Proceedings from Conference '97: Searching for Quality. Joint Meeting of the Australian Avocado Grower's Federation, Inc. and NZ Avocado Growers Association, Inc., 23-26 September 1997. J. G. Cutting (Ed.). Pages 131-137.

IMPROVING BORON NUTRITION IMPROVES 'HASS' AVOCADO FRUIT SIZE AND QUALITY

Timothy E. Smith[1,3], Peter J. Hofman[2], Russell A. Stephenson[3], Colin J. Asher[1], and Suzan E. Hetherington[1]
[1]Dept. of Agriculture, The University of Queensland, Brisbane Qld 4072, Australia
[2]Horticulture Postharvest Group, Qld Horticulture Institute, Department of Primary Industries, 19 Hercules St, Hamilton Qld 4007, Australia
[3]Centre for Subtropical Fruit, Maroochy Research Station, Qld Horticulture Institute, Department of Primary Industries, PO Box 5083 SCMC, Nambour Qld 4560, Australia

Keywords: avocado, *Persea americana* Mill, boron, ethylene, fruit quality

Abstract

Small 'Hass' avocado *(Persea americana* Mill.) fruit size and poor quality are common problems in the avocado industry worldwide. Tree and fruit mineral nutrition (especially nitrogen, calcium, potassium, and magnesium) have been shown to influence fruit size and quality. Boron (B) is known to influence fruit set, and there is some indication it may also influence fruit quality. This was investigated over 3 years on 'Hass' avocado trees grown on a red volcanic clay soil of low B status, by applying 7 rates of B to the soil annually.

Boron application increased average fruit size by 13-16 %, but did not significantly affect total fruit yield per tree. In 1995 fruit were either ripened at 22 °C until eating soft, stored at 7 °C for 4 weeks then ripened at 20 °C until eating soft, or stored at 2 °C for 7 weeks before ripening at 20 °C. Fruit from control trees reached peak ethylene production 4.4 days before fruit from trees supplied with adequate B, and produced 49% more ethylene at the peak. Shelf life of control fruit was 4.3 days shorter at 22 °C without storage, and 2.4 days shorter at 20 °C following storage at 7 °C, compared to fruit with adequate B. Control fruit stored at 7 °C also had more internal breakdown as indicated by greyish/black discolouration of pulp (mesocarp). The blackening was concentrated near the top of the seed cavity to a depth of >10 mm into the pulp from the cavity. The results show that improved avocado quality is possible when the B status of trees is changed from deficient to adequate.

Introduction

In the current climate of rising world avocado production, markets are becoming more conscious of quality. Therefore, it is important for the avocado industry to be aware of factors affecting fruit quality. The main avocado fruit quality parameters are size, shape, flavour, firmness, shelf and storage life, external blemishes, disease and internal disorders. Most of these can be influenced by on-farm management of nutrition, irrigation, vegetative vigour, disease and handling (see review by Hofman and Smith, 1994). It is important for the industry to be aware of these interactions, and to identify and manipulate those factors which have the greatest impact on quality at harvest.

Boron deficiency has been identified as a problem in the major avocado growing areas of Queensland (Smith *et al.,* 1995), and B deficiency symptoms have been recognised in avocado orchards in other parts of Australia, and in South Africa, Israel and California (A. Whiley, Department of Primary Industries Queensland, personal communication). Foliar B sprays to avocado have improved fruit set and yield (Robbertse *et* a/., 1992; Lovatt *et al.,* 1994; Mans, 1996; Smith *et a*/., 1997), and initial results of increased 'Hass' fruit size due to soil B applications were reported by Smith *et al.* (1995). In this paper we report the final results of the effects of B soil application to 'Hass' trees on fruit size and postharvest quality.

Materials and methods

A B rate trial was conducted at Maleny, Queensland, Australia on 'Hass' avocado trees growing on a kraznozem soil with a clay loam texture, from 1993-96. At the start of the trial, leaf B levels were between 18-25 mg kg^{-1} dry wt, and trees displayed typical B deficiency symptoms of loss of apical dominance in shoots, prostrate growth habit, interveinal crinkling and hooked fruit. A total of 28 trees were used in the experiment. The 7 annual rates of B, equivalent to 0, 0.03, 0.09, 0.23, 0.73, 2.1, and 5.9 g B m^{-2} soil area under the canopy, were applied as 2 even applications of borax to the soil surface directly under the tree canopy. There were 4 single tree replications for each treatment. At maturity, all fruit were harvested, weighed and counted to determine total fruit yield per tree, total fruit number and average fruit weight. Fruit yield data were grouped into consecutive years to compensate for the non-synchronised biennial bearing of trees in the trial.

Fruit quality

In 1995, a subsample of 45 fruit per tree was dipped in 0.55 ml L^{-1} Prochloraz® to reduce postharvest disease. One fruit per tree was placed in individual 1L plastic containers (1 fruit per container) ventilated with ethylene-free air (passed through Purafil®) at a flow rate of 75-100 ml min^{-1} and 90% relative humidity (RH). The fruit were held at 22°C till ripe, and the air from the containers monitored for ethylene every 6 hours using gas chromatography (Smith *et al.* 1997).

In addition, 15 fruit per tree were either stored in single layer trays at 7°C for 4 weeks then ripened at 20°C until eating soft, or at 2°C then ripened at 20°C until eating soft.

On removal from storage, the force (measured as Newtons; N) required to push a 8 mm hemispherical probe 2 mm into the fruit (i.e. the firmness of the fruit) was tested using an Instron Universal Testing Machine model 1122. In general, fruit at harvest had a firmness of about 60 N, 20-25 N at the sprung stage, and 5-8 N at eating soft.

At the eating soft stage (measured by gentle hand pressure), fruit were cut and evaluated for the degree of pulp breakdown. Different disorders were assessed separately and measured using a scale of 1 = 0%; 2 = 1-3%; 3 =4-6%; 4 = 7-9%; 5 = 10-14%; 6 = 15-19%; and 7 = >19% of cut surface area affected by breakdown.

Results

In this paper we present only the results of the control (-B) and the 5.9 g $m^{-2}y^{-1}$ treatment (+B).

The B treatment increased leaf B concentration from marginal (10-50 mg kg^{-1} dry wt) to adequate (50-100 mg kg^{-1} dry wt) (Table 1), as defined by Robinson (1986).

Table 1 **Effect of soil boron (B) treatment on summer flush leaf B concentrations of `Hass' avocado in 1994, 1995 and 1996. -B = control and +B = 5.9 g m^{-2} y^{-1}**

B Treatment	Leaf B (mg kg^{-1})		
	1994	1995	1996
-B	21.98	27.84	27.3
+B (5.9 g m^{-2} y^{-1})	55.75	75.4	88.54

Boron application increased average fruit weight by 14% and 16% (p=0.05) compared to the -B trees in 1994+1995 and 1995+1996 respectively (Figure 1). There were no significant differences in total fruit yield or total fruit number per tree due to large tree to tree variation.

Fruit held at 22°C from the control treatment reached the ripe, eating soft stage 9.4 days after harvest, and those from the +B trees 13.7 days after harvest (Figure 2). The longer shelf life of the +B fruit was further confirmed by the longer time for the fruit to reach the peak rate of ethylene production (11.1 days compared to 6.7 days for -B fruit; LSD = 2.2 d at p=0.05). The -B fruit also produced 49% more ethylene at peak production (Figure 3). Fruit reached eating soft approximately 2.6 days after the time of peak ethylene production.

All of the fruit stored at 7°C for 4 weeks then placed at 20°C were eating soft by 9 days after removal from storage. The -B fruit reached eating soft after an average of 3.1 days and the +B fruit reached eating soft after an average of 5.6 days (LSD=1.28 at p=0.05). There was a trend of increased fruit firmness with B treatment at removal from storage, but this was not significant.

There was a higher internal breakdown around the top of the seed cavity in the -B fruit compared to the +B fruit (p=0.01) (Figure 4). The breakdown occurred as a localised greyish/black discolouration of pulp (mesocarp) initially near the top of the seed cavity. As symptom severity increased, the depth of pulp blackening adjacent to the seed cavity, increased to >10 mm above the seed cavity, tapering down to 1-2 mm at the middle of the cavity, with isolated symmetrical black spots, approximately 4-5 mm in diameter and 2 mm into the pulp, below this point.

There were no significant differences in firmness, days to eating soft or external chilling injury (skin blackening) of-B and +B fruit after removal from storage at 2°C.

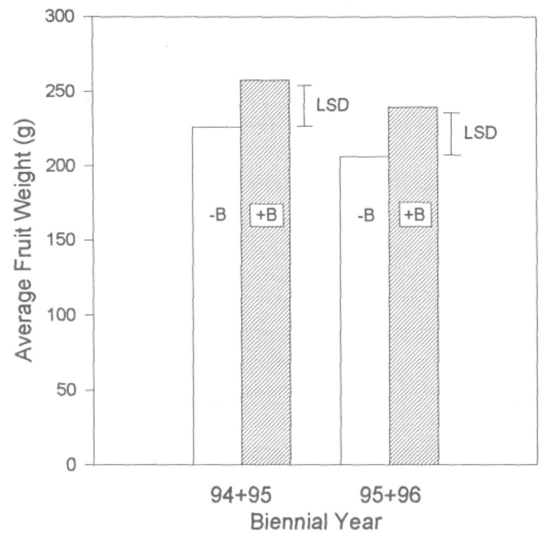

Figure 1 **Effect of soil boron (B) treatment on the average fruit weight of 'Hass' avocado. -B = control and +B = 5.9 g m^{-2} y^{-1}. The bar indicates significance at p=0.05**

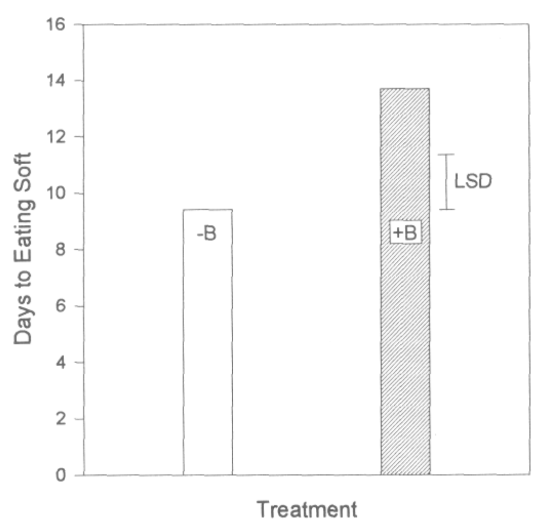

Figure 2 **Effect of soil boron (B) treatment on days to eating soft of `Hass' avocado held at 22°C in individual containers. -B = control and +B = 5.9 g m^{-2} y^{-1}. The bar indicates significance at p=0.05**

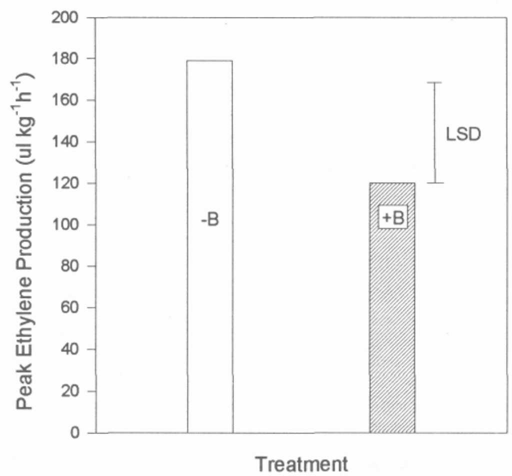

Figure 3 Effect of soil boron (B) treatment on maximum ethylene production rate of `Hass' avocado held at 22°C in individual containers. -B = control and +B = 5.9 g m $^{-2}$y^{-1}. The bar indicates significance at p=0.05

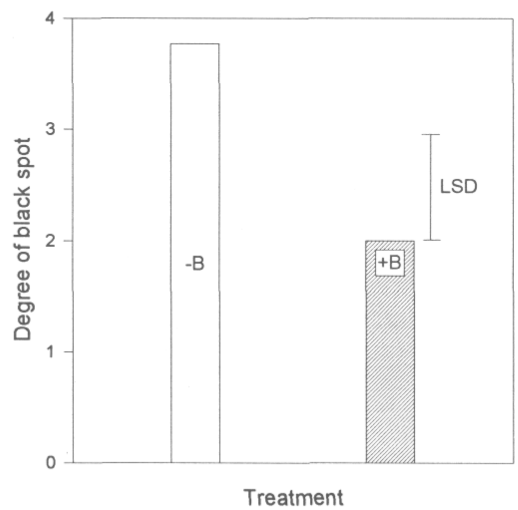

Figure 4 Effect of soil boron (B) treatment on severity of black spot in `Hass' avocado mesocarp after storage at 7 °C for 4 weeks, then ripening to eating soft at 20 °C. -B = control and +B = 5.9 g m^{-2} y^{1}. The bar indicates significance at p=0.05

Discussion

The response to B of increased fruit size confirms the initial results reported by Smith *et al.* (1995). This effect probably occurred through a combination of: improved cell reproduction and growth during early fruit development; improved root growth and supply of assimilates to fruit; and a longer period of seed coat viability.

The current results also indicate that tree B nutrition can influence the shelf life and storage performance of avocado. Thus, optimising B nutrition can increase the time for the fruit to ripen, thereby reducing the risk of premature ripening during distribution. This is especially significant following prolonged cold storage, because the time from removal to eating ripe is often short. In addition, the higher maximum ethylene production rate of -B fruit may have commercial implications through increasing the possibility of enhanced ripening where low and high B fruit are placed in the same container.

Boron application also improved storage performance by reducing internal disorders. The internal black spot disorder observed in fruit stored at 7°C appeared to be different from previously documented chilling injury symptoms by Swarts (1985), and may be a disorder closely related to fruit B deficiency.

Similar effects on ripening and disorders in avocado have been noted with Ca (Hofman and Smith, 1994). However, the effects of B in these experiments, appear to be greater than those observed for Ca, especially in relation to days from harvest to eating ripe.

Annual soil B rates will vary due to differences in soil texture, leaching, soil pH, tree size, rootstock and scion variety, application method and severity of root rot symptoms (refer to Smith *et al.,* 1995). Soil texture has a major effect on B availability to avocado. Fine textured soils can require up to 3 times more B than coarse textured soils to change leaf levels from 20 mg B kg^{-1} to >50 mg B kg^{-1}. Increasing summer flush leaf levels to 50 mg B kg^{-1} appears to alleviate B deficiency problems. Further increases in tree B to toxic concentrations are likely to result in decreases in fruit yield, size and quality, as B toxicity of avocado trees causes defoliation, sunburnt fruit, reddish/pink discolouration of the fruit skin, internal fruit breakdown, and possible tree death (unpublished data). Therefore, caution must be used when applying B to orchards. The risk of causing B toxicity with soil applications can be reduced by applying a number of small B doses which add up to an appropriate annual rate. This allows adequate time to collect leaf and soil samples to monitor changes in B levels. Foliar B sprays are also useful for alleviating short term B requirements at critical times of the avocado growth cycle such as anthesis (Smith *et al,* 1997).

In conclusion, adequate supply of B to avocado trees resulted in larger fruit, longer shelf life, and reduced risk of fruit ripening during storage. This indicates that close attention to B nutrition can have significant positive benefits to profitability.

Acknowledgments

The authors would like to thank Lyndall Smith, Janette Mercer, Gil Walters, Geraldine Meiburg, Leigh Barker, Sue-Ellen Dear, and Jenny Barker for their valued assistance.

References

Hofman, P.J. and Smith, L.G., 1994. Preharvest effects on postharvest quality of subtropical and tropical fruit. Champ, B.R., Highley, E. and Johnson, G.I., (eds)

1994. In *Postharvest handling of tropical fruits: proceedings of an international conference,* Chiang Mai, Thailand, 19-23 July 1993. ACIAR Proceedings No. 50. pp 261-268.

Lovatt, C.J., Bertling, I. and Blanke, M., 1994. Comparison of determinate vs. indeterminate inflorences to determine the role of plant growth regulators, carbohydrate, nitrogen and other nutrients in fruit set of 'Hass' avocado. *California Avocado Society Yearbook* 78: 183-186.

Mans, C.C., 1996. Effect of foliar feeding of 'Hass' at various stages of flowering. *South African Avocado Growers' Association Yearbook* 19: 31-32.

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

Robinson, J.B., 1986. *Plant Analysis: an Interpretation Manual.* Reuter, D.J. and Robinson, J.B. (eds), Inkata Press Pty Ltd, Melbourne, Australia, pp 124-125.

Smith, L.G., Hofman, P.J., Jordan, R.A., and Lee C., (1997). An inexpensive, low maintenance, multiple controlled atmosphere system for research on perishable products. *Postharvest Biology and Technology* 11:123-130.

Smith, T.E., Stephenson, R.A., Asher, C.J. and Hetherington, S.E., 1995. Boron nutrition of avocado effects on fruit size and diagnosis of boron status. In *Proceedings of Aust. Avocado Growers' Federation Conference.* 1-3, April 1995. pp 159-165.

Smith, T.E., Stephenson, R.A., Asher, C.J. and Hetherington, S.E., 1997. Boron deficiency of avocado 1. Effects on pollen viability and fruit set. In *Proceedings of Boron 97 International Symposium on Boron in Soils and Plants,* Chiang Mai, Thailand, 7-11 September 1997. In press.

Swarts, D.H., 1985. Postharvest problems of avocados. *Farming in South Africa,* I 3/1985: pp 4.