







## Article

# Effects of Foliar and Soil Boron Fertilization on Yield, Leaf Physiological Traits and Fruit Attributes in Rainfed Almond Orchards

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**Abstract:** Boron (B) fertilizers are recognized as essential for ensuring yield and fruit quality. However, the importance of soil and foliar B fertilization in almond orchards under rainfed conditions is presently unclear. To address this literature gap, in the present study, the impact of soil and foliar application of B on leaf gas exchange, leaf photosynthetic pigments, yield, and fruit quality in almonds was investigated across three consecutive growing seasons. Boron fertilizer was applied to the soil at four rates (0, 1, 2, and 3 kg ha<sup>-1</sup>) in the presence or absence of foliar application (0.36 g L<sup>-1</sup>) of the same micronutrient. Borax pentahydrate was used as the B source. When compared to foliar B fertilization, the soil application of B positively affected the gas exchange parameters, mainly the net CO<sub>2</sub> assimilation rate, stomatal conductance, and transpiration rate (percentage of gain between 15% and 80%), but did not influence the chlorophyll content. The almond yield and fruit characteristics were also enhanced (about 25–72%) in response to lower soil B fertilization rates. In the 3 kg ha<sup>-1</sup> dose, B had an adverse effect on the yield and resulted in lighter fruits. On the other hand, foliar B fertilization did not benefit any of the evaluated parameters. Overall, these results suggest that, under the studied conditions, almond orchards do not respond to higher B rates in soil or foliar B fertilization.

**Keywords:** *Prunus dulcis*; boron; photosynthesis; leaf chlorophyll; yield; fruit quality



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## 1. Introduction

Almond (*Prunus dulcis* (Mill.) D.A. Webb.) constitutes an important tree crop in the Mediterranean region, as it is capable of adapting to very harsh edaphoclimatic conditions, such as drought and high temperatures [1] and poor soil nutrients [2]. Within this region, most almond orchards are grown under rainfed conditions and are located on marginal lands, generating low yields and poor fruit quality [3]. One of the best strategies for achieving high production and reducing environmental problems under these challenging conditions is based on a balanced application of fertilizers [4].

Boron (B) application is critical at the beginning of the annual growth, since it plays a pivotal role in almonds' flowering and fruit set [5]. Boron exhibits a regulatory effect on pollen germination and pollen tube growth, helping to increase flower fertilization and, consequently, crop yield [6,7]. Boron also has an important role in cell structure and cell wall integrity [8,9], as well as in the maintenance of plasma membrane functions [10]

and hull formation [6]. Moreover, this positive effect of boron could be due to its involvement in several physiological and metabolic processes [11], such as sugar transport and carbohydrate, nucleic acid, indole acetic acid (IAA), and phenol metabolism [9]. In almonds, B has high phloem mobility due to the formation of B-polyol complexes [12], which facilitate the re-translocation of sugars and other products of photosynthesis, affecting the photosynthetic capacity of plants [13]. Therefore, adequate B nutrition is essential for obtaining high yields and almond fruit quality [14]. Boron fertilizers can be applied to the soil, for uptake by plant roots, or by a foliar spray. The root uptake of B can be reduced under dry soil conditions, and in these circumstances, the leaf application of B has been seen as a complement to soil application for fulfilling boron requirements [15]. Previous studies on applying B fertilizers via the foliar route have yielded contradictory results. For example, [5] reported a positive influence of B supply on an almond yield, while [2] noted no significant effects on a kernel yield. The available evidence further indicates that the response of almond trees to B fertilization depends on the nutritional level of orchards [2], rate and time of application, and environmental conditions at the time of application [11], among other factors. According to [7], the foliar application of B improves the quality (weight, length, width, and protein content) of almond fruits. However, information on the effect of foliar B fertilization on the physiological performance of almonds under rainfed conditions is limited. Recently, [14] reported that the transpiration and assimilation rates, as well as stomatal conductance, increased seven days after the foliar application of B nanoencapsulates compared to the values obtained for nonfertilized almond trees or trees sprayed with free B, pointing to the role of B supply in the photosynthesis process [13].

Guided by the previously obtained results and the importance of an adequate B supply, the goal of the present study was to elucidate the influence of singular and combined (soil and foliar) B applications on almond trees cv. Glorieta during three consecutive years (2015–2017) under rainfed conditions. In particular, the effects of B supply were assessed through leaf gas exchange and leaf chlorophyll, as well as fruit yield and quality.

## 2. Materials and Methods

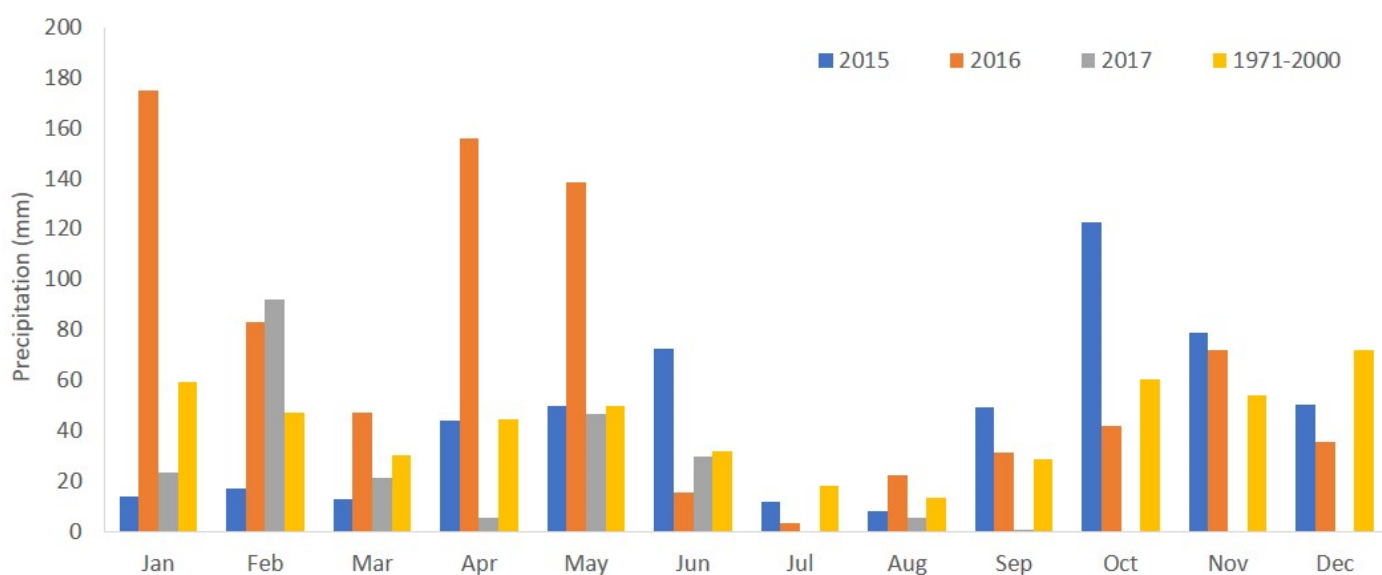
### 2.1. Site Description

The almond orchard (9.5 ha) in focus for this investigation is located near Alfândega da Fé in NE Portugal (41°21' N, 6°57' W, 576 m asl). This commercial orchard was planted in 2003, and individual trees (that belong to the Glorieta cultivar, grafted on GF-677 rootstock) are allocated a 6 × 4 m area. The field experiment was performed under rainfed conditions over three years (2015–2017). Although the almond trees were pruned yearly, this practice was more intensive in 2016. No phytosanitary treatments were applied during the experimental period. The soil of the plot on which the field experiment was conducted is classified as a loamy textured dystric Regosol, and its chemical properties are in Table 1.

The climate of Alfândega da Fé is of the Mediterranean type (Köppen climate classification: Csb). The mean air temperature and the annual precipitation based on the 1971–2000 measurements at the weather station of Mirandela (41°31' N, 7°12' W, 250 m asl) near Alfândega da Fé are, respectively, 14.3 °C and 508.6 mm. The warmest months are July and August, with an average daily temperature of 23.5 °C, and the coldest month is January, with 5.5 °C. Most of the precipitation occurs in the fall and winter, from October to January. The climatic data collected during the study from an automatic weather station located near the experimental orchard revealed that the highest daily temperature was observed in July. The precipitation exhibited marked year-to-year variations during this period, as shown in Figure 1. The highest annual rainfall (820.6 mm) was recorded in 2016, with about 75% of the annual precipitation occurring in the first five months of the year. The intense and continuous precipitation in these months affected the flowering, pollination, and, consequently, the fruit set.

**Table 1.** Mean values of the soil chemical properties at a depth of 0–20 cm, determined at the beginning of the experiment. Adapted from [2,16].

Soil Properties	Value	Method
pH (H <sub>2</sub> O)	5.2	-
pH (KCl)	4.3	-
Oxidizable C	14.8 g kg <sup>-1</sup>	Walkley-Black
Total N	1.5 g kg <sup>-1</sup>	Kjeldahl
NO <sub>3</sub>	55.9 mg kg <sup>-1</sup>	2 M KCl, spectrophotometry UV
NH <sub>4</sub>	36.9 mg kg <sup>-1</sup>	phenate method for ammonia
Extractable B	1.2 mg kg <sup>-1</sup>	Hot-water, azomethine H.
Extractable K	151.4 mg kg <sup>-1</sup>	ammonium-lactate
Extractable P	31.0 mg kg <sup>-1</sup>	ammonium-lactate
Exchangeable Ca	3.7 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7
Exchangeable Mg	0.8 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7
Exchangeable K	0.4 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7
Exchangeable Al	0.2 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7
Exchangeable acidity	0.3 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7
Cation exchange capacity	6.1 cmol <sub>c</sub> kg <sup>-1</sup>	ammonium acetate, pH 7

**Figure 1.** Monthly precipitation during the study period of 1 January 2015–31 August 2017 and monthly precipitation for the 1971–2000 period at the Mirandela weather station (Adapted from [17]).

## 2.2. Boron Treatments and Experimental Design

Four rates of B fertilization (0, 1, 2, and 3 kg ha<sup>-1</sup>) were applied to the soil as borax pentahydrate (Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub>·5H<sub>2</sub>O) (15% B) late in March, shortly after bloom. For foliar application, a foliar spray containing 0.36 g L<sup>-1</sup> B of borax pentahydrate (15% B) was used before and after the harvest. Consequently, in 2015 and 2016, the foliar B application consisted of 1.4 kg B ha<sup>-1</sup>, while 0.7 kg B ha<sup>-1</sup> was applied in 2017. All treatments received soil and foliar phosphorus (P<sub>2</sub>O<sub>5</sub>) and potassium (K<sub>2</sub>O) at 50 kg ha<sup>-1</sup> year<sup>-1</sup>. The experimental setup consisted of a randomized block design with three replications, and three similar trees were used in each replication.

## 2.3. Leaf Gas Exchange Measurements

The leaf gas exchange parameters [net CO<sub>2</sub> assimilation rate (A, μmol CO<sub>2</sub> m<sup>-2</sup>s<sup>-1</sup>), stomatal conductance (g<sub>s</sub>, mmol H<sub>2</sub>O m<sup>-2</sup>s<sup>-1</sup>), and transpiration rate (E, mmol H<sub>2</sub>O m<sup>-2</sup>s<sup>-1</sup>) were measured using an open portable Infrared Gas Analyzer System (LCpro-SD, ADC BioScen-

tific Ltd., Hoddesdon, UK) equipped with a 6.25 cm<sup>2</sup> leaf chamber. The measurements were performed at harvest (September) in situ at midday (14:00–15:30 h) on the uppermost fully expanded leaf from the middle of the canopy of three plants per treatment under a photosynthetic photon flux density (PPFD) that exceeded 1500  $\mu\text{mol m}^{-2}\text{s}^{-1}$ . In addition, the intrinsic water use efficiency (iWUE) was calculated using the  $A/g_s$  ratio ( $\text{mmol m}^{-2}\text{s}^{-1}$ ) following [18].

#### 2.4. Relative Leaf Water Content and Electrolyte Leakage Determination

After the gas exchange measurements, the leaves were immediately placed into airtight containers to determine the relative water content (RWC). The RWC was calculated according to the expression of [19]:  $\text{RWC (\%)} = (\text{FW} - \text{DW}) / (\text{TW} - \text{DW}) \times 100$ , where FW is the fresh weight (g), DW is the dry weight (g) after drying at 70 °C to a constant weight, and TW is the fresh weight at full turgor (g) measured after the immersion of leaf petioles in distilled water for 24 h in the dark at 4 °C. Leaf discs 0.8 cm in diameter were cut from fully expanded leaves and were used to determine the electrolyte leakage (EL), as described by [20]. After washing with deionized water to remove all surface-adhered electrolytes, the leaf discs were placed in tubes containing 10 mL of deionized water. Then, the tubes were incubated at 25 °C on a shaker for 24 h. After this period, the initial electrical conductivity of the solution ( $\text{CE}_1$ ) was determined, and the tubes were then autoclaved at 120 °C for 20 min and were subsequently maintained at 25 °C. A new reading of electrical conductivity ( $\text{CE}_2$ ) was performed, and the EL was calculated using the following equation:  $\text{EL (\%)} = (\text{CE}_1 / \text{CE}_2) \times 100$ .

#### 2.5. Leaf Photosynthetic Pigments

The chlorophyll (chlorophyll *a* (chl *a*), chlorophyll *b* (chl *b*), and total chlorophyll (chl *t*)) contents in the leaf samples were determined in leaf discs of 0.8 cm in diameter, which were collected immediately after the leaf gas exchange readings, frozen in liquid nitrogen, and stored at −80 °C until required for analysis. Chlorophylls were extracted in 80% acetone (*v/v*), applying the method described by [21].

#### 2.6. Yield and Fruit Quality Attributes

At harvest, all almond fruits borne by each tree were collected and weighed fresh, and the almond yield ( $\text{t ha}^{-1}$ ) was determined for each treatment. Three samples per treatment containing 50 fruits each were allowed to dry at room temperature for one month. After that, the quality attributes of the nut and kernel (mass, length, width, and thickness) were evaluated according to the almond descriptors developed by the International Plant Genetic Resources Institute or “IPGRI” [22]. The nut number (the number of fruits per kilogram) was also determined as a measure of the almond yield [23]. The nut and kernel mass were measured using a precision scale, while the nut and kernel length, width, and thickness were measured using digital calipers with 0.01-mm accuracy.

#### 2.7. Statistical Analysis

All data were analyzed using a repeated measures ANOVA with the year of observation as the within-subject factor and the B fertilization routes (soil and foliar) as the between-group factors. A two-way ANOVA was also used to determine the effects of the B supply (soil and foliar) within each year. All data were subjected to the Shapiro–Wilk W statistic and Levene’s test to assess the distribution normality and homogeneity of variance, respectively. Mean differences were separated by applying Tukey’s HSD test at a 5% significance level. A hierarchical clustering analysis using Ward’s method and Euclidean distances was adopted to investigate the similarities among the soil B treatments.

Statistical analyses were performed using the software package IBM SPSS version 23 for Windows (Orchard Road, Armonk, NY, USA).

### 3. Results

#### 3.1. Effect of Year and B Supply on Leaf Gas Exchange Parameters

The three-year data of leaf gas exchange parameters (Table S1) showed that all parameters varied greatly from one year to another ( $p < 0.05$ ). Except for iWUE, the highest E, gs, and A were observed in 2016, and there was no significant difference between 2015 and 2017 (Table 2). These parameters also exhibited high variations concerning soil and foliar fertilization (Table S1).

**Table 2.** Mean values ( $\pm$ standard error) of the leaf gas exchange parameters (E, gs, A, and iWUE); RWC; EL; photosynthetic pigments (chl *a*, chl *b*, chl *t*, and chl *a*/chl *b*); yield, nut number; and nut and kernel attributes (mass, length, width, and thickness) determined during the 2015–2017 period.

	2015	2016	2017
E (mmol m <sup>-2</sup> s <sup>-1</sup> )	0.835 $\pm$ 0.107 b	1.713 $\pm$ 0.154 a	0.984 $\pm$ 0.098 b
gs (mmol m <sup>-2</sup> s <sup>-1</sup> )	17.003 $\pm$ 3.097 b	40.216 $\pm$ 4.555 a	27.321 $\pm$ 3.956 ab
A ( $\mu$ mol m <sup>-2</sup> s <sup>-1</sup> )	2.018 $\pm$ 0.333 b	3.402 $\pm$ 0.285 a	3.046 $\pm$ 0.420 ab
iWUE ( $\mu$ mol mol <sup>-1</sup> )	122.728 $\pm$ 7.385 a	90.693 $\pm$ 3.420 b	114.197 $\pm$ 3.963 a
RWC (%)	71.77 $\pm$ 0.78 c	78.74 $\pm$ 0.51 a	74.60 $\pm$ 0.91 b
EL (%)	37.94 $\pm$ 0.65 a	14.62 $\pm$ 0.34 c	27.88 $\pm$ 0.83 b
chl <i>a</i> (mg g <sup>-1</sup> )	2.825 $\pm$ 0.079 b	2.405 $\pm$ 0.084 c	4.020 $\pm$ 0.084 a
chl <i>b</i> (mg g <sup>-1</sup> )	1.019 $\pm$ 0.035 b	1.193 $\pm$ 0.042 b	3.398 $\pm$ 0.042 a
chl <i>t</i> (mg g <sup>-1</sup> )	3.843 $\pm$ 0.105 b	3.598 $\pm$ 0.122 b	7.415 $\pm$ 0.386 a
chl <i>a</i> /chl <i>b</i>	2.839 $\pm$ 0.046 a	2.022 $\pm$ 0.030 b	1.583 $\pm$ 0.102 c
Yield (t ha <sup>-1</sup> )	4.41 $\pm$ 0.20 a	0.09 $\pm$ 0.02 b	4.23 $\pm$ 0.20 a
Nut number	238 $\pm$ 2 b	224 $\pm$ 2 c	347 $\pm$ 2 a
Nut mass (g)	4.38 $\pm$ 0.02 b	4.69 $\pm$ 0.03 a	2.99 $\pm$ 0.02 c
Nut length (mm)	37.95 $\pm$ 0.08 b	38.43 $\pm$ 0.09 a	32.85 $\pm$ 0.06 c
Nut width (mm)	22.97 $\pm$ 0.05 b	24.50 $\pm$ 0.05 a	21.46 $\pm$ 0.04 c
Nut thickness (mm)	16.48 $\pm$ 0.03 b	17.66 $\pm$ 0.04 a	15.57 $\pm$ 0.02 c
Kernel mass (g)	1.05 $\pm$ 0.09 b	1.32 $\pm$ 0.01 a	0.92 $\pm$ 0.01 c
Kernel length (mm)	26.18 $\pm$ 0.05 a	25.92 $\pm$ 0.06 b	23.02 $\pm$ 0.04 c
Kernel width (mm)	13.00 $\pm$ 0.03 b	14.25 $\pm$ 0.03 a	12.10 $\pm$ 0.02 c
Kernel thickness (mm)	6.55 $\pm$ 0.02 b	7.44 $\pm$ 0.02 a	6.91 $\pm$ 0.02 b

Different letters in each line indicate significant differences according to Tukey's HSD test,  $p < 0.05$ .

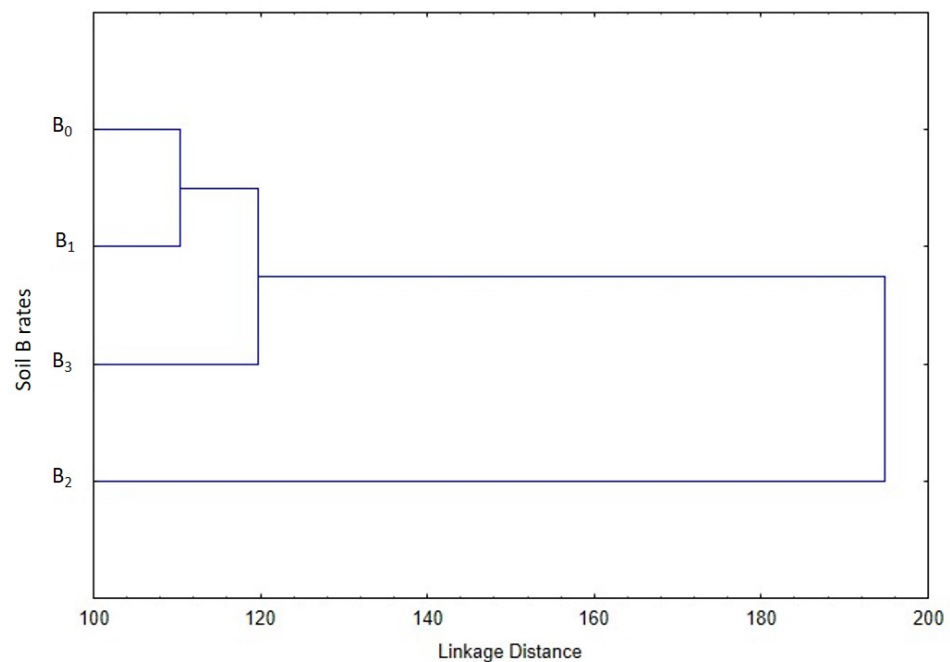
The photosynthetic performance of almond trees was higher in the absence of foliar B fertilization (Table 3). When the data obtained in individual years were analyzed separately, soil B fertilization (treatments B<sub>1</sub>–B<sub>3</sub>) significantly affected almost all gas exchange parameters in 2015 and 2017 (Table 2). In these years, the highest values of E, gs, and A were observed with the application of 2 kg ha<sup>-1</sup> (B<sub>2</sub> treatment). Conversely, no significant effect of B soil fertilization was found in iWUE ( $p > 0.05$ ). The values of E, gs, A, and iWUE in the trees subjected to foliar B application (F<sub>2</sub>) were not as high as in the treatment with no foliar B application (F<sub>0</sub>) in any of the individual years (Table 3). Although significant for many of the parameters measured, the combination of soil and foliar B supply did not have a positive effect on E, gs, A, or iWUE. In fact, in all years, the highest values of the gas exchange parameters were achieved in trees fertilized by B via soil application in the absence of foliar B supplementation (Table 3).

The cluster analysis identified similarities between the B<sub>0</sub>, B<sub>1</sub>, and B<sub>3</sub> treatments (Figure 2). However, the B<sub>0</sub> and B<sub>1</sub> branched more closely to each other than the B<sub>3</sub> treatment. The B<sub>2</sub> treatment formed a separate cluster demonstrating its superiority compared to the other soil B rates.

**Table 3.** Mean values ( $\pm$ standard error) of the gas exchange parameters (transpiration rate (E), stomatal conductance (gs), net CO<sub>2</sub> assimilation rate (A), and water-use efficiency (iWUE)) of almond leaves measured in the 2015–2017 period.

Year	Fertilization	E (mmol m <sup>-2</sup> s <sup>-1</sup> )	gs (mmol m <sup>-2</sup> s <sup>-1</sup> )	A ( $\mu$ mol m <sup>-2</sup> s <sup>-1</sup> )	iWUE ( $\mu$ mol mol <sup>-1</sup> )	
2015	Soil	B <sub>0</sub>	0.848 $\pm$ 0.097 b	14.300 $\pm$ 1.741 b	1.980 $\pm$ 0.302 b	142.801 $\pm$ 20.237 a
		B <sub>1</sub>	0.570 $\pm$ 0.095 b	11.658 $\pm$ 2.496 b	1.421 $\pm$ 0.374 b	118.251 $\pm$ 14.995 a
		B <sub>2</sub>	1.408 $\pm$ 0.296 a	33.993 $\pm$ 9.624 a	3.606 $\pm$ 1.003 a	112.603 $\pm$ 3.606 a
		B <sub>3</sub>	0.512 $\pm$ 0.069 b	8.787 $\pm$ 0.989 b	1.066 $\pm$ 0.204 b	117.257 $\pm$ 15.650 a
	Foliar	F <sub>0</sub>	0.941 $\pm$ 0.208 A	22.737 $\pm$ 5.781 A	2.742 $\pm$ 0.584 A	133.619 $\pm$ 10.222 A
		F <sub>2</sub>	0.728 $\pm$ 0.054 B	11.269 $\pm$ 0.834 B	1.295 $\pm$ 0.164 B	111.838 $\pm$ 10.099 A
	Two-way ANOVA					
		Soil (S)	0.000	0.000	0.000	0.471
		Foliar (F)	0.022	0.000	0.000	0.152
		S $\times$ F	0.000	0.000	0.000	0.414
2016	Soil	B <sub>0</sub>	1.722 $\pm$ 0.285 a	35.408 $\pm$ 7.569 a	2.997 $\pm$ 0.495 a	88.743 $\pm$ 5.441 a
		B <sub>1</sub>	1.235 $\pm$ 0.158 a	31.378 $\pm$ 4.369 a	3.149 $\pm$ 0.391 a	102.376 $\pm$ 5.413 a
		B <sub>2</sub>	1.967 $\pm$ 0.467 a	52.493 $\pm$ 14.792 a	3.909 $\pm$ 0.877 a	84.999 $\pm$ 10.183 a
		B <sub>3</sub>	1.930 $\pm$ 0.205 a	41.585 $\pm$ 5.979 a	3.555 $\pm$ 0.477 a	86.652 $\pm$ 3.853 a
	Foliar	F <sub>0</sub>	2.093 $\pm$ 0.233 A	53.831 $\pm$ 6.760 A	4.189 $\pm$ 0.392 A	83.419 $\pm$ 5.568 A
		F <sub>2</sub>	1.334 $\pm$ 0.134 B	26.602 $\pm$ 2.711 B	2.616 $\pm$ 0.272 B	97.966 $\pm$ 2.881 B
	Two-way ANOVA					
		Soil (S)	0.081	0.058	0.517	0.100
		Foliar (F)	0.020	0.000	0.004	0.011
		S $\times$ F	0.016	0.008	0.217	0.041
2017	Soil	B <sub>0</sub>	0.987 $\pm$ 0.138 ab	23.578 $\pm$ 4.094 b	2.844 $\pm$ 0.502 ab	120.665 $\pm$ 4.115 a
		B <sub>1</sub>	0.815 $\pm$ 0.134 b	24.210 $\pm$ 6.056 b	2.893 $\pm$ 0.697 ab	121.949 $\pm$ 5.865 a
		B <sub>2</sub>	1.281 $\pm$ 0.322 a	41.090 $\pm$ 13.164 a	4.315 $\pm$ 1.358 a	106.565 $\pm$ 5.027 a
		B <sub>3</sub>	0.853 $\pm$ 0.098 b	20.407 $\pm$ 3.011 b	2.132 $\pm$ 0.408 b	107.607 $\pm$ 13.101 a
	Foliar	F <sub>0</sub>	1.289 $\pm$ 0.144 A	40.174 $\pm$ 5.847 A	4.315 $\pm$ 0.649 A	106.910 $\pm$ 6.237 A
		F <sub>2</sub>	0.679 $\pm$ 0.049 B	14.468 $\pm$ 1.110 B	1.777 $\pm$ 0.158 B	121.483 $\pm$ 4.137 A
	Two-way ANOVA					
		Soil (S)	0.021	0.002	0.029	0.356
		Foliar (F)	0.000	0.000	0.000	0.075
		S $\times$ F	0.004	0.000	0.006	0.006

Different lowercase letters indicate significant differences among B soil (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>), and capital letters represent significant differences between B foliar (F<sub>0</sub> and F<sub>2</sub>) treatments within each year, according to Tukey’s HSD test ( $p < 0.05$ ).



**Figure 2.** Cluster analysis (Euclidean distances and Ward’s hierarchical method) based on the leaf gas exchange parameters of different soil B rates.

### 3.2. Effect of Year and B Supply on Leaf Relative Water Content and Electrolyte Leakage

The leaf relative water content (RWC) and electrolyte leakage (EL) were significantly influenced by year and foliar fertilization (Table S1). In general, the highest RWC values were obtained in 2016, followed by 2017 and 2015 (Table 2). In turn, the highest and the lowest EL values were obtained in 2015 and 2016, respectively (Table 2). On the other hand, throughout the study period, similar leaf RWC and EL (Table 4) were obtained for all soil treatments ( $p > 0.05$ ). Foliar B application only influenced the leaf RWC in 2017 and EL in 2015 and 2017 (Table 4), but the interaction between soil and foliar fertilization did not have a significant effect on the leaf RWC or EL values (Table S1).

**Table 4.** Mean values ( $\pm$ standard error) of the RWC and EL under different B soil rates (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>) associated with the absence or presence of foliar B supplementation in the 2015–2017 period. In each column, different lowercase letters indicate significant differences among the B soil rates (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>) within each year.

Year	Soil B Rates	RWC (%)		EL (%)	
		Foliar B Supplementation			
		Absence	Presence	Absence	Presence
2015	B <sub>0</sub>	72.24 $\pm$ 1.64 aA	68.81 $\pm$ 1.82 aA	39.21 $\pm$ 1.41 aA	37.82 $\pm$ 1.31 aA
	B <sub>1</sub>	68.02 $\pm$ 3.66 aA	74.39 $\pm$ 1.70 aA	35.63 $\pm$ 2.14 aA	39.08 $\pm$ 2.02 aA
	B <sub>2</sub>	73.91 $\pm$ 2.59 aA	70.98 $\pm$ 1.37 aA	34.74 $\pm$ 2.35 aB	41.48 $\pm$ 1.19 aA
	B <sub>3</sub>	71.94 $\pm$ 2.05 aA	74.08 $\pm$ 1.76 aA	38.12 $\pm$ 2.06 aA	37.79 $\pm$ 1.37 aA
2016	B <sub>0</sub>	78.73 $\pm$ 0.72 aA	78.13 $\pm$ 1.36 aA	13.73 $\pm$ 0.83 aA	16.18 $\pm$ 0.93 aA
	B <sub>1</sub>	78.60 $\pm$ 1.16 aA	77.84 $\pm$ 1.51 aA	13.11 $\pm$ 1.07 aA	13.86 $\pm$ 0.66 aA
	B <sub>2</sub>	80.84 $\pm$ 1.30 aA	79.90 $\pm$ 1.85 aA	14.05 $\pm$ 0.94 aA	15.01 $\pm$ 0.83 aA
	B <sub>3</sub>	78.71 $\pm$ 1.87 aA	76.96 $\pm$ 1.41 aA	15.63 $\pm$ 0.94 aA	15.46 $\pm$ 1.32 aA
2017	B <sub>0</sub>	79.82 $\pm$ 1.45 aA	73.74 $\pm$ 2.79 aA	26.62 $\pm$ 1.24 aA	31.05 $\pm$ 2.00 aA
	B <sub>1</sub>	77.63 $\pm$ 1.70 aA	70.35 $\pm$ 1.40 aB	25.20 $\pm$ 2.15 aB	32.73 $\pm$ 3.23 aA
	B <sub>2</sub>	81.17 $\pm$ 1.73 aA	70.72 $\pm$ 2.22 aB	22.34 $\pm$ 1.76 aB	32.95 $\pm$ 2.27 aA
	B <sub>3</sub>	74.47 $\pm$ 3.01 aA	68.09 $\pm$ 2.72 aA	25.09 $\pm$ 1.43 aA	28.89 $\pm$ 2.04 aA

In each line, different capital letters represent significant differences between the absence and presence of foliar B supplementation in each B soil rate within each year, according to Tukey's HSD test ( $p < 0.05$ ).

### 3.3. Effect of Year and B Supply on Leaf Photosynthetic Pigments

The chlorophyll content (chl *a*, chl *b*, and chl *t*) varied among the years ( $p < 0.001$ ) (Table S1) and was the highest in 2017 (Table 2). In addition, the chl *a*/chl *b* ratio followed a decreasing trend during the three-year growing seasons (Table 2). In 2017, the chl *a*/chl *b* ratio was ca. 45% and 22% lower than the values obtained in 2015 and 2016, respectively (Table 2). In general, applying B to the soil or as a foliar spray did not influence the contents of leaf photosynthetic pigments in individual years (Table 5). In 2015 and 2016, the chl *a*/chl *b* ratio was influenced by soil B fertilization, but its effects exhibited different patterns. In 2015, this ratio was the highest in the absence of soil B application, but no differences were noted between the B<sub>1</sub> and B<sub>3</sub> treatments. In turn, in 2016, the highest and the lowest ratio was observed in the B<sub>1</sub> and B<sub>0</sub> treatments, respectively (Table 5). For most of the leaf photosynthetic pigments, the interaction between soil and foliar B fertilization did not produce significant effects ( $p > 0.05$ ). The exceptions to this finding are the chl *a*/chl *b* ratio in 2015, the chl *t* value in 2016, and the chl *a* content in 2017.

**Table 5.** Mean ( $\pm$ standard error) photosynthetic pigments content (chl *a*, chl *b*, chl *t*, and chl *a*/chl *b*) of almond leaves measured in the 2015–2017 period.

Year	Fertilization		chl <i>a</i> (mg g <sup>-1</sup> )	chl <i>b</i> (mg g <sup>-1</sup> )	chl <i>t</i> (mg g <sup>-1</sup> )	chl <i>a</i> /chl <i>b</i>	
2015	Soil	B <sub>0</sub>	2.727 $\pm$ 0.127 a	0.917 $\pm$ 0.050 a	3.643 $\pm$ 0.176 a	3.000 $\pm$ 0.050 a	
		B <sub>1</sub>	2.834 $\pm$ 0.152 a	1.035 $\pm$ 0.067 a	3.868 $\pm$ 0.212 a	2.778 $\pm$ 0.070 ab	
		B <sub>2</sub>	2.673 $\pm$ 0.133 a	1.073 $\pm$ 0.091 a	3.745 $\pm$ 0.192 a	2.657 $\pm$ 0.138 b	
		B <sub>3</sub>	3.080 $\pm$ 0.195 a	1.055 $\pm$ 0.065 a	4.134 $\pm$ 0.258 a	2.926 $\pm$ 0.072 ab	
	Foliar	F <sub>0</sub>	2.787 $\pm$ 0.109 A	0.997 $\pm$ 0.038 A	3.783 $\pm$ 0.146 A	2.795 $\pm$ 0.031 A	
		F <sub>2</sub>	2.864 $\pm$ 0.110 A	1.042 $\pm$ 0.060 A	3.906 $\pm$ 0.153 A	2.885 $\pm$ 0.089 A	
	Two-way ANOVA						
		Soil (S)		0.259	0.397	0.407	0.022
		Foliar (F)		0.578	0.528	0.541	0.250
		S $\times$ F		0.526	0.366	0.639	0.017
2016	Soil	B <sub>0</sub>	2.556 $\pm$ 0.183 a	1.310 $\pm$ 0.078 a	3.865 $\pm$ 0.256 a	1.941 $\pm$ 0.057 b	
		B <sub>1</sub>	2.621 $\pm$ 0.149 a	1.208 $\pm$ 0.053 a	3.828 $\pm$ 0.199 a	2.160 $\pm$ 0.056 a	
		B <sub>2</sub>	2.121 $\pm$ 0.161 a	1.116 $\pm$ 0.121 a	3.235 $\pm$ 0.266 a	1.970 $\pm$ 0.069 ab	
		B <sub>3</sub>	2.311 $\pm$ 0.168 a	1.139 $\pm$ 0.073 a	3.450 $\pm$ 0.240 a	2.010 $\pm$ 0.046 ab	
	Foliar	F <sub>0</sub>	2.360 $\pm$ 0.096 A	1.191 $\pm$ 0.044 A	3.549 $\pm$ 0.136 A	1.983 $\pm$ 0.037 A	
		F <sub>2</sub>	2.452 $\pm$ 0.141 A	1.196 $\pm$ 0.074 A	3.648 $\pm$ 0.205 A	2.022 $\pm$ 0.050 A	
	Two-way ANOVA						
		Soil (S)		0.130	0.425	0.209	0.041
		Foliar (F)		0.670	0.945	0.705	0.203
		S $\times$ F		0.041	0.056	0.038	0.375
2017	Soil	B <sub>0</sub>	4.245 $\pm$ 0.284 a	3.987 $\pm$ 0.480 a	8.230 $\pm$ 0.754 a	1.293 $\pm$ 0.163 a	
		B <sub>1</sub>	4.037 $\pm$ 0.259 a	3.664 $\pm$ 0.494 a	7.698 $\pm$ 0.723 a	1.383 $\pm$ 0.166 a	
		B <sub>2</sub>	3.776 $\pm$ 0.331 a	2.909 $\pm$ 0.560 a	6.683 $\pm$ 0.866 a	1.897 $\pm$ 0.241 a	
		B <sub>3</sub>	3.783 $\pm$ 0.343 a	2.815 $\pm$ 0.509 a	6.597 $\pm$ 0.819 a	1.778 $\pm$ 0.215 a	
	Foliar	F <sub>0</sub>	4.006 $\pm$ 0.194 A	3.226 $\pm$ 0.360 A	7.230 $\pm$ 0.540 A	1.675 $\pm$ 0.147 A	
		F <sub>2</sub>	3.912 $\pm$ 0.235 A	3.472 $\pm$ 0.374 A	7.381 $\pm$ 0.588 A	1.486 $\pm$ 0.141 A	
	Two-way ANOVA						
		Soil (S)		0.636	0.299	0.386	0.097
		Foliar (F)		0.685	0.678	0.909	0.433
		S $\times$ F		0.047	0.082	0.059	0.194

Different lowercase letters indicate significant differences among B soil (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>), and capital letters represent significant differences between B foliar (F<sub>0</sub> and F<sub>2</sub>) treatments within each year, according to Tukey's HSD test ( $p < 0.05$ ).

### 3.4. Effect of Year and B Supply on Almond Yield and Fruit Quality Attributes

The analyses revealed marked variations in the annual yield (Table S3), ranging from 0.09 t ha<sup>-1</sup> in 2016 to about 4.4 t ha<sup>-1</sup> in 2015 and 2017 (Table 2). The almond yield was also affected by soil B fertilization (Table S3), which was substantially reduced in trees fertilized with 3 kg ha<sup>-1</sup> (B<sub>3</sub> treatment), especially in 2017 (Table 6). Additionally, foliar B application did not improve the almond yield ( $p > 0.05$ ) (Table 6).

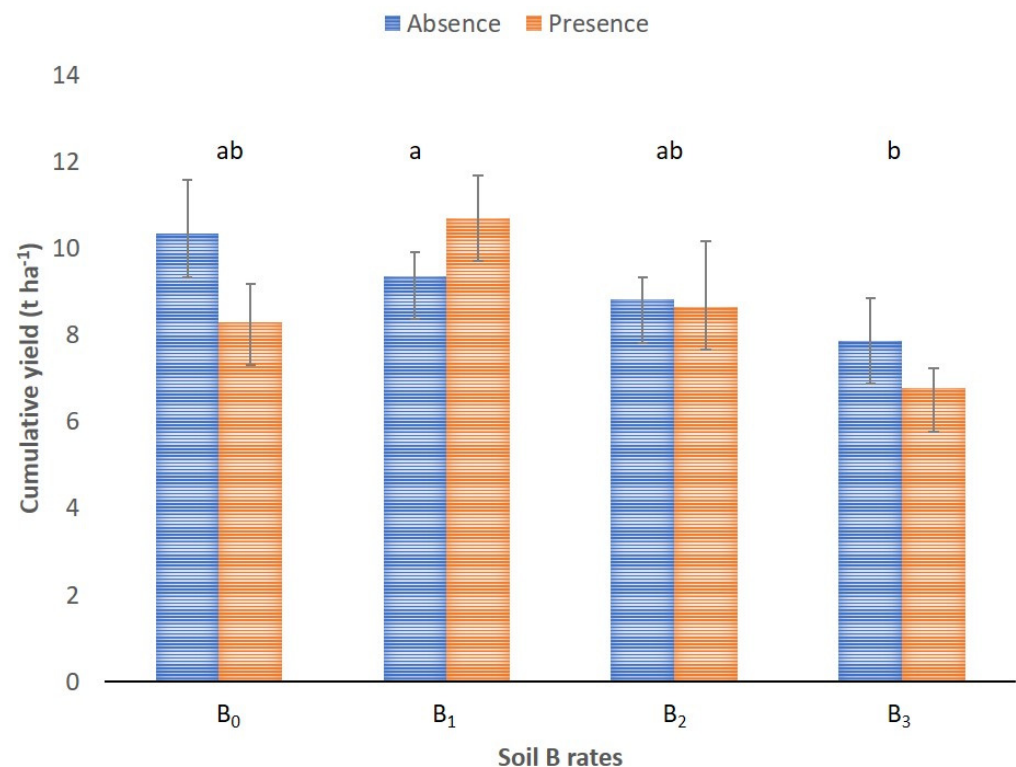
When the data of each year were analyzed separately, the findings indicated that foliar B application had no significant effect on the almond yield, while the soil application had a significant effect in 2017 only (Table 6). In this year, the highest almond yield was observed in the B<sub>1</sub> treatment (5.28  $\pm$  0.38 t ha<sup>-1</sup>), but this value was not significantly different from that obtained for the control treatment (4.08  $\pm$  0.39 t ha<sup>-1</sup>). In all the years, the lowest nut yield was observed under the B<sub>3</sub> treatment (Table 6).

The cumulative, three-year almond yield was significantly affected by soil B fertilization ( $p < 0.05$ ). The highest yield (ca. 10.00  $\pm$  0.83 t ha<sup>-1</sup>) was recorded with B application in the 1 kg ha<sup>-1</sup> amount but was not statistically different from the yields obtained in the control and the B<sub>2</sub> treatment (Figure 3). The application of B at rates exceeding 2 kg ha<sup>-1</sup> did not positively affect the almond yield, as the lowest yield was recorded with the application of 3 kg ha<sup>-1</sup>. Moreover, foliar B application did not improve the almond yield ( $p > 0.05$ ).

**Table 6.** Mean almond yield and nut number ( $\pm$  SE) under different B soil rates ( $B_0$ ,  $B_1$ ,  $B_2$ , and  $B_3$ ) associated with the absence or presence of foliar B supplementation in the 2015–2017 period.

Year	Soil B Rates	Yield ( $t\ ha^{-1}$ )		Nut Number	
		Foliar B Supplementation			
		Absence	Presence	Absence	Presence
2015	$B_0$	$5.42 \pm 0.78$ aA	$4.28 \pm 0.37$ aA	$231 \pm 3$ bB	$269 \pm 5$ aA
	$B_1$	$4.61 \pm 0.38$ aA	$4.46 \pm 0.71$ aA	$224 \pm 4$ bA	$233 \pm 4$ bA
	$B_2$	$4.41 \pm 0.29$ aA	$4.58 \pm 0.89$ aA	$222 \pm 4$ bB	$235 \pm 3$ bA
	$B_3$	$4.12 \pm 0.53$ aA	$3.25 \pm 0.25$ aA	$246 \pm 4$ aA	$241 \pm 5$ bA
2016	$B_0$	$0.08 \pm 0.02$ aA	$0.07 \pm 0.03$ aA	$223 \pm 3$ bB	$236 \pm 4$ bA
	$B_1$	$0.11 \pm 0.05$ aA	$0.09 \pm 0.03$ aA	$208 \pm 3$ cB	$222 \pm 5$ bA
	$B_2$	$0.22 \pm 0.09$ aA	$0.04 \pm 0.02$ aA	$185 \pm 2$ dB	$225 \pm 4$ bA
	$B_3$	$0.07 \pm 0.02$ aA	$0.05 \pm 0.02$ aA	$234 \pm 4$ aB	$257 \pm 6$ aA
2017	$B_0$	$4.39 \pm 2.98$ abA	$3.71 \pm 2.54$ aA	$353 \pm 5$ aA	$344 \pm 5$ bA
	$B_1$	$4.66 \pm 3.63$ aA	$5.98 \pm 4.64$ aA	$360 \pm 6$ aA	$370 \pm 5$ aA
	$B_2$	$4.19 \pm 3.42$ abA	$4.04 \pm 2.23$ aA	$306 \pm 5$ bB	$360 \pm 6$ abA
	$B_3$	$3.68 \pm 2.46$ bA	$3.27 \pm 2.38$ aA	$325 \pm 5$ bB	$355 \pm 5$ abA

In each column, different lowercase letters indicate significant differences among the B soil rates ( $B_0$ ,  $B_1$ ,  $B_2$ , and  $B_3$ ) within each year. In each line, different capital letters represent significant differences between the absence and presence of foliar B supplementation in each B soil rate within each year, according to Tukey's HSD test ( $p < 0.05$ ).

**Figure 3.** Cumulative almond yield ( $t\ ha^{-1}$ ) after three consecutive harvests by soil B rates ( $B_0$ ,  $B_1$ ,  $B_2$ , and  $B_3$ ) with the absence and presence of foliar B supplementation. Data are the means  $\pm$  standard error. Different lowercase letters indicate significant differences among the B soil rates, according to Tukey's HSD test ( $p < 0.05$ ).

The nut number (Table S3) was affected by the study year, the soil, and foliar B fertilization ( $p < 0.001$ ). As can be seen from Table 2, the nut number was the lowest in 2016 ( $224 \pm 2$ ) and the highest in 2017 ( $347 \pm 2$ ). The soil and foliar fertilization, as well as their interaction, had a significant effect on this parameter (Table S1). In all the years, the best results were observed under soil treatments  $B_1$  and  $B_2$  and in the absence of foliar fertilization (Table 6).

The year, soil, and foliar fertilization effect on the fruit characteristics were significant (Table S3). The majority of the nut and kernel attributes increased from the first to the second experimental year, decreasing substantially thereafter (Table 2). Independently of the year, both the nut and kernel dimensions were influenced by soil and foliar fertilization and their interaction (Table S3). In general, B applied via foliar sprays did not positively influence the nut and kernel dimensions, since the highest values were observed under soil fertilization (Tables 7 and 8). Comparing all B soil treatments, the 2 kg ha<sup>-1</sup> application rate yielded the best results for these parameters (Tables 7 and 8).

**Table 7.** Mean values (±SE) of the nut attributes (mass, length, width, and thickness) under different B soil rates (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>) associated with the absence or presence of foliar B supplementation in the 2015–2017 period.

Year	B Soil Rates	Nut Mass (g)		Nut Length (mm)		Nut Width (mm)		Nut Thickness (mm)	
		Foliar B Fertilization							
		Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence
2015	B <sub>0</sub>	4.45 ± 0.06 aA	3.93 ± 0.08 bB	37.62 ± 0.25 bA	37.08 ± 0.20 bA	22.94 ± 0.13 bA	22.15 ± 0.12 bB	16.50 ± 0.09 bA	15.88 ± 0.09 bB
	B <sub>1</sub>	4.65 ± 0.08 aA	4.46 ± 0.07 aA	39.00 ± 0.25 aA	38.02 ± 0.24 aB	23.86 ± 0.17 aA	22.96 ± 0.16 aB	16.97 ± 0.08 aA	16.59 ± 0.08 aB
	B <sub>2</sub>	4.65 ± 0.06 aA	4.33 ± 0.05 aB	38.09 ± 0.22 bA	38.35 ± 0.20 aA	23.22 ± 0.14 bA	22.81 ± 0.12 aB	16.90 ± 0.08 aA	16.41 ± 0.07 aB
	B <sub>3</sub>	4.19 ± 0.06 bB	4.42 ± 0.09 aA	37.55 ± 0.24 bA	37.87 ± 0.25 abA	22.80 ± 0.15 bA	22.98 ± 0.16 aA	16.15 ± 0.10 cB	16.46 ± 0.10 aA
2016	B <sub>0</sub>	4.61 ± 0.06 cA	4.45 ± 0.08 bcA	38.59 ± 0.25 bA	38.54 ± 0.29 aA	24.32 ± 0.14 bA	24.46 ± 0.17 aA	17.18 ± 0.09 cA	17.39 ± 0.11 bA
	B <sub>1</sub>	4.94 ± 0.06 bA	4.76 ± 0.08 aA	39.27 ± 0.19 bA	38.74 ± 0.22 aA	24.85 ± 0.12 aA	24.43 ± 0.14 aB	17.82 ± 0.08 bA	17.95 ± 0.10 aA
	B <sub>2</sub>	5.49 ± 0.06 aA	4.67 ± 0.09 abB	40.13 ± 0.16 aA	38.08 ± 0.27 aB	25.32 ± 0.10 aA	24.67 ± 0.15 aB	18.51 ± 0.07 aA	17.87 ± 0.12 aB
	B <sub>3</sub>	4.46 ± 0.08 cA	4.17 ± 0.08 cB	37.68 ± 0.24 cA	36.44 ± 0.29 bB	24.15 ± 0.16 bA	23.78 ± 0.16 bA	17.18 ± 0.12 cA	17.33 ± 0.13 bA
2017	B <sub>0</sub>	2.94 ± 0.05 cA	2.99 ± 0.04 aA	32.82 ± 0.17 bcA	32.28 ± 0.18 aB	21.24 ± 0.10 bA	21.39 ± 0.11 bA	15.34 ± 0.07 bA	15.70 ± 0.07 aB
	B <sub>1</sub>	2.88 ± 0.04 cA	2.79 ± 0.04 bA	32.29 ± 0.19 cA	32.55 ± 0.17 aA	20.75 ± 0.12 cB	21.86 ± 0.11 aA	15.01 ± 0.07 cB	15.50 ± 0.07 aA
	B <sub>2</sub>	3.38 ± 0.05 aA	2.88 ± 0.05 abB	34.39 ± 0.19 aA	32.72 ± 0.16 aB	21.96 ± 0.11 aA	21.64 ± 0.11 abB	15.98 ± 0.07 aA	15.63 ± 0.07 aB
	B <sub>3</sub>	3.17 ± 0.04 bA	2.91 ± 0.04 abB	33.56 ± 0.17 bA	32.37 ± 0.15 aB	21.50 ± 0.12 bA	21.31 ± 0.10 bA	15.78 ± 0.06 aA	15.63 ± 0.06 aA

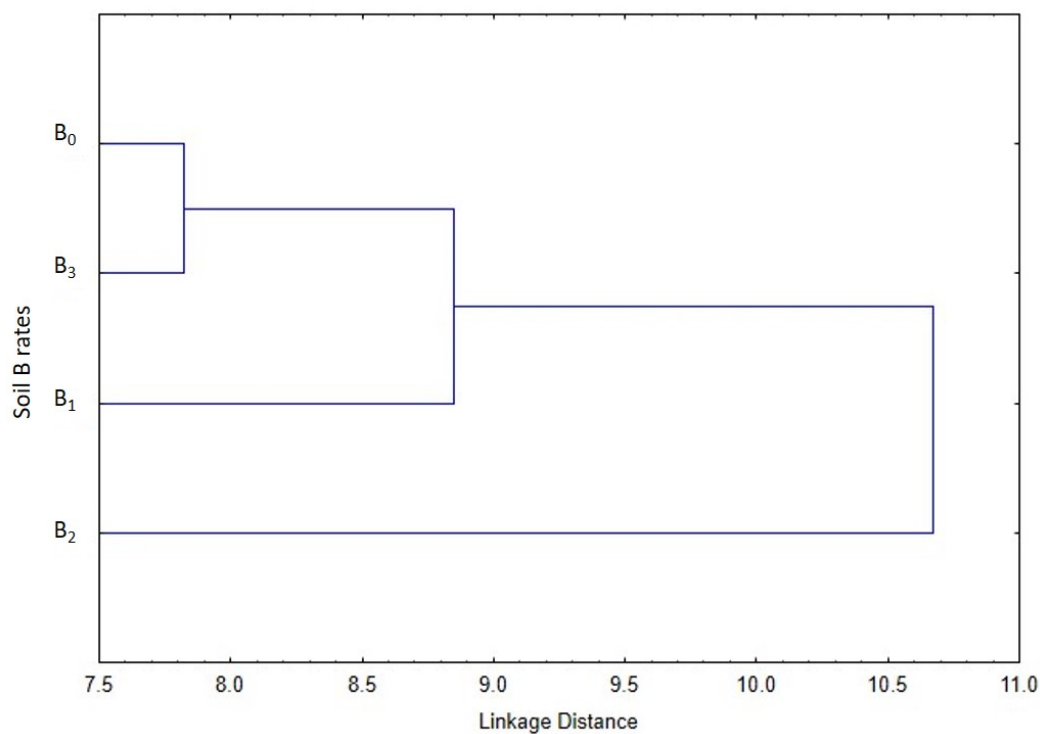
In each column, means with different lowercase letters indicate significant differences among the B soil rates. In each row, means with different capital letters represent significant differences between the absence and presence of foliar B supplementation within each year, according to Tukey’s HSD test ( $p < 0.05$ ).

**Table 8.** Mean values (±SE) of the kernel attributes (mass, length, width, and thickness) under different B soil rates (B<sub>0</sub>, B<sub>1</sub>, B<sub>2</sub>, and B<sub>3</sub>) associated with the absence or presence of foliar B supplementation in the 2015–2017 period.

Year	B Soil Rates	Kernel Mass (g)		Kernel Length (mm)		Kernel Width (mm)		Kernel Thickness (mm)	
		Foliar B Fertilization							
		Absence	Presence	Absence	Presence	Absence	Presence	Absence	Presence
2015	B <sub>0</sub>	1.08 ± 0.02 bA	0.91 ± 0.01 bB	26.09 ± 0.17 aA	25.80 ± 0.14 aA	13.09 ± 0.08 abA	12.55 ± 0.07 bB	6.78 ± 0.05 bA	6.05 ± 0.04 bB
	B <sub>1</sub>	1.06 ± 0.02 bA	1.02 ± 0.02 aA	26.49 ± 0.16 aA	26.29 ± 0.14 aA	13.31 ± 0.09 aA	12.83 ± 0.08 abB	6.33 ± 0.04 cB	6.47 ± 0.04 aA
	B <sub>2</sub>	1.15 ± 0.01 aA	1.03 ± 0.01 aB	26.57 ± 0.15 aA	26.18 ± 0.14 aB	13.27 ± 0.07 abA	12.90 ± 0.07 aB	6.95 ± 0.04 aA	6.57 ± 0.04 aB
	B <sub>3</sub>	1.09 ± 0.01 bA	1.01 ± 0.02 aA	26.12 ± 0.14 aA	25.85 ± 0.17 aA	13.01 ± 0.08 bA	13.04 ± 0.08 aA	6.80 ± 0.04 abA	6.43 ± 0.04 aB
2016	B <sub>0</sub>	1.28 ± 0.02 bA	1.26 ± 0.02 bcA	25.95 ± 0.14 aA	25.86 ± 0.19 aA	14.11 ± 0.08 bcA	14.21 ± 0.09 aA	7.37 ± 0.04 bA	7.32 ± 0.05 bA
	B <sub>1</sub>	1.38 ± 0.02 aA	1.38 ± 0.02 aA	26.46 ± 0.13 aA	26.25 ± 0.15 aA	14.39 ± 0.07 abA	14.48 ± 0.09 aA	7.50 ± 0.04 abA	7.56 ± 0.05 aA
	B <sub>2</sub>	1.43 ± 0.02 aA	1.35 ± 0.02 abB	26.95 ± 0.11 aA	25.74 ± 0.17 aB	14.56 ± 0.07 aA	14.50 ± 0.08 aA	7.59 ± 0.05 aA	7.59 ± 0.04 aA
	B <sub>3</sub>	1.28 ± 0.02 bA	1.24 ± 0.02 cA	25.53 ± 0.16 bA	24.57 ± 0.20 bB	13.94 ± 0.09 cA	13.82 ± 0.11 bA	7.33 ± 0.05 bA	7.26 ± 0.07 bA
2017	B <sub>0</sub>	0.91 ± 0.01 bA	0.89 ± 0.01 abA	23.07 ± 0.11 bA	22.77 ± 0.12 aA	12.05 ± 0.06 bA	11.98 ± 0.06 aA	6.86 ± 0.04 bcA	6.96 ± 0.05 aA
	B <sub>1</sub>	0.87 ± 0.01 cA	0.87 ± 0.01 bA	22.60 ± 0.13 cA	22.61 ± 0.10 aA	11.91 ± 0.06 bA	12.02 ± 0.06 aA	6.81 ± 0.04 cA	6.70 ± 0.05 bA
	B <sub>2</sub>	1.00 ± 0.01 aA	0.90 ± 0.01 abB	24.00 ± 0.12 aA	22.83 ± 0.10 aB	12.54 ± 0.06 aA	11.97 ± 0.05 aB	6.96 ± 0.04 bA	6.87 ± 0.05 abA
	B <sub>3</sub>	0.98 ± 0.01 aA	0.92 ± 0.01 aB	23.33 ± 0.13 bA	22.98 ± 0.10 aB	12.33 ± 0.06 aA	12.01 ± 0.06 aB	7.16 ± 0.03 aA	7.07 ± 0.05 aA

In each column, means with different lowercase letters indicate significant differences among the B soil rates. In each row, means with different capital letters represent significant differences between the absence and presence of foliar B supplementation within each year, according to Tukey’s HSD test ( $p < 0.05$ ).

The cluster analysis performed on all nut and kernel data revealed high similarities between the B<sub>0</sub> and B<sub>3</sub> treatments, but they did not substantially differ from the B<sub>1</sub> treatment. On the other hand, the B<sub>2</sub> treatment formed a separate group (Figure 4).



**Figure 4.** Cluster analysis (Euclidean distances and Ward’s hierarchical method) based on the fruit characteristics (nut and kernel mass, length, width, and thickness) of different soil B rates.

#### 4. Discussion

This study revealed that the boron application method had different effects on the physiological performance, yield, and fruit quality of almond trees. Under the conditions adopted for this experiment, almond trees responded favorably to boron application in the soil. The soil B rates tended to increase the leaf gas exchange parameters, including net CO<sub>2</sub> assimilation rate, stomatal conductance, and transpiration rate. This observation is consistent with the results obtained in other studies on tree nuts and illustrates the pivotal role of B fertilization in several physiological processes affecting photosynthesis [13]. The positive effect of B on the photosynthetic performance of almond trees is especially significant when applied at a 2 kg ha<sup>-1</sup> dose to the soil, since the highest leaf photosynthetic and transpiration rates, as well as the stomatal conductance, were observed in this treatment in all years of the study. The results of this study also indicated a tendency of increased RWC and decreased EL values in leaves subjected to this B rate, further substantiating the assertion that almond trees under this treatment exhibited better physiological performances. At a higher B rate (3 kg ha<sup>-1</sup>), the values of all the gas exchange parameters declined, suggesting that this amount of B fertilizer was unnecessary under the studied conditions. Moreover, it is widely established that excessive B application may hinder photosynthesis [24–26] and reduce yield [27,28]. During the study period, especially in the first and second years, B application at the highest rate (3 kg ha<sup>-1</sup>) resulted in the lowest yield, but the difference relative to other B rates was not statistically significant. This finding was unexpected, since the role of B in yield is well-documented [29]. Highly significant year-by-year yield variations were also observed, whereby similar values were obtained in 2015 and 2017, while a sharp decline was noted in 2016. This pattern is indicative of the alternate bearing that is characteristic of the species and is probably due to the harsh meteorological conditions observed in 2016. The intense precipitation in the first five months of 2016 during the bloom period caused flower drops and reduced flower pollination activity, severely impacting the yield [2]. However, it is important to point out that the observed decrease in the almond yield was less pronounced when B was applied at low rates, suggesting their beneficial influence on the yield during low production periods. This statement was also corroborated

by the results obtained for the nut number and fruit quality parameters, which varied significantly among the years. The highest dimensions (mass, length, width, and thickness) of the nuts and kernels were observed in 2016 and were strongly associated with a reduction in the nut number. Comparing all soil B treatments, B application at a  $2 \text{ kg ha}^{-1}$  rate increased the nut and kernel size, and this effect was consistent across all three years.

Even though foliar boron application is often seen as more effective in improving plant nutrition, crop yield, and fruit quality than soil fertilization [30,31], the results did not confirm these observations. Foliar B application, either alone or in combination with soil fertilization, did not result in significant yield augmentation or the superior physiological performance of almond trees in any of the study years. Moreover, B sprays did not influence the physical attributes of almonds. The number of fruits increased, and the average yield and fruit mass (nut + kernel) decreased in response to foliar sprays. In their study focusing on hazelnut (cv. Butler), [32] noted that B sprays did not affect the fruit set and yield. Their findings contrasted with those reported by [11,33], which indicated that the foliar application of B enhanced the fruit set and yield in almond trees (cv. Butte, Mono, and Ruby). Moreover, [7] noted that foliar B significantly increased the fruit set and quality traits of almonds (cv. Azar). More recently, [14] found that the foliar application of B nanoencapsulated in almond trees (cv. Avijor) led to a significant increase in the yield. The B availability in the soil could justify the absence of the beneficial influence of foliar B fertilization in our study. According to [2], the B level in the soil of the almond orchard ( $1.2 \pm 0.02 \text{ mg kg}^{-1}$ ) is considered high for rainfed managed orchards, indicating that B requirements are very low. As stated by [34], foliar B application is more effective in correcting B deficiencies than soil-derived B in leaves. The discrepancy in the effectiveness of foliar B sprays in almonds can also be potentially attributed to the B requirements of cultivars and the timing of foliar B application. In the present study, the first foliar B spray occurred in the spring, and the second was performed after the harvest [2]. At this time, there was no foliage in the trees, which could have compromised the translocation and B metabolism [11].

## 5. Conclusions

The results of the present study indicate that foliar B application had no significant effect on the physiological performance of almond trees, yield, or almond quality, which contrasted with low B fertilization rates applied to the soil. Therefore, under the conditions at which the study was performed, foliar B supplementation and a high B fertilization rate ( $3 \text{ kg ha}^{-1}$ ) are ineffective and represent an unnecessary cost. However, further studies are needed to determine the best source, doses, and time of foliar boron application in almonds grown in rainfed conditions.

**Supplementary Materials:** The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/agronomy12092005/s1>, Table S1: Results from repeated measures ANOVA of the effects of soil and foliar B fertilization throughout time (year) on the leaf gas exchange parameters (E ( $\text{mmol m}^{-2}\text{s}^{-1}$ ), gs ( $\text{mmol m}^{-2}\text{s}^{-1}$ ), A ( $\mu\text{mol m}^{-2}\text{s}^{-1}$ ), and iWUE ( $\mu\text{mol mol}^{-1}$ )); RWC (%); and EL (%). Table S2: Results from repeated measures ANOVA of the effects of soil and foliar B fertilization throughout time (year) on the leaf photosynthetic pigments (chl *a*, chl *b*, chl *t*, and chl *a*/chl *b*). Table S3: Results from repeated measures ANOVA of the effects of soil and foliar B fertilization throughout time (year) on the yield; nut number; and nut and kernel attributes (mass, length, width, and thickness).

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