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RESEARCH PAPER

## The effect of foliar boron spraying on the fruit features of Brigitta and Legacy highbush blueberry (*Vaccinium corymbosum*) cultivars

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### Abstract

**C. Meriño-Gergichevich, E. Pacheco, and M. Reyes-Díaz. 2016. The effect of foliar boron spraying on the fruit features of Brigitta and Legacy highbush blueberry (*Vaccinium corymbosum*) cultivars. Cien. Inv. Agr. 43(3):452-463.** Boron (B) is associated with reproductive and antioxidant metabolism in plants, and in southern Chile, the deficiency of this micronutrient is ameliorated through foliar applications that are a part of agricultural management, thus ensuring the productivity of crops including highbush blueberry (*Vaccinium corymbosum* L.). However, the appropriate B dosage for this species is unknown, so the aim of this study was to evaluate foliar B application on fruit quality in highbush blueberry in southern Chile. During the 2014-2015 season, Brigitta and Legacy cultivars were sprayed with B at rates of 0 (control), 200, 400 and 800 mg L<sup>-1</sup> three times (10% bloom, full bloom, and fruit set), and fruit set (%), firmness (g mm<sup>-2</sup>), soluble solids (°Brix), weight (g) and size (mm) of the fruits were determined. In addition, antioxidant activity was measured by ORAC (oxygen radical absorbance capacity) and DPPH (2,2-diphenyl-1-picrylhydrazyl). The results showed that a low rate of B (200 mg L<sup>-1</sup>) increased the fruit set and soluble solids in Brigitta, whereas Legacy required higher B concentrations (400 and 800 mg L<sup>-1</sup>). In both cultivars, firmness, fresh fruit weight, dry matter (%) and antioxidant activity increased under the 200 and 400 mg B L<sup>-1</sup> treatments, whereas this last parameter was reduced under a high B concentration. A low B rate showed to be more effective at improving fruit quality in Brigitta, while Legacy required higher B application rates. Future research should be performed over several seasons and different cultivars to confirm these results.

**Key words:** Antioxidant, DPPH, fruit quality, micronutrient, ORAC.

### Introduction

Boron (B) is considered an essential micronutrient that is associated with both vegetative growth and

plant reproductive development, and it has been involved in the antioxidant systems of vascularized plants (Blevins and Lukaszewski, 1998). Boron is also involved in changes in concentration and metabolism of phenolic compounds in vascular plants, in response to its excess or deficiency (Dahajipour *et al.*, 2011; Moalemi *et al.*, 2012).

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The B requirements have also been reported to be greater in reproductive than vegetative structures due to it is involved in several processes, such as flowering, pollen tube growth, and fruit ripening (Herrera-Rodríguez *et al.*, 2010). A research performed on the Asian pear tree (*Pyrus pyrifolia*) found an increase in pollen germination and tube growth after two postharvest foliar B applications at a dose of 200 mg B L<sup>-1</sup>, which increased the fruit set percentage in the following season (Lee *et al.*, 2009). In European hazelnut (*Corylus avellana* L.), Ferrán *et al.* (1997) found that foliar B applications of 0.6 and 1.2 g ha<sup>-1</sup> increased fruit set and the yield of nuts, but Hanson (2001) reported no effect on the fruit yield of Jersey and Bluecrop highbush blueberry (*Vaccinium corymbosum* L.) cultivars sprayed with doses from 125 to 500 mg B L<sup>-1</sup> in several seasons. This author also described foliar B levels of 15 ppm as sufficient for these cultivars. Another study of the same species cultivated in Missouri, USA found that three foliar B applications increased the fruit yield of Collins and Bluejay cultivars up to 31% (Blevins *et al.*, 1996).

In contrast, B-deficient soils have been defined as having less than 10 mg B kg<sup>-1</sup>, mainly in the form of an immobile reservoir (Shorrocks, 1997). In the Andisol of southern Chile, B deficiency is mainly augmented by acidity (pH≤5.5), high organic matter (OM) content, heavy rainfall and the use of acidifying fertilizers or calcareous amendments, which can have an antagonistic relationship with B (Marschner, 1995; Shorrocks, 1997). According to Pinochet and Matus (2001), the B concentration in acid soils ranges from 0.5 to 1.0 mg kg<sup>-1</sup>, so to maintain an adequate B concentration in plant tissues, different application methodologies, such as foliar spraying of B to crops during the reproductive season, are applied. Compared to soil applications, this method has the advantages of requiring lower application rates, a more uniform distribution and more rapid plant responses to application of nutrients (Saadati *et al.*, 2013). However, one important aspect of fruit crop management is to ascertain the real crop demand to avoid deficiencies and

toxicity caused by this micronutrient and based on the physiological and biochemical function in cropped plants.

In Chile, highbush blueberry is cultivated over an area of 15,500 ha in the Regions of Coquimbo and Los Lagos (Chilean Blueberry Committee, 2015), and the fruit of this crop is consumed for its high nutrient content (Rimantas *et al.*, 2016). In Chile, from two to three foliar B applications are included in the agronomical management during the blueberry reproductive season to ensure a good fruit set and increased yield, and the applications are combined with other nutrients, such as calcium (Ca) (Stückrath *et al.*, 2008). However, the effects of B fertilization on highbush blueberry are unknown as there have been few studies relating this practice to the productive parameters and nutritional properties of this fruit. Therefore, the aim of this study was to evaluate the effect of B spraying on the fruit features of two highbush blueberry cultivars grown in an Andisol in southern Chile.

## Materials and methods

The study was conducted during the 2014-2015 production season on a commercial farm owned by Berries San Luis (38° 29' S, 72° 23' W), Lautaro, La Araucanía Region, Chile. The study area has an annual precipitation fluctuates between 1,200 and 1,500 mm: 400-500 mm in fall; 700 mm in winter; 250-400 mm in spring and 150-200 mm in summer. Blueberries were planted in 2009 with a spacing of 3.5×0.8 m (3571 bushes per ha) in an Andisol belonging to the Temuco series with a generally flat topography with gentle slopes and good drainage (CIREN, 2002). The chemical characteristics of the study soils are shown in Table 1; composite soil samples for chemical analyses were taken prior to B spraying (September 2014) from a 0-30 cm layer along the bush row in each plot. The assayed cultivars were Brigitta and Legacy, which have been frequently cultivated in southern Chile and are very productive

plants with early to intermediate ripening. In the study area, the harvest time is from the end of December to the middle of February. For the B application treatments, healthy and homogenous plants were selected according to their size and vigor, and B was sprayed three times per season, at 10% bloom, at full bloom and at fruit set (5 mm), on clear, precipitation-free days (72 h before and after application) according to the recommendations for the commercial B product. In each spray treatment, B was applied at rates of 0 (control=water), 200, 400 and 800 mg B L<sup>-1</sup> (Organichem Boro 8.7% p/v, Chemie S.A.) in approximately 500 L ha<sup>-1</sup> of water using a backpack sprayer (SOLO® 425 15 L, SOLO Kleinmotoren GmbH, Stuttgarter Str. 41, D-71069 Sindelfingen, Germany). Agronomic management was the same throughout the orchard and included the phytosanitary inspection, fertilization and irrigation required for the fruit to be exported, so none of

these practices had any influence on the study results. The annual fertilization management on the entire orchard plantation was 100 kg N ha<sup>-1</sup>, 70 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> and 100 kg K<sub>2</sub>O according to the standard recommendations for commercial blueberry plantations.

The experiment was performed by two-factor (B rate and cultivar), randomized complete block design with three replicates per treatment, and each experimental unit was a plot (36 m<sup>2</sup>) with 15 bushes (Figure 1). Following the recommendations of the orchard staff, the fruit was picked between 8:30 and 11:00 a.m., based on the marketable attributes and blue color of the skin, during the first week of January 2015. After harvesting, the fruit was taken for packing, where it remained for one hour at 12 °C to reduce the temperature. Total fresh fruit yields were obtained for each plot, for which the mean berry weight was measured by weighing 50

**Table 1.** Soil chemical properties (Andisol Temuco Series) of the studied blueberry orchard. Each composite soil sample from the two orchards (Brigitta and Legacy) comprised three subsamples taken from every plot (depth of 0–30 cm). Values represent the mean of three replicates ± standard error (S.E.).

Soil concentration	Orchard values	
	Brigitta	Legacy
N (mg kg <sup>-1</sup> )	30±1.22	32±1.40
P (mg kg <sup>-1</sup> )	30±0.33	27±0.3
K (mg kg <sup>-1</sup> )	145±5.97	164±4.51
pH (water)	5.54±0.63	5.05±0.33
Organic matter (%)	11±0.09	12±0.18
K (cmol+ kg <sup>-1</sup> )	0.37±0.02	0.47±0.01
Na (cmol+ kg <sup>-1</sup> )	0.08±0.01	0.10±0.02
Ca (cmol+ kg <sup>-1</sup> )	7.08±0.01	8.41±0.01
Mg (cmol+ kg <sup>-1</sup> )	1.55±0.01	2.58±0.01
Al (cmol+ kg <sup>-1</sup> )	0.15±0.01	0.79±0.01
Al saturation (%)	1.53±0.01	6.83±0.14
CICE (cmol+ kg <sup>-1</sup> )	2.23±0.04	2.35±0.13
∑ bases (cmol+ kg <sup>-1</sup> )	9.23±0.46	12.35±0.82
B (ppm)	0.62±0.04	0.45±0.04
Zn (ppm)	1.33±0.03	0.99±0.04
Cu (ppm)	2.27±0.05	2.11±0.04
Fe (ppm)	44.2±2.35	38.4±1.45
Mn (ppm)	2.75±0.35	1.87±0.67
S (ppm)	33±0.04	41±0.88
Al Ext. (ppm)	608±11.04	1092±12.73

Plant number	Row number														
	1	5	9	13	17	21	25	29	33	37	41	45	49	53	56
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
1-20															
20-40			0												
41-60			400												
61-80			200										200		
81-100			800										0		
101-120								0					400		
121-140								200					800		
141-160								800							
161-180								400							
181-200															
201-220															

**Figure 1.** Experimental randomized block design with replicated plots for B rates of 0, 200, 400 and 800 mg L<sup>-1</sup>. Each plot (36 m<sup>2</sup>) comprises 15 bushes planted in 2009 with a spacing of 3.5 × 0.8 m (3571 bushes per ha) in an Andisol Temuco series. The distribution of blocks was similar to that found in both Brigitta or Legacy orchards.

randomly selected marketable berries from each plot. In each treatment plot, four bud stems were tagged (October 2014) and monitored throughout the season to determine the number of flowers and the fruit setting percentage. The fruit set from each tagged bud was recorded to estimate the final fruit set before harvest. Thirty fruits per plot collected from the first harvest (1<sup>st</sup> week of January 2015) were selected to determine quality parameters such as firmness (Texturometer Brookfield QTS 25), size (digital caliper CALDI-6MP, Truper, Mexico), fruit weight (precision balance Model Snug III-3000, Jadever Weigtech, Inc., Vaughan, Ontario, Canada) and soluble solids with a portable thermocompensated refractometer (Ref-113). Dry matter was evaluated by weighing 30 g of fresh fruit from each plot after drying in a forced air oven (410 Memmert, Schwabach, Germany) at 65 °C for 96 h to a constant dry weight.

For determination of antioxidant activity, oxygen radical absorbance capacity (ORAC) methodology was applied using a Synergy H1 multimode microplate reader at an excitation of 485 nm and an emission of 520 nm according to Huang *et al.* (2002). For 2,2-diphenyl-1-picrylhydrazyl (DPPH), fresh fruit samples were homogenized with 1 ml of methanol (80% v/v) and centrifuged for 5 min at 10,000 rpm (4°C). The supernatant was then collected and stored at -80 °C until analysis (Yu *et al.*, 2002).

The collected data were assessed with two way analysis of variance (ANOVA), in which the factors were B rates and cultivar with a 95% confidence interval; the interactions between the factors are shown in Table 2. The data were subjected to a normality test, and the means were compared by Tukey’s test at P≤0.05.

## Results and discussion

In fruit species, B imbalances are implicated in poor pollen germination and tube growth, mainly affecting flowering and fruit set (Chen *et al.*, 1998). Our results showed that there was a significant cultivar (C) × boron (B) interaction effect on marketable fruit yields per bush ( $\text{kg bush}^{-1}$ ) (Table 2). Spraying B on Brigitta at all three rates increased fruit production relative to the control ( $0 \text{ mg L}^{-1}$ ), although the rate of  $200 \text{ mg L}^{-1}$  resulted in a higher fruit yields per plant ( $3.3 \text{ kg bush}^{-1}$ ) (Figure 2). These yields increases were significantly correlated with final fruit set percentage ( $r=0.95$ ), which significantly increased by 89, 66 and 72% in B-sprayed Brigitta plants at rates of 200, 400 and  $800 \text{ mg B L}^{-1}$ , respectively, compared to the control (Figure 2). However, the  $200 \text{ mg B L}^{-1}$  rate had a greater effect on this parameter than the rates 400 and  $800 \text{ mg B L}^{-1}$  ( $P \leq 0.05$ ).

In the Legacy cultivar, the fruit set increased by 42 and 35% with the 400 and  $800 \text{ mg B L}^{-1}$  treatments, respectively, compared to the control ( $P \leq 0.05$ ; Figure 3), and these increases may be attributed to improved pollen germination and tube growth. The B concentration is strongly associated with precursors of pollen tube formation (polypeptides, glycoproteins and arabinofuranosyl, among others), and polysaccharides, allowing to B binding to these complexes, which can be translocated more efficiently through biological membranes to promote cell wall development in reproductive organs (Lee *et al.*, 2009). In this context, an increase in the fruit set percentage was observed in the Asian pear tree (*P. pyrifolia*) by Lee *et al.* (2009) in the season following postharvest foliar applications of B ( $200 \text{ mg B L}^{-1}$ ). By contrast, Chen *et al.* (1998) detected no significant differences in fruit set between B treatments ( $400 \text{ mg L}^{-1}$ ) in 12 lowbush blueberry (*V. angustifolium* Ait.) clones.

In our study, both cultivars presented constituent genotypic differences in fruit set in the control treatment, so the application of  $200 \text{ mg B L}^{-1}$  increased the fruit set in Brigitta by 67% com-

pared to Legacy ( $P \leq 0.05$ ; Table 2), with the latter maintaining this fruit set percentage in relation to the control (Figure 3). The 400 and  $800 \text{ mg B L}^{-1}$  treatments had similar fruit set percentages (83-92%) to the control, which suggests that the application of B at higher rates homogenized the fruit set in both cultivars (Figure 3).

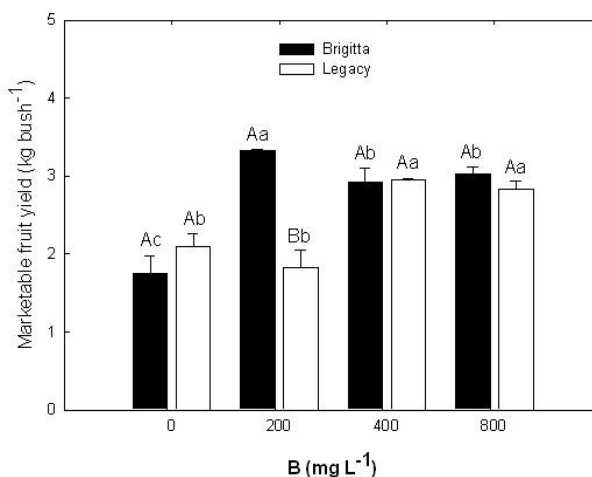
A significant C × B interaction was found for Brigitta fruit (1<sup>st</sup> harvest) firmness ( $\text{g mm}^{-2}$ ) (Table 2) with averages of  $676 \text{ g mm}^{-2}$  in the control and  $848 \text{ g mm}^{-2}$  in the fruit treated with  $400 \text{ mg B L}^{-1}$ , representing an increase of ~25% ( $P \leq 0.05$ ; Figure 4). The firmness values of the other B rates did not differ statistically from the control; the average firmness was 14% lower than that of the  $400 \text{ mg B L}^{-1}$  treatment ( $P \leq 0.05$ ). In Legacy, the firmness was increased by 48% at  $200 \text{ mg B L}^{-1}$  over the control and the  $400 \text{ mg B L}^{-1}$  ( $P \leq 0.05$ ). Whereas a higher firmness 75% under  $400 \text{ mg B L}^{-1}$  was found in comparison to  $800 \text{ mg B L}^{-1}$  treatment ( $P \leq 0.05$ ; Figure 4). The loss of firmness in the Legacy fruits, but not in Brigitta treated with 400 and  $800 \text{ mg B L}^{-1}$  is explained by environmental and genotypic factors that might be influence by the many cellular processes driving division and elongation.

In terms of B spray rates, Brackmann *et al.* (2016) found decreased flesh firmness in fruits of the apple cv. Galaxy after two pre-harvest foliar B applications ( $1.5 \text{ kg ha}^{-1}$ ); according to the author, excessive B triggered an increase in ethylene production and respiration rate, resulting in fruits with a faster metabolism and ripening compared to non-treated fruits. The differences among treatments and among the treatments and the control indicated a sustained and significant trend toward firmer fruit at harvest from Legacy and even more so from Brigitta with foliar B at rates of 200 and  $400 \text{ mg L}^{-1}$ , respectively. In addition to firmness, the soluble solid (SS) content measured in °Brix is an important quality parameter of fresh fruit. The SS content determines the moment of maturity for harvest and is a key factor in the post-harvest life of the fruit (Bizyak *et al.*, 2013).

**Table 2.** Variance analysis of the yield and fruit set, firmness, soluble solids (SS), fresh weight (FW), dry matter (DM), equatorial diameter (ED), polar diameter (PD), and antioxidant capacity by ORAC and DPPH.

Mean square	Source of variation		
	Cultivar (C)	B rates (B)	C×B
Yield	9.9 <sup>2</sup>	20.3 <sup>3</sup>	14.8 <sup>3</sup>
Fruit set	9.2 <sup>2</sup>	19.9 <sup>3</sup>	14.4 <sup>3</sup>
Firmness	69.2 <sup>3</sup>	16.0 <sup>3</sup>	30.2 <sup>3</sup>
SS	2.2 ns	4.2 <sup>1</sup>	1.5 ns
FW	71.7 <sup>3</sup>	17.9 <sup>3</sup>	0.1 ns
DM	49.1 <sup>3</sup>	2.2 ns	0.7 ns
ED	0.5 ns	1.3 ns	0.5 ns
PD	1.6 ns	0.6 ns	1.5 ns
ORAC	8.5 <sup>2</sup>	111.0 <sup>3</sup>	31.8 <sup>3</sup>
DPPH	9.9 <sup>2</sup>	2.9 <sup>1</sup>	3.9 <sup>1</sup>

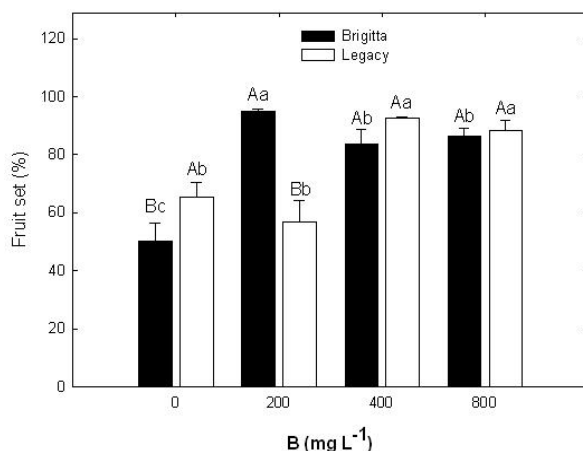
Significance designated as ns: not significant; <sup>1</sup>P≤ 0.05; <sup>2</sup>P≤ 0.01; <sup>3</sup>P≤ 0.001



**Figure 2.** Marketable fruit yield by plant (kg bush<sup>-1</sup>) in Brigitta and Legacy blueberry cultivars by B spraying rate (0, 200, 400 and 800 mg L<sup>-1</sup>). The bars represent the average of three replicates ± standard error (S.E.). Upper case letters indicate differences (P≤0.05) between cultivars for the same B rate, and lower case letters indicate differences (P≤0.05) among B rates for the same cultivar.

In our study, no significant C×B interaction was found, and the SS content in Brigitta fruit increased by 12.5% with 200 mg B L<sup>-1</sup> compared to the control (P≤0.05; Figure 5), whereas in Legacy, all of the B treatments yielded average SS contents between 14.7 and 15.4 °Brix and no significant differences among them were found. These SS values resulting from the different treatments represented increases of 16, 15 and 11%, respectively, compared to the control (P≤0.05). Following applications of foliar B (0.2 kg ha<sup>-1</sup> = 400 mg L<sup>-1</sup>), similar increases in SS were

reported by Wojcik (2005) in Bluecrop blueberry cultivar and by Khallifa *et al.* (2009) in apple. Martínez *et al.* (2008) reported that a B deficiency in Cape gooseberry (*Physalis peruviana* L.) significantly decreased the SS by 66% compared to the control. Our results are consistent with those of Marschner (1995), who indicated that B facilitates the transport of sugars produced by the formation of B-sugar complexes or the increased leaf photosynthesis rate caused by the role of B on physiological processes (Wimmer and Eichert, 2012).



**Figure 3.** Fruit set (%) in Brigitta and Legacy blueberry cultivars according to B spraying rate (0, 200, 400 and 800 mg L<sup>-1</sup>). The bars represent the average of three replicates  $\pm$  S.E. Upper case letters indicate differences ( $P \leq 0.05$ ) between cultivars for the same B rate, and lower case letters indicate differences ( $P \leq 0.05$ ) among B rates for the same cultivar.

There were significant effects of B and C on the fresh weight (g) of berries from both of the evaluated blueberry cultivars (Table 2). The 400 and 800 mg B L<sup>-1</sup> treatments presented a 20% increase in Brigitta fruit weight (1.78 g) compared to the control ( $P \leq 0.05$ ; Table 3), whereas in Legacy, the fresh weight (FW) of the fruit increased by as much as 31% (2.22 g) at harvest ( $P \leq 0.05$ ). In addition to water, fruits are rich in sugars, two constituents for which B plays a key role in translocation (Wimmer and Eichert, 2012), but Wojcik (2005) reported no effect on the fresh weight of fruits after several applications of B (400 ppm) in the Bluecrop highbush blueberry cultivar, which could be due to differences in genotypic performance. In terms of the dry matter (DW) of Brigitta and Legacy fruits, there was an observed increase of between 6 and 15% under the different application treatments compared to the control ( $P \leq 0.05$ ; Table 3). Regardless of the B rates, the Legacy cultivar exhibited greater fruit weight, dry matter percentage and water content in its fruits ( $P \leq 0.05$ ; Table 3), which can be attributed to the genotypic traits of the cultivar.

No C  $\times$  B interaction was observed on the physical parameters of fruits. In terms of fruit size, under

all B rates, an average equatorial diameter (ED) of 16.02 and 15.51 mm was observed in Brigitta and Legacy, respectively, while the average polar diameter (PD) was 11.42 mm in Brigitta and 11.15 mm in Legacy (Table 3). There was no C  $\times$  B interaction or individual effects of C and B on the equatorial diameter (ED) of the berries, which averaged  $16.0 \pm 0.62$  mm and  $15.5 \pm 0.69$  for Brigitta and Legacy, respectively whereas polar diameter (PD) did not show any differences with averages of  $11.4 \pm 0.31$  and  $11.15 \pm 0.46$ . These results are consistent with those reported by Chen *et al.* (1995) in lowbush blueberry and Wojcik (2005) in highbush blueberry, who found no differences in fruit size between the application of B (400 mg L<sup>-1</sup>) and the control. Conversely, Khalifa *et al.* (2009) observed increases in the sizes of apples (*Malus domestica* Borkh) from four-year-old trees sprayed with B (as 0.025, 0.05 and 0.1% boric acid) in two seasons and attributed the physiological role of B to cell elongation and carbohydrate transport to reproductive tissues such as flowers and fruits.

The role of B in the reduction of the oxidative stress related to the increase in reactive oxygen species (ROS) has been reported in the nuts of

**Table 3.** Effect of foliar B application on the fresh weight (g), dry matter (%) and water content (%) of blueberry fruits from Brigitta and Legacy cultivars according to foliar B treatment (0, 200, 400 and 800 mg L<sup>-1</sup>). The values represent the average of three replicates ± S.E. Upper case letters indicate differences (P≤0.05) between cultivars for the same B rate, and lower case letters indicate differences (P≤0.05) between B rate for the same cultivar.

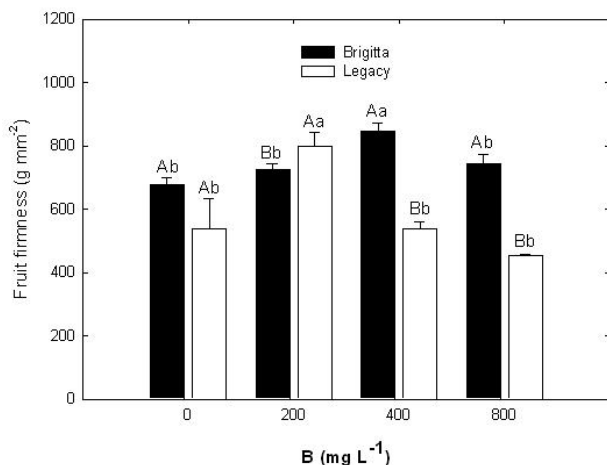
B rate (mg L <sup>-1</sup> )	Fresh fruit weight (g)	Dry matter (%)	Water content (%)
Brigitta			
0	1.48±0.06 bB	10.95±0.46 bB	89.05±0.46 aA
200	1.43±0.01 bB	11.53±0.60 abB	88.47±0.59 aA
400	1.78±0.07 aB	12.67±0.99 aB	87.33±0.98 aA
800	1.78±0.07 aB	12.08±1.47 aB	87.92±1.48 aA
Average	1.62±0.05	11.80±0.88	88.20±0.87
Legacy			
0	1.70±0.04 bA	15.53±0.56 bA	84.47±0.56 aB
200	2.00±0.06 aA	14.15±1.21 bA	85.85±1.21 aB
400	2.22±0.11 aA	16.32±0.90 aA	83.68±0.89 aB
800	2.13±0.08 aA	16.51±0.98 aA	83.49±0.98 aB
Average	2.20±0.07	15.62±0.91	84.37±0.91

species such as European hazelnut (Mishra *et al.*, 2010), but there is no information about the effect of this nutrient on the antioxidant traits of blueberry fruits. In our study, there was a significant C×B interaction on the antioxidant activity, evaluated by the ORAC method, in the harvested fruit (Table 2). ORAC was increased by 35 and 50% in Brigitta and Legacy, respectively, under the 200 mg L<sup>-1</sup> treatment (P≤0.05; Figure 4). However, the Brigitta fruits showed a significant ORAC reduction (up to 67%) under the 800 mg L<sup>-1</sup> treatment compared to the control. The strong increases in ORAC observed in Brigitta and Legacy (200 mg L<sup>-1</sup>) may be due to the increasing B concentration and the metabolism of phenolic compounds (Blevins and Lukaszewski, 1998), which significantly contribute to ORAC activity (Ehlenfeldt and Prior, 2001). Although deficient B contents have been linked to an increase in phenol content, its excess can restrict the enzyme activity related to the synthesis of phenolic compounds like phenylalanine ammonium-lyase (Dahajipour Heidarabadi *et al.*, 2011), which should be explained by the significant reduction in ORAC of Brigitta with the highest B application rates. The ORAC values observed in control fruits were higher than those reported by Ehlenfeldt and Prior (2001)

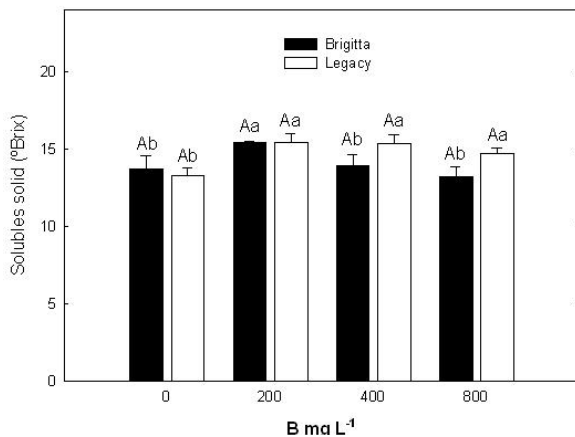
for Brigitta (17.7 μmol TE g<sup>-1</sup> FW) and Legacy (13.5 μmol TE g<sup>-1</sup> FW), which were similar to those reached in fruits from plants treated with 800 mg L<sup>-1</sup>. This result was consistent with that reported by Ribera *et al.* (2010), indicating that highbush blueberry fruits grown in southern Chile have exceptionally higher antioxidant activity in comparison to those cultivated in the Northern Hemisphere. The DPPH methodology used to determine antioxidant activity indicated a C×B (P≤0.05; Table 2), which increases the activity in Legacy fruits treated with 200 and 400 mg L<sup>-1</sup> compared to the control (P≤0.05; Figure 4). According to the results, differences were observed between cultivars as the DPPH was higher in the fruit harvested from Legacy than Brigitta plants subjected to B treatments (P≤0.05).

In the experiment, the foliar application of B on highbush blueberry differentially increased the fruit set and yield per bush depending on the spray rate and the cultivar. The lowest B rate (200 mg L<sup>-1</sup>) had a more favorable effect on these parameters in Brigitta, whereas higher rates (400 and 800 mg L<sup>-1</sup>) brought about increases of approximately 40% in comparison to the non-treated bushes in Legacy. This suggests that the





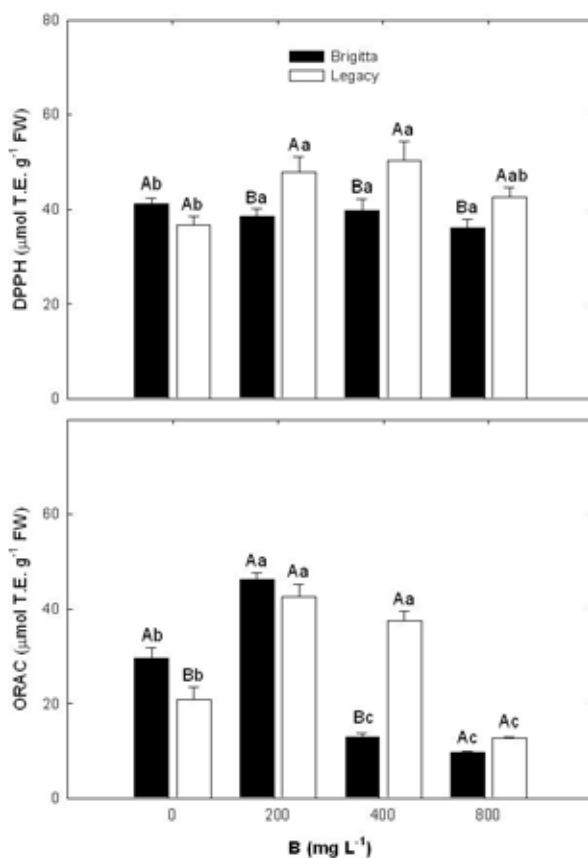
**Figure 4.** Firmness (g mm<sup>2</sup>) at harvest of blueberry fruits from Brigitta and Legacy cultivars by B spraying rate (Control, 200, 400 and 800 mg L<sup>-1</sup>). The bars represent the average of three replicates ± S.E. Upper case letters indicate differences (P≤0.05) between cultivars for the same B rate, and lower case letters indicate differences (P≤0.05) among B rates for the same cultivar.



**Figure 5.** Soluble solids (°Brix) at harvest in blueberry fruits from Brigitta and Legacy cultivars by B spraying rate (0, 200, 400 and 800 mg L<sup>-1</sup>). The bars represent the average of three replicates ± S.E. Upper case letters indicate differences (P≤0.05) between cultivars for the same B rate, and lower case letters indicate differences (P≤0.05) among B rates for the same cultivar.

application of B homogenizes the fruit set and production in both highbush blueberry cultivars but at different rates. As a micronutrient related to cell integrity, the B treatments also affected the studied cultivars; rates between 200 and 400 mg L<sup>-1</sup> promoted firmness in Legacy and Brigitta, respectively. In relation to the color and total SS content of the fruit at the moment of the

harvest, low B application rates were observed to differentially increase the transport of sugars to the fruits in Brigitta. This demonstrates the facilitating role of B in sugar transport that has been reported in different fruit species (Wimmer and Eichert, 2012). After three applications of B during the reproductive season, the fresh and dry weight of the fruit was differentially



**Figure 6.** Antioxidant capacity (ORAC and DPPH) in blueberry fruits from Brigitta and Legacy cultivars by B spraying rate (0, 200, 400 and 800 mg L<sup>-1</sup>). The values represent the average of three replicates  $\pm$  S.E. Upper case letters indicate differences ( $P \leq 0.05$ ) between cultivars for the same B rate, and lower case letters indicate differences ( $P \leq 0.05$ ) among B rates for the same cultivar.

increased in the evaluated cultivars, although it had no effect on fruit size. With respect to the antioxidant activity measured by ORAC and DPPH, higher values were observed at the low application rate in Brigitta and at the intermediate rate in Legacy, but high concentrations of B negatively impacted this parameter. Finally, the results suggest that foliar applications of B in spring must be determined according to the cultivar. These studies must be extended to more of the cultivars the frequently grown in southern Chile, and treatments must be applied

over several seasons to ensure improved fruit quality parameters.

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### Resumen

**C. Meriño-Gergichevich, E. Pacheco y M. Reyes-Díaz. 2016. Efecto de la aplicación foliar de boro sobre la calidad de fruta en los cultivares Brigitta y Legacy de arándano alto (*Vaccinium corymbosum*). Cien. Inv. Agr. 43(3):452-463.** El boro (B) está asociado al metabolismo reproductivo y antioxidante en plantas. En el sur de Chile, su deficiencia es resuelta con aplicaciones foliares de este micronutriente como parte del manejo agronómico, asegurando así la productividad en cultivos como arándano alto (*Vaccinium corymbosum* L.). Sin embargo, la información sobre dosis adecuadas para esta especie es escasa. Se evaluó la aplicación foliar de B sobre parámetros de calidad en fruta de arándano alto del sur de Chile. En la temporada 2014-2015, plantas de cultivares Brigitta y Legacy, fueron asperjadas con B en dosis de 0 (control), 200, 400 y 800 mg L<sup>-1</sup> en tres momentos durante la temporada (10% floración, plena flor y fruto cuajado), determinándose: frutos cuajados (%), firmeza (g mm<sup>-2</sup>), sólidos solubles (°Brix), peso (g) y calibre (mm), además de la actividad antioxidante mediante ORAC (oxygen radical absorbance capacity) y DPPH (2,2-diphenyl-1-picrylhydrazyl). Una baja dosis de B (200 mg L<sup>-1</sup>) incrementó la cuaja y sólidos solubles en Brigitta, mientras que Legacy requirió mayores concentraciones de B (400 y 800 mg L<sup>-1</sup>). En ambos cultivares aumentó la firmeza, peso fresco y seco de la fruta, así como la actividad antioxidante al ser tratada con 200 y 400 mg B L<sup>-1</sup>, mientras en alta concentración disminuyó este último parámetro. Una baja dosis de B resultó ser efectiva mejorando la calidad de la fruta en el cultivar Brigitta, mientras que Legacy requirió dosis de B más alta. Futuras investigaciones deberían ser realizadas en diferentes temporadas y cultivares para confirmar esta tendencia.

**Palabras clave:** Antioxidantes, DPPH, calidad de fruta, micronutriente, ORAC.

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