Effect of Foliar Boron Fertilization on Chemical Properties and Fatty Acid Compositions of Corn (*Zea mays* L.)

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Boron is a member of the metaloid group of elements and is an important essential microelement needed for normal crop growth and development. This research was conducted in 2015 in Hatay (Mediterranean region of Turkey) to determine foliar application of Boron effect on protein ratio, starch ratio and oil yield and oil components of corn. To evaluate the response of foliar application of boron to corn, four boron doses (control, 4, 6 and 8 mg/m^2) were applied at the three growing stages (V2; 2 leaves with visible collars, V4; 4 leaves with visible collars,V2V4; half dosage was applied V2 and half dosage was applied V4). The experiment was carried out in a split plot design with three replicates using cultivar 82 May 70. Ears were harvested and randomly selected for analysis of protein ratio, starch ratio, oil yield and fatty acid composition. Even though there was no significant difference in Boron treatments in terms of protein and starch, significant difference was determined in oil yield and fatty acid composition. In general, foliar application of higher Boron doses (6, 8 mg /m^2) increased oleic acid, palmitic acid, stearic acid. In the early development period (V2), foliar application of boron caused an increase in the content of linoleic acid and linolenic acid of corn.

Keywords: Boron, Fat, Fatty acid content, corn

Corn, one of the most important cereals, is cultivated for human and for livestock feed. It is a raw or processed material of the oil industry throughout the World. Corn is the third most widely cultivated cereal crop which ranks after wheat and rice [6]. Although corn has a relatively low oil content of about 4 % on a dry-weight basis, corn crop production is so large worldwide that the total amount of corn oil produced by the corn plants is huge [18]. In addition, corn is used in many areas of industry [11]. which has stimulated corn cultivation around the world. It is known that corn has a relatively short growing period but giving more yields compared to other crops in cereal family. It is composed of 61-78 % starch, 6-12% protein, 3.1-5.7 % fat, 1-3% sugar, and 1.1-3.9 % ash (Miller et al. 1981; Watson, 2003). It was reported that, in general, fatty acid composition of corn ranges from 38 to 64 % linolenic acid, 0.5 to 2% linolenic acid, 19 to 51 oleic acid, 9 to18 % palmitic acid, and 1 to 4 stearic acid (Jellum and Widstrom 1983; Goffman and Böhme 2001; White and Weber 2002; [5]. In addition, unrefined corn oil contains triglycerides (79 %), sterols (4.5%), mono and diglycerides (3.9 %), hydrocarbons- sterol esters (2.9 %), free fatty acids (1 %), polar lipids (8.7 %), and minor amounts of waxes, tocopherols, and carotenoids (Lambert, 2001). Generally oil mixture and fatty acid content of corn are affected by genotype, environmental conditions such as heat, location, latitude and sowing time and other factors such as kernel, color, maturity, growing period [5,10,13,19].

The fatty acid composition of oils is significantly influenced by the cultivar, ecological conditions, latitude, irrigation and fertilisation management and area of production[3,10,14]. There are many ways to develop quality corn with a desirable fatty acid composition, one of which is fertilization [13].

Boron is an essential micronutrient for plant growth, but it is not required for development of fungi and bacteria. It is one of the most important micro elements for plant cultivation. Boron is reported to be involved in keeping cell wall structure and maintaining membrane function in crops [15]).

Stangoulis and Graham (17) reported that B improved the strength of the membrane and cell wall with the cross-linked polymer and strengthened the plants vascular bundles which hold back the invasion of pathogens. The boron foliar fertilizing in some plants has been a popular practice used by farmers as economic and effective for years [8] It is mainly used at grain filling stage of corn. The literature revealed the effect of boron on fatty acid composition of oil[8,9,12].

The aim of this study was to investigate the chemical characteristics of foliar boron applied to seeds at three different growing stages. Therefore, the effect of different boron dosages on protein, starch, oil, and fatty acid composition of corn in different stages of growth were evaluated.

Experimental part

Material and methods

Field study and data collection

The field trials were carried out in the experimental field of Mustafa Kemal University, in east Mediterranean region of Turkey located at 36° 15' N and 36° 30' during 2015 main crop season. The soil used in the study site was loamy, *p*H was neutral and slightly alkali. Also it had no salinity problem, rich in terms of lime and potassium. The soil had a moderate level of organic matter and phosphor (Yylmaz et al. 2015). Throughout the plants growing period, adequate plant protection measures were taken to avoid yield loss due to weeds and pests. Harvest was made in 18/08/2015 with hand-picking.

The experiment was set up in a split plot design with three replicates using cultivars 82 may 70. Three levels of boron dosage (4, 6 and 8 mg/m^2) as Di sodium octaborax

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tetrahydrate ($Na2B8O13.4H_2O$) were applied at three different growing stages V2 (two leaves with visible collars), V4 (four leaves with visible collars), and V2-V4 (half dosages were applied to V2 and half dosage was applied to V4) by spraying. For all three growing stages, three different boron doses and no boron application were used to make 10 different application trials. After harvesting chemical analyses mentioned below were performed on harvested seeds.

Crude Protein, Starch, Oil Yield, and Fatty Acid Determination

Protein and starch ratios were determined according to NIT *(Near Infrared Spectroscopy)* procedure. The NIT method of protein and starch was applied on Foss Tecator *Infrared 1241 Grain Analyzer Flour Model*. In order to determine oil yield, corns were crushed in blender and dried at 103±2 °C till the constant weight. Crude oils of seeds were extracted with the soxhlet method for 6 h. Recovered crude oils were taken to a rotary evaporator at 35 °C (Anderson, 2004). Oil samples obtained were filtered and stored at 4°C in dark glass bottles until performing analyses.

For the determination of fatty acid composition, the methyl-esters were prepared by vigorous shaking of oil solution in *n*-heptane (0.1 g in 2 mL) with 0.2 mL of 2N methanolic potassium hydroxide. The methyl esters were analysed by Agilent gas chromatography system (Agilent 6850, U.S.A) equipped with a hydrogen flame ionization detector (FID) and a capillary column DB-23 of 60 m length x 0.25 mm i.d. and 0.25μm of film thickness. The carrier gas was helium at 1.0 mL/min. Injector, oven and detector temperatures were 250, 230 and 280 °C, respectively. The results were expressed as relative area percent of total fatty acid methyl esters. The injection volume was 1μL. Fatty acids were determined by comparing their retention times with those of reference compounds [7,4].

All data were processed by analysis of variance (ANOVA) procedures using the MSTAT-c. Duncan Multiple Range Test was used to determine statistical differences between samples ($Pd \leq 0.05$).

Results and discussions

Table 1 shows the protein, starch and oil yield values of corn. While oil yield and fatty acid composition showed statistical differences, starch and protein content were not found to be significant.

The oil yields varied between 3.93 and 4.71%. While the highest oil yield was determined as 4.71% in 4 mg /m^2 B application of V2, the lowest oil yield was determined as 3.93% in the in the control treatment. As the application time of B was delayed, the content of oil yield decreased (table 1). Low doses of boron increased the content of oil yield in the corn kernels. Jellum et al. [9] stated that boron fertilization had no effect on any of the chemical characteristics in corn, but this study shows that foliar application of boron increased oil yield and fatty acid composition. This could be the result of foliar application of boron in this study comparison with soil application of boron in the study of Jellum et al. [9].

The content of starch ranged between 72.5 and 73.4% but these differences were not significant. While the highest content of starch was determined in V2 leaves period of the application rate of 8 mg /m^2 boron (73.4%), the lowest content was determined in V2V4 leaves period of the application rate of 4 mg /m^2 boron (72.5%).

When the protein content was evaluated, it varied between 7.30 and 8.14% and the differences were not significant. While the highest percentage of protein content was detected in control treatment (8.14%), the lowest percentage of protein was detected in V2 leaves period and 4 mg/ m^2 boron application (7.30%).

The fatty acid composition of corn oil samples are shown in table 2. Significant changes were observed in fatty acid profile with boron treatment in early growth period. The major fatty acids were palmitic (C16:0), stearic (C18:0), oleic (C18:1) and linoleic (C18:2) acids. Linolenic acids (C18:3), arachidic (C20:0) and behenic (C22:0) acids were also detected in minor amounts. Therefore they are not shown in the table.

The values of palmitic acid determined in the study were given in table 2. The palmitic acid values ranged from 17.97 to 11.96 %. As seen in the table 2, the highest palmitic acid value was found to be 17.97 % in the highest boron (8 mg / m^2) application of the V2V4 growing period. Weihrauch and Matthews (1977) reported that palmitic acid ranged from 22 to 6 % and the mean value was 11 %.

The stearic acid values ranged from 4.26 to 2.20. The lowest value was determined in the application of 8 mg / m^2 boron in the growing period of V2. Boron doses applied in early growing period (V2 and V4) caused an increase in the amounts of palmitic and stearic acid. Jabenn et. al (2013) reported that foliar application of boron increased palmitic and stearic acid.

The oleic acid content is shown in table 2. The oleic acid values ranged from 42.80 to 28.74%. The highest oleic acid rate values were determined in growing periods in V2V4 of 8 mg / m^2 boron dosages and in V2V4 of 6 mg /m^2 boron dosages, 42.8 and 40.29%, respectively. The lowest value of oleic acid was determined in V2 of 8 mg /m^2 boron application (27.94%) and no boron application (29.99%). Bellaloui et al. (2009) reported that a significant increase in oleic acid in soybean with foliar application of Boron,

Table 1

EFFECT OF FOLIAR APPLICATION OF BORON ON PROTEIN, STARCH AND OIL YIELD OF CORN KERNEL

	Starch (%)	Protein (%)	Oil Yield (%)
Control	72.86 ns	8.14ns	3.93 c*
V_2 (4mg/ha B)	73.03	7.30	4.71 a
V_2 (6 mg/ha B)	72.60	7.76	4.40 ab
V_2 (8 mg/ha B)	73.40	7.68	4.67 a
V4 (4 mg/ha B)	72.73	7.97	4.60 a
V4 (6 mg/ha B)	73.20	7.79	4.66 a
V4 (8 mg/ha B)	72.93	8.06	4.33 a-c
V_2V_4 (4mg/ha B)	72.50	8.04	4.30 a-c
V_2V_4 (6 mg/ha B)	73.30	7.89	4.45 ab
V_2V_4 (8 mg/ha B)	73.17	8.05	4.13 bc
CV (%)	0.92	4.17	5.42
LSD			**0.41**

**Mean values with different letters in the same line express significant statistical differences($Pd \leq 0.05$)*

	Palmitic acid (C16:0)	Stearic acid (C18:0)	Oleik acid (C18:1)	Linoleic acid (18:2)	Linolenic Acid (18:3)
Control	12.53 e*	2.45 e	29.99 d	51.57 c	1.04 bc
V2 (4mg/m^2 B)	16,20 b	3.57 b	29.83 d	48.45 e	1.61 a
V2 (6 mg/ m^2 B)	13.80 d	3.02 d	32.04 c	47.19 f	1.06 bc
V2 (8 mg/ m^2 B)	11.96 f	2.20 f	27.94 g	54.73 a	1.06 bc
V4 (4 mg/ m^2 B)	12.37 ef	2.31 ef	28.95 ef	52.90 b	0.92 c
V4 (6 mg/ m^2 B)	12.20 ef	2.39 e	28.74 f	52.74 b	1.08 bc
V4 (8 mg/ m^2 B)	12.10 ef	2.31 ef	29.46 de	53.58 b	1.08 bc
V2V4 (4mg/ m^2 B)	12.25 ef	2.46 e	31.70 c	50.61 d	1.04 bc
V2V4 (6 mg/ m^2 B)	14.50 c	4.26 a	40.29 b	36.86 g	0.89 c
V2V4 (8 mg/ m^2 B)	17.97 a	3.97 c	42.80 a	32.5 h	1.28 b
CV (%)	**2.10**	**2.84**	**1.03**	**1.12**	**12.5**
LSD	**0.48**	**0.14**	**0..57**	**0.92**	**0.23**

Table 2
EFFECT OF FOLIAR APPLICATION OF BORON ON MOST FATTY ACID COMPOSITION OF CORN KERNEL OIL

**Mean values with different letters in the same line express significant statistical differences (Pd"0.05)*
*****As palmiteloic, arachidic and behenic acid values are under the below 0.1, they are not shown in the table***

when compared with non spray control plant. The most important fatty acid is oleic acid due to its effect of reducing cardiovascular risks (Perz-Jimenez et all. 2002). Downey and Rimmer (1993) reported that higher levels of oleic and linoleic acid improve oil quality.

The fatty acid with the highest amount in the corn oil is linoleic acid. The linoleic acid values ranged from 54.73% to 36.86%. The highest linoleic acid content was determined during the early stage of development (V2) and at high concentration (8 mg /m^2). The lowest linoleic acid content was determined in high boron doses (6, 8 mg/m^2) during growing periods (V2V4). Both early stage (V2, and V4) and in high dosages (8 mg/m^2) of foliar application of boron, linoleic acid concentration increased. Jabeen et al. (2013) reported that boron was found to increase linoleic acid, which is required to maintain the quality of edible oil. This result is in agreement with the findings of Jabeen et. al. (2013), as they observed an increase in linoleic fatty acid with the increasing levels of leaf boron in sunflower oil.

The linolenic acid values ranged from 1.61% to 0.89%. The highest value of linoleic acid was determined at the lowest boron (4 mg/m^2) dose during the V2 period (54.73%). Also the lowest value was determined at the dose of 4 mg/ m^2 boron in the development period of V2V4 (36.86%). In general, the highest fatty acid found in corn kernel. The linolenic acid content in corn ranged from 38 to 64% (White and Weber 2002). Concentration of some fatty acids is found at minimum levels in corn (White and Weber 2002, Koca et. al., 2015).

A significant increase in unsaturated fatty acid (oleic acid) was also reported by Bybordi and Mamedov (2010) in canola, and Zakaria et al. (2001) in cotton seed, and Jabeen et al. (2013) in sunflower seed with the foliar application of essential micronutrients. Foliar spray of boron has no effect on protein and starch in corn kernels composition. It is also not affected by boron application on fatty acid composition (Jellum et al. 1972). Palmitoleic and oleic acid may reduce cardiovascular risks (Perz-Jimenez et al. 2002).

Conclusions

In this work, the effect of different dosages of boron and plant growing period on corn some grain quality characteristics has been determined. Oleic and linoleic acid are found in the highest amount in corn oils. In the study, it can be concluded that boron, applied at different dosages and plant developing periods, caused significant changes in composition of fatty acids and oil yield. As a result of the study, it may be said that foliar boron application is an important microelement for corn oil quantity and quality which is fatty acid concentration. Therefore, foliar boron treatment has a positive effect on human health.

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