Original Article | Open Access

Yar, 2021. 23(1&2): 36-43. J. Environ. Agric. Sci. (ISSN: 2313-8629)

Effect of Different Methods of Boron Application on Growth and Yield Attributes of Maize (*Zea mays* L.)

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Received September 10, 2020
Accepted February 25, 2020
Published Online June 28, 2021

Abstract: Nutrients availability in soils of rain-fed areas of Pothwar is one of the critical issues, which limit plant growth and yield. Deficiency of micronutrients is influenced by different agroclimatic conditions. Maize (*Zea mays* L.) being less adapted to poor soil conditions, therefore producing lower crop yields. This study was conducted in the University Research Farm Koont in 2016. Experimentation had been performed in a randomized complete block design (RCBD) two factorial. Seeds of maize were sown on 5th March 2016. The treatments were as: T_1= Control (no treatment was applied), T_2= Foliar application of boron, T_3= band placement of boron in the soil, T_4= Broadcasting. Different parameters were studied during the whole experiment; ear node diameter, Flag Leaf Area, Days to 50% Silking, Plant Height, Cob Height, Number of Tassel Branches, Number of kernel Rows Ear^{-1},100-grain weight, seed yield. This experiment ultimately helped to find the productive potential of maize under different methods of boron application in rain-fed areas.

Keywords: Biofortification, fertilizer, hidden hunger, micronutrients, seed coating, seed priming,

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Cite this article as Yar, A. 2021. **Effect of different methods of boron application on growth and yield attributes of maize (*Zea mays l.*)**. Journal of Environmental & Agricultural Sciences. 23(1&2): 36-43.

1. Introduction

Maize (*Zea mays* L.) belongs to the family Poaceae and is an annual crop. It is well adapted to different climates, as it is a tropical crop and hence its maturity varies from 70-210 days. Among the cereals, corn is ranked third after wheat and rice. As compared to advanced countries, maize grain productivity (3427 kg ha^{-1}) in Pakistan is very low (Gerpacio and Pingali, 2007). Maize is utilized in the cooking oil industry, paper production, corn starch, textile, maize syrup, flakes, bread production, and in many other food factories.

Maize contributed 0.5 percent to the national GDP in 2016 (Government of Pakistan, 2016). Pakistan's average maize production is very low because of insufficient nutrients supplements, improper planting density, presence of weeds, outbreak of insects and low yielding cultivars (Tahir et al., 2008). In crop nutrition, macro and micronutrients play a crucial role and have importance in achieving a higher yield. Boron (B) is a vital micronutrient and important in vascular plants (Marschner, 1995; Vatansever et al., 2017). Although a lot work has been done yet Boron importance for plants has been not fully described (Mengel et al., 2001).

Among the sixteen essential nutrient elements, B is also necessary for plant production (Tariq and Mott, 2006; Mach, 2014; Kihara et al., 2017). Boron is essential for many biophysical processes in plants i.e. water relations, formation of cell wall, cation-anion accumulation and metabolisms of nitrogen, phosphorous, carbohydrates and fats in crops (Oyinlola, 2007). Scarcity of B within crops stopped the growth of bud. Transportation of glucose, development of pollens and development of grains along with nodules establishment is exaggerated due to deficiency of B. Moreover, crop yield is decreased because of lack of B availability (Sillanpae, 1982).

Journal of Environmental & Agricultural Sciences (JEAS). Volume 23, Issue 1&2

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To remove the scarcities of nutrients, foliar technique has been considered as an essential procedure because it is absorbed easily through leaves and resulted in economical productivity (Parveen and Rehman, 2000). The average concentration of B in the soils is ranged from 20-200 ppm of dry weight, that mostly inaccessible for the crop (Mengel and Kirkby, 2001). Amount of available B differs among soils. Our maximum land contains below 10 ppm of B and most areas have B deficiency (Woods, 1994).

Tariq and Moth, (2006) compared the foliar effect as compare to land B application at various phases of crop in an experiment on cultivar Akbar on a research farm, during summer. Consequences showed 0.5% B foliar spray as boric acid resulted in thicker stem girth (5.21), taller plants (195.05 cm), less dry matter plant^{-1} (3), the maximum amount of green leaf plant^{-1} (8) at early, mid and late whorl stages.

Soil applied B at rate of 2 kg ha^{-1} had shown ineffectiveness on development by corn in comparison with application of B in liquid form. This proved during various developmental phases in combination to suggested NPK fertilizer amounts and 0.5% B foliar application is considered best for improving corn fodder produce in the prevailing environment. Nadim et al. (2012) observed the increase in 1000 grain weight in the wheat plant while soil and foliar spray of B for 2 kg ha^{-1} as well as improved grain per spike (54.25) while comparing it with side dressing and soil application.

John and Lester, (2011) stated that under normal and water stress conditions, foliar application of B (1%) enhanced the quality of grain and oil quality, increased yield attribute and all physiological parameters of maize. Application of B enhances oil contents, crude protein contents, and contents of starch in grains (Bukhsh et al., 2009). Hamzeh and Florin, (2014) reported that the foliar technique is a promising method to apply fertilizers through agricultural techniques due to which these minerals enable quick intake of the minerals through accumulating in stomatal openings that move into compartments.

By the foliar-applied B nutrient singly or else along the remaining microelements have the progressive outcome at the growing, productivity and yield factors for the wheat plant. By adjusting the fertilizer applications and in combination with the foliar technology developed the fertilization proficiency which reduced the topsoil contamination. Single or shared foliar-applied technique for B during various development phases with other micronutrients exhibited effectiveness with the effective use of B through wheat, so increasing the seed setting with increased revenue, number of seeds, spikelet amount and thousand seed heaviness.

Foliar application of B improved the wheat seed in water-stressed conditions (Moeinian et al., 2011). Moreover, proline contents in the seed were found to be provoked by foliar spray of B along with water applications. Tahir et al. (2008) compared performances of different maize hybrids in an experiment. Planting density, plant length, cobs quantity, number of seed per ear, cob-1seed amount, highest 100-seed mass then ultimately the maximum yield had been recorded by the corn variety.

The present study was conducted to report the effectiveness of the foliar application of boron on yield and other parameters of maize cultivars under rain-fed conditions of the Pothwar region of Pakistan.

2. Materials and Methods

2.1. Study setting

Maize research had been sown during 2016 at University Research Farm Koont, P.M.A.S Arid Agriculture University, Rawalpindi, Pakistan. Experimentation had been performed in Randomized complete block design (RCBD) two factorial along with three replications, comprising the net plot size of 16 m^2 (4m × 4m) after deep plowing and field was cultivated two times, each followed by planking. Seeds of maize were sown on 5th March 2016. Maize hybrids WWRI-1221, P-16 (NP3C) and C-18 1217 were used. Fertilizer was applied boric acid 4.5g mix with 0.5 kg soil for side dressing on both sides respectively, in broadcast 8.85g boric acid mix with 1kg soil, 5.85g boric acid was mixed with 5L water and 2.5g of detergent was applied 2-3 times.

One treatment was kept as the control for comparison. Manual weed control was practiced to keep the field weed-free. The treatments were as: T_1= Control (no treatment was applied), T_2= Foliar application of B, T_3= Soil placement of B, T_4=Broadcasting of B. Different parameters were studied during the whole experiment; ear node diameter, flag leaf area, days to 50% silking, plant height, cob height, number of tassel branches, number of kernel rows ear^{-1},100 grain weight and seed yield kgha^{-1}.

3. Results

3.1. Ear node diameter

Various fertility treatments had a significant effect on the ear node diameter of all maize varieties WWRI-1221, P-16 (NP3) and C-18 1217. Maximum field ear node diameter (3.7289 cm) was recorded from plots treated with foliar spray of B (5.85g of boric acid mixed with 5L water and 2.5g surf) followed by controlled treatment (3.4311 cm). The lowest ear node diameter was observed in plots with broadcast (8.5g of boric acid mixed with 1000g of soil) and side dressing (4.5g boric acid mixed with 25g of soil on both sides of ridges) application of B fertilizer (3.0267 and 2.9533 cm) respectively which did not produce statistically significant difference in ear node diameter (Table 1).

Moreover, there interaction revealed the variety WWRI-1221 more responsive to B foliar application with ear node diameter of 4.1 cm as compared to P-16 (NP3) and C-18 1217. Sharma et al., (2005) indicated similar results from his experiment and proved that the diameter of ear node improved by foliar application of B.

3.2. Flag leaf area

Flag leaf area represents the growth rate of crop and photosynthetic efficiency of the plant. The flag leaf area was expressively increased by foliar application method. Foliar application method (5.85g of boric acid mixed with 5L water and 2.5g surf) observed the largest value of flag leaf area (3.0756 cm) followed by controlled (no application method of B) treatment valued 2.7333 cm.

The smallest value for flag leaf area was observed in side dressing (4.5g boric acid mixed with 25g of soil on both sides of ridges) (2.3133 cm) but the broadcast method (8.5g of boric acid mixed with 1000g of soil) was also significantly not different (2.4111 cm) from side-dressing method of B application (4.5g boric acid mixed with 25g of soil on both sides of ridges). The interactions showed that variety P-16 (NP3) reported the highest flag leaf area (2.94 cm) countered by WWRI-1221 and C-18 1217 with low values and non-significant to each other. In cotton crop by application of B at both 80 and 105 DAS stages 2 percent foliar spray improved flag leaf area (Pettigrew, 1999; Kubar et al., 2013) (Table 1).

3.3. Days to 50 percent silking

Table 2 showed pronounced results among treatments and different varieties of maize regarding time taken in 50% silk emergence. The largest days for 50% silking (70.889days) was recorded in broadcast (8.5g of boric acid mixed with 1000g of soil) followed by side-dressing application of B (4.5g boric acid mixed with 25g of soil on both sides of ridges) and control (no application method of B) respectively but they were not statistically different from each other.

The smallest number of days to 50% silking (64.444 days) was taken by foliar spray of B (5.85g of boric acid mixed with 5L water and 2.5g surf) on variety WWRI-1221 which was at par statistically with the varieties P-16 (NP3) and C-18 1217. All foliar treatments of B showed a reduced number of days for 50% silk maturity and pollen detaching as related to all other treatments. The initial silk emergence quickens the lifespan of tassel that improved seed produce in maize for the given area

Table 1. Genotypic variations in ear node diameter and flag leaf area in response to different methods of boron application

	Ear Node Diameter				Flag Leaf Area			
	WWRI-1221	**P-16 (NP3)**	**C-18 1217**	Mean	**WWRI-1221**	**P-16 (NP3)**	**C-18 1217**	Mean
Control	4.50 a	2.38 h	3.41 ef	**3.43 b**	2.57def	3.10abc	2.73 cd	**2.73 B**
Foliar Spray	4.30 ab	2.75 g	4.14bc	**3.73 a**	3.27 ab	3.59a	2.37 def	**3.07 A**
Side Dressing	3.90 cd	1.97 i	2.99 g	**2.59 c**	2.03 f	2.74 bcd	2.17 ef	**2.31 C**
Broadcast	3.70 de	2.03 i	3.35 f	**3.03c**	2.57 de	2.33 def	2.33 def	**2.41 C**
Mean	**4.10 a**	**2.28 c**	**3.47 b**		**2.56 B**	**2.94 A**	**2.40 B**	

Means sharing dissimilar letter(s) in a row or in a column are statistically significant ($p \leq 0.05$, $n = 3 \pm SE$).

Table 2. Genotypic variations in days to 50% silking and plant height in response to different methods of boron application

	Days to 50% silking				Plant Height (cm)			
	WWRI-1221	**P-16 (NP3)**	**C-18 1217**		**WWRI-1221**	**P-16 (NP3)**	**C-18 1217**	
Control	60.0 f	74.67 ab	72.0 bc	**68.89 A**	234.0 cde	226.9 de	223.8 ef	**228.2 B**
Foliar Spray	52.33 g	72.0 bc	69.0 cd	**64.44 B**	261.0 a	248.5 abc	251.5 ab	**253.7A**
Side Dressing	67.0 de	72.67 abc	72.33 abc	**70.67 A**	222.0 ef	187.9 h	203.9 g	**204.6C**
Broadcast	64.3 ef	76.67 a	71.67 bc	**70.89 A**	232.7de	211.6 fg	238.9 bcd	**227.7 B**
	60.92 C	**74A**	**71.25B**		**237.4 A**	**218.73 C**	**229.5 B**	

Means sharing dissimilar letter(s) in a row or in a column are statistically significant ($p \leq 0.05$, n = 3 ± SE).

As a result of quick silk emergence, period of grain filling had been prolonged which results in good nutrients concentration. B fertilizer application improved the days to 50% silking (Samad et al., 1984).

3.4. Plant height

During the study period of crop the plant height helps in determining the growth attained by the crop. Plant height of maize crop increased with enhanced uptake of B through foliar spray (5.85g of boric acid mixed with 5L water and 2.5g surf) as shown in (Table 2). The greatest value of plant height (253.69 cm) was recorded in foliar spray of B in variety WWRI-1221 (237.42 cm) followed by controlled, broadcast (8.5g of boric acid mixed with 1000g of soil) and side dressing (4.5g boric acid mixed with 25g of soil on both sides of ridges), 228.22, 227.71 and 204.6 respectively.

The lowest plant height was examined in P-16 (NP3) (218.73 cm). Intermediate plant height (229.52 cm) was observed in variety C-18 1217 at recommended doses of B with split doses. The good grain yield of maize crop was displayed by position of ear in the center of plant height as compared to lower or upper position of central axis.

Foliar application increase the length of nodes in maize crop and also showed fixed number of nodes, because of which plant height had enhanced, that increased the photosynthetic concentration which results in improved grain yields. All foliar treatments of B exhibited the position of ear in the center of maize crop.

As a result of better enzyme activity, maximum value of plant height was achieved at higher uptake of B due to which translocation of photosynthesis was improved from leaf to grain (Akhtar et al., 2003) as a result of which, maize plant achieved maximum height. In wheat crop B and urea (both) foliar application at rate of 2% on 65, 90, 115 DAS improved length (Amal et al., 2011). Length of maize was improved by the application of B at 15 kg ha^{-1} (Akram et al., 2010).

3.5. Number of tassel branches

Number of tassel branches is a significant parameter indicating reproductive potential of plants. Number of tassel branches showed non-significant results for both foliar spray (5.85g of boric acid mixed with 5L water and 2.5g surf) and control (17.278, 17.156) respectively. The smallest value of number of tassel branches was recorded in side-dressing method (4.5g boric acid mixed with 25g of soil on both sides of ridges) (13.378). The variety WWRI-1221 showed maximum number of tassel branches (17.475) which is statistically at par with P-16 (NP3) (15.358) and C-18 1217 (14.783) and non-significant to each other (Table 3). Kubar et al., (2013) and William (2008) stated the similar results in maize as exhibited by this study.

Table 3. Genotypic variations in tassel branching and kernel rows per ear in response to different methods of boron application

	Days to 50% silking				Plant Height (cm)			
	WWRI-1221	**P-16 (NP3)**	**C-181217**		**WWRI-1221**	**P-16 (NP3)**	**C-18 1217**	
Control	18.0 ab	18.13 ab	15.3 cd	**17.16 A**	13.5 ab	12.27cd	12.33 cd	**12.71A**
Foliar Spray	20.03 a	16.47 bc	15.3 cd	**17.28 A**	13.0 bc	14.13 a	11.87 d	**12.88A**
Side Dressing	13.33 d	13.0 d	13.8 d	**13.38 C**	11.9d	11.87 d	12.0 d	**13.0 A**
Broadcast	18.53 ab	13.83 d	14.7 cd	**15.68 B**	12.6cd	13.83 a	12.2cd	**11.92 B**
	12D	**12.2CD**	**12.1B**		**12.758A**	**13.02 A**	**12.1B**	

Means sharing dissimilar letter(s) in a row or in a column are statistically significant ($p \leq 0.05$, n = 3 ± SE).

Table 4. Genotypic variations in 100-grain weight and seed yield in response to different methods of boron application

	100-grain weight (g)				Seed yield (kg ha^{-1})			
	WWRI-1221	**P-16 (NP3)**	**C-18 1217**		**WWRI-1221**	**P-16 (NP3)**	**C-18 1217**	
Control	31.57 e	41.87bc	23.77 g	**31.21 B**	3450 B	3470 BC	3046.7 C	**3322.2 C**
Foliar Spray	23.77 g	38.47d	23.63 g	**42A**	4419.3 A	4572 A	4059.7 AB	**4350.3 A**
Side Dressing	44.27 ab	44.43 a	37.3 d	**32.4B**	4440 A	3993.7 AB	3320.3 BC	**3918 AB**
Broadcast	26.6 f	41.34 c	25.7f g	**28.623C**	4099 AB	3431.7 BC	3151.7 C	**3918 BC**
	41.49 A	**31.56B**	**27.63 C**		**4102.1A**	**3761AB**	**3500.4 B**	

Means sharing dissimilar letter(s) in a row or in a column are statistically significant ($p \leq 0.05$, n = 3 $\pm$ SE).

3.6. Number of kernel rows per ear

In maize crop by the application of B the number of kernel rows per ear was significantly affected. Side dressing application of B (4.5g boric acid mixed with 25g of soil on both sides of ridges) achieved maximum number of rows per ear (13), in contrast with foliar and control. Minimum number of rows per ear (11.922) had been documented in the broadcast (8.5g of boric acid mixed with 1000g of soil). Variety P-16 (NP3) yielded the maximum number of rows of grain (13.025) as compared to WWRI-1221 and C-18 1217mathematically but is not different statistically. There is a strong positive relationship between grain yield and number of kernel rows per ear. Quantity for grain rows per ear was improved by the application of B (Akhtar et al., 1999; Grzebisz et al., 2003; Akram et al., 2010) (Table 3)

3.7. Grain weight

100 – Seed weight has an association with features which effect yields greatly. Different fertility treatments among plots had major consequence as 100 – grain weight of corn (Table 4). Fol`iar spray (5.85g of boric acid mixed with 5L water and 2.5g surf) resulted better for 100 – grain weight (42 g), as compare to side dressing (4.5g boric acid mixed with 25g of soil on both sides of ridges) and control (32.4, 31.213 g), respectively. Minimum 100 – grain weight was observed in broadcast treatment (28.623 g).

While 100 – grain weight comparison of all three varieties the WWRI-1221 variety expressed the highest value (41.486 g), which is statistically at par from P-16 (NP3) and C-18 1217.With the increase in uptake level of B the grain yield increases. This result of present study was supported by the findings of (Rasool et al.,1987; Sharif and Hussain, 1993; Sadiq and Jan, 2001; Abdi et al., 2002; Akhtar et al., 2003; Khan et al., 2006; Akram et al., 2010; Hammad et al., 2011) who stated that 100-grain weight is increased by the increase in uptake level of B because enzyme activation increases with increase in the availability of B as a result of which there is an increase in partitioning of nutrients from leaf to grain and due to which seed weight increased.

3.8. Seed yield

Seed yield is product of numerous physiological as well as morphological procedures which occur throughout development of plant. Examined figures of seed yield of corn in contrast to fertility changes showed major changes between treatments. Foliar application contributed highest harvest (4350.3 kg ha^{-1}) as compare with control (3322.2 kg ha^{-1}) then all other treatments. Produce of variety WWRI-1221 (4102.1kg ha^{-1}) was statistically at par with P-16 (NP3) and C-18 1217.

There is proved from the results that area, where boron was supplied with foliar application, showed highest yield as compared with other fertilizer applied plots. Similar results were presented in earlier reports indicating improved crop yield with the boron application. This can be attributed to better enzymatic movement in plants resulted in improved transportation of photosynthates from source (leaves) to sink (seed) (Malik et al., 1984; Stauffer et al., 1995; Chaudhary and Malik, 2000; Akhtar et al., 2003; Hussein, 2005; Ali et al., 2007; Mesbah, 2009; Hasina et al., 2011; John and Lester, 2011).

In wheat crop the grain yield is significantly increased by foliar application of boron (Tisdale et al., 1985; Xu et al., 1999; Aown et al., 2012). Under drought and normal conditions foliar application of boron (at rate of 1%) at the reproductive stage improved the grain yield (Farooqi et al., 2012), and when applied at 6% yield of rice crop could be produced comparable to the yield produced as a result of the soil application (Ali et al., 2007). As compare to Mg and Zn foliar application, B foliar application at the rate of 2% increased the yield of mung bean plants (Stauffer et al., 1995; Thalooth et al., 2006). During the early heading stage and water deficit the foliar application of 2% and 3% in wheat crop improved the grain yield (Aissa and Mhiri, 2002). Ali et al., 2005 proved that in rice crop higher yield was obtained by foliar application of micronutrients.

4. Conclusion

Foliar application showed better results for plant height, number of grains per cob, number of tassel branches, leaf area, and grains yield kgha^{-1} rest of other B application methods. It is concluded that foliar application of B performed better results. As B is very essential for many important physiological plant functions in maize i.e. B plays an important role in sustaining stability among sugar and starch. So, the results of foliar spray expressed higher the results for ear node diameter (3.73 cm), flag leaf area (3.08 cm), plant height (253.69 cm), number of tassel branches (17.28), number of kernel row per ear (12.88), 100-grain weight (42 g) and seed yield kg ha^{-1} (4350.3). Conclusively it is recommended that foliar application technique exhibited good outcomes as compared with remaining methods. It is economical as well as practicable as results in maximum net profit through minimum input rate. Therefore B foliar spray has fulfilled B requirements of corn at crucial phases among different fertilizer application methods of boron fertilizer on maize cultivars under rained conditions.

Acknowledgement:

Author acknowledges the assistance of staff at PMAS Arid Agriculture University to conduct this study. There was no financial assistance attained to conduct this study.

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