Boron Does Not Increase Hazelnut Fruit Set and Production

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Abstract. In a 3-year experiment in two drip-irrigated orchards on the Mediterranean coast, boron (B) sprays applied at rates of 0.6 and 1.2 g per tree and a soil B application of 12 g per tree did not increase fruit set or production of *Corylus avellana* L. 'Negret' and 'Pauetet' hazelnuts with mid to low foliar B levels (14.3 to 21.8 $\mu\text{g}\cdot\text{g}^{-1}$ dry mass). The average fruit set and nut yields of the trials were, respectively, 66% and 3.54 kg per tree for 'Pauetet', and 50% and 4.54 kg per tree for 'Negret'. The lack of response to B applications might be due to 1) initial fruit set levels were high; 2) the current B recommendation guidelines (25 to 30 $\mu\text{g}\cdot\text{g}^{-1}$ dry mass) might be adequate for fruit set and yield; 3) the rates of B applied might be too low; and 4) weather and soil conditions, cultivars, and biennial bearing may have masked any response to foliar B application.

Boron (B) applications reportedly have increased fruit set in hazelnut and other fruit species (Brown et al., 1996; Chaplin et al., 1977; Hanson, 1991; Shrestha et al., 1987), even when leaf B concentrations appeared satisfactory, suggesting that the accepted B concentrations for normal vegetative growth may not be sufficient for optimum fruit set. In 'Barcelona' hazelnut trees that were not considered to be B-deficient according to leaf analysis standards [26 to 86 $\mu\text{g}\cdot\text{g}^{-1}$ dry mass (DM)] (Painter and Hammar, 1964), B sprays increased fruit set by 17% to 23% (Shrestha et al., 1987), suggesting that the guidelines for B recommendation need revision. Results of field trials of B applications are variable; Baron (1973) reported some enhanced fruit set, whereas Kelley (1980) in Oregon and Germain (1994) in France found no response.

Hazelnut fruit production depends mainly on total number of flowers per tree and the percentage of flowers that set fruit (Tous et al., 1994). Therefore, maximizing fruit set is economically important. The purpose of this study, conducted for 3 years in the hazelnut production areas of the Mediterranean coast of Spain, was to determine if fruit set and yield could be increased by B applications under Mediterranean conditions and nut cultivars.

Materials and Methods

Field trials were conducted during three growing seasons, from 1991 to 1993, in two 15-year-old drip-irrigated hazelnut orchards

near the Mas Bové Agricultural Research Station in Reus on the Mediterranean coast of Spain. One orchard, La Selva, contained trees of the cultivar Negret (with 'Gironell' as a pollinator) that were spaced 4 × 6 m. The other orchard, Mas Bové, contained trees of the cultivar Pauetet (with 'Negret' as pollinator), and were spaced 4 × 7 m. Average annual temperatures were between 15.3 and 15.8 °C. January was the coldest month of the year with average temperatures of 8.3, 9.5, and 6.9 °C for 1991, 1992, and 1993, respectively. During the same years, the annual rainfall during the growing seasons was 580, 373, and 369 mm.

The soil type in both orchards was Typic Xerofluvent sandy loam, with 1% organic matter and pH was 7.9 to 8.3. Soil B was measured at two depths, 0–30 cm and 31–60 cm, in both orchards. The La Selva orchard soil had B concentrations of 0.2 $\text{mg}\cdot\text{kg}^{-1}$ at 0–30 cm and 0.1 $\text{mg}\cdot\text{kg}^{-1}$ at 31–60 cm. At Mas Bové, soil B was 0.2 $\text{mg}\cdot\text{kg}^{-1}$ at 0–30 cm and 0.03 $\text{mg}\cdot\text{kg}^{-1}$ at 31–60 cm. Annual fertilization consisted of N at 100 $\text{kg}\cdot\text{ha}^{-1}$, P_2O_5 at 40 $\text{kg}\cdot\text{ha}^{-1}$, and K_2O at 80 $\text{kg}\cdot\text{ha}^{-1}$.

Four treatments, applied every year, included a nontreated control, foliar B sprays (300 and 600 $\text{mg}\cdot\text{L}^{-1}$), and a soil application of 12 g of B per tree. The concentrations of foliar-applied B were identical to those reported by Shrestha et al. (1987) in Oregon (U.S.A.) and the amount of B applied to the soil was similar to that used by Radua et al. (1975) in Catalonia, Spain. Boron sprays were applied with a handgun as Solubor (U.S. Borax and Chemical Corp., Los Angeles), a product with a B concentration of 208 $\text{g}\cdot\text{kg}^{-1}$, using 2 L per tree. Consequently, each tree received 0.6 or 1.2 g of B, depending on the treatment. Control trees were sprayed with the same volume of water. In the soil treatment, B was applied as Fertibor (U.S. Borax and Chemical Corp.), a fine-granulated product with B at 150 $\text{g}\cdot\text{kg}^{-1}$.

Boron was applied to the soil during the last week of April, while the foliar spray treatments were applied in mid-May, just be-

fore ovule fertilization and flower induction. At the time of foliar B application, canopies were fully developed. Shrestha et al. (1987) recommended delaying sprays to avoid damaging young leaves and shoot tips.

The experimental design was a randomized complete block with five replications per treatment at La Selva and four replications per treatment at Mas Bové. Each replication consisted of five trees, with measurements being made on the three central trees of each replication. Rows with experimental trees were separated by a border row. Trees were subjected to similar cultural practices during the experiment.

To study the evolution of the leaf mineral contents, trees were sampled four times at ≈15-d intervals from late June to mid-August. Two subsamples of 24 leaves (eight leaves per tree, from all sides of the plant) were collected from each experimental unit from the middle of current-year shoots and analyzed separately. The average of the two subsamples was used for the statistical analysis. Leaves were washed with distilled water and nonionic detergent to remove dust, oven-dried at 70 °C for 48 h and ground in a Wiley mill to pass a 0.50-mm mesh screen.

Nitrogen was determined by an automated Kjeldahl apparatus. The samples were analyzed for P, K, Ca, Mg, Na, Fe, Cu, Zn, Mn, and B by inductively coupled plasma (ICP) emission spectroscopy after dry-ashing at 500 °C in a muffle furnace. Ashes were dissolved with 18% HCl, and the equivalent of 1 g of dry tissue was diluted to 50 mL before ICP analysis.

Fruit set was evaluated in 1991 and 1992 by counting the flowers on 6 to 10 terminal shoots per tree before fruit set and the number of clusters and nuts on the same shoots after fruit set. The average percentage of fruit set [(number of nuts/number of initial flowers) × 100] of the three trees (subsamples) within each experimental unit was used for statistical analysis. In 1993, fruit set was not evaluated because of lack of response in the two previous years. The number of nuts per cluster was determined to evaluate the proportion of clusters with one, two, three, or more nuts. Individual nut mass was determined by weighing a sample of 100 nuts per replication and the same sample was used to calculate the shelling percentage.

The data were analyzed using repeated measures analysis of variance with the GLM procedure of SAS (version 6, SAS Institute, Cary, N.C.).

Results and Discussion

Fruit set. B applications did not increase fruit set significantly in any location (Table 1), and fruit set for 'Pauetet' was 34% higher than for 'Negret'. These responses to B application are different than those reported in hazelnut and other species of fruits (Chaplin et al., 1977; Hanson, 1991; Shrestha et al., 1987), but they agree with those reported by Germain (1994) in France. Shrestha et al. (1987), working with 'Barcelona' hazelnuts in Oregon,

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found that B sprays increased fruit set levels from 30.5% to 39.3% and from 49.1% to 56.5%, while the B leaf content increased from 40 to 50 to 90 to 130 $\mu\text{g}\cdot\text{g}^{-1}$ DM. The main reason for these contrasting results could be the already high initial fruit set levels in our experiments, even with low soil B content. Other explanations include 1) cultivars respond differently to B applications; 2) the rates of B applied to these genotypes were too low to significantly increase fruit set; 3) as has been reported in prunes (Hanson and Breen, 1985), the effectiveness of B sprays was higher during cool than warm springs when the set was generally high. The spring temperatures in Oregon are generally lower than in the Mediterranean coast of Spain.

Hazelnuts per cluster. Hazelnuts per cluster for 'Negret' were 2.2 and 2.0 in 1992 and 1991, respectively, whereas in the same years 'Pauetet' averaged 1.7 and 1.9 nuts per cluster (data not shown). Boron treatments did not affect the number of nuts per cluster, which agrees with other reports (Bergougnoux et al., 1978). However, when yield was added to the model as a covariate, nut mass was not consistently affected by treatment.

Most of the clusters bore two, three, or four nuts, as reported previously (Bergougnoux et al., 1978; Mehlenbacher, 1991; Thompson et al., 1978). The percentage of clusters carrying one, two, or three nuts was 17%, 44%, and 37%, respectively. Only 2% of the clusters had four or more nuts. Boron treatments did not influence this distribution.

Nut mass and shelling percentage. Boron applications did not significantly increase average nut mass in any cultivar (Table 1), although 'Negret' appeared to produce heavier nuts following B applications.

Soil-applied B also seemed to increase nut mass, perhaps because of lower (although not statistically significant) nut yields.

The average shelling percentages, 46.2% for 'Negret' and 47.7% for 'Pauetet', were not significantly affected by B applications (data not shown). These results are similar to those reported previously (Bergougnoux et al., 1978; Vidal-Barraquer and Tasis, 1976).

Effects of B applications on fruit yield. Boron applications did not increase yield, which was significantly affected by the cropping year (Table 1). Average yield of trees with soil B applications was lower than for control trees.

Boron applications, at the rates used in these trials, did not appear to enhance hazelnut production, mainly because B did not increase fruit set. The annual variations due to weather or to alternate bearing may have masked clear expression of the B effects. Alternatively, although similar to those used in other studies (Radua et al., 1975; Shrestha et al., 1987), the rates of B applied may have been too low to elicit any response. Consequently, our results, although in agreement with trials carried out in France (Germain, 1994), differ from other reports with hazelnuts or cherry trees where B enhanced fruit production (Hanson, 1991; Shrestha et al. 1987).

Seasonal changes in B content in leaves.

The seasonal changes of leaf B contents were very similar during the 3 years of the experiment (Fig. 1). Leaf B increased slightly over time in control trees. In sprayed trees, however, B levels were high early in the season and then decreased somewhat late in the growing season, approaching levels similar to control trees 2 months after B applications. Similar findings were reported by Hanson (1991) and Shrestha et al. (1987). Apparently, B was diluted through vegetative growth or by translocation. Boron levels of 'Pauetet' leaves were higher than the 'Negret' leaves, although the initial soil B content of the plots was slightly higher for the latter orchard.

Boron content increased in leaves from trees receiving soil-applied B throughout the sampling period to levels at least twice that of the foliar treatments, and reached an average of 171.5 $\mu\text{g}\cdot\text{g}^{-1}$ DM for 'Pauetet' and 86.1 $\mu\text{g}\cdot\text{g}^{-1}$ DM for 'Negret'. This could be due to higher rates of B used in the soil treatment compared with the foliar treatments. Leaf B concentrations of the control trees ranged from an average of 14.3 $\mu\text{g}\cdot\text{g}^{-1}$ DM for 'Negret' to 21.8 $\mu\text{g}\cdot\text{g}^{-1}$ DM for 'Pauetet', which are below the critical levels of 25–30 $\mu\text{g}\cdot\text{g}^{-1}$ DM (Painter and Hammar, 1964; Shrestha et al., 1987; Stebbins, 1977). In our study, B applications did not significantly affect fruit set, number of nuts per cluster, or nut mass. According to Diagnosis and Recommendation Integrated System (DRIS) indices, B was not considered the most limiting element in our field trials (Pericón, 1994).

Lower nut yields were associated with soil-applied B treatments, suggesting a possible B toxicity. Leaf B contents of this treatment were above 100 $\mu\text{g}\cdot\text{g}^{-1}$ DM, which is considered excessive for hazelnuts (Westwood, 1978). However, no visual symptoms were detected. Shrestha et al. (1987) also reported

leaf B contents of 90–130 $\mu\text{g}\cdot\text{g}^{-1}$ DM without visual symptoms of B toxicity.

Conclusions

Boron applications to hazelnut trees with mid to low foliar B levels (14.3 to 21.8 $\mu\text{g}\cdot\text{g}^{-1}$ DM) did not increase fruit set or nut production. These findings, although in agreement with French results, contrast with the reports from Oregon where B fertilization increased fruit set and production (Baron, 1973; Shrestha et al., 1987; Stebbins, 1977). Shrestha et al. (1987) observed an increase in nut set of 17% to 23% with B sprays applied to Barcelona trees that were not considered B-deficient according to leaf analysis.

Several factors might be responsible for the different effects of B applications in Oregon vs. the Mediterranean coast: 1) The initial fruit set levels in the Mediterranean experiments, 48% and 66% for 'Negret' and 'Pauetet' trees, respectively, were already high. In Oregon, the control trees averaged 40% fruit set and the B sprayed trees, 48%. 2) The critical B levels reported by Shear and Faust (1980) and Painter and Hammar (1964) might be adequate for nut set under the conditions of the experiment, thus were not limiting fruit set and yields. 3) The rates of B applied, although similar to those used in other studies (Radua et al., 1975; Shrestha et al., 1987), were too low to increase yield. 4) Nut yields were affected by weather and soil conditions, cultivars used, and biennial bearing, and these masked expression of the B effects.

Literature Cited

- Baron, L.C. 1973. The value of boron sprays on filberts. Proc. Nut Growers Soc. of Oregon and Washington 58:43–44.
Bergougnoux, F., E. Germain, and J.P. Sarraquigne.

Table 1. Effects of boron (B) applications on fruit set, nut mass, and nut yield of two hazelnut cultivars.

B treatments (g/tree)	Fruit set (fruits/100 flowers)		Nut mass (g)		Nut yield (kg/tree)	
			Cultivar			
	Negret	Pauetet	Negret	Pauetet	Negret	Pauetet
1991						
Control	37.3	70.7	1.473	1.919	3.8	2.26
Foliar (0.6)	40.5	71.1	1.523	1.831	3.48	2.21
Foliar (1.2)	44.3	71.4	1.565	1.862	3.76	3.26
Soil (12)	39.3	71.2	1.621	1.897	3.45	2.02
1992						
Control	59.0	61.1	1.312	1.352	6.61	6.26
Foliar (0.6)	60.7	64.0	1.320	1.297	5.98	6.25
Foliar (1.2)	58.1	62.5	1.340	1.325	6.37	6.14
Soil (12)	61.3	61.2	1.392	1.337	6.28	5.80
1993						
Control	---	---	1.756	1.855	3.62	2.47
Foliar (0.6)	---	---	1.765	1.777	3.72	2.52
Foliar (1.2)	---	---	1.774	1.811	3.84	2.32
Soil (12)	---	---	1.886	1.922	3.2	1.96
Significance						
Between subjects effects						
Replication	NS	*	NS	NS	NS	**
B treatment	NS	NS	NS	NS	NS	NS
Within subjects effects						
Year	*	*	*	**	**	*
Year $\times$ B treatment	NS	NS	NS	NS	NS	NS

ns, *, ** Nonsignificant or significant at $P \leq 0.05$ or 0.01, respectively, by repeated measurements analysis of variance.

Fig. 1. Seasonal changes in mean B content ($\mu\text{g}\cdot\text{g}^{-1}$ dry mass) of leaves of two hazelnut cultivars receiving different B treatments over 3 years.

1978. Le noisetier, production et culture. Ed. Invuflec. Paris.
- Brown, P., H. Hu, A. Nyomora, and M. Freeman. 1996. Foliar boron application enhances almond yields. Better Crops 80:20-23.
- Callan, N.W., M.M. Thompson, H.H. Chaplin, R.L. Stebbins, and M.N. Westwood. 1978. Fruit set in 'Italian' prune following fall foliar and spring boron sprays. J. Amer. Soc. Hort. Sci. 103: 253-257.
- Chaplin, M.H., R.L. Stebbins, and M.N. Westwood. 1977. Effect of fall-applied boron sprays on fruit set and yield of "Italian" prune. HortScience 12:500-501.
- Germain, E. 1994. The reproduction of hazelnut (*Corylus avellana* L.): A review. Acta Hort. 351:195-209.
- Hanson, E.J. 1991. Sour cherry trees respond to foliar boron applications. HortScience 26:1142-1145.
- Hanson, E.J. and P.J. Breen. 1985. Effects of fall boron sprays and environmental factors on fruit set and boron accumulation in 'Italian' prune flowers. J. Amer. Soc. Hort. Sci. 110:389-392.
- Kelley, J.R. 1980. An analysis of the effects of boron and plant growth regulators on flower development in filbert, *Corylus avellana* L. MS Thesis, Oregon State Univ., Corvallis.
- Mehlenbacher, S.A. 1991. Hazelnuts (*Corylus*). Acta Hort. 290:789-836.
- Painter, J.H. and H.E. Hammar. 1964. Effect of differential levels of applied K and B on 'Barcelona' filbert trees in Oregon. Proc. Amer. Soc. Hort. Sci. 82:225-230.
- Pericón, J.R. 1994. Aplicación del boro y su efecto en los cultivos de avellano del Campo de Tarragona. Proyecto Final Carrera. Univ. de Lleida, Lleida, Spain.
- Radua, M., P. Ferrer, and J.M. Banús. 1975. Resultados de cuatro años de experiencias de aplicación de boro a los avellanos. Union 148:7.
- Shear, C.B. and M. Faust. 1980. Nutritional ranges in deciduous tree fruits and nuts. Hort. Rev. 2:142-163.
- Shrestha, G.K., M.M. Thompson, and T.L. Righetti. 1987. Foliar-applied boron increases fruit set in 'Barcelona' hazelnut. J. Amer. Soc. Hort. Sci. 112:412-416.
- Stebbins, R. 1977. Leaf analysis, boron and foliar feeding. Proc. Nut Growers Soc. of Oregon and Washington 62:76-82.
- Thompson, M.M., P. Romisondo, E. Germain, R. Vidal-Barraquer, and J. Tacias. 1978. An evaluation system for filberts (*Corylus avellana* L.). HortScience 13:514-517.
- Tous, J., J. Girona, and J. Tacias. 1994. Cultural practices and costs in hazelnut production. Acta Hort. 351(1):455-461.
- Vidal-Barraquer, R. and J. Tacias. 1976. Elección varietal y técnica de cultivo del avellano, p. 51-93. In: Proc. I Congreso Internacional de Almendra y Avellana. Feria Oficial de Muestras de Tarragona, Reus, Spain.
- Westwood, M.N. 1978. Temperate-zone pomology. W.H. Freeman, New York.