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Influence of Foliar Boron Application on Fruit Set and Yield of Hazelnut

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ABSTRACT

Boron (B) application to fruit crop has been recommended to improve fruit quality and fruit setting although the results of this practice on hazelnut are controversial. Thus, an experiment was conducted using trees of cv. Butler, with low B content (6.14 to 22.10 ppm), on two consecutive years (1995 and 1996), to evaluate the effect of three B treatments (300, 600, and 900 mg L^{-1}) on fruit set, productivity, nut and kernel mass and blank fruits, when applied at four different stages: ovules differentiation (May 5), fertilization stage (May 29), heart-shaped embryo (June 20) and appearance of leaf primordia and embrional radicle (July 11). Boron sprays had no significant effect on fruit set and productivity, however there were differences between years that were attributed to climate conditions. Nut and kernel mass shows significant increase ($P < 0.001$)

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with boron sprays. The occurrence of blank fruits was not significantly affected by the time and concentration of B sprays, however there was a tendency for an increase of blank fruits with boron sprays.

Key Words: *Corylus avellana*; Filbert; Nutrition.

INTRODUCTION

Mineral nutrition has been reported to influence yield in hazelnut,[1] although few studies have referred to levels on fertilization and time of application. Boron (B) fertilization in hazelnut has been even less studied, however, has been reported to have a major influence on quality in other fruit crop such as prune,[2,3] macadamia,[4] cherry,[5] and apple.[6,7]

In hazelnut, yield is mainly dependent on the total number of female flowers and fruit set ratio[8] which requires more information any factor that could influence these processes. Boron has been referred as having a significant influence on fruit set.[2,3] Reports on the effect of B application on hazelnut are often contradicting. In 1973, B found fruit set increase after a B foliar application which was supported by later studies,[9] but others authors[10,11] found no response to this mineral fertilization, suggesting that studies are needed for further clarifications. In these studies the influence of time of B application has also been questioned. Cool and wet weather conditions have been reported to have a positive influence of B sprays on prune fruit setting when compared to warmer climate conditions. Such findings prompt studies with hazelnut in which different time applications have been forward, from May to July[9] and May and June when the foliar leaf activity was the highest.[12] Boron fertilization has been done either in foliar or soil applications. In the first situation concentrations were between 300 and 600 ppm[9,11] or 1 kg/ha/year,[13] while soil applications were 12 g/tree.[14] However, there are also some contradictions on the effect of these levels on hazelnut quality.

The aim of this study, was to determine the influence of B sprays on fruit set, productivity ($g\,m^{-3}$) and nut weight in one of the most promising cultivars (cv. Butler) worldwide as well as in the northern soil and climatic conditions of Portugal.

MATERIALS AND METHODS

A 2-year experiment was conducted in a hazelnut orchard in the northern region of Portugal at 470 m, 41°19′ N and 7°44′ W, on a Typic Dystrochrept silt loam soil. Climate is of transition from Csb to Csa of Köpen which corresponds to C2B′2s2b′4 transition to B2B′2sb′4 of Thornthwait.[15] In this region the warmest months are July and August and the coldest are December and January, with average temperatures of 22–23°C and 6–7°C, respectively. The average annual rainfall is about 1000 mm, most of which occurs during the coldest months. Five-year old trees were set at 4×3 m spacing in a sandy-loam soil type of low cation exchange capacity (2.56 meq g^{-1}) and with low levels of organic matter (1.5%), potassium (120 ppm), phosphorus (40 ppm), and boron (0.2 mg kg^{-1}) content. Water was supplied by a drip irrigation system.

Five trees per treatment, with comparable morphological features such as canopy volume, trunk diameter and leaf boron concentrations (6.14–22.10 ppm) were selected to guarantee a homogeneous sample. Levels of B in these trees were relatively lower when compared to recommended normal levels.[16] For every tree high, width, trunk diameter and the number of glomerules in three selected branches were determined. Three B treatments 300, 600, and 900 mg L^{-1} were tested using *Solubor* (78% $Na_2B_8O_{13} \cdot 4H_2O$ and 20% $Na_2B_4O_7 \cdot 5H_2O$) (US Borax Company). These rates were applied at four different stages comprehensively described elsewhere: [17] ovules differentiation (May 5), fertilization stage (May 29), heart-shaped embryo (June 20) and appearance of leaf primordia and embrional radicle (July 11). These dates corresponded, respectively, to 100, 125, 150, and 170 days after full blooming in 1995 and 1996. Concentrations and time of application of B were selected according to the methodology by Shrestha et al.[9]

Sprays were applied to the point of drip with a handgun sprayer (34 L min^{-1}). Control trees were sprayed with the same volume of water.

Every following year after treatment in 1996 and 1997 respectively, at beginning of August, the number of fruits were recorded to allow fruit set calculation (number of nuts/number of initial flowers $\times$ 100). New records of high and trunk diameter for every tree were taken at harvest for the evaluation of canopy volume ($4/3\,\pi ab^2$ where a and b represent half of height and width, respectively) according to Lagerstedt and Painter.[18] Individual tree yield components were recorded from a 100 nuts sample. Every fruit and kernel was weighed and the percentage of blank fruits was determined in 1995 and 1996. Productivity was expressed as g m^{-3}, and calculated from the ratio between yield and canopy volume. Productivity, fruit weight and blank fruits were evaluated within the year of treatment.

For the statistical analysis of the data the analysis of variance using a SuperAnova package (1.1, Abacus Concepts Inc., 1989) was performed. For mean comparisons the Scheffe's test at 95% was used.

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RESULTS AND DISCUSSION

Effects of Boron Sprays on Fruit Set

Boron sprays had no significant effect on fruit set of hazelnut cv. Butler (Table 1), but annual differences were significant ($P < 0.001$) in such way that fruit set was generally higher in 1996 than in 1997 (Table 2). Similar results were obtained for the productivity of hazelnut ($g\,m^3$) (Table 3). In 1996 productivity ($52.2\,g\,m^3$) was significantly ($P < 0.001$) higher than in 1997 ($12.9\,g\,m^3$).

The highest fruit set was observed when the lowest B rate was applied 170 days after bloom, although on average the May application have induced higher fruit set (Table 2), probably due to the highest leaf activity[19] which induce a better mobility of solutes in the plant and higher productivity. Romisondo et al.[12] also reported a beneficial effect of foliar applications at the higher leaf activity stage. On average fruit set was similar to the reported values by Ferrán et al.[11] but much higher (approximately 30%) than the fruit set mentioned by Shrestha et al.[9] who have used trees with B deficiencies. It must be stressed that even the control treatment showed higher fruit set than the results presented by these authors because our control trees have higher B concentrations (6.14 to 22.10 ppm).

Thus, it that when experiments are conducted under Mediterranean conditions boron applications do not have a significant effect as reported by different authors.[11,19,20] However, when experiments were conducted under cooler spring climatic conditions such as Oregon, B applications have

Table 1. *F* test significance between years, boron treatments, application dates and fruit set, productivity, nut and kernel mass, and blank fruits.

Source	Fruit set	Productivity	Nut mass	Kernel mass	Blank fruits
Year (Y)	***	***	***	***	**
B spray (B)	NS	NS	***	***	NS
$Y \times B$	NS	NS	***	***	NS
Date (D)	NS	NS	***	***	NS
$B \times D$	NS	NS	***	***	NS

, * Significant at $P < 0.05$, $P < 0.010$.
Key: NS, Non-significant.
Note: *F* test.

Table 2. Effects of boron treatments and applications dates on fruit set in 1996 and 1997, the following year after treatments.

B treatments ($mg\,L^{-1}$)	Days after blooming	Fruit set (fruits/100 flowers) 1996	1997
Control		68 ± 0.6	45 ± 8.3
300	100	72 ± 17.6	66 ± 23.8
	125	58 ± 3.6	53 ± 0.7
	150	75 ± 3.6	31 ± 2.3
	170	84 ± 5.6	45 ± 7.7
600	100	78 ± 5.3	70 ± 24.2
	125	54 ± 26	44 ± 14.0
	150	74 ± 24	25 ± 4.8
	170	61 ± 11	29 ± 0.2
900	100	63 ± 5.6	33 ± 0.9
	125	54 ± 26	40 ± 24.9
	150	78 ± 4.1	21 ± 8.0
	170	57 ± 8.6	41 ± 0.2

significant effects on fruit set. These results suggest that climate conditions might have a strong influence on the translocation and boron metabolism since this mineral is known to be involved in cell division, synthesis of nucleic acids and translocation and metabolism of sugars.[21] Thus, it is likely that cooler spring conditions might induce a better use of this mineral and higher fruit set to promote higher metabolic rates.

Effects of Boron Sprays on Nut and Kernel Mass

The efficiency of B applications is highly dependent on other factors such as the mineral nutrient supply with other minerals[22,23] and climatic factors.

Nut and kernel mass was significantly ($P < 0.001$) affected by boron sprays (Table 1). The highest nut and kernel mass were observed in 1995, which corresponds to the year of lowest productivity as a result of higher rates of source/sink. Thus, as in other fruit crops,[24] a reduced number of fruit will increase its mass due to less partitioning of photoassimilates. These results showed that an improvement of nut and kernel weight is achieved when B is

Table 3. Effects of boron treatments and applications dates on productivity, nut and kernel mass and % of blank fruits in 1995 and 1996, the years of treatments.

B treatments	Date	Productivity ($g\,m^{-3}$)	Nut mass (g)	Kernel mass (g)	Blank fruits (%)
			1995		
Control		12.2 ± 6.6	2.6 ± 0.1	0.8 ± 0.1	4.12 ± 0.6
300	100	9.3 ± 1.4	2.7 ± 0.1	0.8 ± 0.1	40.5 ± 16
	125	16.7 ± 1.9	3.5 ± 0.0	1.6 ± 0.1	9.6 ± 1.2
	150	2.5 ± 0.1	3.8 ± 0.0	1.8 ± 0.1	14.3 ± 1.3
	170	15.1 ± 2.4	4.2 ± 0.1	1.9 ± 0.0	22.5 ± 9.0
600	100	14.6 ± 4.1	3.0 ± 0.1	0.9 ± 0.1	6.2 ± 0.2
	125	18.0 ± 0.8	3.5 ± 0.0	1.6 ± 0.3	19.6 ± 8.2
	150	13.4 ± 1.9	3.9 ± 0.1	1.8 ± 0.1	18 ± 0.3
	170	5.5 ± 0.1	4.2 ± 0.0	1.9 ± 0.0	9.1 ± 0.2
900	100	13.5 ± 4	3.5 ± 0.1	1.2 ± 0.1	15.1 ± 6.9
	125	14.1 ± 6.8	3.5 ± 0.0	1.5 ± 0.2	5.7 ± 0.7
	150	19.8 ± 4.3	3.9 ± 0.1	1.7 ± 0.0	10.6 ± 5.6
	170	16.2 ± 1.1	4.2 ± 0.1	1.9 ± 0.1	5.4 ± 2.9
			1996		
Control		55.8 ± 8.2	2.9 ± 0.1	1.3 ± 0.0	8.2 ± 0.6
300	100	66.6 ± 18.8	3.0 ± 0.1	1.2 ± 0.0	12.4 ± 6.8
	125	50.4 ± 12.9	3.2 ± 0.1	1.3 ± 0.1	8.2 ± 4.1
	150	52.8 ± 12.9	3.4 ± 0.0	1.4 ± 0.4	5.6 ± 0.0
	170	57.8 ± 17.6	3.2 ± 0.1	1.4 ± 0.1	8.0 ± 4.4
600	100	56.7 ± 10.8	3.1 ± 0.1	1.5 ± 0.0	5 ± 0.8
	125	82.2 ± 22.6	3.3 ± 0.1	1.3 ± 0.0	7.9 ± 2.0
	150	37.9 ± 3.9	3.5 ± 0.1	1.5 ± 0.1	14.3 ± 0.0
	170	45.1 ± 0.5	3.1 ± 0.1	1.3 ± 0.0	6.3 ± 2.2
900	100	30.4 ± 8.6	3.1 ± 0.1	1.2 ± 0.1	11.2 ± 1.7
	125	39.5 ± 11.4	3.2 ± 0.1	1.3 ± 0.1	10.4 ± 3.3
	150	39.5 ± 11.4	3.6 ± 0.1	1.6 ± 0.0	6.5 ± 3.6
	170	59.9 ± 10.2	3.3 ± 0.1	1.4 ± 0.1	1.9 ± 1.8

applied late during the period of rapid embryo growth (150 and 170 days after blooming on 1995 and 150 days after blooming on 1996)[25] and at higher concentrations (600 and 900 ppm) (Fig. 1). The positive answer to these treatments is probably due to the involvement of B on plant metabolism as already mentioned. Ferrán et al.[11] also showed a tendency for similar results in the cultivar Negret although without significant differences.

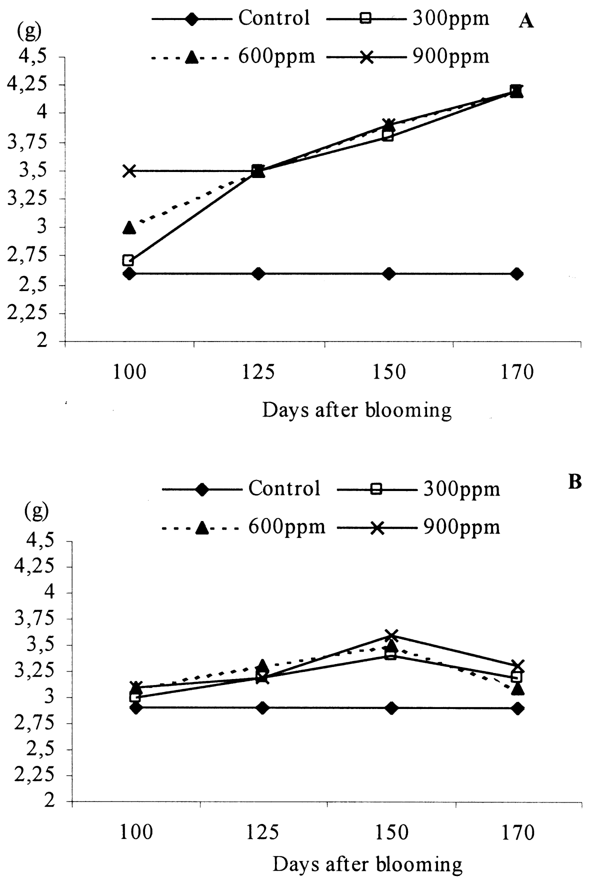

Figure 1. The effect of three boron treatments applied at four different dates on nut mass. **A**, 1995; **B**, 1996.

Effects of Boron Sprays on Blank Fruits

The occurrence of blank fruits was not significantly affected by the time and concentration of B sprays; however, there was a tendency for an increase of blank fruits with boron sprays, which is in agreement with findings by Llavaneres[20] in cv. Pauetet. Between years, in 1996 the percentage ($9\% \pm 0.81$) was significantly lower ($P < 0.01$) than in 1995 ($14\% \pm 2.4$) (Table 3). The inter annual variation of blank fruit occurrence was also showed in several studies[19,26,27] which supports that the effect of boron sprays is interacted by the influence of climatic conditions between years.

In this study B sprays had no significant effect on fruit set, productivity and blank fruits however in nut and kernel mass there was a significant positive effect.

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