Foliar application of boron to improve ‘Hass’ avocado productivity

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Abstract

Avocado is an edible crop with increasing economic significance. ‘Hass’ is the primary avocado cultivar, gaining high popularity among consumers and dominating the world industry. ‘Hass’ cultivation areas expand each year, but growers consistently report issues of irregular bearing and low yields. Leaf mineral analyses revealed that leaf boron (B) levels are significantly lower than the standard deficiency threshold in many avocado orchards in Israel. B deficiency is known to decrease vegetative growth and enhance environmental stress susceptibility and is suggested to impair pollen grain development and germination. In the present work, B sprays were carried out at the beginning and middle of the flowering season in orchards suspected of B deficiency. The experiments were conducted over 3 years in four different orchards in Israel’s Galilee region with varying concentrations of B products (B7000 and Nutrivant™). The effects on fruit-set and yield were evaluated, together with histologic examinations of the flower pistil. B-treated flowers exhibited higher levels of pollen germination. Some of the B treatments improved fruit set and final yield, but results were inconsistent across years and orchards. Further research is required to better understand the impact of B on fruit production and to develop an efficient protocol for B application in avocado orchards.

Keywords: boric acid, *Persea Americana*, stigma, style

INTRODUCTION

Avocado (*Persea americana*), originated in central America, is an important crop with a rapidly increasing global market. ‘Hass’ is the dominatant cultivar in the avocado industry, but suffers from poor fruit set and low yields. Boron (B) absorbed from the soil solution by the roots is an essential micronutrient for plant development (Gupta and Solanki, 2013) that is absorbed from the soil solution by the roots. B is involved in physiological plant functions, including cell formation (Abdel-Motagally and El-Zohri, 2018), pollen germination (Korkmaz and Güneri, 2019) and fruit-set (Ganie et al., 2013). B deficiency was found to negatively affect avocado vegetative and reproductive growth (Tesfay et al., 2012). B concentration is commonly evaluated in leaves. However, flower B content is more indiciative of plant productivity (Boldingh et al., 2016). Foliar B applications were found to improve yields of several fruit trees, including olive (Perica et al., 2001; Larbi et al., 2011), almond (Nyomora et al., 1999), pecan (Wells et al., 2008), apple (Asgharzade et al., 2012) and mango (Bibi et al., 2019). Foliar-applied B resulted in increased cumulative yield over 3 years for avocado and was more effective than soil application (Lovatt, 1999). However, the orchards in that study had sufficient B levels even before the treatment initiation and the B treatment purpose was to overcome climatic challenges by additive nutrient availability. The present work tested the effect of foliar B application on commercial avocado orchards that were found to suffer from low B levels and aimed to overcome productivity obstacles by improving the pollen germination and fruit-set.

MATERIALS AND METHODS

The research was conducted during 2018, 2019 and 2020. Four orchards with low B levels (<20 ppm B, the threshold for deficiency) according to leaf analysis were chosen in Israel's Western Galilee region. The orchards were located in Kabri (33°1'15.23"N, 35°8'56.4"E), Saar (49°42'5"N, 6°34'11"E), Shomrat (32°57'4.32"N, 35°5'44.15"E) and Yehiam (32°59'45"N, 35°13'14"E). Diagnostic leaves were sampled in autumn, after harvest. Leaf B concentrations were 11.9 ppm (mg B kg^{-1} dry matter) (Kabri), 11.4 ppm (Saar), 16.0 ppm (Shomrat) and 10.6 ppm (Yehiam). B treatments were applied using two commercial products: B7000 and Nutrivant™ (ICL, Israel). B7000 (350 ppm) and Nutrivant at 3% (540 ppm B) were sprayed once at the beginning of the flowering season. Nutrivant at 2% (360 ppm B) was sprayed twice – at the beginning of the flowering season and 2 weeks later. In total, there were four treatments (B7000, Nutrivant 3%, Nutrivant 2% ×2 and control). All treatments were applied early in the morning with a mist blower orchard sprayer at 1,500 L ha^{-1}. In each orchard, six plots of eight trees were chosen randomly for each treatment. In total, each treatment contained 48 trees. Flowers from all treatments were sampled (50 per replicate plot) for B analysis a week after the second spray was applied – three weeks after the initial sprays. The flowers were washed in distilled water and dried at 70°C. Each sample was ground and homogenized. B was determined by digesting the dry powdered material with nitric acid and H_2O_2 and analyzed using ICP-OES 5100 (Agilent Technologies). Fruit set surveys were conducted three times each year, in May, June and August. For these surveys, two similar trees were chosen in each replication. Twenty uniform inflorescences per tree were marked before the B spray were applied and the number of fruitlets per inflorescence was counted in each survey. For pollen germination assessment, female-positioned 'Hass' flowers were sampled from the experimental trees (B7000 and control) and inserted into agar wells. The flowers were taken to the lab and hand-pollinated with 'Ettinger' anthers under a stereoscope. After 30 h of incubation at room temperature, the flowers were taken out of the agar wells and put into ethanol:acetic acid (3:1 v/v) solution for fixation. Twenty-four hours later, the fixation solution was replaced with 70% ethanol, and the samples were preserved at 4°C for 2 months. For histological observations, pistils were separated from flowers and rehydrated by serial soaking in 70, 50, and 30% ethanol solution for 10 min. The tissue was softened by submerging it in 10 M NaOH overnight at room temperature. It was then washed three times with a potassium-phosphate buffer (K_2HPO_4, KH_2PO_4 and H_2O, pH 7.6) and stained with aniline blue for 8 h in the dark. Before visual observation under a UV microscope, the tissue was rinsed in the potassium-phosphate buffer.

Using JMP software, statistical analyses were ANOVA followed by the Tukey-Kramer test at $p<0.05$.

RESULTS

B treatments significantly increased flower B concentrations over control treatments (Figure 1).

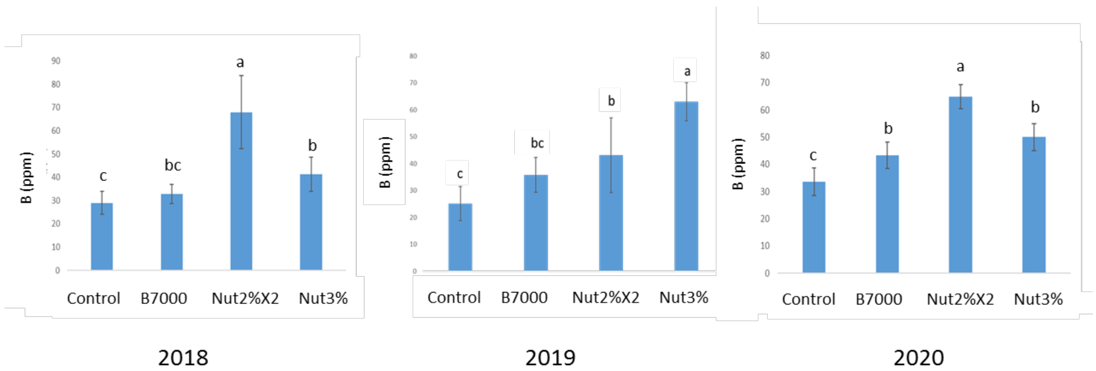

Figure 1. Effects of B treatments on B concentrations in avocado flowers from the Kabri orchard (n=50).

The proportion of flowers with germinating pollen grains was significantly higher in B7000 treated trees as compared with controls (Figure 2A).

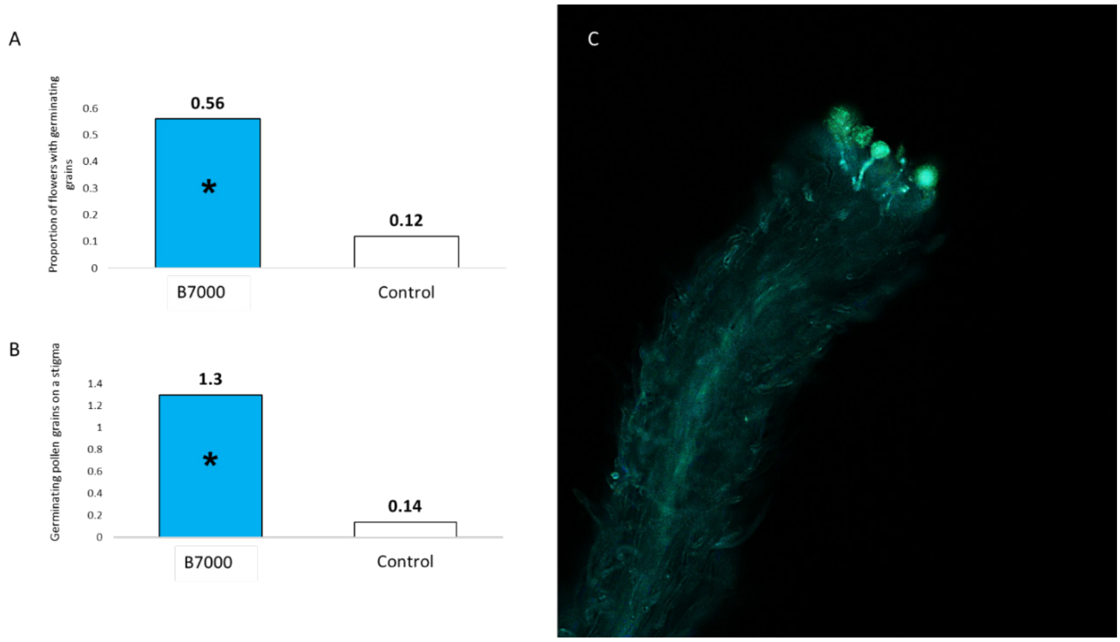

Figure 2. Effects of B treatments on pollen germination in 'Hass' avocado flowers from Kabri orchard. A) Stigmas with germinating pollen grains (%); B) number of germinating pollen grains on a single stigma; C) germinating pollen grains on 'Hass' stigma, stained with aniline blue.

B7000 treated flowers had significantly more germinating pollen grains on a stigma (Figure 2B).

B7000 treatment significantly increased 'Hass' yields in two instances: by 54% in Kabri 2018 and by 33% in Shomrat 2019 (Table 1). Nutrivant 3% increased the yield only in Shomrat 2019 (23%). Nutrivant 2% ×2 had a negative effect in most cases.

Table 1. Effect of B treatments on 'Hass' yields (t ha^{-1}).

Treatment	Kabri 2018	Saar 2018	Kabri 2019	Shomrat 2019	Kabri 2020	Yehiam 2020
Control	11.6	18.1	31.1	17.4	11.5	17.1
B7000	17.9*	17.6	22.3	23.2*	11.0	13.9
Nut 2% ×2	13.8	12.4	25.5	15.5	6.4	12.8
Nut 3%	13.6	10.7	24.4	21.4*	10.7	15.0

* represents a significant increase in the yield as compared with the control treatment.

DISCUSSION

A study in New Zealand found that the optimal flower B concentration for high avocado yield was 50-65 ppm (Dixon et al., 2005). Our foliar treatments raised the B flower concentration from 25 to 35 ppm in control to 45-65 ppm (Figure 1). The improvement in pollen germination rates reflected this increase (Figure 2). Pollen germination is affected by B levels as it is involved in cell-wall formation and in the recognition mechanism of the pollen grain and stigma (Shivanna, 2020). The fruit set surveys did not reveal consistent significant beneficial effects of B treatments over the control (data not shown). This lack of response was possibly attributable to several spring heat waves that enhanced fruit drop. This climate challenge might also be a reason for the inconsistent yields (Table 1). We suggest that a later B application or a combination of early and late sprays, which are relevant for late blooms, could be more effective. However, the total amount of applied B must be managed as excessive B can damage avocado roots (Coetzer et al., 1993). Variable effectiveness of foliar B treatments is recognized. Explanations include varying physicochemical properties of formulations, environments under which sprays are applied, and/or leaf characteristics (Fernández and Brown, 2013). Penetration routes via trichromes, the cuticle and/or stomata ideally need to be identified. That is, it remains to to identify penetration sites and validate optimal times for B application; such as during night hours when stomata are closed and the formulation remains longer on the leaf or during the day when it dries quickly but stomatal pores are open.

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