial testing facility located in Hamilton, New Zealand for plant material.

Fruit counts were made before the first fruit drop at about one month after application of the treatments on the 22/12/2004 for Orchard 1 and 16/12/2004 for Orchard 2 and after the first main fruit drop on the 25/1/2005 for Orchard 1 and 28/1/2005 for Orchard 2.

The data was analysed as treatments nested within tree replicates. Where appropriate the data was square root transformed to meet the assumption of normality for One way analysis of variance using MINITAB version 13.31. Means presented in tables are untransformed means.

RESULTS

Effect on mineral content of inflorescences

Foliar application of boron increased the boron content of inflorescences by up to 2 fold compared to control inflorescences (Table 1). Application of nitrogen alone did not increase inflorescence nitrogen or boron concentration relative to control inflorescences. A combination spray of low biuret urea and boron generally increased the boron content of inflorescences compared to control inflorescences but the boron content was only greater than the boron only treatment for Orchard 2 inflorescences. There was no effect of treatment on the concentration of the other minerals analysed (Table 1).

and this pattern did not change after the December fruit drop. The optimum boron concentration in the inflorescence for maximum fruit number was between 50 to 65 ppm for each orchard. Inflorescences with boron concentrations above or below 50 to 65 ppm were not different in their average fruit counts (Figure 1).

Table 1. Mineral content of inflorescences sampled after 8 days foliar application of 1% low biuret urea and/or Solubor® at 100g per 100L.

Orchard 1							Mineral					
Treatment	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
				%					Mg/kg dry weight			
Control	2.7	0.3	1.7	0.2	0.4	0.2	0.02	63.3	47.0	47.0	12.0	44.5a[1]
Nitrogen	2.8	0.3	1.5	0.2	0.3	0.2	0.02	58.5	36.0	40.3	10.5	57.3ab
Boron	2.8	0.3	1.6	0.2	0.4	0.2	0.02	59.8	35.3	44.8	13.0	82.0c
N+B	2.7	0.3	1.6	0.2	0.4	0.2	0.02	63.5	45.0	40.3	12.0	76.0bc

Orchard 2							Mineral					
Treatment	N	P	K	S	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
				%					Mg/kg dry weight			
Control	2.5	0.3	1.9	0.2	0.4	0.2	0.01	56.6	43.3	37.0	23.0	34.8a
Nitrogen	2.5	0.3	1.8	0.2	0.4	0.2	0.01	57.5	41.0	35.3	27.0	41.5ab
Boron	2.4	0.3	1.8	0.2	0.4	0.2	0.01	57.5	44.5	35.8	24.0	51.3b
N+B	2.4	0.3	1.8	0.2	0.4	0.2	0.02	55.8	43.8	35.0	27.8	73.3c

[1]*Means followed by the same letter are not different according to a One-way analysis of variance using Tukeys family error rate of 5%.*

Effect on fruit set

Fruit numbers were between 200% and 300% greater in Orchard 2 than Orchard 1 (Table 2) at similar concentrations of boron in the inflorescence while the flowers at the optimum boron concentration had increased fruit set between 30 to 60% compared to the untreated controls (Figure 1). There was a similar pattern of fruit numbers per branch with boron concentration in the inflorescences (Figure 1). The average fruit count per branch was related to the average boron content of the inflorescence in a curvilinear manner

There was no obvious visual negative effect on fruit set of applying boron in combination with nitrogen, nor did there appear to be deformed fruit in the boron plus nitrogen treatment. Average fruit counts per branch were similar for all treatments in Orchard 1 but were greater in the boron only treatment for Orchard 2 after the first fruit drop (Table 2). For trees in Orchard 1 the average fruit count for the nitrogen only treated branches was twice that of the control branches but the difference was not significant due to one of the nitrogen only treated branches having an extreme fruit set of 591 fruit skewing the average. When the fruit count of the branch with the very high fruit set was removed from the statistical analysis as an outlier the branches treated with nitrogen only still tended to have the greatest fruit numbers before and after the fruit drop. For Orchard 1 the nitrogen only treatment had the greatest fruit count while the boron only treatment had the greatest fruit count in Orchard 2.

Table 2. Average fruit count of branches treated with 1% low biuret urea, Solubor® (100 g per 100L) or a combination of low biuret urea and Solubor® one month after application and after the first fruit drop.

	Orchard 1		Orchard 2	
Treatment	**22/12/2004**	**25/1/2005**	**16/12/2004**	**28/1/2005**
Control	34.8[1]	2.2	106.4	12.5a[2]
Nitrogen	48.3 (70.9)[3]	3.3 (4.5)	113.9	12.8ab
Boron	33.0	1.2	129.3	17.6b
N+B	38.8	2.7	95.6	12.2a

[1]Average number of fruit per branch; [2] Means followed by the same letter are not different according to a One-way analysis of variance using Tukeys family error rate of 5%; [3]Figures in brackets are the average fruit count including the branch with 591 fruit.

DISCUSSION

Applying foliar boron and/or nitrogen to avocado inflorescences when the flower buds have started to expand had an inconsistent effect on fruit set that was orchard dependant. Such variable results on fruit set have been reported previously (Torres *et al*., 2002; Lovatt, 1999; Li *et al*. 1997) but no explanation has been given as to why some treatments work on some orchards but not others. The results presented here imply that boron or nitrogen alone were not limiting fruit set on the trees used in this study, as there was a large difference between trees from different orchards in the number of fruit initially set. The trees used in this study from each orchard were of similar size and shape and managed in a similar manner therefore there is an unknown tree factor influencing fruit set.

The optimum boron concentration in the inflorescence for maximum fruit number was between 50 to 65ppm and is similar to that reported by Robbertse *et al*. (1992) in South Africa. That the optimum boron concentration in the inflorescence is limited to 50 to 65 ppm may explain why there are variable results from orchard to orchard when foliar boron is applied. If the boron content of the inflorescences was already in the optimum range at the time of foliar boron application then additional boron would appear to decrease fruit set from the optimum. Increasing inflorescence boron above the optimum range would in effect be a waste of time as the fruit set would be similar to the fruit set if foliar boron was not applied. Application of foliar boron would be worthwhile if the boron in the flowers was less than 50ppm and the additional boron did not raise flower boron levels beyond 65ppm. In this study the boron content of individual branches was not determined but the expectation would be that variation in boron content of inflorescences is large between branches on the same tree, between trees within an orchard and trees from different orchards. By determining the variability in boron content between trees and branches it should be possible to further refine the optimum boron concentration for fruit set. If there are large differences between trees and branches within a tree the effect on fruit set of a foliar application of nitrogen and/or boron may depend largely on the boron state of each tree being treated.

This study investigated the effect of a single foliar application of boron and/or nitrogen to the early

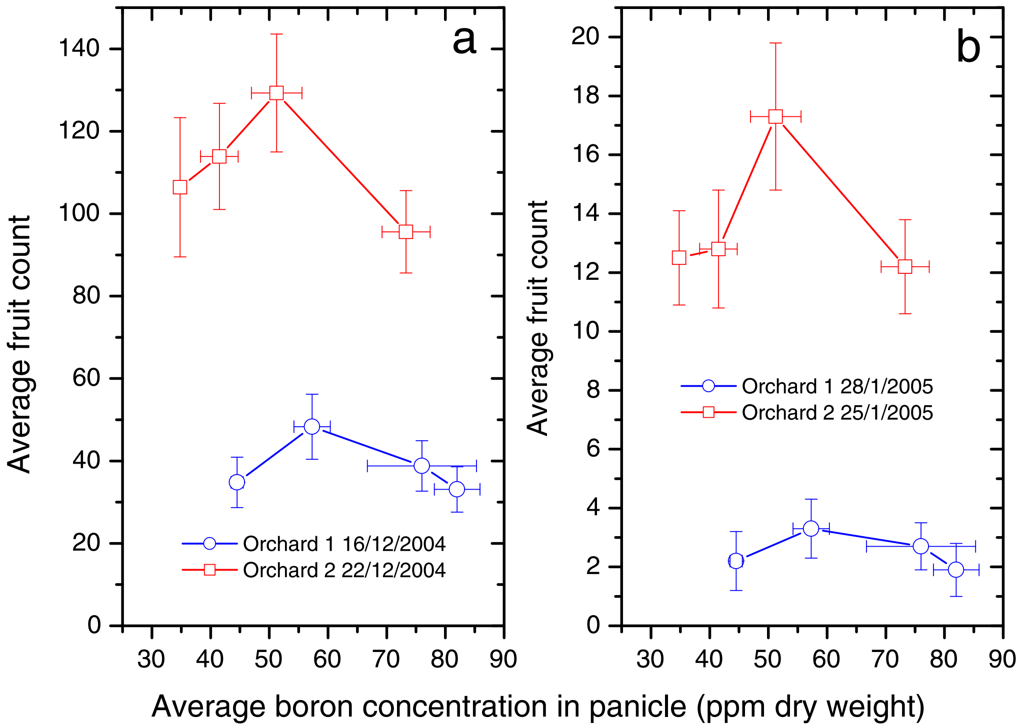

Figure 1. Relationship between average fruit count per branch at a) before first fruit drop and b) after first fruit drop and boron content of inflorescences following foliar applications of low biuret urea and boron or a combination of low biuret urea and boron to individual branches. Vertical bars represent standard error of the mean of fruit counts and horizontal bars represent standard error of the mean of boron concentrations in the inflorescences.

stage of inflorescence development. A common industry recommendation is for three foliar applications of boron over the course of the bloom. The results reported here suggest that multiple applications of foliar boron would raise the inflorescence boron well past the optimum levels found in this study. If a single application of foliar boron can raise boron levels to between 80 to 90ppm then a multiple application may raise boron levels to where they reduce fruit set. It is equally possible that the boron is utilised by the developing flowers and newly set fruit so that multiple applications of boron will be beneficial to fruit set as the flowering and emergence of new fruit and shoot flush occur. A further study investigating multiple applications of foliar boron and/or nitrogen and the relationship between leaf and flower levels of boron is required to better refine the use of boron at flowering.

CONCLUSIONS

The optimum flower boron concentration for fruit set is between 50 to 65ppm. Above or below these values there is the equivalent fruit set. A blanket spray of soluble boron cannot guarantee that the flower boron will not exceed 65 ppm and therefore the additional applied boron will be wasted. Further research is required on the effect of multiple boron sprays and to confirm that the orchard to orchard variation in fruit set is not related to flower boron levels.

REFERENCES

Abou, Aziz A.B., Desouki, I. and El-Tanahy, M.M. (1975). Effect of nitrogen fertilization on yield and fruit oil content of avocado trees. *Scientia Horticulturae* **3**: 89-94.

Jaganath, I. and Lovatt, C.J. (1995). Efficacy studies on prebloom canopy applications of boron and/or urea to 'Hass' avocados in California. *Proceedings of the World Avocado Congress III* pp. 181-184.

Klein, I. and Zilkah, S. (1986). Urea retention and uptake by avocado and apple leaves. *Journal of Plant Nutrition* **9**: 1415-1425.

Lahav, E. and Whiley, A.W. (2002). Irrigation and mineral nutrition. *In The Avocado: Botany, Production and Uses.* (Eds A.W. Whiley, B. Schaffer and B.N. Wolstenholme) CAB International Oxon, New York.

Li, Y.C, Crane, J.H., Davenport, T.L. and Balerdi, C.F. (1997). Preliminary findings on the effects of foliar-applied urea and boron on plant nutrition, fruit set and yield of avocado trees. *Proceedings of the Florida State Horticultural Society* **110**: 136-138.

Lovatt, C.J. (1999). Timing of citrus and avocado foliar nutrient applications to increase fruit set and size. *HortTechnology* **9**: 607-612.

Robbertse, P.J., Coetzer, L.A. and Bessinger, F. (1992). Boron: Uptake by avocado leaves and influence on fruit production. *Proceedings of Second World Avocado Congress* Vol. I: 173-178.

Torres, M.D., Farré, J.M. and Hermoso, J.M. (2002). Foliar B, Cu and Zn applications to Hass avocado tree, penetration, translocation and effects on tree growth and cropping. *Acta Horticulturae* **594**: 105-111.

Whiley, A.W., Smith, T.E., Saranah, J.B. and Wolstenholme B.N. (1996). Boron nutrition of avocados. *Talking Avocados* **7**: 12-15.

Zilkah, S., Klein, I., Feigenbaum, S. and Weinbaum, S.A. (1987). Translocation of foliar applied urea ^{15}N to reproductive and vegetative sinks of avocado and its effect on initial fruit set. *Journal of the American Society of Horticultural Science* **112**: 1061-1065.

