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Full Length Article

Boron Foliage Application Mediates Growth, Oil Yield and Quality of Sunflower in Yermosols of Southern Punjab

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Abstract

Sunflower is sensitive to boron (B) deficiency and requires greater quantities to fulfill metabolic activities. A pot experiment was conducted to examine the role of B in oil yield and quality of sunflower. The experiment was consisted of two sunflower hybrids *viz*., S-278 and Hysun-33 with four B concentrations *viz*., control (0%), 1, 1.5 and 2% as foliar application. Results revealed that foliar applied 1% B significantly improved sunflower growth, yield and quality in both hybrids except capitulum diameter and oil contents, which were recorded better in 1.5% B. Between hybrids, S-278 produced maximum stem diameter, number of achenes per capitulum, 1000-achene weight, achene and biological yield and chlorophyll contents with 1% B and capitulum diameter and oil contents at 1.5% B application. Moreover, hybrid S-278 had maximum capitulum and stem diameter, number of achenes per capitulum, 1000-achene weight, achene and biological yield, chlorophyll contents and oleic acid while hybrid Hysun-33 showed significantly maximum plant height, oil and protein contents, linoleic, palmitic and stearic acid. Furthermore, plant height, linoleic and stearic acid was maximum in Hysun-33 with 1% B. Protein contents, oleic and palmitic acid interaction was found non-significant. In crux, application of 1% and 1.5% B significantly improved the growth, yield and quality of sunflower. © 2019 Friends Science Publishers

Keywords: Sunflower; Foliar application; Chlorophyll; Oil contents; Boron

Introduction

Sunflower (*Helianthus annuus* L.) is an important source of premium quality vegetable oil (Hegde, 2009). Sunflower positioned third among groundnut and soybean in the world total oil production. It is an important oilseed crop with almost 20–27% and 40–47% protein and oil contents, respectively (Saleem *et al*., 2003). Moreover, it contains oleic acid (16.2%) and linoleic acid (72.5%) with high percentage of about 60% polyunsaturated fatty acid. Sunflower seed cake is the by-products after oil extraction with 35% protein and 18–20% carbohydrates being used for cattle feed due to good source of protein (Dedio, 2005). It is also used for forage, silage and as a green-manuring crop (Dedio, 2005). World's sunflower area under cultivation is about 23.70 million hectares with annual production and average yield of 31.33 MT and 1322 kg, respectively (Hegde, 2009). In Pakistan, sunflower positioned second after cotton as a source of domestic oil production (Zahoor *et al*., 2011). In 2017–2018, area under its cultivation was about 203 thousand ha and with annual production of 104 and 40 thousand tones seed and oil, respectively (GOP, 2017). However, local annual oil production is only 0.503 MT, which fulfill the domestic requirement of only 18% while remaining 82% is imported (Dawn, 2017).

Boron (B) is a micronutrient primarily presents in the form of borates in soil. Its availability improves meristematic growth through cellulosic cross links of cell wall by incorporation of diol containing groups in cell membrane (Bolanos *et al*., 2004; Rehman *et al*., 2018). Moreover, B is essential for association of rhamnogalacturonan and pectin, which imparts vigor to cell wall (Kunal and Naresh, 2014). Boron is immobile micronutrient and thus needed continuously to plants at all growth stages (Bolanos *et al*., 2004). Among other micronutrient deficiency, B deficiency is the second most dominant problem globally (Alloway, 2008). Most of areas across Pakistan face 50–60% B deficiency (Rashid *et al*., 2002) due to calcareous alluvium soils (Rashid and Ryan, 2008). It's deficiency at flowering stage, resulted in deformation of pollen tube and inhibits fertilization which caused empty seed (Soylu *et al*., 2005). Moreover, at reproductive phase, inhibited flower and fruit development as well as seed setting occurs as result of B deficiency

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(Bolanos *et al.,* 2004). Boron deficiency also lower chlorophyll levels with low rate of photosynthesis (Bolanos *et al*., 2004). Likewise, deficiency of B results into poor translocation rate of assimilates (Saleem *et al*., 2016). Subsequently, a yield decline occurs, and hence potential yield cannot be attained (Korkmaz and Askin, 2015). Besides, B deficiency arbitrated devastation in assimilate partitioning through decline in indole acetic acid and cytokinin biosynthesis, ultimately, growth of cells is arrested (Muhammad *et al.,* 2013). Boron application is reported to improve germination and early seedling growth (Rehman *et al*., 2012). Boron deficiency in sunflower resulted in death of seedling and roots, wrinkled and deformed leaves and empty seeds primarily in the central regions of the capitulum (Vaknin *et al*., 2008). Sunflower has been found sensitive to B deficiency (Oyinlola, 2007) and therefore, require greater quantities to fulfill its metabolic needs (Bolanos *et al.,* 2004).

Boron use efficiency can be improved by several strategies for example addition in soil, foliar application or band placement in soil (Ashraf *et al.,* 2016). However, foliar and soil application often transcend other methods of nutrient application in terms of benefits (Das, 2014; Rehman *et al.,* 2014a, b). Foliar application of B improved the seed yield under drought conditions as result of positive effects on physiology and growth of plant (Bolanos *et al.,* 2004; Kandi *et al.,* 2012). Optimum concentration/dose at specific time has prominent role in yield and quality enhancement of sunflower (Bolanos *et al.,* 2004). However, accurate and enough concentration of B is required throughout the whole growing season for the crop development, quality and yield (Soylu *et al.,* 2005).

In Pakistan, induction of high yielding hybrids of sunflower has a potential to encounter the country demands of oil but still there is a thicker gap between potential and farmer yield of sunflower hybrids. Although various studies have explored role of B in plant life cycle, little information is available regarding the comparative efficacy of foliar applied B for different sunflower hybrids under semiarid environments of Southern Punjab. Furthermore, behavior of sunflower for applied B in yermosols is not reported yet, which is a common soil types in experimental region. The current study was, therefore, conducted to find suitability of foliar applied B for different sunflower hybrids under semiarid environments of Southern Punjab, Pakistan.

Materials and Methods

Present experiment was conducted at Agronomic Research Area, Bahauddin Zakariya University, Multan (30.10°N, 71.25°E and 421 ft. altitude above sea level) during spring 2016 in earthen pots (25×40 cm^{-2}) filled with soil. Before sowing of seed, soil was tested for different physico-chemical properties. Soil pH was measured in immersed soil saturation paste by utilizing a pH meter (Beckman 45 Modal, US) and it was found 8.43. Electrical conductivity was measured in saturation extract by utilizing advanced EC meter (VWR Conductivity Meter DIG2052) and was 12 dS m^{-1}. The organic matter content in the soil was 0.78% as indicated by Walkely-Block strategy. Soil textural class as dictated by hydrometer technique was silty clay loam. This soil belongs to Sindhlianwali soil series (hyperthermic, sodic haplocambids) in USDA Haplic Yermosols in FAO classification. According to analysis, it was deficient in B with only 0.42 mg kg^{-1} B.

The experiment was laid out according to completely randomized design with factorial arrangement. There were two sunflower hybrids *viz*., S-278 and Hysun-33 with four B concentration *viz*., B (Control, water spray with 0 B), 1% B, 1.5% B and 2% B and each treatment was replicated five times. Boric acid (H_3BO_3) (17% B) was used as source of B. For the formulation of 1%, 1.5% and 2% B solution, 17 mg, 25.5 mg and 34 mg H_3BO_3 was weighted on electrical weighing balance (BL3200HL Japan) and each was dissolved in to 100 mL of distilled water separately. Foliar application of these B solutions was done before flowering stage with the help of knapsack sprayer.

Before sowing, pots were irrigated with canal water. Total ten seeds per pot with two seeds per hole were sown on 1st March, 2016. Recommend doses of N, P and K @ 45, 35 and 15 kg ha^{-1} in the form of N, P_2O_5 and K_2O, were uniformly applied at sowing in all pots on soil weight basis. Twenty days after sowing, thinning was performed to have uniform number of plants in all the pots and three plants per were kept. The foliar application was performed at the 9th leaf stage by using a knapsack sprayer at 1.5 ft. plant height during vegetative growth stage. Plants were grown till maturity and harvested on 1st July, 2016, after which capitula were separated from the plants and air dried. After oven drying in a forced air oven at 70ºC dry weight of capitula was recorded. Achenes were separated manually from the capitula and their dried weight was also recorded.

Different growth, yield and quality attributes were recorded before and after harvesting the plants. Plant height (cm) was recorded at maturity with help of meter rod. Stem diameter (cm) was recorded from bottom, middle and top of the plant with Vernier caliper and then averaged. Capitulum diameter (cm), was measured with scale while achenes from capitulum were threshed and counted to take number of achenes per capitulum. Total achene weight (g) was recorded by weighing achenes from each capitulum separately on an electrical balance. The 1000 achene were counted and weighed on electrical balance. After drying, whole capitulum was weighed for dry weight (g). Total dry matter per plant (g) was also measured by weighing the whole dried plant on the balance. Biological yield (kg plant^{-1}) was recorded by weighing the whole plant at the time of harvesting. To measure the chlorophyll contents, three leaves were randomly chosen from each plant and leaf chlorophyll contents were observed by using chlorophyll meter (SPAD 502 plus Minolta, Japan). For oil contents, three samples of 80 g were taken from each hybrid and each experimental unit. Achenes were crushed and fed to Soxhlet extractor fitted with 1 L round bottom flask and a condenser. The extraction was accomplished through 0.5 L *n*-hexane on a water bath for 6 h. The solvent was distilled off in a vacuum under rotary evaporator and oil contents was recorded. Mature capitula were selected from the treatments and each was divided into three concentric, ring-shaped zones, which was sampled for six adjoining achenes from 3, 6, 9 and 12 o'clock positions. These 12 samples from each capitulum were dried and after which the hulls (pericarp) from the achenes were removed. These samples were ground in a mortar with sand and extracted with petroleum ether. The samples were analyzed by gas chromatography. Relative amounts of the four major fatty acids of sunflower oil *viz*., palmitic, stearic, oleic and linoleic acids were calculated by means of an electronic digital integrator (Hewlett-Packard model 3370B). Crude protein contents were determined by using Kjeldahl method.

Data Analysis

Data collected were statistically analyzed by Fisher's analysis of variance and treatment means were compared using least significant difference at 5% probability level (Steel *et al.*, 1997).

Results

Exogenous applied B had significant effects on sunflower growth, yield and oil content (Table 1 and 2). From both hybrids, Hysun-33 expressed 20% higher plant height than S-278 (Table 1). Among different treatments, 1% B produced 3.8% higher plant height than 2% B and control while control and 2% B had similar height with each other. Moreover, Hysun-33 with 1% B produced 26.25% higher plant height than S-278 with 2% B and other treatments (Table 1). Concentration of 1% B expressed 4.27% higher chlorophyll contents than other concentrations. Moreover, 1.5 and 2% B were statistically similar with control. Hybrid S-278 at 1% B showed 8.16% had higher chlorophyll contents than 2% B and control (Table 1). Likewise, stem diameter of S-278 was recorded 10.2% higher than Hysun-33 (Table 1). Boron application of 1% produced 12.3% thicker stem than B 2% (Table 1).

Among different B concentrations, 1.5% B had 17.7% more capitulum diameter than 2% B and control. Statistically S-278 with 1.5% B produced 64.1% higher capitulum diameter than Hysun-33 with control (Table 2). The hybrid S-278 showed 2.1% higher capitulum diameter than Hysun-33 under different doses of B concentration (Table 2). Among different B concentrations, 1% B produced 10.8% higher number of achenes per capitulum in S-278 followed by similar B concentration in Hysun -33 and 1.5% B in S-278 (Table 2). The hybrid S-278 showed 2.73% maximum number of achenes per capitulum than Hysun-33 under different concentrations of B. Similarly, maximum 1000-achene weight was recorded for 1% B that was 17.9% higher than control. Statistically, S-278 with 1% B produced 36.3% higher 1000-achene weight than Hysun-33 with control and it was significantly higher than other treatments (Table 2). Between two hybrids, a 10.5% higher 1000-achene weight was recorded in hybrid S-278 than Hysun-33 (Table 2). Owing to the improved yield traits, achene yield was significantly improved with B application and among different treatments, foliar applied 1% B produced 19.3% higher achene yield than control, which was significantly higher than other treatments. Moreover, S-278 with 1% B gave 39.9% higher achene yield than Hysun-33 with control and other treatments. From both hybrids, S-278 produced 16.4% higher achene yield than Hysun-33 (Table 2). Almost same trend was recorded for biological yield. Application of 1% B concentration produced 13.9% more biological yield than control, which was also significantly higher than other B treatments (Table 2). Between tow hybrids, biological yield of S-278 was 9 % more than Hysun-33 (Table 2).

Oil contents and quality traits were also significantly affected by B application. Exogenous application of 1.5% B produced 9.29% higher oil contents than 2% B. Application of 1.5% B recorded 11.40% more oil contents in both hybrids than S-278 with 2% B (Table 3). Hysun-33 recorded 4.67% higher oil contents than S-278 (Table 3). Exogenous application of B significantly affected protein contents and 1% B gave 15.90% more protein contents than 2% B and other concentrations (Table 3). Overall, the hybrid Hysun-33 presented 5.75% higher protein contents than S-278 (Table 3). Regarding linoleic acid, among different B concentrations, 1% B concentration exhibited 5.71% higher linoleic acid than 2% B and other B concentrations. Hysun-33 produced 1.03% higher linoleic acid than S-278 (Table 3). Boron concentration of 1% contributed 5.23% higher oleic acid than 2% B. Sunflower hybrid S-278 attained 4.29% more oleic acid than Hysun-33 (Table 3). Maximum palmitic acid was noted in 1% B that was 31.46% higher than 2% B. Between two hybrids, Hysun-33 produced 16.22% higher palmitic acid than S-278 (Table 3). Application of 1% B produced 12.77% higher stearic acid than 2% B (Table 3). Hybrid Hysun-33 with 1% B produced significantly higher stearic acid that was 17.55% higher than S-278 with 2% B, while S-278 with control and 1% B were statistically at par with Hysun-33 with 1.5 and 2% B concentration. Stearic acid of Hysun-33 was 5.36% higher than S-278 (Table 3).

Discussion

Application of B as a foliar on sunflower prior to flowering stage has significant effects on growth, yield and oil quality. Different growth, yield and quality traits of sunflower were improved with foliage B (Kandi *et al.*, 2012). Improvement in plant height with B might be due to appropriate concentration of B, which plays an important role in cell

Table 1: Influence of exogenous applied boron on plant height, chlorophyll content and stem diameter of sunflower

Treatments	Plant height (cm)			Chlorophyll contents (SPAD value)			Stem diameter (cm)		
	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean
Control	172.91 d	206.44 c	189.67 C	40.42 b	39.21 cd	39.82 BC	1.75 c	1.51 e	1.63 C
Foliar B (1%)	172.19 d	221.75 a	196.97 A	42.42 a	40.01 bc	41.22 A	1.96 a	1.73 c	1.79 A
Foliar B (1.5%)	172.49 d	217.19 b	190.37 B	40.47 b	40.04 bc	40.26 C	1.85 b	1.45 f	1.70 B
Foliar B (2%)	163.55 e	206.31 c	189.40 C	38.96 d	39.96 bc	39.46 C	1.51 e	1.63 d	1.57 D
Mean	170.28B	212.92 A		40.57 A	39.81 B		1.76 A	1.58 B	
LSD at 5%	Hybrids (H): 0.38; B levels (B): 0.54; H × B: 0.76			Hybrids (H): 0.49; B levels (B): 0.70; H × B: 0.99			Hybrids (H): 0.01; B levels (B): 0.01; H × B: 0.02		

Table 2: Influence of foliage applied boron on different yield traits of sunflower

Treatments	Capitulum diameter (cm)			Number of achenes per capitulum			1000-achene weight (g)			Achene yield (kg pot^{-1})			Biological yield (kg pot^{-1})		
	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean
Control	18.68 c	8.05 f	13.36 C	1168.9 d	1101.7 e	1135.3 D	52.19 c	40.63 f	46.41 D	0.31 d	0.22 g	0.27 D	1.17 d	0.92 h	1.05 D
Foliar B (1%)	20.65 b	9.78 e	15.21 B	1324.3 a	1274.0 b	1272.2 A	63.75 a	56.31 b	56.56 A	0.37 a	0.32 c	0.33 A	1.27 a	1.21 c	1.22 A
Foliar B (1.5%)	22.40 a	9.65 e	16.02 A	1270.4 b	1157.9 d	1241.1 B	56.81 b	47.06 d	55.41 B	0.34 b	0.26 f	0.32 B	1.23 b	1.00 g	1.14 B
Foliar B (2%)	16.89 d	9.46 e	13.18 C	1111.6 e	1208.2 c	1159.9 C	45.88 e	51.69 c	48.78 C	0.29 e	0.29 e	0.29 C	1.04 f	1.15 e	1.09 C
Mean	19.65 A	19.24 B		1218.8 A	1185.5 B		54.66 A	48.92 B		0.33 A	0.27 B		1.17 A	1.07 B	
LSD at 5%	Hybrids (H): 0.18; B levels (B): 0.26; H × B: 0.37			Hybrids (H): 5.68; B levels (B): 8.03; H × B: 11.36			Hybrids (H): 0.52; B levels (B): 0.74; H × B: 1.04			Hybrids (H): 0.003; B levels (B): 0.004; H × B: 0.005			Hybrids (H): 0.008; B levels (B): 0.012; H × B: 0.017		

Table 3: Influence of foliar application of boron on oil, protein contents and different oil quality traits of sunflower

Treatments	Oil contents (%)			Protein contents (%)			Linoleic acid (%)			Oleic acid (%)			Palmitic acid (%)			Stearic acid (%)		
	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun-33	Mean	S-278	Hysun -33	Mean
Control	41.69 d	43.02 c	42.35 C	16.78	15.79	16.28 C	44.60 d	44.73 d	44.67 C	45.43	43.43	44.43 C	4.66	5.57	5.11 C	2.10 d	2.16 c	2.12 C
Foliar B (1%)	42.97 c	43.47 b	43.22 B	48.76	17.6	18.18 A	45.89 b	46.89 a	46.39 A	46.91	44.92	45.91 A	5.89	6.88	6.39 A	2.25 b	2.45 a	2.35 A
Foliar B (1.5%)	44.39 a	44.58 a	44.48 A	17.6	16.78	17.18 B	45.34 c	45.82 b	45.58 B	46.1	44.1	45.09 B	5.41	6.37	5.89 B	2.15 c	2.28 b	2.21 B
Foliar B (2%)	39.50 f	41.20 e	40.35 D	15.79	14.79	15.29 D	43.60 f	43.88 e	43.74 D	44.43	42.6	43.51 D	3.88	4.88	4.38 D	2.02 e	2.10 d	2.05 D
Mean	42.07 B	44.13 A		16.24 B	17.23 A		44.86 B	45.33 A		45.72 A	43.76B		4.96 B	5.92 A		2.12 B	2.24 A	
LSD at 5%	Hybrids (H): 0.15; B levels (B): 0.21; B × B: 0.30			Hybrids (H): 0.18; B levels (B): 0.26; C × B: NS			Hybrids (H): 0.09; B levels (B): 0.13; H × B: 0.19			Hybrids (H): 0.13; B levels (B): 0.18; H × B: NS			Hybrids (H): 0.12; B levels (B): 0.17; H × B: NS			Hybrids (H): 0.02; B levels (B): 0.04; H × B: 0.05		

elongation, rate of photosynthesis, transpiration and other biochemical reactions (Bilen *et al*., 2011). Moreover, decrease in plant height in absence or low dose of B was due to decrease in enzymatic reactions that control cell division and elongation, while to an excessive level resulted also result in imbalance of different enzyme resulting in reduction of plants height (Silva *et al*., 2011; Zahoor *et al.*, 2011). Foliar applications of 1% B significantly gained more stem diameter (Table 1) also reported by Silva *et al.* (2011). The stem diameter of sunflower was increased with B applied at flowering stage (O'Neill *et al.,* 2004). Boron plays important role in carbohydrate transport, sugar translocation and increased by borate-sugar complex formation, which is a strong evidence of thicker stems of sunflower by B (O'Neill *et al*., 2004). Boron deficiency affects the cell enlargement in growing tissues as B is involved in cell structure therefore reduces stem diameter of sunflower (Silva *et al*., 2011).

Different yield related traits of both sunflower hybrids were improved with foliar application of B in Yermosols (Table 2). Maximum capitulum diameter, number of achenes per capitulum, 1000-achene weight, achene yield and biological yield were improved with 1% and 1.5% B (Table 2). Zahoor *et al.* (2011) also reported that foliar application of B helps to increase in capitulum diameter. Appropriate B concentrations enhanced the metabolic process and translocation of photo assimilates from vegetative to reproductive parts, which improved the plant growth (Reddy *et al.*, 2003; Shekhawat and Shivay, 2008). Present results agree with Ghani *et al.* (2000) that sunflower with foliage application of B helped in increasing the number of achenes per capitulum. Appropriate dose of B had important role in translocation of photo assimilates from source to sink and it also improved pollen tube germination that ultimately increased the number of achenes per capitulum (Silva *et al.*, 2011). Likewise, B played important role in pollination and thus achenes filling rate, which contributed to improved weight of achenes (Oyinlola, 2007; Bilen *et al.,* 2011). Deficiency of B affected the inner tissues of the stem top, which may lead to achenes fall consequently lowering achene and biological yield (Gitte *et al.,* 2005). Results further confirm that B plays an important role in cell elongation, cell division and biomass accumulation (Reddy *et al.,* 2003). There is positive correlation between B and other micronutrients and enzymatic activity. Moreover, yield attributes increased at optimum B concentration ultimately improved the yield of sunflower (Shekhawat and Shivay, 2008). Boron is reported for its vital role in transport of carbohydrates, cellular differentiation, development of anther/pollen, pollen tube growth and germination which is the strong reason for improvement in performance of plants because of B application (Durbak *et al.,* 2014; Zhang *et al.,* 2017).

Foliar application of B @ 1 and 1.5% significantly improved oil and protein contents of sunflower in Yermosols (Table 3). Earlier it is reported that maximum achene oil content was produced when B applied at bud initiation stage of sunflower (Ahmad *et al.,* 2005). Moreover, Zahoor *et al.* (2011) found that direct proportionality exists in timing of B application and photosynthetic rate in crop plant. Increased in concentration of B resulted in increased achene oil contents in sunflower. Likewise, significant improvement in oil quality traits *viz*., stearic acid, plasmatic acid, oleic acid and linoleic acid was recorded with 1% B in both sunflower hybrids. An inverse relationship is found between oil and protein contents as if increase in protein contents was accompanied by decrease in oil content (Oyinlola, 2007). Genetic inheritance of the hybrids is also found a reason for increased acids percentage and inverse relationship between protein and oil (Bellaloui *et al.,* 2009b). Acids percentages were relatively stable compared than oil and protein contents (Bellaloui *et al.,* 2009b). Limited information is available regarding the effect of B on seed composition. Moreover, seed protein and acids were influenced by different B concentration advocates an indirect role of B in seed composition (Bellaloui *et al.,* 2009a). Our results suggested that foliar application of B can altered the seed composition through increasing protein and fatty acids percentage and decreasing the oil contents. The increasing trend in fatty acids by foliar application of B might be due to the effect of B on the activity of the enzymes responsible for the accumulation and conversion of unsaturated fatty acids (linoleic, oleic, palmitic and stearic acids) (Bellaloui *et al.,* 2009a). Moreover, B was applied by using water and might be the combined effects of both B and water during the application may have transiently impact on photosynthesis and photo assimilate (Bellaloui *et al.,* 2009a).

Conclusion

Exogenous application of B to foliage of sunflower before flowering stage improved sunflower growth and production. In calcareous soils, due to high soil pH in arid and semiarid areas like of present experiment, sunflower production can be improved with foliar application of B. Although applying B on foliage of sunflower is simple, however, B concentration of 1% B should be used for better results.

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