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Effect of boron treatments on boron distribution and fresh leaf yield of tea plant

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Abstract

A two-year fixed field experiment was designed in Artvin, Turkey, with the aim of determining the effect of soil and foliar boron treatment on fresh leaf yield, shoot length, and also the transport and distribution of boron in the shoots of the tea plant. The experiment was conducted in a domestic producer's tea garden indicating boron deficiency in Arhavi district of Artvin. In the experiment, 400 g B da^{-1} to the soil and 400 mg B L^{-1} to the leaves of the tea plant were applied in a liquid form. DOT (Disodium Octaborate Tetrahydrate, $Na_2B_8O_{13}.4H_2O$) with 20.8 % B was used as a boron source. At the end of the experiment, it was determined that soil and foliar boron treatment caused a substantial increase in the fresh leaf yield, the shoot length, and also the boron concentration of the shoots of the tea plant. However, the boron concentration of the leaves at the tip of the shoots was still under the critical level.

Keywords: Boron transport, boron distribution, tea plant, boron fertilization

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Introduction

Tea plant has a substantial importance for the world and Turkey in terms of consumption and economic aspects. Global tea consumption increasingly reached approximately 5 million tonnes with China (33 %), India (21 %) and Turkey (5 %) taking up the top places. Total tea production in the world has exceeded 5 million tonnes a year of which about 38 % is produced only in China while 24 % in India and 9% in Kenya (FAO, 2015). Tea consumption in Turkey tripled between 1945 and 1950; therefore, the land cultivated with tea plant reached from 3.000 ha to 76.000 ha (Kacar, 2010). As reported in CAYKUR 2015 tea sector report, Turkey ranks 8th in the world in the extent of land for cultivating tea, 6th in tea production, 3rd in tea consumption and 1st in tea yield obtained from per unit of harvested area.

Apart from being a popular beverage worldwide, ingredients of tea boosts the body's vitality, strengthens bones and teeth, reduces heart disease and cancer risk, has a positive effect on weight problems and diabetes (Naito and Yoshikawa, 2009; Yang and Wang, 2010; Goenka et al., 2013; Kim and Kim, 2013). Researches show that boron is effective in yield as well as taste and smell of black tea and, moreover, it is effective on quality of tea as it increases the tannin content of tea leaves (Pethiyagoda and Krishnapillai, 1971; Kacar, 2010). Boron deficiency in plants is frequently observed in acid-reactive soils where rainfall is abundant. In the Eastern Black Sea region where tea cultivation is intensively carried out, the research results, showing 97 % boron deficiency detected in the soil cultivated with tea plants and 98 % boron deficiency in Artvin province (Taban et al., 2015), have helped to shape the subject and area of this research. In order to raise the quality of tea leaf prevent severe environmental and health problems, it is necessary to know the concentration of essential plant nutrients of the tea plant and its soil as well as the optimal doses of the nutrients to be applied, their application methods, optimum forms, application times and frequency.

Within the frame of the topics mentioned above, the aim of this research is to determine the effect of the foliar and soil boron treatment on a) yield, b) shoot height, c) boron concentration of shoot leaves, d) general distribution of boron in shoots of the tea plant.

Materials and Methods

The Establishment and Implementation of the Experiment

A two-year fixed field experiment was carried out in a tea garden run by a domestic producer in Yemişli village of Arhavi district in Artvin province (primary coordinates: 37T0692339 E, 4577909 N, secondary coordinates: 41,32837 N, 41,29641 E, altitude: 22 m). The experiment was conducted on 3 April 2014 in the first year and on 25 March 2015 in the second year. The field experiment was laid out with randomized block design with 5 replications. The experimental field was divided into twenty 2x1 m plots with 0.5 m and 1 m buffer area between the plots and the blocks, respectively.

A soil sample was collected from a few points (0-20 cm in depth) of the experimental field according to the productivity principle as reported by Jackson (1962). The soil samples collected from the experimental field were air-dried at room temperature, crushed and passed through 2 mm sieve to be prepared for the analysis.

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The available boron analysis was carried out with hot water method developed by Bingham (1982). Soil pH and EC was determined in a 1:2.5 ratio of soil:water suspension (SSDF, 1951; Grewelling and Peech, 1960); soil texture by using Bouyoucos hydrometer (Bouyoucos, 1951); organic C by using modified Walkey-Black method (Jackson, 1962); the total N by using Kjheldahl method (Bremner, 1965); available P by using Bray Kurtz No. 1 method mainly developed for acidic soils (Bray and Kurtz, 1945); exchangable K^+, Ca^{++} and Mg^{++} by extracting in 1 N NH_4OAc (pH 7,0) (Pratt, 1965); available Zn, Fe, Cu ve Mn 0,005 M DTPA+0,01 M $CaCl_2$+0,1 M TEA (pH 7,3) (Lindsay and Norvell 1978). As a result of the analysis, the available boron concentration was very low (0.35 mg kg^{-1})and the reaction of the soil was very acidic (pH 4,39). Some other characteristics of the soil were as follows: texture clay; EC 568 µS cm^{-1} (without salt); organic matter 57.0 g kg^{-1} (excess); available P 55.6 mg kg^{-1} (too much); total N 8.20 g kg^{-1} (excess); NH4OAc extractable K^+, Ca^{++} and Mg^{++} (mg kg^{-1}) 298 (medium), 1224 (sufficient) and 434 (sufficient), respectively; DTPA extractable Fe, Cu, Zn , Mn (mg kg^{-1}) 211 (good), 0.72 (sufficient), 4.11 (excess) and 73.6 (excess), respectively. The concentration of the elements extracted in solution was read by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry, Perkin Emler Model DV 2100) (Boss and Fredeen 2014).

Fertilizing

During the experimental process, boron was applied to the soil and leaves in the form of DOT (Disodium Octaborate Tetrahydrate, $Na_2B_8O_{13}.4H_2O$) according to the application plan (Table 1). Trademark Etidot-67 (% 20,8 B) was used as a boron source during the preparation of the treatments.

Soil boron fertilization was carried out on 4 April 2014 in the first year and on 26 March 2015 in the second year. Boron fertilizers in liquid form were homogeneously sprayed onto the soil surface and also mixed thoroughly with the soil using a hoe. Foliar boron fertilization was carried out in each year a) at the stage of the conduction of the experiment and b) after the first two harvest. Foliar boron fertilizers were applied on 4 April, 16 May, 10 July in 2014; and on 26 March, 31 May and 25 July in 2015. During the application process, fertilizers were meticulously applied to the soil and plant by taking any precautions against contamination; furthermore, spreader-adhesive was used in the solution aiming to prevent flow and washing. Basic fertilization was planned considering the soil analysis results; therefore, 12.5 kg N da^{-1}; 2.5 kg of P_2O_5 da^{-1}; 5 kg K_2O da^{-1} were applied in the form of compound NPK (25:5:10) on 25 March 2014 in the first year and on 1 March 2015 in the second year.

Sampling of the Leaves

Ten branches of the tea plant were randomly chosen from each plot and marked. The leaves of the 10 of the 8 branches marked with white tags were sampled considering their location in the stem while the other 2, marked with red tags, were evaluated generally (Figure 1).

The leaves above the harvest base were collected starting from the top of the shoots (from the leaves under the apical bud) considering their location on the stem in the 8 of the 10 marked branches and coded as “L1”, “L2”, “L3”, “L4”, “L5”. The shoot leaves of the other 2 branches were randomly collected without considering their location with the aim of determining the general boron concentration of the shoot leaves and coded as “G”, short for general (Figure 1).

Leaf sampling was carried out before harvesting on 14 May, 8 July, 1 September in 2014; 29 May, 23 July and 10 September in 2015.

Harvesting

Harvesting was carried out within the campaign season declared by General Directorate of Tea Enterprises (CAYKUR) on 15 May, 9 July and 2 September in 2014; 30 May, 24 July and 11 September in 2015. Tea plucker preferred by the farmers in the region was used for harvesting which was meticulously performed following the directions of CAYKUR. The leaves harvested from each parcel were weighed while the shoot length of the marked branches was measured before sampling.

The Analysis of the Leaf Samples

Total boron concentration of the samples was determined with the use of microwave wet digestion method and the solution extracted from the leaves was read by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry, Perkin Emler Model DV 2100) (Boss and Fredenn, 2014).

Statistical Analysis

Fisher's least significant difference (LSD) test was used to determine the significant differences among the means. JMP Statistical Software (ver: 9.0.2) was used for all statistical computations.

Meteorological data of the experimental field

Previous research suggests that the annual average temperature should not be below 14 °C, rainfall should be over 2000 mm and relative humidity should be 70% in order to be able to grow tea plant in an economic sense (Tanton, 1982; Kacar, 2010). According to the data gathered from Turkish State Meteorological Service (TSMS), the average annual temperature is 14.51 °C, the average monthly rainfall is 2253 mm and the average annual relative humidity is 72.07 % in the area where the experiment was conducted (Table 2).

Results

The Effect of Boron Treatment on Fresh Tea Yield

Boron treatments had a positive effect on fresh tea yield in all three harvest season in both years, and this effect was found statistically significant at $p < 0.01$. When examined considering harvest seasons, it was seen that fresh tea yield was increased in the 2nd harvest in comparison to the 1st harvest and decreased in the 3rd harvest in both years. Except for the control group, each of the boron treatments increased the fresh tea yield (Table 3).

In the experimental field, boron deficiency symptoms were observed in the control group. Growth failure and deformed leaves were the first manifestations of the symptoms (Pethiyagoda and Krishnapillai, 1971) in the shoots of the control group (Figure 2). Not surprisingly, the least fresh tea yield was obtained from control groups (S0L0) in all three harvest season in both years (Table 3).

Considering statistical analysis, it is not possible to comment on a treatment coming to the forefront; however, when it is compared to the yield obtained from S0L0, the treatments were generally lined as S1L1> S0L1> S1L0 in all three harvest season in both years. Boron treatments had a positive effect on total fresh tea yield in both years, and this effect was found statistically significant ($p < 0.05$). In the first year, the effect of S1L1 on the total tea yield was different from other treatments and control group.

Even though their effect on the yield is different from control group, none of the treatments differed from each other considering their effect on the fresh tea yield in the second year (Table 3).

Table 1. Boron doses of the soil and foliar treatments.

Soil Boron Treatments	Doses	Foliar Boron Treatments	Doses
S0	0 g B da^{-1}	L0	0 mg B L^{-1}
		L1	400 mg B L^{-1}
S1	400 g B da^{-1}	L0	0 mg B L^{-1}
		L1	400 mg B L^{-1}

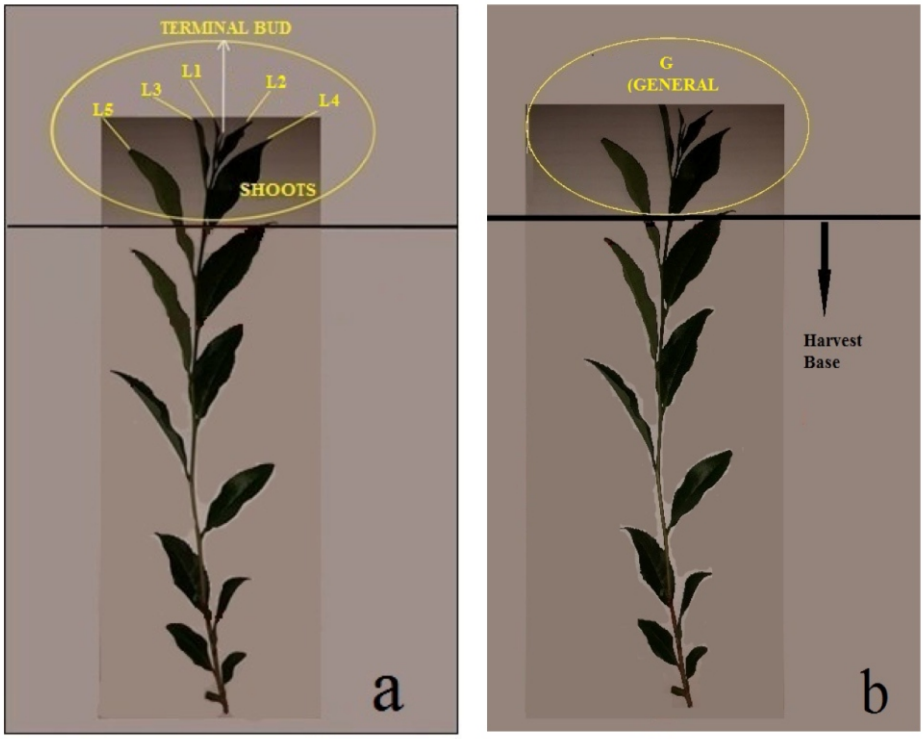


Figure 1. Leaf sampling a) considering the location b) without considering the location.

Table 2. Meteorological data of Arhavi-Artvin during the harvest season.

MONTHS	Temperature °C			Total Precipitation (mm)	Average Humidity (%)
	Average	Lowest	Highest		
			2014		
May	16.9	10.3	21.3	23.2	80.2
June	19.7	12.7	23.8	114	80.2
July	22.2	16.4	26.4	75.2	83.4
August	23.2	17.8	27.1	121	84.0
September	19.3	10.6	23.5	323	81.8
			2015		
May	15.4	6.4	19.5	12.8	80.4
June	19.0	13.6	22.6	57.4	89.9
July	21.0	15.5	24.5	18.0	85.5
August	22.9	15.6	27.3	326	87.5
September	21.6	15.7	25.8	80.6	82.2

Table 3. Effect of boron treatments on fresh tea yield (kg da^{-1}) in the first and second year of the experiment.

YEAR I								
Treatments	**1st Harvest**	**Increase, %**	**2nd Harvest**	**Increase, %**	**3rd Harvest**	**Increase, %**	**Total**	**Increase, %**
S0L0	492b	-	505c	-	190c	-	1187c	-
S0L1	523b	6	644a	28	271b	43	1438b	21
S1L0	507b	3	581b	15	271b	43	1359b	14
S1L1	639a	30	654a	29	322a	69	1614a	36
F Value	24.6***		54.3***		18.4***		12.5*	
LSD	42		29		39		142	
Treatments				YEAR II				
S0L0	476c	-	534c	-	314c	-	1324c	-
S0L1	575b	21	693a	30	348b	11	1616ab	22
S1L0	552b	16	643b	20	370a	18	1566b	18
S1L1	666a	40	689a	29	390a	24	1745a	32
F Value	25.8***		28.3***		22.7***		8.81*	
LSD	48		43		21		167	

*: p<0.05, ***: p<0.001 a, b, c ↓ : Different lower cases in the same column represent statistically significant differences among the treatments

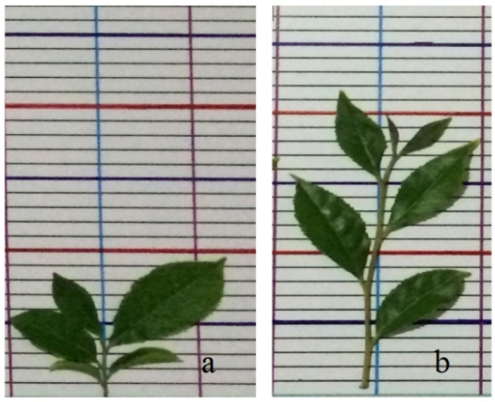


Figure 2. a. Boron deficiency in the control group (S0L0) (leaves: darker and thicker than normal, terminal bud: in hibernate), b. a healthy tea-shoot grown in the plots on which S1L1 was applied.

YEAR I						
Treatments	**1st Harvest**	**Increase, %**	**2nd Harvest**	**Increase, %**	**3rd Harvest**	**Increase, %**
S0L0	12.2c	-	14.2c	-	11.9b	-
S0L1	15.5ab	27	17.8b	25	14.6a	23
S1L0	14.6b	20	18.0b	27	14.6a	23
S1L1	15.7a	29	19.6a	38	14.9a	25
F Value	23.0***		63.5***		35.5***	
LSD	1.04		0.88		0.72	
Treatments			YEAR II			
S0L0	16.2c	-	17.2c	-	12.8b	-
S0L1	19.4a	20	19.5b	14	15.8a	23
S1L0	19.4a	20	20.3ab	18	16.5a	29
S1L1	18.7b	15	20.5a	19	16.1a	26
F Value	45.2***		24.8***		20.0***	
LSD	0.70		0.94		1.16	

***: p<0.001 a, b, c ↓ : Different lower cases in the same column represent statistically significant differences among the treatments

Table 4. Effect of boron treatments on shoot length (cm) of the tea plant in the first and second year of the experiment.

The Effect of Boron Treatment on Shoot Length

Boron treatments had a positive effect on the shoot length of the tea plant in all three harvest seasons in both years and this effect was found statistically significant at $p < 0.01$. The shortest shoot lengths were determined in the control groups in all three harvest seasons in both years. Except for the control group, each of the boron treatments increased the shoot length of the tea plant. Considering statistical analysis, it is not possible to comment on an treatment coming to the forefront in both years (Table 4).

The Effect of Boron Treatment on Boron Concentration of the Tea Shoots

In both year and each harvest season, individual and co-effects (interactions both boron treatment and leaf) of the boron treatments and each leaf of the tea shoots were found to be important on boron concentration and this effect was found to be statistically significant at $p < 0.001$. The boron concentration of the shoot leaves increased significantly after the soil and foliar boron treatment no matter whether applied separately or together. The highest boron concentration was identified in the 5th leaves (L5) while the least boron concentration was found in the 1st leaves (L1) since the data show a steady decrease starting from the L5 to the L1. Except for control groups, each of the treatment increased the boron concentration of the each leaf of the shoot. In all three harvest seasons in both years, the highest level of boron concentration was generally determined in the shoots on which S1L1 was applied, additionally, S1L1 treatment was followed by S1L0 and S0L1, respectively. On the other hand, when assessed statistically, it is not possible to mention an treatment coming to the forefront in terms of its effect on the boron concentration of the shoot leaves. The S0L1 treatment did not elevate the boron concentration of the shoots to the desired level in any harvest season during both years of the experiment. Except for the 1st harvest of the first year, none of the treatments could manage to raise the boron concentration above the critical limit in L1 and L2 in any harvest season in both years (Table 5; Figure 3, 4).

Discussion

As a result of the analysis, it is concluded that boron treatments had a positive effect on the yield in each harvest season in both years. This situation might suggest that the lack of boron nutrition of the experimental field and tea plant cultivated in this land might be the reason of this positive outcome. The deficiency of boron concentration in tea cultivated lands has been reported by a number of different researchers who conducted experimentation on the issue in Eastern Black Sea region (Kacar et al., 1979; Ozyazıcı et al. 2015; Taban et al., 2015; Ozkutlu et al., 2016). The treatments caused an increase in the boron concentration of the shoots (Table 5) and it is considered that this increase had a positive effect on the yield of the tea plant. By means of soil and foliar treatment, Taban et al. (2015) managed to increase the fresh tea yield of 21.87 % in a tea cultivated land detected boron deficiency at 96.62% in the Eastern Black Sea region.

Boron helps feed the plant by transporting the photosynthesis products to the necessary organs when there is a need. Boron forms boron-sugar complexes in plants and plays an important role in the short and long-distance transport of sugars (Matoh et al., 1996; Kaneko et al. 1997; Jackson, 1991). Blaser et al. (1967) reported that the lack of boron is sensed by the plant more acutely especially in the meristematic development stages. There is no evidence to indicate the direct effects of boron on nitrogen metabolism; however, in the absence of it, protein synthesis is reduced in the plant (Amberger, 1975). Likewise, boron is also effective in pectin synthesis and fat metabolism. In case of boron deficiency, the thickening, brittleness, and breakage of cell walls are explained by the inadequacy of pectin synthesis (Spurs, 1957; Kacar, 2010). One of the theories about the role of boron in plant metabolism is its effect on the stability of plant hormone level. Dyar and Webb (1961) found that boron plays an important role in auxin and IAA biosynthesis of the plants at the cambium tips. In the presence of boron, the increase in intake of some plant nutrients also might be related to the increase in yield. Pollard et al. (1977) found that the P uptake of plants fed with boron was higher than the ones grown in the boron-deficient environment. Marscher (1995) reported that the loss of K through washing was more common in boron deficient leaves. Similarly, the loss of sugar, amino acids, and phenols through washing is much more in case of boron deficiency and can be removed by addition of boron.

Table 5. The boron concentration (mg kg^{-1}) of each leaf of the shoots (L1, L2, L3, L4, and L5) and general boron concentration of the shoot leaves (G) in all three harvest season of the first and second year of the experiment.

Treatments	1st Harvest						2nd Harvest						3rd Harvest					
	L1	L2	L3	L4	L5	G	L1	L2	L3	L4	L5	G	L1	L2	L3	L4	L5	G
YEAR I																		
S0L0	15.9Db	16.3Db	16.5Db	17.0Db	20.8Da	17.2D	11.7Bb	11.9Bb	12.3Cab	12.7Ba	12.9Ba	11.9B	9.10Cc	9.55Dbc	9.63Dbc	10.6Cab	11.4Da	9.90C
S0L1	22.5Cb	23.2Cb	23.1Cb	24.8Cab	28.4Ca	25.9C	14.0Bb	14.1Bb	14.9Cab	15.4Bab	16.3Ba	15.3B	11.6Bc	12.5Cc	12.4Cc	14.6Cb	15.8Ca	13.4B
S1L0	30.9Bd	40.7Bc	48.9Bb	53.4Bb	60.8Ba	47.2B	22.3Ac	22.6Ac	29.1Bb	35.1Ab	42.1Aa	29.6A	18.3Ad	19.8Bcd	23.0Bbc	25.3Bb	31.2Ba	23.5A
S1L1	40.8Ae	50.0Ad	57.5Ac	66.9Ab	73.6Aa	54.3A	22.4Ac	25.0Ac	35.8Ab	39.9Aab	49.2Aa	33.1A	20.6Ae	23.9Ad	28.0Ac	31.8Ab	36.7Aa	26.6A
Treatment (T)			***			***			***			***			***			***
Leaves (L)			***						***						***			
T X L int			***						***						***			
YEAR II																		
S0L0	10.3Cc	10.3Cc	11.8Cb	11.8Db	13.8Ca	11.8C	9.63Cb	11.1Db	11.2Cb	12.9Ca	13.1Da	11.3C	9.02Dc	9.21Cbc	9.56Bbc	10.1Db	11.7Da	10.4C
S0L1	15.8Bc	17.2Bc	22.1Bb	23.5Cb	27.0Ba	20.3B	13.4Bc	16.0Cbc	18.8Bb	24.5Ba	24.7Ca	20.0B	11.0Cc	13.2Bb	12.8Bb	13.6Cb	17.9Ca	14.2B
S1L0	20.4Ac	21.1Ac	25.1ABbc	28.9Bab	30.6Ba	26.0A	16.0Bd	18.2Bd	22.2Bc	26.5Bb	31.0Ba	23.6B	12.2Bd	17.2Ac	21.5Ab	24.0Bab	27.2Ba	22.5A
S1L1	19.6Ac	23.4Abc	27.3Ab	38.3Aa	41.0Aa	30.2A	20.5Ad	25.2Ac	28.4Ac	35.3Ab	43.5Aa	33.1A	14.0Ad	15.1ABd	21.3Ac	28.6Ab	35.4Aa	23.4A
Treatment (T)			***			***			***			***			***			***
Leaves (L)			***						***						***			
T X L int			***						***						***			

***: $p<0.001$; A, B, C, D ↓ : Different upper cases in the same column represent statistically significant differences among the treatments; a, b, c →: Different lower cases in the same row represent statistically significant differences among the leaves

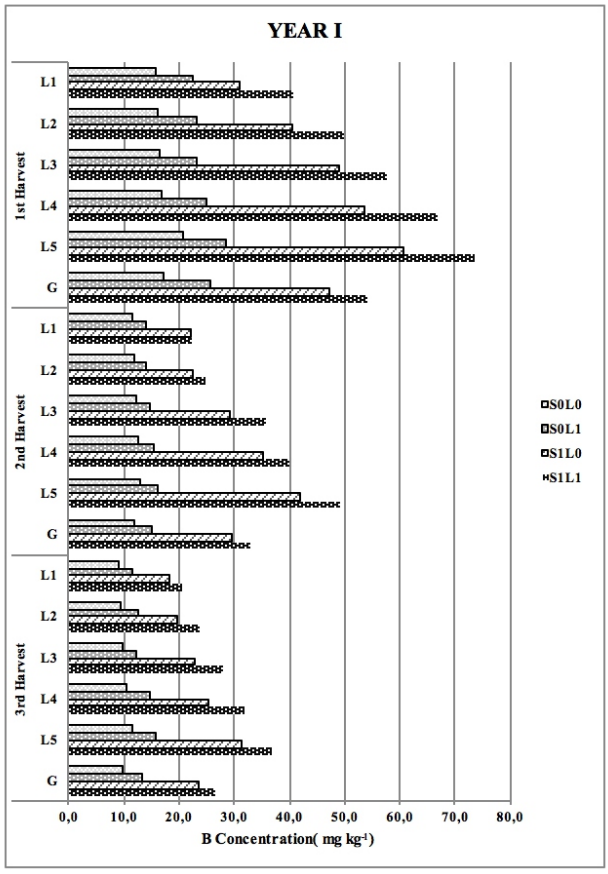


Figure 3. The effect of boron treatment on the boron concentration of each leaf of the shoots (L1, L2, L3, L4 and L5) and general boron concentration of the shoot leaves (G) in all three harvest season of the first year of the experiment.

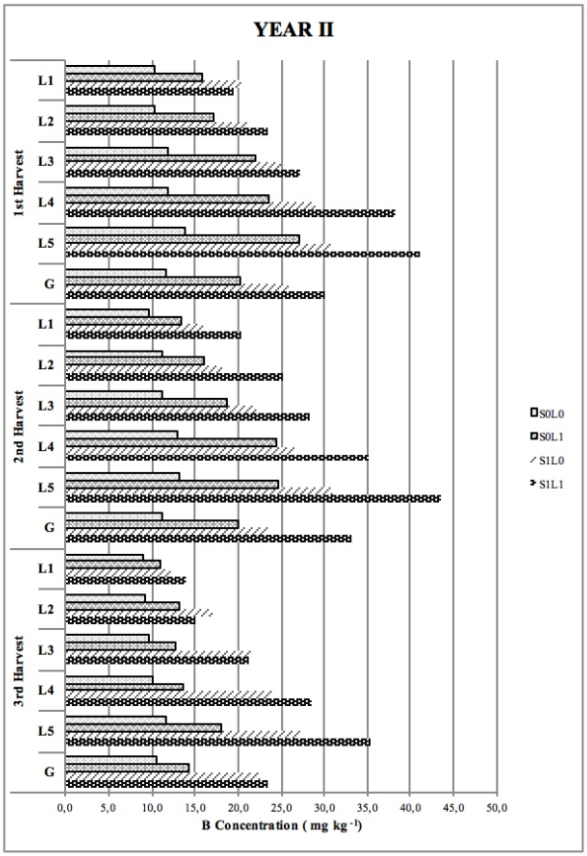


Figure 4. The effect of boron treatment on the boron concentration of each leaf of the shoots (L1, L2, L3, L4, and L5) and general boron concentration of the shoot leaves (G) in all three harvest season of the second year of the experiment.

When examined considering harvest seasons, it was seen that fresh tea yield (kg da^{-1}) was increased in the 2nd harvest in comparison to the 1st harvest and decreased in the 3rd harvest, in both years (Table 3). According to the meteorological conditions during the experiment, the average temperature recorded in the 2nd harvest in July showed a significant rise in comparison to the records in the 1st harvest in May (Table 2). Due to the fact that the tea is a tropical plant, the fresh tea yield is more likely to be affected by the increase in the temperature in July as well as the application of boron. Depending on the increase in temperature, the soil temperature also rises, thus ion movement in the soil also increases with the increasing kinetic energy. The 2nd harvest precipitation averages in June, are also relatively higher than the 1st harvest. Plant nutrients in soil increasing in activity with the rising temperature can more easily reach the plant roots with the help of increasing precipitation, so that they can be more available for the plant (Gunes et al. 2010).

According to Urs and Fischer (1994), nitrogen metabolism changes from assimilation to remobilization, nitrite reducing enzymes decrease, catabolic enzymes increase and chloroplasts begin to degrade due to the harvest seasons. Researchers noted that the plant growth was rapid in the early stages of the harvest season due to the availability of nutritions reserved in vegetative storage organs. However, the mineral content of the plant drops during the ripening and young plant tissues contains more NPK since the nutrient uptake of the plant decreases in time and dry matter formation continues. The changing inclines of the plants in mineral uptake depending on the age are seen as another reason for the difference between the vegetation periods (Korkmaz et al., 1993; Aktas, 1995). In the experiment, 25-5-10 was applied as a base fertilizer and did not repeated during the harvest season in both years. The plant nutrients applied to the soil are quickly lost due to precipitation, fixation, and evaporation.

The average fresh tea yield obtained from per unit of the harvested area varies between 1300 and 1700 kg da^{-1} (CAYKUR 2015). In the experiment, the average yield obtained from the control group (S0L0) remained below the average of Turkey in the first year with 1187 kg da^{-1} and slightly above in the second year with 1324 kg da^{-1} while the yield obtained from the plots especially from the ones soil and foliar fertilizers applied in together (S1L1) was between or above the average values of Turkey.

It is believed that the factors causing the increase of fresh tea yield are also valid for the increase of the shoot length of the tea plant. As a result of the boron deficiency, the distance of internodes shortens and dwarfism is seen since the development of the plant is regressed and apical meristem hibernates; therefore the shoot length of the plant become shorter than usual (Neales, 1960; Pethiyagoda and Krishnapillai, 1971; Lovatt and Dugger, 1984; Lukaszewski and Blevins, 1996) (Figure 2). Gohain et al. (2000) found that the distance of internodes lined up as 2.43; 2.47; 2.43 and 2.48 cm as a result of the boron treatment in the boric acid form in 0; 0.5; 1 ve 1.5 kg ha^{-1}, respectively.

When all three harvest seasons in two years are generally evaluated, none of the soil and foliar treatments used in the experiment could bring the boron concentration of the first two leaves (L1 and L2) of the shoots above the critical level needed for a healthy growth of tea plant. The S0L1 treatment could not bring the boron concentration of the shoots to the desired level in any harvest season of both years. In order for the foliar treatment to be successful, the fertilizer must be able to be absorbed by the leaf and transported to the necessary organs (Bukovak and Wittwer, 1957; Haslett et al., 2001), and in this case, phloem transport comes into question. There is no evidence for the presence of the polyol-complexes in tea plant which help to transport boron in the phloem. The plant needs water uptake and boron was carried to the upper organs with the help of it as a result of the water loss which occurs in the plant organs during the day . According to Pate (1975), inside the dead cells of xylem transport occurs from the roots to the greens of the plant. Bell (2016) noted that the highest accumulation of boron in the plant occurs in the old leaves; more specifically, on their tips and edges.

The age of the plants is also one of the important factors affecting the uptake and transport of boron since the upward concentration gradient decreases with the age (Shelp et al., 1987; 1992). It is expressed in many local and foreign academic sources that the biological lifespan of a tea plant (*Camellia sinensis var. sinensis*) is 100 years and its economic lifespan is 70-80 years. If the 1940s is based on for the Eastern Black Sea, today's tea plantations in Turkey is about 80 years old; in other words, they are about to complete their biological lifespan as well as appearing to be at the boundary of their economic lifespan (Kacar, 2010).

As a result of the research, it was found that the foliar boron treatment also significantly increased the yield, shoot length and boron concentration of the tea plant in addition to the soil treatment (Table 3, 4, 5). This result shows that during the times when the soil treatment is difficult to conduct, boron deficiency can be eliminated with a foliar treatment. Besides being more economical, the foliar treatment gives the opportunity to apply the fertilizer more homogeneously and also removes the deficiency in a shorter time than the soil treatment. On the other hand, using soil treatment, the nutrient can be kept in the soil for a longer time and the repetition of fertilization is less frequently needed (Amiri et al., 2008).

Conclusion

As a result of the analysis, the boron concentration of the soil of the experimental field and also tea plant cultivated in this area were found insufficient for a healthy growth of the tea plant. After the soil and foliar boron treatment, fresh tea yield, shoot length and boron concentration of the tea plant increased; in other words, tea plant deprived of boron gave a positive reaction to the boron fertilization. When evaluated in general, it is seen that the boron concentration of the each leaves of the shoots was raised with the help of S1L1 and S1L0 treatment. Although foliar treatment alone (S0L1) did not bring the boron concentration of any of the shoot leaves above the desired value, it could significantly increase the yield and shoot length compared to the control group (S0L0) in most harvest season. This result shows that during the times when the soil treatment is difficult to conduct, boron deficiency can be eliminated with a foliar treatment.

One of the important findings of the research that the changing values of the yield, shoot length and boron concentration of the shoots depend on the vegetation period. This result shows that the plant nutrients accumulated in the storage organs was used by the plant and consumed up until the 3rd harvest.

Moreover, the nutrients, even though added to the soil by fertilization, are quickly lost due to precipitation, fixation, and evaporation. In order to prevent such losses, it is needed to keep it ready in the soil when it is most needed; furthermore, it is necessary not to give all of the base fertilizer at once but divided into pieces to be able to apply during the different stages of the plant development.

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