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EFFECTS OF BORON ON YIELD, QUALITY AND LEAF NUTRIENTS OF ISABELLA (*Vitis labrusca* L.) GRAPE CULTIVAR

Hatice Bilir Ekbic[1]✉, Nihan Gokdemir[1], Halil Erdem[2]

[1] Department of Horticulture, Faculty of Agriculture, University of Ordu, 52200, Ordu, Turkey
[2] Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Gaziosmanpasa Üniversitesi, Tokat

ABSTRACT

The present study was conducted in 2014 vegetation season in a vineyard of Giresun Hazelnut Research Institute. Isabella (*Vitis labrusca* L.) grape cultivar were treated with four different boric acid (H_3BO_3) doses (control, 0.1%, 0.2%, 0.3%) at two different periods (a week before and after full-bloom). The effects of foliar boron treatments on yield, quality and leaf nutrients were investigated. Boric acid treatments positively influenced cluster weight, width and volumes and increasing values were observed with increasing boron doses. Boric acid treatments also influenced berry homogeneity and yielded more homogeneous appearance. Chlorophyll contents increased with increasing boron treatments. The greatest yield, cluster length, cluster volume, cluster size, cluster width, berry width and leaf area were obtained from 0.3% boric acid treatments. In general, leaf nitrogen, phosphorus, calcium, magnesium, zinc and copper concentrations increased, but potassium and iron concentrations decreased with increasing boron doses. As compared to control treatment, all treatments had broader leaf sizes and higher chlorophyll contents. Especially 0.3% boric acid treatments had quite positive influences on quality, size and color homogeneity. Considering the nutrients and pH level of experimental soils, it was concluded that foliar nutrient treatments may support plant growth and development and 0.3% boric acid treatments were recommended for high quality and quantity yields in Isabella grape cultivar.

Key words: fox grapes, foliar fertilization, boric acid, quality, macro nutrient, micro nutrient

INTRODUCTION

Among the ecological factors, temperature and precipitations have great impacts on productivity of agricultural activities, species diversity, ripening durations and distributions [Dogan 2008]. Isabella is a grape cultivar in *Vitis labrusca* L. species and the cultivar with resistance to fungal diseases and special strawberry-like aroma is commonly grown along the coastal sections of Black Sea region. Black Sea region is located in northern sections of Turkey and the region has quite precipitated climate. Such high precipitations result in chemical weathering and thus regional soils usually have acidic characteristics. Boron deficiency is a widespread problem in sandy and alkaline soils [Wang et al. 2015]. In such cases, foliar absorption of micro nutrients is more efficient and economical [Fageria et al. 2009, Fernandez et al. 2013, Christensen et al. 2016]. Among the micro nutrients, boron has a special significance. The sufficient and toxic boron levels are quite close to each other.

✉ haticebilirekbic@gmail.com

This element was specified as an essential nutrient for tall plants 84 years ago [Wagar et al. 2012]. Available boron content, pH, types of exchangeable ions, type and quantity of minerals, organic matter content and moisture content of soils greatly influence plant boron uptakes from the soil [Keren et al. 1985, Goldberg 1997]. Boron deficiency is quite common in acidic soils of Black Sea region [Kim et al. 2000, Boyd 2002]. Boron deficiency was also reported in 132 plant species in 80 different countries [Shorrocks 1997]. Boron requirements are usually higher in fruit formation period than the other growth stages [Dell and Huang 1997]. Shelp and Brown [1997] reported the greatest boron concentration in leaves and reproductive organs and the least concentrations in root, fruit and seeds. Boron had positive effects on sugar transport, cell membrane synthesis, ascorbate metabolism, nitrogen fixation, aluminium toxicity, indole acetic acid metabolism, respiration, lignification, cell wall structure, carbohydrate, RNA and phenol metabolisms, membrane biology and functional characteristics [Lukaszewski and Blevins 1996, Camacho-Cristobal et al. 2008, Ahmad et al. 2009] and fruit growth and development [Faust 1989]. Under boron deficiency, inter-nodes narrowed, decoloring is observed in tip leaves starting from the leaf edges and extending to inner sections, leaf dry outs and shrinkages are seen. Under excessive boron deficiency, dried leaves fall off and several offshoots are formed. Lignification and defoliation starts from shoot tips and moves downward. Reduced cluster fruit sets were reported in boron deficiency [Mengel et al. 2001]. Foliar boron application has been researched in different fruit species such as pomegranate, pistachio, pears, almonds to find the application time and effects on fruit set and fruit quality [Acar et al. 2016, Davarpanah et al. 2016, Sarafi et al. 2017]. However there are few researchs that foliar boron application on vine to find effects to yield and quality.

The present study was conducted to improve berry and cluster size and homogeneity of Isabella (*V. labrusca* L.) grape cultivar, well-adapted to soil and climate conditions of Black Sea region [Celik et al. 2015] and to investigate the effects of foliar boric acid treatments on yield, quality and leaf macro and micro nutrients of Isabella grapes. In addition, the optimum boric acid dose was tried to be determined in this research.

MATERIAL AND METHODS

Experimental vineyard

About 11-years old Isabella vines (*Vitis labrusca* L.) were used in this study. Guyot-trained vines with double T-support system have 3 m row spacing and 2 m on-row vine spacing. The experimental site has a dominant Black Sea climate. The highest temperature (29°C) was measured in August and the lowest temperature (–1.3°C) was measured in December. The experimental site had an annual precipitation of 1200 mm. Soil samples were taken from 0–20 and 20–40 cm depths to determine some physical and chemical soil characteristics. Experimental soils had sandy texture [Bouyoucus 1951] with a pH of 5.67 [Jackson 1959], organic matter content of 3.36–2.80% [Nelson and Sommers 1982], available K concentration of 142 mg kg^{-1} [Klute et al. 1986] and available P concentration of 126.68 mg kg^{-1} [Olsen et al. 1954]. Available micro element concentrations were determined with DTPA extraction method developed by Lindsay and Norwell [1978]. Soil iron (Fe) concentrations varied between 52.61–54.00 mg kg^{-1}, manganese (Mn) concentrations varied between 2.55–2.89 mg kg^{-1}, zinc concentrations varied between 7.17–4.61 mg kg^{-1} and copper concentrations varied between 0.40–0.38 mg kg^{-1}. Available boron concentration was determined as 0.39 mg kg^{-1} [Cartwright et al. 1983]. Wolf [1971] categorized soils based on their available boron concentrations as low (0.4–0.9 ppm), sufficient (1.0–2.4 ppm) and excessive (2.5–4.9 ppm). Present boron concentration was quite below these concentrations (tab. 1).

Table 1. The feature of experimental soils

Depth (cm)	pH	Organic matter (%)	Micro (ppm)				
			Fe	Mn	Zn	Cu	B
0–20	5.67	3.36	52.61	2.55	7.17	24.35	0.40
20–40	5.64	2.80	54.00	2.89	4.61	39.18	0.38

Experimental design

Experiments were conducted in randomized plots experimental design with 3 replications with 4 vines in each replication (12 vines were used for each treatment) in 2014 vegetation season.

Different boric acid (H_3BO_3) doses (0, 0.1%, 0.2% and 0.3%) were applied through foliar sprays at two different periods (1 week before and 1 week after full bloom). In present experiments, 0.1 kg ha^{-1} nitrogen (ammonium nitrate) and K_2O (potassium nitrate) and 0.5 kg ha^{-1} P_2O_5 (triple super phosphate) were applied to all vines. Winter and summer pruning were also performed. Manual weed control was practiced and pests and disease control was practiced only for vine mildew.

Statistical analysis

Data were subjected to ANOVA and means were compared with LSD test at 5% level. Statistical analyses were performed with JMP 10.0 statistical software.

Leaf nutrient content

Leaf nutrient concentrations were determined to see the efficiency of foliar boric acid treatments. Petiole samples were taken from the sections of clusters of each treatment vine at veraison period. Samples were washed, dried and ground in an agate mortar and then subjected to dry-ashing [Kacar and Inal 2008]. Total nitrogen (%) was determined with Kjeldahl method [Bremner 1965]. Phosphorus content (%) was determined with Barton [1948] method. Potassium (%), calcium (%), magnesium (%), iron (ppm), zinc (ppm), manganese (ppm) and copper (ppm) analyses were performed on dry-ashed samples in an atomic absorption spectrophotometer [Chapman et al. 1961].

Leaf area (cm^2)

Leaf samples were taken from 1/3 section of summer shoots with identical vigor at veraison period. Leaf area was measured with a planimeter (KOIZUMI-KP-90N).

Cluster and berry characteristics and stum chemical composition

These analyses were performed on ripened clusters. 20 Berries were sampled from mid-sections (1/3) of each cluster. Cluster and berry weights (g) were determined with a precise balance (±0.01 g). Cluster length (cm) and widths (cm) were measured with a ruler. Berry lengths and widths (mm) were measured with a digital caliper. Cluster sizes (cm^2) were calculated by multiplying average cluster lengths with cluster widths. Berry sizes (mm^2) were measured by multiplying average berry lengths with berry widths. Cluster and berry volumes were measured with a graduated cylinder. Berry size and color homogeneity were classified as either homogeneous (+) or non-homogeneous (–). Vine yields (g vine^{-1}) were calculated by multiplying the number of clusters of each vine with average cluster weight. Stum was obtained through pressing the berries selected from the mid-sections of clusters. Then, soluble solids (SS) was determined with a digital refractometer (HI96801) and pH was measured with a pH meter (HI 2211-02). The titrable grape juice acidity (%, g 100 ml^{-1} grape juice) was measured with 0.1 N sodium hydroxide titration method in three repetitions. Maturity index was calculated as SS/Acidity.

RESULTS AND DISCUSSION

Effects of boric acid treatments on leaf macro nutrient concentrations

Foliar boric acid treatments applied at different doses had significant effects on leaf nitrogen, phosphorus, magnesium and calcium contents ($P < 0.05$). Leaf nitrogen contents of both periods varied between 2.23–2.48 %. Present values were within the optimum values (1.6–2.8%) specified by Mills and Jones [1996] for vines. The greatest nitrogen concentration (2.48%) was obtained from 0.1% boric acid treatment at full-bloom. In this study, nitrogen concentrations increased with increasing boric acid doses. The greatest phosphorus concentration was observed in 0.2% boric acid treatments (0.30%). Following the control treatment, the lowest phosphorus concentration was observed in 0.3% boric acid treatment (0.26%). Current phosphorus concentrations were found to be sufficient as compared to the values reported by Kenworthy and Martin [1996] (0.10–0.40%). Alıcı and Oncel [2008] indicated that boron toxicity could be eliminated with phosphorus treatments. With this information, the effects of increasing phosphorus concentrations in present study were found to be positive. Boric acid treatments increased magnesium concentrations of the leaves sampled and such an increase was quite remarkable in leaves sampled. The greatest magnesium concentration was obtained from 0.3% boric acid treatment (0.44%). The lowest magnesium concentration was observed in control treatment. Present values were within the optimum magnesium values (0.3–0.5%) specified by Robinson et al. [1982]. Calcium concentration increased with increasing boric acid doses. The greatest calcium concentration was observed in 0.3% boric acid treatment (2.74%). The lowest calcium concentration was observed in control treatment (2.37%) (tab. 2). Present calcium values were higher than the optimum values (1.2–1.8%) specified by Funt et al. [1999]. Generally, foliar B fertilizer application increased N, P, Ca, Mg content in leaf in this study. These results are similar to those obtained by Mills and Jones [1996], Gunes et al. [2015] for grapevines. However K content in leaf was reduced by increased boric acid doses. This result was not similar the results of researchs above.

Effects of boric acid treatments on leaf micro nutrient concentrations

Foliar boric acid treatments had significant effects on leaf zinc, iron and copper concentrations ($P < 0.05$). Increasing zinc concentrations were observed with increasing boric acid doses. The lowest zinc concentration was observed in control treatments. The greatest zinc concentration was observed in 0.3% boric acid treatments (35.99 ppm). Scardena et al. [1999] indicated that the greatest zinc concentrations should be between 30–50 ppm. There were not any problems with regard to Zn nutrition of treated-vines and it was observed that boric acid treatments had positive contributions to leaf zinc concentrations. The result in Zn was similar to Gunes et al. [2015]. The greatest iron concentrations were observed in control treatments (254.22 ppm). The lowest iron concentration was observed in 0.3% boric acid treatment (204.76 ppm Fe). All these concentrations were within the limiting values specified by Fregoni [1984] and Mills and Jones [1996] (50–300 ppm; 60–175 ppm). These results of Zn and Fe content in leaf are similar to those obtained by Mills and Jones [1996], Gunes et al. [2015] for grapevines, Singh and Singh [1983] for lentil.

Boric acid treatments had significant effects on leaf copper concentrations and increasing copper concentrations were observed with increasing boric acid doses. Leaf copper concentrations increased with increasing boric acid doses and the greatest concentration was observed in 0.3% boric acid treatment (8.33 ppm). For copper (Cu), Fregoni [1984] reported the optimum values as between 5–20 ppm. Considering these values, it was observed that all vines had sufficient copper nutrition and improved Cu concentrations were achieved with increasing boric acid doses. While the effects of boric acid treatments on leaf manganese concentrations were significant ($P < 0.05$). The greatest manganese concentration was observed in 0.3% boric acid treatment (209.36 ppm) and it was respectively followed by 0.2% (155.19 ppm) and 0.1% (138.99 ppm) boric acid treatments Fregoni [1984]

Table 2. Effects of increasing boric acid treatments on leaf nutrients

Boric acid doses	Total Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Zinc (ppm)	Iron (ppm)	Copper (ppm)	Manganese (ppm)	Leaf area (cm^2)
0%	2.23 b	0.22 d	1.87 a	2.37 c	0.31 b	24.37 d	254.22 a	6.62 b	137.24 c	115.6 b
0.1%	2.48 a	0.28 b	1.84 a	2.53 b	0.32 b	27.90 c	259.27 a	3.82 c	138.99 c	118.1 ab
0.2%	2.42 a	0.30 a	1.40 b	2.57 b	0.41 a	32.49 b	206.85 b	7.90 a	155.19 b	120.3 ab
0.3%	2.43 a	0.26 c	1.29 b	2.74 a	0.44 a	35.99 a	204.76 b	8.33 a	209.36 a	121.1 a
LSD 5%	0.06	0.01	0.12	0.10	0.05	2.69	21.46	0.54	6.05	4.8

Table 3. Effects of increasing boric acid treatments on cluster characteristics

Boric acid doses	Yield (g $vine^{-1}$)	Cluster weight (g)	Cluster length (cm)	Cluster width (cm)	Cluster size (cm^2)	Cluster volume (ml)
0%	2373 c	81.5 c	11.2 c	6.6 d	74.3 c	83 c
0.1%	3147 b	101.5 b	11.1 c	7.5 c	85.6 c	114 b
0.2%	2942 b	106.8 b	12.6 b	8.7 b	110.0 b	115 ab
0.3%	4011 a	132.1 a	13.5 a	10.4 a	140.2 a	122 a
LSD 5%	323	6.9	0.8	0.5	11.7	7

reported manganese concentrations as between 20–400 ppm and such values indicated that all treatments, including control treatment, had sufficient manganese nutrition (tab. 2). Results of Mn content in the study is similar to results obtained by Gunes et al. [2015].

Leaf area (cm^2)

Effect of different boric acid doses on leaf area was found to be significant ($P < 0.05$). The lowest leaf areas were observed in control treatments (115.6 cm^2). The greatest leaf area was observed in 0.3% boric acid treatment (121.1 cm^2) (tab. 2). Boron is important to be available for new reproductive tissues and vegetative growth [Marschner 1995]. Vine growth improvement due to using boron may be due to the simulative effect it on cell division in meristematic tissues [Adriano 1985, Fawzi et al. 2014].

Cluster characteristics

Foliar boric acid spray treatments at different doses had significant effects on yields ($P < 0.05$). The yield in 0.3% boric acid treatments was measured as 4011 g $vine^{-1}$. All boric acid-treated vines had higher yields than the control vines. Several other researchers mentioned increasing yields with boric acid treatments [Bhakare et al. 2006, Er et al. 2011, Akl et al. 2014, Fawzi et al. 2014]. Cluster weight, length, width, size and volume also increased with increasing boric acid doses. All these effects on cluster parameters were found to be significant ($P < 0.05$). The 0.3% boric acid treatment, with the greatest yield, had the greatest effects on other parameters (tab. 3). Kumar et al. [2004] carried out a micro element fertilization research in Muscat grapes and reported increased cluster weights with single boron or combined boron + zinc treatments. Similar findings were also reported for cluster parameters by Mostafa et al. [2006], Akl et al. [2014], Fawzi et al. [2014] and Güneş et al. [2015]. Cangi et al. [2006] carried out a study to determine ampelographic characteristics of aromatic fox grapes and reported the greatest cluster size as 86.4 cm^2 and the lowest cluster size as 59.0 cm^2. As compared to those sizes, present findings revealed significant increases in cluster sizes with boric acid treatments.

Table 4. Effects of increasing boric acid treatments on berry characteristics

Boric acid doses	Berry weight (g)	Berry length (mm)	Berry width (mm)	Size homogeneity	Color homogeneity	Berry size (mm^2)	Berry volume (ml)
0%	2.66 b	17.0	15.5 b	–	–	263.5 b	2.52 b
0.1%	2.63 b	17.1	16.0 ab	+	+	274.4 ab	2.57 b
0.2%	3.35 a	17.8	16.2 ab	+	+	284.0 a	3.13 a
0.3%	3.32 a	17.4	16.5 a	+	+	288.6 a	3.20 a
LSD 5%	0.16	NS	0.8	+	+	18.6	0.13

Berry characteristics

Boric acid treatments had significant effects on berry weight, width, size and volumes (P < 0.05). Higher values were obtained from 0.2 and 0.3% boric acid treatments than the control and 0.1% boric acid treatments. The greatest berry weights were respectively observed in 0.2% (3.35 g) and 0.3% (3.32 g) boric acid treatments and the berry weight of control treatment was measured as 2.66 g. Positive effects of boric acid treatments on berry weights were also reported by Haggag [1987], Bhakare et al. [2006], Akl et al. [2014] and Fawzi et al. [2014]. The greatest berry width (16.5 mm) and berry size (288.6 mm^2) was obtained from 0.3% boric acid treatment. The lowest berry size (263.5 mm^2) was observed in control treatment (tab. 4). Increasing berry widths and lengths and consequently increasing berry sizes with boron treatments were also reported by Fregoni [1977] and Fawzi et al. [2014]. The results on berry volume were parallel to the results on berry size and weights. The greatest berry volume (3.20 ml) was again observed in 0.3% boric acid treatment (tab. 4). Similar to present findings, [Haggag 1987] also reported increasing berry volumes with boron treatments.

Grape juice chemical characteristics

The greatest soluble solid (SS) was obtained from 0.1% boric acid treatment (17.2%) and it was followed by the control treatment (16.2%). The SS contents of 0.2 and 0.3% boric acid treatments were respectively measured as 14.5 and 14.9% (P < 0.05). The greatest grape juice pH value was observed in control treatment (3.44) (P < 0.05). Effects of increasing boric acid doses on acidity were also found to be significant (P < 0.05). The greatest acidity was observed in 0.3% boric acid treatment (0.026%) and it was followed by 0.2% boric acid treatment (1.002%) and the lowest value was seen in 0.1% boric acid treatment. Maturity index values were parallel to SS and acidity values. The greatest maturity index was observed in 0.1% boric acid treatment (19.5), it was followed by control treatment (17.2) and the lowest and closer values were seen in 0.2% (12.6) and 0.3% (12.5) boric acid treatments. It was observed in this study that low boric acid doses reduced SS contents (tab. 5). Dabas and Jindal [1985] reported the greatest SS content in Thomson Seedless grape cultivar as 19.87% for 0.3% boric acid treatment. Haggag [1987] recommended 0.2% boric acid treatment for high SS contents. Aksentyuk and Zhuravel [1983], Singh and Rethy [1996] and Bhakare et al. [2006] reported increasing SS values and decreasing acidity values with increasing boric acid treatments. On the other hand, Ebadi et al. [2001] indicated that boron did not change water soluble dry matter content and acidity values. These study results differed from the results of the researchers. Isabella is more suitable for use in the grape juice. A certain amount of acidity is also required for the flavor besides the soluble solids. The maturity index is an important criterion for assessing in this respect. 0.1% boric acid dose was found to be most suitable in terms of the maturity index.

Table 5. Effects of increasing boric acid treatments on stum chemical characteristics

Boric acid doses	SS* (%)	pH	Acidity (%)	Maturity index
0%	16.2 b	3.44 a	0.960 ab	17.2 b
0.1%	17.2 a	3.29 b	0.879 b	19.5 a
0.2%	14.5 c	3.24 b	1.002 a	12.6 c
0.3%	14.9 c	3.31 b	1.026 a	12.5 c
LSD 5%	0.9	0.09	0.085	1.3

* soluble solid

CONCLUSION

Experimental soils were generally sufficient in nutrients, but quite deficient in boron levels. Since soil applications may yield outcomes in long time, foliar boron treatments were preferred in this study. Leaf nitrogen, phosphorus, calcium, magnesium, zinc and copper concentrations increased, but potassium and iron concentrations decreased with increasing boron doses. As compared to control treatment, all treatments had broader leaf sizes. Boric acid treatments positively influenced cluster weight, width and volumes and increasing values were observed with increasing boron doses. Boric acid applications also influenced berry homogeneity and yielded more homogeneous appearance. The greatest soluble solid (SS) and maturity index were obtained from 0.1% boric acid treatment. Water soluble dry matter contents decreased, but acidity values increased with increasing boron doses. Boric acid treatments generally had positive effects on berry characteristics and the greatest values were obtained from 0.3% boric acid treatment. In general, foliar boric acid sprays had positive effects on yield and quality parameters. Boric acid application yielded a better appearance and sizes. Especially 0.3% boric acid treatments had quite positive influences on quality, size and color homogeneity. Considering the nutrients and pH level of experimental soils, it was concluded that foliar nutrient treatments may support plant growth and development.

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