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RESEARCH ARTICLE

Foliar application of Zinc and Boron improved the productivity and net returns of maize grown under rainfed conditions of Pothwar plateau

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Abstract

Under rainfed conditions, farmers rarely use micro-nutrients for crop production, due to which soils become deficient especially in zinc (Zn) and boron (B). Secondly, farmers apply nutrients through soil application but scarcity/less availability of moisture make the nutrients unavailable for crop plants. Under such circumstances, foliar application of Zn and B may play a key role for better crop growth and yield. Therefore this field study was conducted to investigate the role of Zn and B application alone and in combination through seed, soil and foliar application methods on growth, yield and net returns of maize grown under rainfed conditions. Results showed that combined application of Zn and B on foliage improved relative water contents, SPAD chlorophyll values, leaf area index (LAI), crop growth rate (CGR), and grain yield due to substantial expansion in entire yield related traits. Combined foliar application of Zn and B harvested 12% and 45% more yield compared with seed priming and control treatments, respectively. The foliar application of Zn and B in combination counteracted the low rainfall effect by producing higher relative water contents that helped in improving SPAD-chlorophyll values, LAI and CGR. Higher net returns and benefit: cost ratio was also obtained by foliar application of Zn and B in combination. In conclusion, combined foliar application of B and Zn improved maize yield due to significant expansion in allometric and yield related traits and thus improved net returns of maize grown under rainfed conditions of Pothwar plateu in Pakistan.

Keywords: Boron, Foliar application, Grain yield, Maize, Proline contents, Zinc

1. Introduction

Maize (*Zea mays* L.) is considered as leading cereals in the world as far as its production per unit area is concerned (FAO, 2010). Among cereal crops of Pakistan, it ranks third after wheat and rice with annual production of 4.94 million tons and average yield of 4.32 tons per hectares from an area of 11.42 million hectares (Govt. of Pakistan, 2015). In Pakistan, its average yield is very low as compared to developed countries especially in rainfed region compared to irrigated areas (Govt. of Pakistan, 2009), due to low soil fertility and less availability of moisture at later crop growth stages. In addition to macronutrients like nitrogen (N), phosphorus (P), and potassium (K), most of the cereals mainly maize suffer micronutrients dearth, zinc (Zn) and boron (B) in particular (Rashid and Ryan, 2004). Maize, being C_4 crop, is responsive to nutrients at all growth stages; and with adequate supply, it gives higher production (Song and Dia, 2000).

Crops grown in arid or semi-arid regions are mostly exposed to low soil fertility and exhibit multiple nutrient deficiencies due to low organic matter and alkaline calcareous nature that limit the crop production (Rafique *et al.*, 2006). The rainfed soils of Pakistan are deficient in Zn and B as compared to irrigated areas. The prime reason of this deficiency is the unavailability of irrigation water to apply the nutrients to crop plants under field conditions in rainfed regions. Secondly, most of the Pakistani farmers do not apply micronutrient especially Zn and B (Kanwal *et al.*, 2010) that lead to their deficiency in soil and causes yield reduction.

Zinc being essential nutrient plays a significant role in stomatal regulation and reducing the tensions of less water by creating ionic balance in plants system (Baybordi, 2006) and is involved in various physiological processes such as synthesis of protein and carbohydrates (Yadavi *et al.*, 2014). Similarly, B application improves growth, and enhances stress tolerance in plants and improves grain production (Hussain *et al.*, 2012). Both Zn and B play an important role in the basic plant functions like photosynthesis, protein and chlorophyll synthesis (Cakmak, 2008). These nutrients (Zn and B) are also involved in root growth, synthesis of proteins and carbohydrates, increase flower setting (Moeinian *et al.*, 2011) and reduce kernel abortion especially (Wahid *et al.*, 2011).

The nutrient deficiency can be corrected by applying micronutrient containing fertilizers. The nutrients can be applied to crop plants in a variety of ways like seed treatment, soil application and foliar spray. Every method has its advantages and disadvantages (Rehim *et al.*, 2012), depending upon the soil and climatic conditions of the area. Soil application of Zn and B is highly helpful in improving the maize productivity (Kanwal *et al.*, 2010). However, according to economic point of view, seed treatment and foliar application are better options because these are economical than soil application. Seed priming with different B solutions reduces time to 50% germination and improves the final germination percentage in rice (Farooq *et al.*, 2011). Foliar application of micronutrients is 6 to 20 times more useful than the soil application and improves the nutrition (Arif *et al.*, 2006). Foliar application of Zn reduces the micronutrient deficiencies and it is an efficient method because nutrients are easily absorbed through leaves and is best option to compensate micronutrient deficiencies in shorter period of time under rainfed regions (Nasiri *et al.*, 2010). Foliar application of B at earlier, middle and later growth stages along with recommended dose of NPK resulted in higher maize food and fodder yield (Soomro *et al.*, 2011). Similarly, in B and Zn deficient soils, their combined soil application significantly increased the plant height, root length, leaf area index,

shoot and root dry weight and chlorophyll content (Panhwar *et al*., 2011).

Though the role of micronutrients, like Zn and B, application in improving maize performance is well documented; however very little is known about the effect of combined application of B and Zn through different methods on maize performance grown under rainfed conditions. Therefore, this field study was designed to evaluate the role of Zn and B application alone and in combination with different methods in improving productivity and net returns of maize grown under rainfed conditions of Pothwar plateau.

2. Materials and Methods

2.1. Experimental site

This field experiment was conducted at University Research Farm Chakwal Road, PMAS-Arid Agriculture University Rawalpindi, Pakistan (32.56°N, 72.52°E and 513 m above sea level) during kharif season on sandy clay loam soil. The chemical properties of the 0-30 cm soil were as follows; pH 7.15, EC 0.7 ds m^{-1}, organic matter 0.42%, available phosphorus (P) 4.25 ppm, available potassium (K) 80 ppm, B 0.9 ppm and Zn 1.93 ppm. The climate of the region is semi-arid, and the climatic data for the whole crop season are presented in Figure 1.

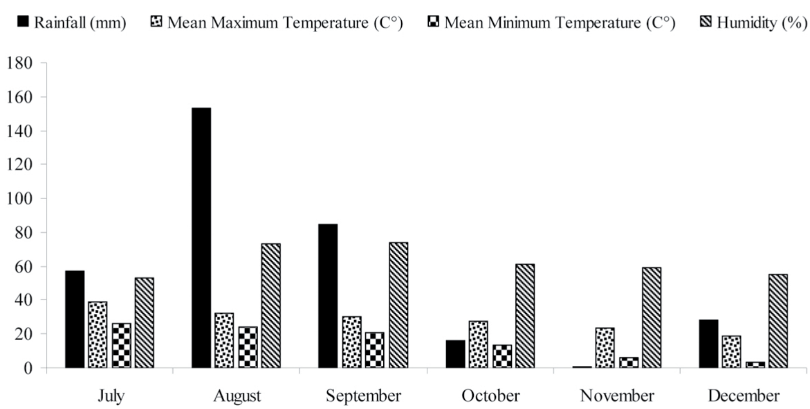

Figure 1. Climatic data for whole crop season

2.2. Experimental details

Seeds of maize variety Agaiti-2002 (recommended for rainfed cultivation) were obtained from National Agricultural Research Center, Islamabad, Pakistan and used as experimental material. B and Zn were applied alone and in combination by using three application methods viz. seed priming, soil application and foliar application. For seed priming, seeds were soaked in aerated solution of 1% zinc sulphate and 0.01% B for 24 h. The ratio of seed weight to solution volume was 1:5 (g/ mL). After priming, seeds were rinsed thoroughly, dried with forced air near to their original weight under shade and stored at 5 °C until sowing. In soil application, Zn and B were applied to the soil at the time of sowing at the rate of 2 and 15 kg ha^{-1}, respectively while control plots received nothing. For foliar application, Zn and B were applied as a foliar spray of 1% zinc sulphate and 0.01% B, when crop reached at the 5-leaf stage (V5) and silking

stage (R1). In case of control, seeds were soaked in water during seed priming and plants were sprayed with water regarding foliar application of nutrients. Granular zinc sulphate (33%) for Zn and Indiplex B (17%) a product of "United Distributors Pakistan Limited" having B (17%) in the form of fully water soluble formulation were applied according to the treatments. The experiment was laid out according to randomized complete block design with split plot arrangement by keeping nutrient application in main plots and application methods in sub plots. The experiment was replicated four times having a net plot size of 6 m × 4.5 m.

2.3. Crop husbandry

Seedbed was prepared with the help of tractor mounted cultivator followed by planking four days after occurrence of rainfall when the field reached to workable moisture conditions. The crop was sown on August 13, 2012 on well prepared seedbed with single row hand drill at a seeding rate of 25 kg ha^{-1} and a seedling depth of 2 cm keeping row to row distance of 75 cm. For maintaining an appropriate plant to plant distance of 20 cm, thinning was made at 4-leaf stage. Based on soil testing, all the treatments received 150 kg ha^{-1} N and 100 kg ha^{-1} P_2O_5 as a basal dose by using urea and di-ammonium phosphate (DAP) respectively. Both the fertilizers were applied at the sowing time, because crop was not applied supplemental irrigation and fully grown under rainfed conditions. Weeds were controlled by manual hoeing at 4-leaf stage. Furadan 3G (Carbofuran) was applied at 4-leaf stage to control the attack of shoot borer. Crop was harvested manually at physiological maturity, sundried for 10 days and then shelled using mechanical sheller.

2.4. Measurements

Crop allometry

Above ground biomass and leaf area index (LAI) were determined from five consecutive plants having an area of 0.75 m^2, cut at ground level from the central rows of each experimental unit. The sample were collected at 25 days interval starting from 40 days after sowing (DAS) i.e. at V8 (8^{th} leaf stage) and terminated at 115 DAS i.e. at R6 (physiological maturity). Total leaves from all plants were separated from stem for measurement of leaf area, measured using leaf area meter (CI-202 Area Meter, CID, INC, USA). On the basis of leaf area, LAI was then calculated as a ratio of leaf area to the land area. Then, the entire plant biomass was oven-dried at 70 °C to a constant weight for 48 h which was then used to determine crop growth rate (CGR) following Hunt (1978).

SPAD chlorophyll and relative water contents

Ten plants were randomly selected from each experimental unit at R1 (silking) stage and SPAD chlorophyll value was measured non-destructively with the portable SPAD-502 Chlorophyll Meter (Minolta Co., Ltd.) from the flag leaf of each plant, and then averaged. During measurements with the SPAD-502, the sensor head was shaded with the operator's own body as recommended by the manufacturer to avoid direct sunlight from reaching the instrument.

To determine leaf relative water contents (RWC), three plants from each experimental unit were randomly selected and their youngest leaves were harvested and then weighed to measure fresh weight (FW). Then, the leaves were immersed in deionized water in beakers for 24 h and fully turgid weight (TW)

was measured. Then, the leaves were oven dried at 70 °C until constant weight and dry weight (DW) of leaves was measured. Leaf RWC (%) were calculated using the below given formula:

RWC = (FW —DW/TW —DW) X 100

Yield and related traits

At physiological maturity each experimental unit was harvested manually, sun dried for 8 days and tied into small bundles. When bundles were fully dried, these were weighed to record biological yield and then converted into t ha^{-1}. After recording biological yield, the cobs and stalk were separated. Ten cobs were randomly selected from each experimental unit to measure cob length (cm). Cobs were then shelled with the help of mechanical sheller and weighed to record grain yield per plot, which then converted into t ha^{-1}. 1000-grains were counted from each shelled plot and weighed to determine 1000-grain weight. Harvest index (HI) was estimated as a ratio between grain and biological yield and expressed in percentage (%).

2.5. Statistical analysis

Data collected using standard procedures were statistically analyzed using Statistix 8.1 software using tukey test. Analysis of variance technique and tukey test at 5% probability level was used to compare the differences among treatment's means (Steel *et al*., 1997). Moreover, Microsoft Excel Program was used for the graphical presentation of data using standard error (± S.E.).

2.6. Economic analysis

An economic analysis was carried out to assess the economic feasibility of different nutrient treatments and application methods used. Total expenses for growing maize were included primary tillage operations, land rent, seedbed preparation, seed, sowing, fertilizers, nutrient application, weeding, harvesting and shelling of crop. Gross income was estimated according to current market price for the maize grain in the country. Moreover, net income was worked out by deducting the total expenses from gross income while benefit-cost ratio (BCR) was calculated as a ratio of gross income to total expenses by using the methodology as described in CIMMYT (1988).

3. Results

Different nutrient treatments, application methods and their interaction significantly affected the allometric traits such as LAI and CGR in maize crop. Foliar application of both Zn and B in mixture produced higher LAI compared with other nutrient treatments and application methods while reduced LAI was recorded in control plots where neither of the nutrients (Zn, B) was applied (Figure 2). Similarly, maximum CGR was observed at 90 DAS, after which it started to decline with higher value under soil applied B and Zn mixture. Maize grown without micronutrient application produced less CGR; however, improvement in CGR was observed with application of B and Zn with higher value under soil application, which was at par with foliarly applied Zn and B mixture (Figure 3).

Different nutrients treatments, methods of application and their interaction significantly affected leaf relative water contents (RWC) and SPAD chlorophyll (Table 1).

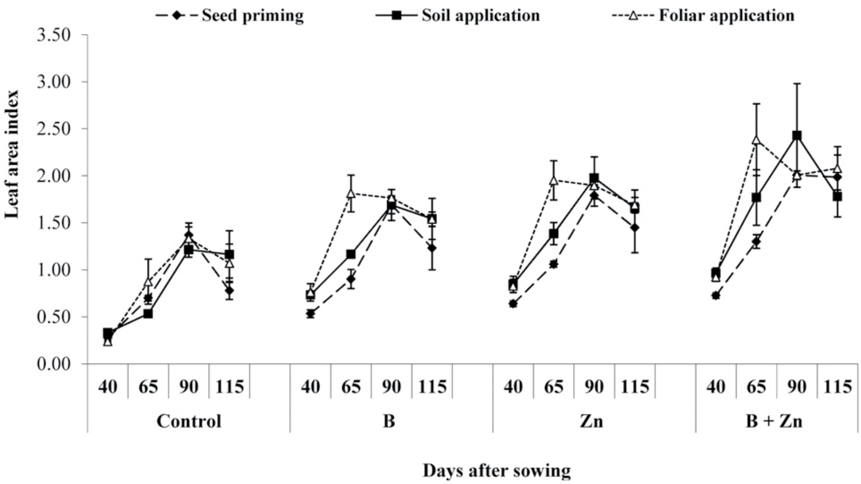

Figure 2. Leaf area index as affected by nutrients treatments and application methods ± S.E.

Application of both Zn and B in combination improved RWC in maize. The foliar application of Zn and B in combination recorded higher leaf RWC while lower RWC contents were recorded in control plots (Table 1). Similarly, higher SPAD chlorophyll value was observed in maize grown by the application of both Zn and B in mixture with minimum SPAD chlorophyll grown in control treatment. However, foliar application of nutrients improved SPAD chlorophyll compared with soil application and seed priming with minimum value observed in seed priming (Table 1). Different nutrients and their methods of application had significant effect on cob length and number of grains per cob (Table 2). Among application methods, foliar application and nutrient treatments, combined application of Zn and B improved cob length and number of grains per cob compared with other treatments (Table 2). Regarding interaction among application methods and treatments application, combined foliar application of Zn and B improved cob length and number of grains per cob followed by Zn alone; however, maize produced smaller cobs with lesser number of grains per cob in control treatments (Table 2).

Nutrient treatments, application methods and their interaction significantly affected 1000-grain weight, grain and biological yield (Table 3, 4). Application of Zn and B mixture improved 1000-grain weight followed by sole applied Zn and B compared with control (Table 3). Similarly, maize grown through foliar application of nutrients produced healthy seed and resulted in higher 1000- grain weight compared with seed priming and soil application (Table 3). However, foliar application of Zn and B mixture improved 1000-grain weight followed by sole application of Zn and B through soil and foliage; while, non-availability of nutrients caused reduction in 1000-grain weight (Table 3). Similarly, plants fertilized with Zn, B mixture produced more grain yield than other nutrient treatments and produced 45% more yield than control (Table 3). Similarly, foliar application produced about 9% higher yield than seed priming. However, plants grown through foliar application of Zn, B mixture produced 54% higher yield compared with all other nutrients treatments and application methods (Table 3). Maize grown with Zn and B mixture produced 39% higher yield than controlled treatments, while foliar application produced 6% higher biological yield compared with seed priming (Table 4).

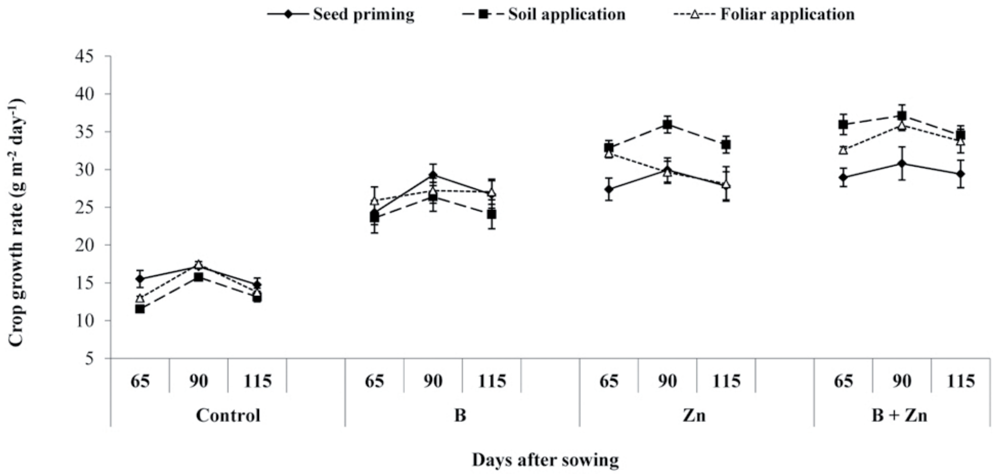

Figure 3. Crop growth rate (g m^{-2} day^{-1}) as affected by nutrients treatments and application methods ± S.E.

It is indicated that foliar application of Zn and B mixture produced a higher biological yield compared with other treatments (Table 4). However, nutrient treatments and application methods had non-significant on harvest index of maize (Table 4). Economic analysis of the experiment indicated that application of B and Zn alone and in combination using all tested methods of application improved the net income and benefit: cost ratio (BCR) against control plots (Table 5). However, foliar application followed by soil application of B and Zn in combination observed the maximum gross income, net income and BCR of maize grown under rainfed conditions (Table 5).

Table 1. Effect of nutrient treatments and application methods on relative water contents and SPAD chlorophyll in maize

Methods (M)	Relative water contents (%)					SPAD chlorophyll				
	Nutrient treatments (T)									
	DS	B	Zn	B+Zn	Mean	DS	B	Zn	B+Zn	Mean
SP	29.77 ± 0.29 h	32.5 ± 0.26 g	34.19 ± 0.26 ef	35.03 ± 0.13 de	32.87 ± 0.53 c	29.78 ± 0.79 h	32.5 ± 0.20 g	34.19 ± 0.18 ef	35.03 ± 0.22 de	32.88 ± 0.55 c
SA	33.19 ± 0.19 fg	35.93 ± 0.16 d	37.73 ± 0.17 bc	38.87 ± 0.09 a	36.43 ± 0.56 b	33.19 ± 0.31 fg	35.98 ± 0.36 cd	37.19 ± 0.31 bc	39.04 ± 0.31 a	36.35 ± 0.57 b
FA	35.0 ± 0.14 de	37.16 ± 0.19 c	38.3 ± 0.22 a b	38.93 ± 0.09 a	37.35 ± 0.39 a	35.01 ± 0.44 de	37.17± 0.29 bc	38.3 ± 0.27 ab	38.75 ± 0.18 a	37.31 ± 0.40 a
Means	32.65 ± 0.66 d	35.20 ± 0.60 c	36.74 ± 0.56 b	37.61 ± 0.55 a		32.66 ± 0.71 d	35.22 ± 0.62 c	36.56 ± 0.54 b	37.61 ± 0.56 a	
LSD (0.05)	T = 0.69, M = 0.24, T×M = 1.09					T = 0.74, M = 0.49, T×M = 1.43				

Means not sharing the same letter do not differ significantly at $p \leq 0.05$ ± S.E.

DS = dry seeding, B = boron application, Zn = zinc application, B+Zn = zinc and boron application, SP = seed priming, SA = soil application, FA = foliar application

Table 2. Effect of nutrient treatments and application methods on cob length and grains per cob in maize

Methods (M)	Cob length (cm)					Number of grains per cob				
	Nutrient treatments (T)									
	DS	B	Zn	B+Zn	Mean	DS	B	Zn	B+Zn	Mean
SP	12.58 ± 0.23 c	13.82 ± 0.36 bc	14.05 ± 0.38 bc	14.17 ± 0.40 bc	13.66 ± 0.23 b	271.25 ± 6.25 h	286.25 ± 3.15 g	282.75 ± 5.79 gh	306.75 ± 6.5 de	286.75 ± 4.14 c
SA	13.13 ± 0.24 c	13.17 ± 0.25 c	15.72± 0.64 ab	15.72 ± 1.17 ab	14.44 ± 0.45 a	279.25 ± 5.68 gh	299.50 ± 0.50 ef	303.75 ± 3.09 de	330.00 ± 6.77 b	303.12 ± 5.11 b
FA	13.85 ± 0.25 bc	14.32 ± 0.32 bc	13.90± 0.34 bc	17.27 ± 1.04 a	14.84 ± 0.45 a	288.25 ± 4.25 fg	313.75 ± 5.54 cd	323.75 ± 4.73 bc	350.50 ± 11.38 a	319.06 ± 6.57 a
Means	13.18 ± 0.20 c	13.77 ± 0.22 bc	14.56 ± 0.35 b	15.72 ± 0.62 a		279.58 ± 3.54 c	299.83 ± 3.90 b	303.42 ± 5.61 b	329.08 ± 6.99 a	
LSD (0.05)	T = 1.09, M = 0.76, T×M = 2.19					T = 10.85, M = 5.14, T×M = 10.28				

Means not sharing the same letter do not differ significantly at $p \leq 0.05$ ± S.E.

DS = dry seeding, B = boron application, Zn = zinc application, B+Zn = zinc and boron application, SP = seed priming, SA = soil application, FA = foliar application

Table 3. Effect of nutrient treatments and application methods on 1000-grain weight and grain yield in maize

Methods (M)	1000-grain weight (g)					Grain yield (kg ha^{-1})				
	Nutrient treatments (T)									
	DS	B	Zn	B+Zn	Mean	DS	B	Zn	B+Zn	Mean
SP	169.70 ± 1.25 d	173.30 ± 2.02 cd	176.73 ± 8.58 cd	186.10 ± 8.4b c	176.46 ± 3.16 c	1545.7 ± 47.14 f	1748.5 ± 59.41 def	1941.3 ± 39.12 cd	2131.4 ± 50.87 abc	1841.7 ± 60.51 b
SA	170.20 ± 4.89 cd	176.38 ± 3.54 cd	199.00 ± 4.85 ab	204.35± 8.96 a	187.48 ± 4.58 b	1496.0 ± 44.88 f	1770.7 ± 62.17 def	2078.7 ± 45.31 bc	2260.3 ± 39.33 ab	1901.4 ± 78.53 b
FA	180.81 ± 4.67 cd	199.80 ± 3.73 ab	206.35 ± 5.93 a	209.00 ± 6.81 a	198.99 ± 3.74 a	1619.9 ± 46.3 ef	1892.4 ± 47.14 cde	2214.4 ± 59.5 ab	2382.2 ± 66.64 a	2027.2 ± 79.82 a
Means	173.57 ± 2.58 c	183.16 ± 3.94 bc	194.02 ± 5.14 ab	199.82 ± 5.18 a		1553.9 ± 28.55 d	1803.9 ± 35.18 c	2078.1± 42.16 b	2258.0 ± 41.63 a	
LSD (0.05)	T = 12.347, M =6.3232, T×M = 12.646					T = 136.94, M = 90.271, T×M = 260.55				

Means not sharing the same letter do not differ significantly at $p \leq 0.05$ ± S.E.

DS = dry seed sowing, B = boron application, Zn = zinc application, B+Zn = zinc and boron application, SP = seed priming, SA = soil application, FA = foliar application, T = treatments, M = methods

Table 4. Effect of nutrient treatments and application methods on biological yield and harvest index in maize

Methods (M)	Biological yield (kg ha^{-1})					Harvest index (%)				
	Nutrient treatments (T)									
	DS	B	Zn	B+Zn	Mean	DS	B	Zn	B+Zn	Mean
SP	3772.2 ± 48.27 g	4044.5 ± 29.02 ef	4571.3 ± 46.97 d	5049.5 ± 57.87 bc	4359.4 ± 128.54 c	41.040 ± 1.74	43.220 ± 1.31	42.463 ± 0.67	42.197 ± 0.6	42.230 ± 0.56
SA	3654.3 ± 54.95 g	4211.7 ± 48.12 e	4871.0 ± 30.91 c	5228.9 ± 47.17 ab	4491.5 ± 157.72 b	40.988 ± 1.54	42.023 ± 1.2	42.683 ± 1.03	43.237 ± 0.87	42.232 ± 0.57
FA	3844.5 ± 59.88 fg	4312.6 ± 62.23 de	5006.6 ± 66.31 bc	5419.9 ± 51.52 a	4645.9 ± 159.48 a	42.133 ± 0.99	43.930 ± 1.53	44.207 ± 0.7	43.953 ± 1.15	43.556 ± 0.55
Means	3757.0 ± 37.03 d	4189.6 ± 41.83 c	4816.3 ± 60.78 b	5232.8 ± 53.18 a		41.387 ± 0.78	43.058 ± 0.75	43.118 ± 0.49	43.129 ± 0.52	
LSD (0.05)	T = 85.298, M = 102.79, T×M = 296.70					NS				

Means not sharing the same letter do not differ significantly at $p \leq 0.05$ ± S.E.

DS = dry seed sowing, B = boron application, Zn = zinc application, B+Zn = zinc and boron application, SP = seed priming, SA = soil application, FA = foliar application, T = treatments, M = methods

Table 5. Economic analysis for the effect of different nutrients treatments and application methods on maize performance under rainfed conditions

Treatments	Total Expenditure (US $ ha^{-1})	Gross Income (US $ ha^{-1})	Net Income (US $ ha^{-1})	Benefit-Cost Ratio
T_1M_1	279.09	351.30	72.21	1.26
T_1M_2	279.09	340.01	60.91	1.22
T_1M_3	279.09	368.15	89.06	1.32
T_2M_1	280.23	397.39	117.16	1.42
T_2M_2	297.27	402.44	105.17	1.35
T_2M_3	280.91	430.08	149.17	1.53
T_3M_1	296.36	441.20	144.84	1.49
T_3M_2	315.45	472.43	156.97	1.50
T_3M_3	306.36	503.26	196.90	1.64
T_4M_1	291.14	484.41	193.27	1.66
T_4M_2	301.82	513.69	211.88	1.70
T_4M_3	293.64	541.42	247.78	1.84

T_1 = Control, T_2 = B application T_3 = Zn application, T_4 = B + Zn application, M_1 = Seed priming, M_2 = Soil application, M_3 = Foliar spray

4. Discussion

Findings of this study indicated that foliar application of Zn and B improved dry matter and grain yield due to improvement in allometric traits, chlorophyll and relative water contents, and increase in yield components (Figure 2-3, Table 1-4). Maize, being C_4 crop, is responsive to water and nutrients with high nutrient requirement at all growth stages; and with their adequate supply, it gives higher yield. But, the deficiency of nutrients especially Zn and B retards maize growth, hence reduces crop yield (Aref, 2011). Application Zn and B increased the photosynthesis and chlorophyll production that ultimately increases the dry weight and CGR leading to increased yield (Tariq *et al*., 2014).

Plant leaves act as a source for capturing light and assimilate production. In the current study, plants treated with foliar application of Zn and B mixture produced more LAI which might be due to increase in indole acetic acid hormone through B fertilization (Zhou *et al*., 2016). Moreover the substantial improvement in leaf RWC recorded 75 days after sowing (even under dry conditions; Figure 1) due to combined application of Zn and B might lead to higher LAI (Figure 2); as more leaf RWC are linked with leaf elongation due to higher turgidity. Leaf RWC is one of the indictors for yield improvement under low water conditions. Increased RWC under Zn and B mixture might be due to the fact that Zn is involved in stomatal regulation (Baybordi, 2006; Marschner, 2012).

This might be due to leaf membrane stability (Sayed, 1998) by B application, as foliar appli¬cation of micro-nutrients increases resistance in plants against abi¬otic stresses (Tariq *et al*., 2004). It might also be due to increase in length and width of leaves, because Zn is involved in cell division (Zhu *et al.*, 2015) which increases chlorophyll production (Samreen *et al.*, 2013). Leaves plays a significant role and act as assimilatory organs therefore, reduction in LAI under controlled treatment and seed priming might be responsible for declined CGR and the reverse the case under foliar application of Zn and B mixture. Secondly, less chlorophyll in control treatment might be a possible reason for reduction in CGR. Higher CGR under foliar application of Zn and B mixture might be due to higher chlorophyll and LAI which leads to more biomass production. Increased CGR might be due to activation of different physiological processes like stomatal regulation, chlorophyll formation, enzyme activation and biochemical processes due to foliar application of micronutrients which resulted in increased dry matter production (Cakmak, 2008: Khan *et al.*, 2010; Marschner, 2012). Foliar applied Zn and B increased the photosynthesis and chlorophyll production that ultimately increases the dry weight and CGR (Tariq *et al*., 2014). Moreover, the deficiency of these micronutrients cause discoloration of the foliage and necrosis of upper leaves (Monreal *et al*., 2015). Grain yield is the combined effect of different yield related traits. Increase in grain yield under foliar applied Zn and B mixture might be attributed to notable expansion in entire yield related traits (Table 1-3). Similarly, it might be due to higher translocation of carbohydrates to grains (Rajaie and Ziaeyan, 2009), which ultimately resulted in higher grain yield under foliar application of micronutrients. Increase in cob length by the foliar applied Zn and B mixture might be due to higher CGR (Figure 3). Increase in 1000-grain weight through foliar application of Zn and B mixture might be attributed higher CGR (Figure 2). It is the fact that B application enhanced the pollen tube germination, grain setting which is involved in metabolism, increased root growth, synthesis of proteins carbohydrates (Moeinian *et al*., 2011) which improved the grain yield due by the application of B and other micronutrients (Tabrizi *et al.*, 2009). Several researchers have also reported the higher 1000-grain weight in maize by the foliar application of micronutrients (Tabrizi *et al*., 2009). Increase in biological yield might be to due increased LAI, CGR, chlorophyll contents and grain yield. It might be due to activation of different physiological processes like stomatal regulation, chlorophyll formation, enzyme activation and biochemical processes through application of micronutrients (Cakmak, 2008; Khan *et al*., 2010) which resulted in high dry matter production.

Farmers adopt any technology by considering its economic feasibility in terms of cost and profit involved for growing any crop (Khan *et al*., 2012). Economic analysis of the current study showed that foliar application of both B and Zn found superior over other nutrient treatments and application methods to achieve maximum net income and BCR (Table 5) due to increased maize yield, which is main concern of the farmers.

5. Conclusion

Results of this field study disclosed that application of Zn and B had improved leaf chlorophyll and relative water contents, which in turn improved crop allometry, yield components and productivity of maize. Moreover, the foliar application of Zn and B in combination performed better and improved the net returns of maize grown under rainfed conditions of Pothwar plateau in Pakistan.

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