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

J. Dixon, D.B. Smith, T.A. Elmsly, A.C. Greenwood and E.M. Dixon
Avocado Industry Council Ltd., P.O. Box 13267, Tauranga 3110
Corresponding author: jonathandixon@nzavocado.co.nz

ABSTRACT

In previous research a single foliar application of boron and/or nitrogen to 'Hass' avocado inflorescences indicated there was an optimum flower boron concentration between 50 to 65ppm for fruit set. The research did not test for the effects of multiple applications of foliar boron on fruit set, leaf boron content, or response of trees to additional boron in an "on" or "off" year of the alternate bearing cycle. Two further studies were conducted in 2005 and 2006 of applying foliar boron up to three times, once with foliar nitrogen and a combination of foliar boron and nitrogen. These treatments were examined for their ability to enhance fruit set. Application of foliar boron and/or nitrogen to inflorescences when they started to expand did not enhance fruit set. No optimum boron level for fruit set was apparent in the flowers treated in 2005 and 2006. Multiple applications of foliar applied boron did not enhance fruit set or increase the boron content significantly beyond that of a single application of boron to flower buds when they first started to expand. Multiple applications of boron also did not enhance fruit set when an orchard was in an "off" year. Such results suggest that applying boron multiple times during flower development is not required for good fruit set nor can multiple applications overcome the effect of alternate bearing on fruit set. The lack of a consistent enhancement of fruit set through using foliar applications of boron over three years is an unnecessary orchard practice as long as a balanced fertilizer programme is used on the orchard.

Keywords: *minerals, flowers*

INTRODUCTION

The essential trace element boron and macro element nitrogen have been applied to avocado flowers in California, Florida and South Africa with the objective of increasing fruit set and ultimately yield (Jaganath and Lovatt, 1995; Li *et al.*, 1997; Robbertse *et al.*, 1992). A single foliar application of boron and/or nitrogen to New Zealand 'Hass' avocado inflorescences (Dixon *et al.*, 2005) appeared to indicate there was an optimum flower boron concentration between 50 to 65ppm for fruit set. Above or below these boron concentrations there was equivalent fruit set. It is common practice to apply up to three foliar applications of boron over flowering to 'Hass' avocado trees in New Zealand. Exceeding a flower boron concentration of 65ppm was found to be easily possible with foliar boron applications as the initial boron content of the tree may be high. If an inflorescence concentration above 65ppm is not effective in enhancing fruit set and exceeding 65ppm boron in the inflorescence can be achieved with one foliar application of boron multiple applications of foliar boron may have no effect on improving fruit set. The previous trial did not test for the effects of multiple applications of foliar boron. It is not known if further applications of foliar boron will increase inflorescence boron levels to point where they are toxic or reduce fruit set. Additional boron could be used by the developing flowers, newly set fruit and new shoot flush so that foliar boron will help to maintain boron levels when demand for boron is high and could therefore lead to greater yield.

Leaf boron concentrations reach their lowest values in September when flower buds are developing for spring flowering (Dixon *et al.*, 2006). The lower leaf boron levels at flowering have been hypothesized to be re-allocated from the leaves to the developing inflorescence and shoots (Lahav and Whiley, 2002). In the previous research project the boron content of leaves on treated and untreated branches was not measured so the effect of treatment on leaf boron content is unknown. The effect on fruit set of applying foliar boron could not be separated from the initial boron state of the tree. The leaf boron content of the branches treated and untreated with foliar boron could be used to establish the initial boron state of the trees when the treatments were applied. Leaf boron content could then be compared to flower boron content to determine the optimum leaf concentration at the optimal flower boron content for fruit set.

Another factor that was not considered in the 2004 study was the possible different response of trees to additional boron in an "on" or "off" year of the alternate bearing cycle. In 2004 there was a greater difference in fruit set between orchards at the same boron level than between boron levels. The large difference in fruit set between orchards implied that boron was not limiting fruit set. The trees used in 2004 were in an "on" cropping year. Application of foliar boron may have more effect when applied in an "off" year than in an "on" cropping year. Two further studies were conducted in 2005 and 2006 applying foliar boron and/or nitrogen to 'Hass' avocado trees. In 2005 trees on one orchard in an "off" year cropping cycle were treated up to three times with foliar boron and once with foliar nitrogen and a combination of foliar boron and nitrogen. In 2006 two orchards in an "on" cropping year were treated up to three times with foliar boron and once with foliar boron and a combination of foliar nitrogen and boron. These treatments were examined for their ability to enhance fruit set.

MATERIALS AND METHODS

Treatments in 2005

Eight avocado trees, cultivar 'Hass' on seedling 'Zutano' rootstock, were selected from one commercial orchard in the Western Bay of Plenty region (37°S, 176°E) for treatment with foliar applications of 1% low biuret urea (46% nitrogen content, <0.2% biuret content) or disodium octaborate tetrahydrate (Solubor® 20.9 w/w boron) dissolved in water at a rate of 100g per 100L. The trees used were 7 years old, between 5 to 6 meters height and breadth and managed according to industry norms but had a heavy last seasons (25+ t/ha) crop, and were irrigated utilizing the soil moisture matrix potential of a 30cm tensiometer and had pollenizer trees at a ratio of 1:9. Twenty-four branches at 1.5 to 2.5m height (4 branches per treatment) on each of eight trees were randomly selected and allocated to one of six treatments at the cauliflower stage of development (Stages 1-2, Dixon *et al.*, 2005):

1) Control: not sprayed
2) Nitrogen only: 1% low biuret urea
3) Boron only: Solubor®
4) Repeat application of born: Solubor® at about 15% flower development (Stages 2-3, Dixon *et al.*, 2005)
5) Second repeat application of Solubor® at about 30-50% flower development with spring flush at about 5cm in length (Stages 3-4, Dixon *et al.*, 2005)
6) Nitrogen and Boron: a combination spray of 1% low biuret urea and Solubor®

The foliar applied fertilizer was applied on 12/9/2005 to run-off and care was taken to restrict the spray only to the branch being treated to avoid cross-contamination by enclosing each individual branch in a large plastic bag to minimize spray drift and sprayed by hand using a 3L "sprayer" until runoff. Both leaves and developing inflorescences were sprayed. All inflorescences and adjacent leaves from one branch per treatment from each tree were selected for mineral analysis 8 days after treatment, by Hill Laboratories, a commercial testing facility located in Hamilton, New Zealand. The mineral content is reported as either percent dry weight for macro elements or mg/kg (ppm) dry weight for micro elements.

Fruit counts were made before the December fruit drop at about 2 months after initial application of treatments on 16/11/2005. There were no fruit remaining after the December fruit drop; fruit counting was discontinued.

Treatments in 2006

This trial was conducted at two commercial orchards in the Western Bay of Plenty (37°S, 176°E). Thirty branches at 1.5 to 2.5m in height (5 branches per treatment) on each of eight trees on each orchard were randomly selected and allocated to one of six treatments as in 2005. The trees used were similar to the trees described for 2005 but were not irrigated and did not have pollenizer trees planted in the same block. The timing of foliar application was set according to the rate of flower bud development. All foliar treatments 2, 3, 4, 5 and 6 were applied on 1/9/2006 for Orchard A and 4/9/2006 for Orchard B at flower bud break. Repeat applications of foliar boron, treatments 4 and 5, were applied on 8/9/2006 at about 15% inflorescence development and the final application of foliar boron was applied, treatment 5, on 6/10/2006 when spring flush was about 5cm long.

All inflorescences and adjacent leaves from one branch per treatment were selected for mineral analysis three days after treatment application. Inflorescences and leaves were collected separately and were sent to Hill Laboratories for mineral analysis. The combined inflorescences or leaves from four trees were analyzed for minerals.

The newly set fruit were counted before the December fruit drop on 7/12/2006 for Orchard A and on the 22/11/2006 for Orchard B and again after the December fruit drop on 11/1/2007 for Orchard A and 7/12/2006 for Orchard B.

The data was analysed by One-Way Analysis of Variance using MINITAB 13.31.

RESULTS

Treatments in 2005

Foliar application of boron alone did not increase the boron content of inflorescences unless combined with low biuret urea (Table 1). Application of foliar nitrogen alone did not increase inflorescence nitrogen content. There was no effect of treatment on the other minerals in the inflorescences. Foliar application of boron alone or nitrogen alone did not increase the boron or nitrogen content of leaves (Table 1). Leaf boron tended to be greatest for the combined foliar boron and nitrogen treatment but this was not

Table 1. Mineral content of inflorescences and leaves sampled 8 days after application of 1% low biuret urea and/or Solubor® at 100g per 100L in 2005.

Inflorescences				**Mineral**						
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
			%					**mg/kg**		
Control	2.6	0.3	1.7	0.2	0.6	0.2	96.8	107.3	55.6	34.3a[1]
Nitrogen	2.7	0.3	1.8	0.3	0.6	0.2	97.3	104.3	62.1	33.3a
Boron x 1	2.5	0.3	1.8	0.3	0.5	0.2	96.9	100.3	56.0	30.6a
Boron x 2	2.5	0.3	1.7	0.3	0.6	0.2	102.8	109.1	55.0	43.5a
N+B	2.6	0.3	1.7	0.3	0.6	0.2	97.8	79.5	51.1	83.5b

Leaves				**Mineral**						
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
			%					mg/kg		
Control	2.5	0.1	0.9	0.3	2.0	0.5	126.3	302.5	25.8	24.0
Nitrogen	2.4	0.1	0.8	0.3	2.2	0.5	70.8	240.0	21.8	20.3
Boron x 1	2.6	0.1	0.9	0.3	2.1	0.5	68.5	150.7	24.3	20.8
Boron x 2	2.5	0.1	0.9	0.3	2.2	0.5	69.3	297.5	25.0	25.0
N+B	2.4	0.1	1.0	0.3	2.1	0.5	119.8	225.9	24.5	29.3

[1]*Means followed by the same letter in a column are not different according to a One-Way Analysis of Variance using Tukey's family error rate of 5%.*

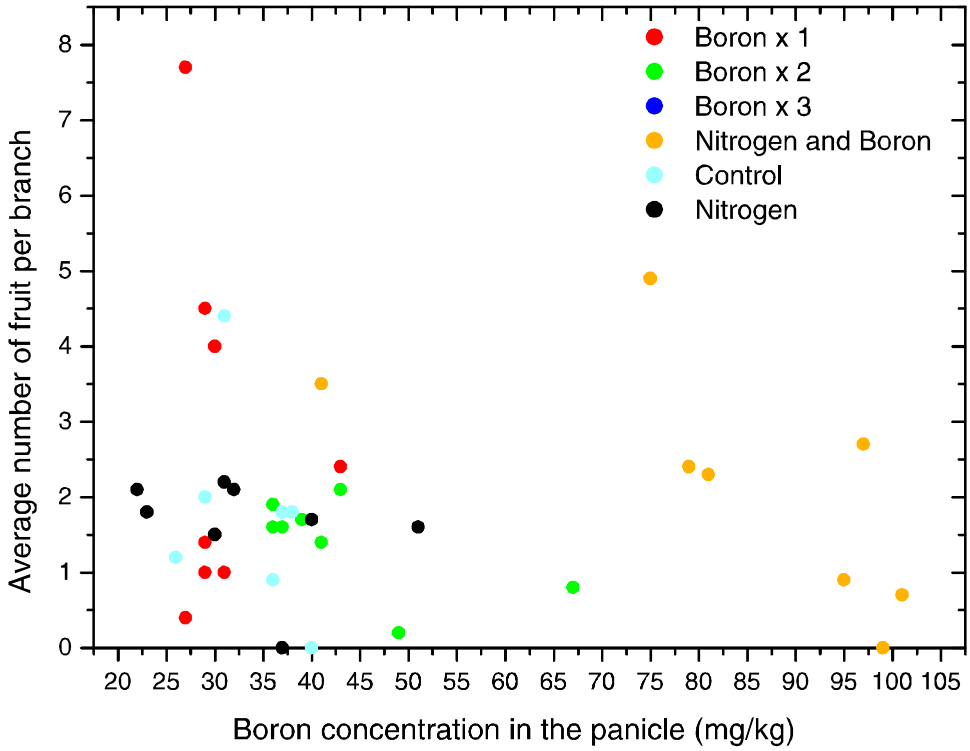

Figure 1. Relationship between inflorescence boron content and initial fruit set following treatment with foliar applications of low biuret urea (Nitrogen), boron applied once (Boron x 1) and repeat application (Boron x 2) then an additional application (Boron x 3), boron applied in combination with nitrogen and not sprayed (Control) in 2005.

significantly different to the leaf boron content in other treatments. There was no effect of treatment on the concentration of other minerals in the leaves.

Initial fruit set was very low on treated branches with an average fruit set of 1 to 3 fruit per branch (Table 2). All of these fruit dropped off in the December drop leaving all the trees with no fruit. There was no obvious visual negative effect on fruit set of applying foliar boron in combination with nitrogen.

There was no clear relationship between initial fruit set and the boron concentration within the inflorescences as there was a similar spread of fruit numbers per branch at each boron content (Figure 1). The fruit numbers at boron concentrations of 80 to 100 mg/kg were similar or lower than fruit numbers where the boron concentration was below 50 mg/kg. The boron concentration in the leaf ranged from about 15 mg/kg to 70 mg/kg across all treatments and there was no clear relationship of leaf boron content to initial fruit set (Figure 2).

The boron content of adjacent leaves and inflorescences on the same branch were positively related to one another (Figure 3). In general, leaf boron concentration was approximately 40 to 75% of the inflorescence boron content.

Table 2. Average fruit count of branches treated with 1% low biuret urea, Solubor® (100g per 100L) or a combination of low biuret urea and Solubor® one month after application, no fruit remained after the December drop.

Treatment	16/11/2005
Control	2.8
Nitrogen	1.4
Boron x 1	2.1
Boron x 2	2.2
Boron x 3	1.8
N+B	1.6

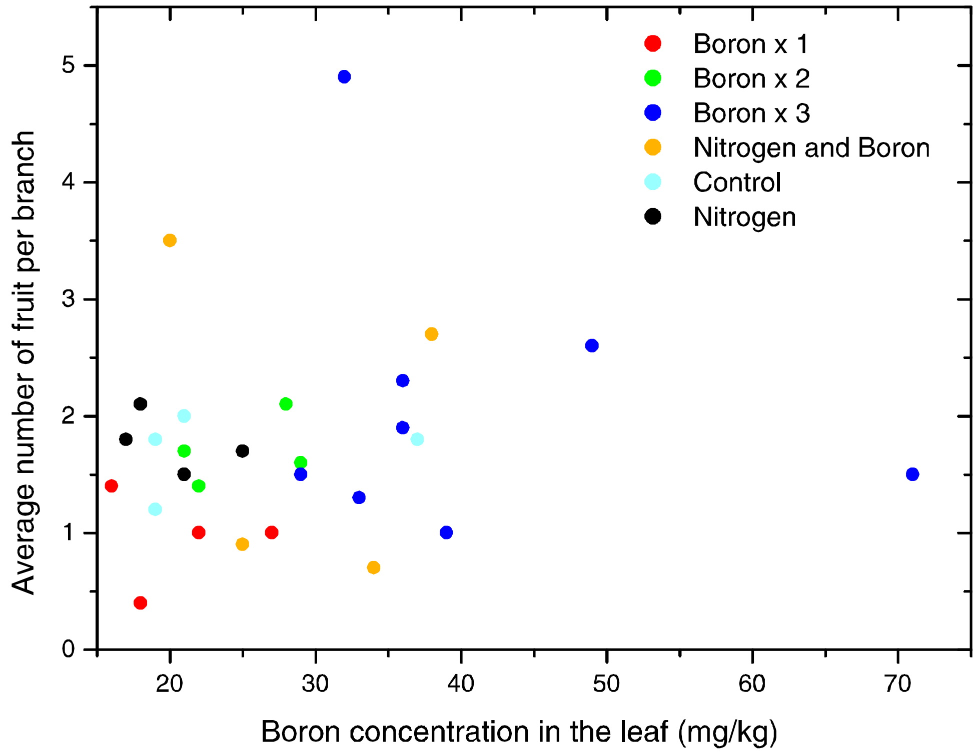

Figure 2. Relationship between boron content of adjacent leaves and initial fruit set following treatment with foliar applications of low biuret urea (Nitrogen), boron applied once (Boron x 1) and repeat application (Boron x 2) then an additional application (Boron x 3), boron applied in combination with nitrogen and not sprayed (Control) in 2005.

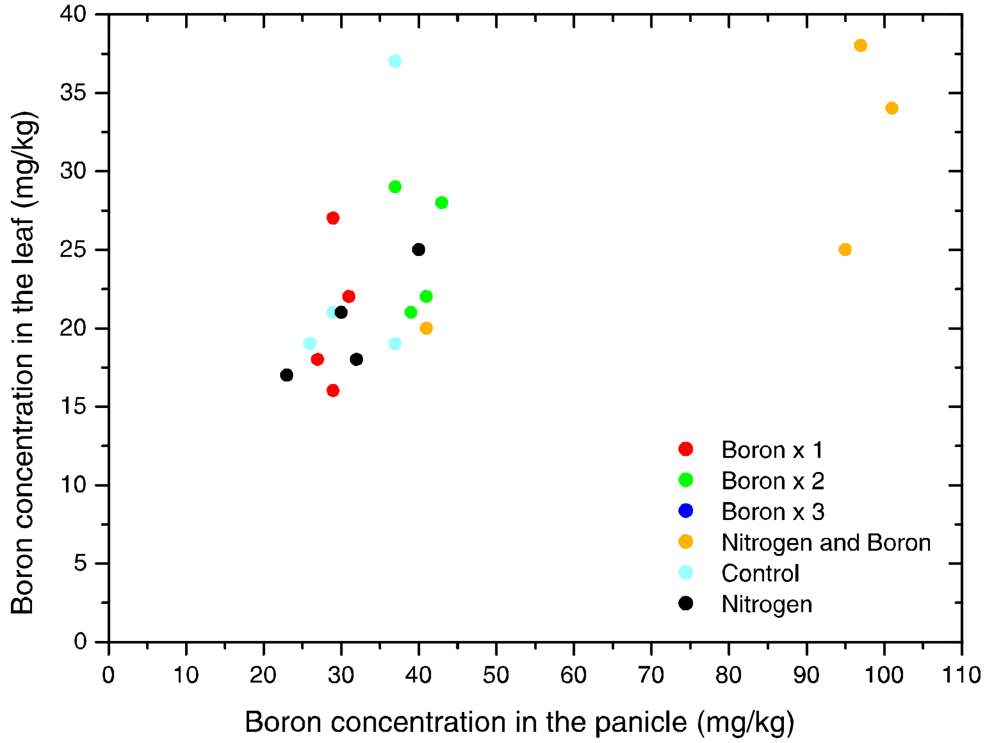

Figure 3. Relationship between leaves adjacent to flowers boron concentration and inflorescence boron content following treatment with foliar applications of low biuret urea (Nitrogen), boron applied once (Boron x 1) and repeat application (Boron x 2) then an additional application (Boron x 3), boron applied in combination with nitrogen and not sprayed (Control) in 2005.

Treatments in 2006

Foliar application of nitrogen and boron had different effects on leaf and inflorescence boron content of 'Hass' avocado trees in each orchard (Tables 3 and 4). A single foliar application of boron when the flower buds were first developing increased the boron content of inflorescences by up to 2 fold compared to control inflorescences in Orchard B (Table 4). By contrast, the boron content of inflorescences was increased a small amount by a single foliar application of boron in Orchard A (Table 3). Repeat applications of boron did not substantially increase the boron content of inflorescences over a single application of foliar boron (Tables 3 and 4). The repeat applications of boron appeared to maintain the flower boron levels while the control inflorescence boron content decreased at each repeat application time. The application of foliar nitrogen alone or in combination with boron did not increase boron content significantly above the control boron content of the inflorescences. The nitrogen treatments did not raise the nitrogen content of the flowers (Tables 3 and 4). There was no effect of treatment on the concentration of the other minerals analyzed. Leaf mineral content was not affected by treatments but there was a general trend for the minerals to decline in the control leaves at the times when boron was applied.

There was no effect of treatment in initial fruit set and fruit numbers after the December drop (Table 5). The numbers of fruit set was similar at both orchards with Orchard A having a later fruit drop than Orchard B.

Table 3. Mineral content of inflorescences and leaves sampled from Orchard A 3 days after application of 1% low biuret urea and/or Solubor® at 100g per 100L in 2006.

Inflorescences	Mineral									
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
	%						mg/kg			
Control 1	3.5	0.5	2.1	0.3	0.6	0.2	105.5	74.5	64.5	74.5
Boron x 1	3.4	0.5	2.1	0.2	0.7	0.2	79.0	75.5	60.0	92.5
Nitrogen	3.6	0.5	2.1	0.2	0.6	0.2	92.5	83.0	54.5	64.0
N+B	3.4	0.4	2.1	0.2	0.5	0.2	48.0	83.0	53.0	76.5
Control 2	3.3	0.4	2.0	0.2	0.4	0.2	66.5	68.0	55.5	67.5
Boron x 2	3.5	0.5	2.2	0.2	0.5	0.2	63.0	84.5	60.0	118.5
Control 3	2.7	0.3	1.8	0.2	0.3	0.2	58.0	43.5	42.5	46.0
Boron x 3	2.5	0.3	1.5	0.2	0.4	0.2	48.0	45.0	39.0	92.0

Leaves	Mineral									
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
	%						mg/kg			
Control 1	2.4	0.14	1.1	0.2	1.8	0.4	99.5	165.0	29.0	26.0
Boron x 1	2.4	0.13	0.8	0.2	1.6	0.4	139.0	180.0	26.0	29.0
Nitrogen	2.4	0.13	0.8	0.2	1.9	0.4	114.0	155.0	22.0	17.5
N+B	2.4	0.13	0.8	0.2	1.7	0.3	104.5	160.0	23.0	20.0
Control 2	2.4	0.14	0.8	0.2	1.6	0.4	100.0	170.0	24.0	20.0
Boron x 2	2.4	0.12	1.0	0.2	1.5	0.3	140.5	155.0	27.5	32.5
Control 3	2.5	0.13	1.0	0.2	1.7	0.4	115.5	180.0	27.0	21.0
Boron x 3	2.3	0.13	0.8	0.2	1.8	0.4	124.5	185.0	30.0	34.5

Table 4. Mineral content of inflorescences and leaves sampled from Orchard B 3 days after application of 1% low biuret urea and/or Solubor® at 100g per 100L in 2006.

Inflorescences Mineral										
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
			%					**mg/kg**		
Control 1	3.1	0.5	2.0	0.2	0.5	0.2	56.0	66.0	51.0	66.0a[1]
Boron x 1	2.9	0.5	2.1	0.2	0.4	0.2	60.0	37.0	51.5	116.0b
Nitrogen	3.3	0.5	2.0	0.2	0.5	0.2	181.0	49.0	51.5	61.5a
N+B	3.4	0.5	2.1	0.2	0.5	0.2	64.5	55.0	56.5	86.0ab
Control 2	3.0	0.4	2.1	0.2	0.5	0.2	50.0	36.0	44.0	73.0
Boron x 2	3.3	0.5	2.1	0.2	0.4	0.2	41.5	31.5	47.5	101.0
Control 3	2.3	0.3	1.8	0.2	0.3	0.2	46.5	35.5	42.0	43.5
Boron x 3	2.4	0.3	1.8	0.2	0.4	0.2	48.0	38.0	40.0	114.5
Leaves Mineral										
Treatment	**N**	**P**	**K**	**S**	**Ca**	**Mg**	**Fe**	**Mn**	**Zn**	**B**
			%					**mg/kg**		
Control 1	2.3	0.2	1.0	0.2	1.2	0.3	114.0	111.0	29.0	23.0
Boron x 1	2.3	0.2	1.0	0.3	2.0	0.4	51.0	180.0	29.5	32.5
Nitrogen	2.3	0.2	0.9	0.2	1.9	0.2	40.0	75.0	25.0	20.0
N+B	2.8	0.2	1.0	0.3	1.6	0.3	47.0	139.0	32.5	31.0
Control 2	2.2	0.2	0.9	0.2	1.8	0.3	54.5	114.0	21.0	21.5
Boron x 2	2.5	0.2	1.0	0.3	1.6	0.3	56.5	94.5	23.0	25.5
Control 3	2.5	0.1	0.9	0.2	1.6	0.3	43.5	131.5	27.5	20.0
Boron x 3	2.2	0.1	0.8	0.2	1.7	0.3	43.5	131.5	24.0	28.0

[1]*Means followed by the same letter in a column are not different according to a One-Way Analysis of Variance using Tukey's family error rate of 5%.*

Table 5. Average fruit count of branches treated with 1% low biuret urea, Solubor® (100g per 100L) or a combination of low biuret urea and Solubor®

	Orchard A		**Orchard B**	
Treatment	**7/12/2006**	**11/1/2007**	**22/11/2006**	**7/12/2006**
Control	23.5	14.3	26.7	6.9
Boron x 1	20.2	11.9	39.0	11.0
Boron x 2	24.5	13.9	24.0	7.4
Boron x 3	26.0	12.6	38.3	12.7
Nitrogen	20.5	7.2	26.6	7.3
N+B	31.7	14.8	42.5	12.3

Initial fruit set and fruit numbers after the December drop appeared to be unrelated to the boron concentration within the inflorescences as there was similar fruit numbers per branch over the range of boron concentrations measured (Figures 4 and 5). The fruit numbers at boron concentrations of 100 to 138 mg/kg were similar to fruit numbers where the boron concentration was below 100 mg/kg. The boron concentration in the leaf ranged from about 15 mg/kg to 40 mg/kg across all treatments and there was no clear relationship of leaf boron content to initial fruit set or after the December fruit drop (data not shown).There was no obvious visual negative effect on fruit set of applying foliar boron in combination with nitrogen.

The boron content of adjacent leaves and inflorescences on the same branch were positively related to one another (Figure 6). In general, leaf boron concentration was approximately 25 to 40% of the inflorescence boron content.

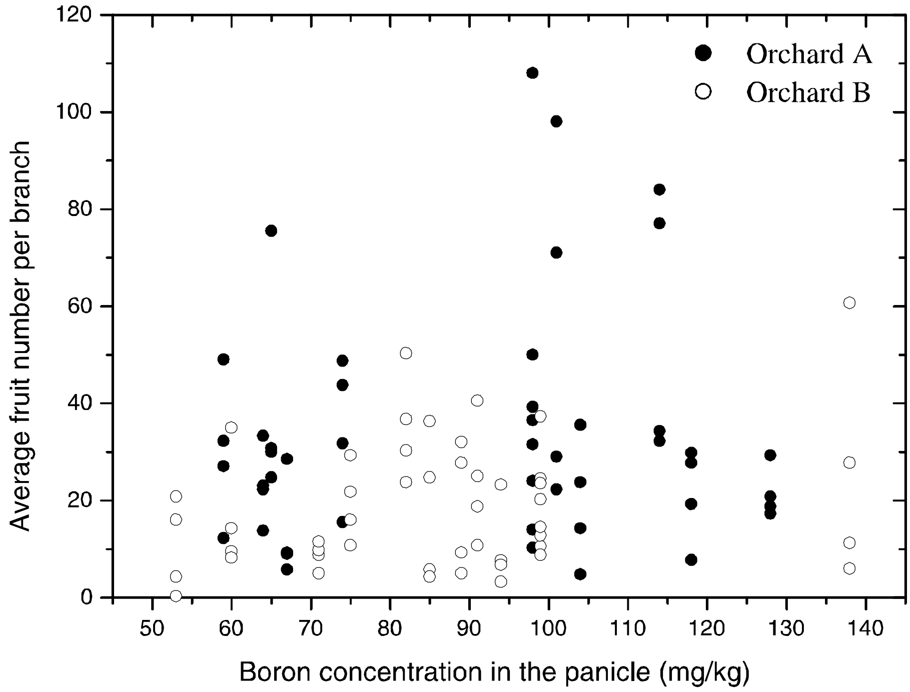

Figure 4. Relationship between inflorescence boron content and initial fruit set, 7/12/2006 for Orchard A and 22/11/2006 for Orchard B, following treatment with foliar applications of low biuret urea and/or boron in 2006.

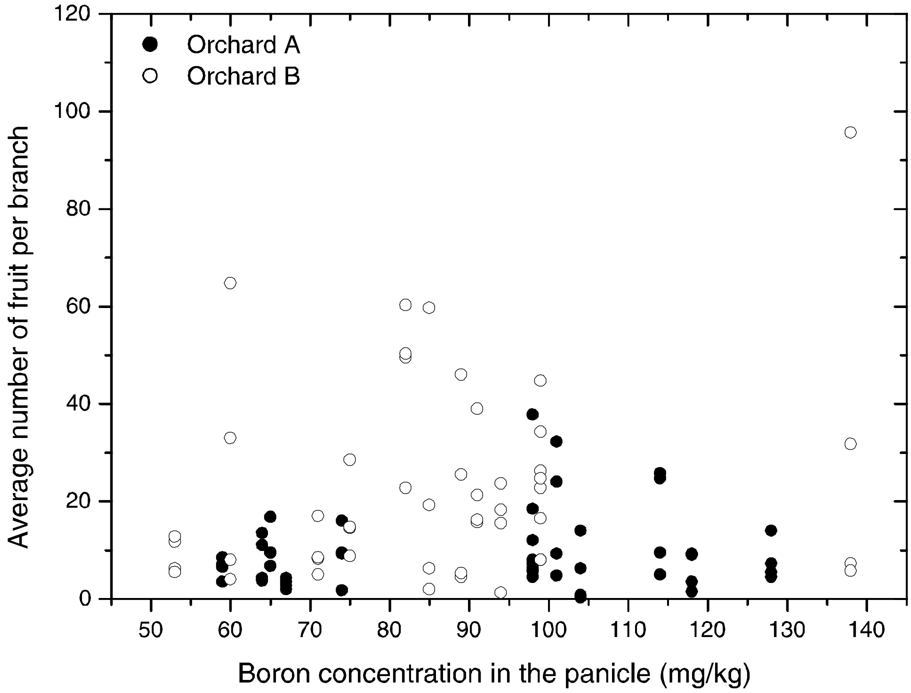

Figure 5. Relationship between inflorescence boron content and fruit numbers after the December fruit drop at 11/1/2007 for Orchard A and 7/12/2006 for Orchard B, following treatment with foliar applications of low biuret urea and boron in 2006.

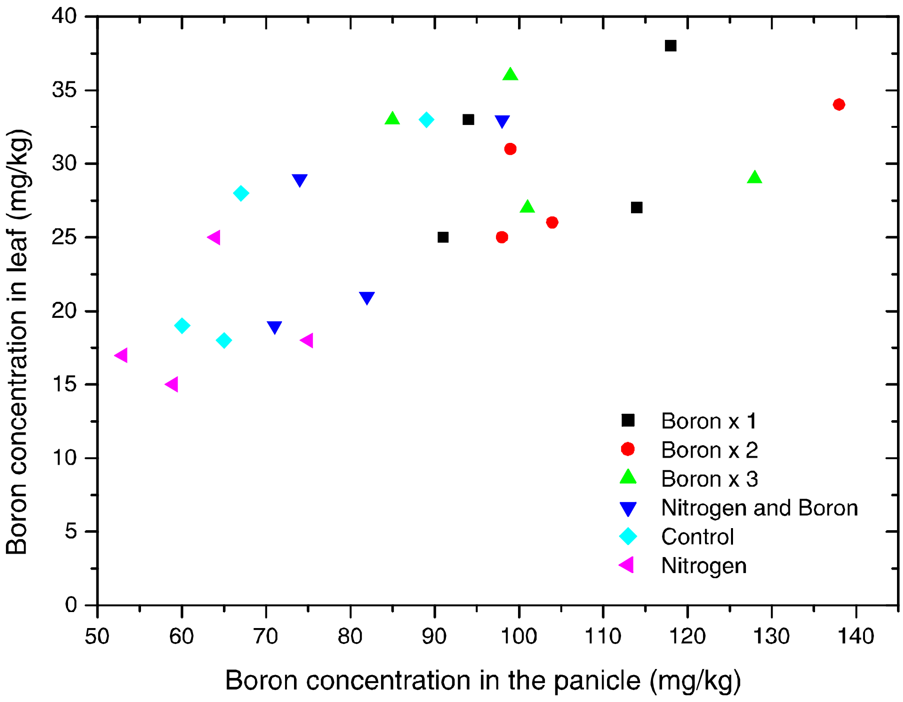

Figure 6. Relationship between leaves adjacent to flowers boron concentration and inflorescence boron content following treatment with foliar applications of low biuret urea and boron in 2006.

DISCUSSION

Application of foliar boron and/or nitrogen to inflorescences when they started to expand did not enhance fruit set in the orchards in 2005 or 2006. This result was consistent with previous research where one orchard had greater fruit numbers after the December drop but there was no difference in fruit set after application of foliar boron and/or nitrogen on another orchard (Dixon *et al.*, 2005). The lack of a consistent enhancement of fruit set through using foliar applications of boron over three years strongly implies that this is an unnecessary orchard practice.

The trees used in this study do not appear to have been boron deficient even though the leaf boron content was in some treatments below 22ppm at flowering. Boron deficiency symptoms are considered to be expressed once the leaf boron content falls below 25 mg/kg (Whiley *et al.*, 1996). Leaf boron content is commonly measured in autumn several months before flowering by which time the boron levels in the leaves may have declined to 20 mg/kg or below (Dixon *et al.*, 2006). Application of foliar boron alone or in combination with nitrogen did not significantly raise the boron level in the leaves. Foliar applied boron tended to increase inflorescence boron levels and could be used successfully to increase the amount of boron in flowers. Based on this study it is probable that for New Zealand 'Hass' avocado inflorescences leaf target levels of boron between 40 to 60 ppm in autumn (Cutting and Dixon, 2004) will supply enough boron to inflorescences for good fruit set. The trees used in this research project were not considered to be deficient in boron as there were no symptoms of boron deficiency on adjacent leaves. However, this research project has not investigated whether applying foliar boron to flowers of trees deficient in boron is a useful treatment for enhancing fruit set.

No optimum boron level for fruit set was apparent in the flowers treated in 2005 and 2006. Inflorescence boron content in 2006 was uniformly high >60 mg/kg when the treatments were first applied. Boron levels of this magnitude would suggest based on previous research (Dixon *et al.*, 2005) that additional boron would be of little benefit to enhance fruit set. In 2005 the boron content of inflorescences was around 30 mg/kg but after application of foliar boron few of the treated inflorescences were in the 50 to 65 mg/kg range. Most of the inflorescences had higher boron content than 65 mg/kg. This highlights a practical problem with application of foliar boron to trees receiving an adequate fertilizer programme in that additional foliar boron may readily increase the boron content of inflorescences past any possible optimal values.

Multiple applications of foliar applied boron did not enhance fruit set or increase the boron content significantly beyond that of a single application of boron to flower buds when they first started to expand. Multiple applications of boron maintained leaf and inflorescence boron content at a high level over flowering when the boron content of leaves declined. This additional boron may not have raised the flower or leaf boron levels through the boron being redistributed to other parts of the plant, such as actively growing shoot tips, that have a large boron requirement (Lahav and Whiley, 2002). Multiple applications of boron also did not enhance fruit set when an orchard was in an "off" year. Such a result suggests that applying boron multiple times during flower development is not required for good fruit set nor can multiple applications overcome the effect of alternate bearing on fruit set.

The variation in boron content between trees and within trees appears to have little relevance in this study as both control and treated branches had similar variability in fruit set. The amount of boron in the inflorescences and leaves was positively related indicating that the leaf boron content can be used to infer if the inflorescence boron content will be adequate for fruit set. Boron is recognised to play an important role in the development of pollen tubes and in the fertilization of embryos (Lahav and Whiley, 2002). Therefore, it is very important to have adequate boron available to the tree for fruit set. Application of foliar boron to avocado flowers has been based on the hypothesis that avocado fruit set is limited by boron availability. The implication is that insufficient boron is available at flowering to maximise fruit set. The results presented in this report suggest that for many New Zealand 'Hass' avocado trees the boron applied through a ground based application as part of a balanced fertilizer programme is adequate for fruit set.

CONCLUSIONS

Applying boron as a single or multiple foliar applications to 'Hass' avocado flowers on trees adequately fertilized did not enhance fruit set. This implies that for most 'Hass' avocado trees in New Zealand applying foliar boron onto developing inflorescences is not required for good fruit set. This assumes that adequate boron is being applied to the trees as part of a well balanced fertilizer programme.

REFERENCES

Cutting, J.G.M. and Dixon, J. (2004). *NZ Avocado Growers' Association Growers Manual*. Avocado Industry Council Ltd, Tauranga.

Dixon, J., Smith, D.B., Elmsly, T.A. and Fields, F.P. (2005). The impact of foliar applications of nitrogen and boron on 'Hass' avocado fruit set in 2004. *New Zealand Avocado Growers' Association Annual Research Report* **5**: 27-34.

Dixon, J., Elmsly, T.A. and Dixon, E.M. (2006). Seasonal variations in leaf mineral content. *New Zealand Avocado Growers' Association Annual Research Report* **6**: 21-34.

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.

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.

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.

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

ACKNOWLEDGEMENTS

Thanks to Jonathan and Kim Cutting for the use of their trees in 2005, Ron and Chris Bailey, Colin Jenkins and Steve Bryant and the Ngai Tukairangi Trust for the use of their trees in 2006.