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Impact of boron nutrition on phenology, growth and yield of Maize (*Zea mays* L.)

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Abstract

Maize (*Zea mays* L.) is one of the most essential cereal crops in Pakistan after wheat and rice. it is used as staple food all over the world because having excellent nutritive value as food for human being as well as feed for live-stock. An experiment was carried out at College of Agriculture, University of Sargodha to assess the impact of boron nutrition on growth, phenology and yield of maize (*Zea mays* L.). The experiment was laid out in randomize complete block design with 3 replications. Five different boron levels (0, 3, 6, 9 and 12kg ha^{-1}) were applied on maize (YSM-112). The data regarding days taken to 50% emergence, days taken to 50% tasseling, days taken to maturity, leaf area index, total dry matter (TDM)kg ha^{-1}, plant height (cm), number of cobs per plant, cob diameter (cm), cob length (cm), number of grain rows per cob, number of grains per cob, 1000 grain weight (g), grain yield (kg ha^{-1}) and harvest index (%) was taken by using the standard procedures and analyzed statistically by using statistix 8.1. The results indicated that maximum value of leaf area index (5.68), total dry matter (TDM) (11097.76g ha^{-1}), plant height (187.68cm), number of cobs per plant (2.21), cob diameter (3.13cm), cob length (16.07cm), number of grain rows per cob (16.51), number of grains per cob (440.52), 1000 grain weight (282.73g), grain yield (4518.25kg ha^{-1}) and harvest index (32.68%) were observed when boron was applied @ 12kg ha^{-1}. Therefore, it is concluded that application of boron @ 12kg ha^{-1} is better to improve the maize production under agro climatic conditions of Sargodha.

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Introduction

Maize (*Zea mays* L.) is a versatile crop belonging to family poaceae which serve as both food and feed purpose (Ali *et al.*, 2020). It is cultivated under both irrigated and rain fed conditions of all the provinces of Pakistan especially Punjab and Khyber Pakhtunkhwa. Maize crop is commonly grown on temperate, tropics and warm sub-tropic region of the world. Maize is the world's third primary cereal crop after wheat and rice which grown mostly for food, feed and fodder. In Pakistan maize is the fourth largest grown crop after wheat, cotton and rice. In Pakistan country maize is grown in winter and summer season (Eleweanya *et al.*, 2005). It contributes 2.1 percent to the value auxiliary in agriculture and 0.4 percent to GDP. Corn grain is a supplemented food as associated to other food grains. The wet grinding of maize products is an assortment of products, by products and value accompaniments. It is mostly used for human consumption best feed for animal. Seeds comprise starch and oil content cultivating mostly in summer season in Pakistan (Amin *et al.*, 2007). Various factors which contributes towards low production of corn in Pakistan are nutritional in-balance, insufficient use of fertilizer, low soil organic matter contents, inadequate plant density, weeds problem, scarce water supply, selection of unsuitable varieties and insect pest attack (Asif *et al.*, 2020).

Boron is an essential plant micronutrient taken up via the roots mostly in the form of boric acid. It's important role in plant metabolism (Milka-Brdar-Jokanovi´c, 2020). It is a compulsory indispensable element for plant growth and reproduction. It is important for metabolism of carbohydrate and translocation (Siddiky *et al.,* 2007) and also plays a vital role in materialization of cell in plants, Integrity of plasma membrane and encouragement of fertilization for seed development (Oosterhuis *et al.*, 2001). It is essential micro nutrient responsible for enhancing the production of nectar in flowers, and thus to increase the attractions of insects for pollination. Furthermore, boron has played important role in the cell structure and also plays a vital role in materialization of cell in plants. Pollen tube growth, integrity of plasma membranes and encouragement fertilization for seed development (Oosterhuis *et al.*, 2001). Boron is necessary for regular growth and plant development. It initiates numerous plant processes: division of tissue cell, formation petal and bud of leaf, integrity of cell wall structure, metabolism of hydrocarbon and sugar and transportation of nutrients. (Ahmad *et al.,* 2010).

Essential micro-nutrients such as boron, zinc and iron are necessary for diverse natural functions of plants that favor plants quality and yield (Shoeib *et al.,* 2003). It also improves stability to drought regime and increase insect and disease resistance (Tariq *et al.*, 2007). The availability of boron for crop plant is less than 5-10% but in the soil boron present concentration usually range from 20 to 200 mg B kg^{-1} (Mengel *et al.,* 2001). However, extreme boron concentration discovered to be harmful to some species of plants (Chapman *et al.,* 1997). However, some species of plants are tolerant to excess concentration of boron (Chapman *et al.,* 1997). Deficiency of boron occurs due to inadequate application of boron, little mining of nutrients and small organic matter percentage due to calcareous soil of Pakistan (Alloway *et al.*, 2008). The absence of boron in soil negative effect on plants structure in many ways such as decrease evolution of pollen, reduce in number of young leaves, stoppage growth of terminal bud, transportation of sugar, nodules development and production of grain and seed (Oyinlola *et al.*, 2007). Therefore, keeping in mind the role of boron in improving crop production an experiment was designed to impact of boron nutrition on Growth, Phenology and Yield of Maize (*Zea mays* L.) under agro climatic condition of Sargodha.

Materials and methods

Site and soil

The experiment was carried out at College of Agriculture, University of Sargodha, Sargodha. The Physico-chemical analysis of soil was carried out before seed sowing and data regarding soil analysis is displayed in Table 1.

Table 1. Physico-chemical soil analysis of crop area.

Soil pH	O.M (%)	Total N (%)	Available P (mg kg^{1})	Available K (mg kg^{-1})	Texture
7.33	1.22	0.061	7.43	165.33	Sandy loam

Experimental design and treatment

The experiment was organized in randomized complete block design (RCBD) with three replications. The boron doses were (0, 3, 6, 9, 12kg ha^{-1}) were applied as basal application Boric acid (10.5 percent boron) was used as a source of boron.

Crop Husbandry

The seed bed was prepared by cultivating the field for 2-3 times with tractor-mounted cultivator each followed by planking. Maize hybrids were sown on ridges, maintaining ridge to ridge distance of 60cm and plant to plant distance 20cm. Nitrogen, Phosphorus and Potassium were applied at the rate of 120, 80 and 40kg ha^{-1} respectively, in all plots. Nitrogen, Phosphorus and Potassium were used in form of Urea, DAP and Potassium sulphate (K_2SO_4). The nitrogen was used in three splits, 1/3rd dose of nitrogen and all of the phosphorus and potash fertilizer were applied at sowing. Remaining 2/3rd of nitrogen was used in two splits, at first irrigation and flowering stage. All other agronomic practices such as hoeing, irrigation and plant protection measure were kept normal for the crop.

Observations

The data regarding days taken to 50% emergence, days taken to 50% tasseling, days taken to maturity, leaf area index, total dry matter (TDM)kg ha^{-1}, plant height (cm), number of cobs per plant, cob diameter (cm), cob length (cm), number of grain rows per cob, number of grains per cob, 1000 grain weight (g), grain yield (kg ha^{-1}) and harvest index (%) was taken by using the standard procedures. To obtain days taken to 50% emergence, crop it was visited daily and number of plants germinated was counted in each plot from a selected area until a uniform and constant plant count was achieved and mean days taken to emergence were worked out from sowing date. For days taken to 50% tasseling, 3 plants were tagged from every plot at random, and noted the date of tasseling. The average numbers of days taken to 50% tasseling were calculated from date of planting. The days taken to maturity was noted when black layer is founded at the base of each kernel. The tagged plants in each plot were subjected to this observation and average days to maturity were counted from date of sowing. The leaf area was measured with leaf area meter (CI-202. Portable Laser Leaf Area Meter) by taking 10 sample of leaf lamina from each plot, Leaf area index (LAI) was calculated as the ratio of leaf Area to land area.

$$\text{LAI} = \frac{\text{Leaf area}}{\text{land area}}$$

Total dry matter was estimated by adding grain and straw yield. To record the data of plant height at maturity 10 plants were nominated at random from each plot and individual plant height was recorded from the soil surface to the tip of the plant with the help of meter rod and average plant height was calculated. To record the data on number of cob per plant 10 plants were nominated at random from each plot and individual number of cobs plant was counted. To find out cob diameter, ten cobs was taken from each plot with the help of Vernier caliper and then average cob girth was calculated. To find out cob length, ten cobs was taken from each plot with the help of measuring tape and average was taken. It was measured in centimeters (cm). To record the number of grains per cob, number of grains were counted and average number of number of grain rows per cob was calculated. To record the number of grains per cob, grains of ten plants from each plot were threshed and grains were separated, counted and average number of grains cob^{-1} was calculated. A sample of 1000-grains was taken from each plot, and then it was oven-dried and weighed through an electric balance and average 1000-grain weight was calculated. Grain yield was recorded on sub-plot basis and then converted tokg ha^{-1}. The harvest index (%) is the ratio of grain yield to biological yield.

Statistical analysis

All the recorded data were examined statistically by using Fisher's Analysis of Variance Technique and HSD test at 5% probability level was used to compare means (Steel *et al.,* 1997).

Results and discussion

Phonological Parameters

Days to 50% emergence

Emergence is important phonological parameter which depend upon plant growth and development. Analysis of variance for days to emergence presented in table 2. Data indicated that application of boron fertilizer significantly influenced days to 50% emergence. The late emergence (13.53) was noted from the plot where no boron was applied and early 50% emergence (9.60) was noted in the plot where boron was applied @ 12kg ha^{-1}. These results are in line with the findings of Shabaz *et al.* (2015) who reported that application of fertilizer significantly influenced the time taken to 50% emergence.

Table 2. Impact of Boron levels on days taken to 50% emergence, days taken to 50% tasseling, days taken to maturity (days), leaf area index and total dry matterkg ha^{-1}.

Boron Levels	Days taken to 50% emergence	Days taken to 50% tasseling	Days taken to maturity (days)	Leaf area index	Total dry matterkg ha^{-1}
0kg ha^{-1}	13.53 a	77.70 a	120.70 a	3.37 e	9874.48 e
3kg ha^{-1}	12.58 b	76.69 b	119.69 b	3.76 d	10116.64 d
6kg ha^{-1}	11.48 c	75.78 c	118.68 c	4.84 c	10388.56 c
9kg ha^{-1}	10.43 d	74.27 d	117.67 d	4.53 b	10599.43 b
12kg ha^{-1}	9.60 e	73.65 e	116.66 e	5.68 a	11097.76 a
Tukey HSD	4.333	4.33	4.333	2.98	4.33

Means having different letters significantly from each other at $p \leq 0.05$

Days to 50% tasseling

The data recording days to 50% tasseling is presented in table (4.2). The data indicated that all the treatments significantly altered the days taken to 50% tasseling. Minimum time was taken (73.65) by the plants which received boron @ 12kg ha^{-1} while maximum time was taken to reach 50% tasseling (77.70) was observed when no boron was applied. Our results are confirmed by the results of Nasim *et al.* (2012) who observed that days taken to 50% tasseling was decreased by increasing boron levels.

Days to maturity

The data regarding impact of boron levels on maize is presented in table 2. Data indicated that application of boron significantly changed the days taken to maturity. Maximum days taken to maturity (120.70) was observed when boron was applied @ 0kg ha^{-1} while application of boron @ 12kg ha^{-1} taken lowest time (116.66) to reach maturity. Our results are confirmed by Khan *et al.* (2002) who reported that days to maturity decreased with micro-nutrient application.

Crop growth parameters

Leaf area index

The applications of different levels of boron significantly differed leaf area index (4.2). Maximum leaf area (5.68) was measured in plots where boron was applied @ 12kg ha^{-1} while minimum leaf area (3.37) was measured in the plot where boron was not applied. These results are in lined with the results of Ahmad *et al.* (2010) who reported that application of boron increased the leaf area index.

Total dry matter (kg ha^{-1})

The data regarding application of boron on maize is presented in table 4.2. The data indicated that application of treatments significantly affected the total dry matter. The maximum accumulation (11097.76kg ha^{-1}) of total dry matter was observed in the treatment where boron was applied @ 12kg ha^{-1} followed by 9kg ha^{-1} (10599.43kg ha^{-1}) whereas, lowest total dry matter (9874.48kg ha^{-1}) was observed from control treatment. These results are in line with khan *et al.* (2007) who reported that application of micronutrients significantly increased the total dry matter.

Yield Components

Plant Height (cm)

Data regarding plant height of maize affected due to boron application is presented in table 4.3. Statistical analysis of the data indicated that plant height was significantly ($P \leq 0.05$) affected by different boron levels. Maximum plants height (187.68cm) was noted when plots were fertilized with 12kg ha^{-1} boron and minimum plant height (175.57cm) was given by control treatment. These results are in according with Nozulaidi *et al.* (2016) who also observed an increase in maize plant height with boron application.

Number of cobs per plant

Data regarding number of cobs per plant of maize affected due to boron application is presented in table 4.3. Statistical analysis of the data indicated that number of cobs per plant was significantly (P ≤0.05) affected by different boron levels. The similar results were obtained by Shehbaz *et al.* (2015) who reported that number of cobs per plant increased with boron application.

Cob diameter (cm)

Data regarding number of cob diameter maize affected due to boron application is presented in table 4.3. Statistical analysis of the data indicated that cob diameter was significantly (P ≤0.05) affected by different boron levels. Maximum cob diameter (3.13cm) was recorded when boron was applied @ 12kg ha^{-1} while lowest value (2.18cm) was observed in control (0kg B ha^{-1}) treatment. The identical results were obtained by Tahir *et al.* (2012) who reported that cob diameter increasing with increased level of boron.

Cob length (cm)

The data regarding cob length of maize affected due to the application of boron is presented in table 3. Data revealed that all the treatments significantly influenced the con length. It is obvious from the data that highest cob length (16.07cm) was resulted by 12kg ha^{-1} application of boron (16.07) while the lowest cob length (13.25cm) was obtained in control treatment. Similar results were observed by Hameed *et al.* (2012) who stated that boron application at the rate of 6kg ha^{-1} in maize crop increased cob length.

Table 3. Impact of Boron levels on plant height (cm), number of cob per plant, cob diameter and cob length (cm).

Boron Levels	Plant height (cm)	Number of cob per plant	Cob diameter	Cob length (cm)
0kg ha^{-1}	175.57 e	1.21 e	2.18 e	13.25 e
3kg ha^{-1}	178.73 d	1.67 d	2.57 d	14.56 d
6kg ha^{-1}	181.65 c	1.85 c	2.62 c	14.69 c
9kg ha^{-1}	184.53 b	2.05 b	2.73 b	14.89 b
12kg ha^{-1}	187.68 a	2.21 a	3.13 a	16.07 a
Tukey HSD	2.98	4.33	4.33	4.33

Means having different letters significantly from each other at p≤0.05

Grain rows per cob

Data regarding number of grain rows per cob of maize affected due to boron application is presented in Fig 1. Statistical analysis of the data indicated that grain rows per cob was significantly (P ≤0.05) affected by different boron levels. Statistical comparison between various levels of boron regarding grain weight showed that, maximum grain rows per cob (16.51) were produced by boron @ 12kg ha^{-1} while lowest grain rows per cob (12.19) were observed in control treatment where no boron was applied. The quite similar result was also observed by Tahir *et al.* (2012) who reported that grain rows per cob influenced by boron application and increased rate of boron improved the grain rows per cob.

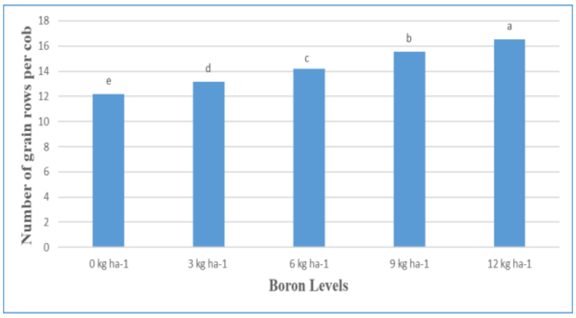

Fig. 1. Impact of boron levels on number of grain rows per cob of maize.

Number of grains per cob

The data regarding number of grains per cob of maize affected due to the application of boron is presented in fig 2. Data revealed that all the treatments significantly influenced the number of grains per cob. Maximum number of grains per cob (440.52) was obtained by the application of boron @ 12kg ha^{-1} while the minimum numbers of grains per cob (351.12) were observed in control treatment. The similar results were recorded by Hameed *et al.* (2012) who reported that application of boron significantly enhanced grain per cob of maize.

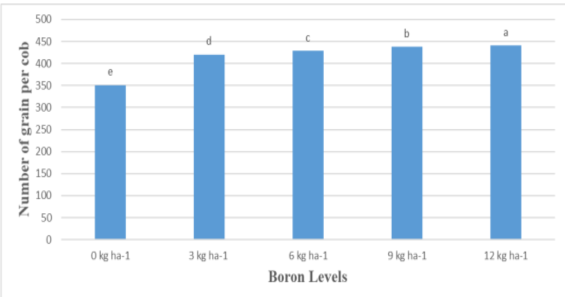

Fig. 2. Impact of boron levels on number of grain per cob of maize.

1000 Grain weight (g)

Statistical analysis of the data revealed that 1000 grain weight was significantly (P ≤0.05) affected by different boron levels (fig. 3). Weight of 1000 grain is an important yield component in maize which contributes significantly towards its final yield. The maximum value of 1000 grain weight (282.73g) was observed in the plot where boron was applied @ 12kg ha-1 whereas the minimum 1000 grain weight (265.67g) was recorded in control. These results were similar with finding of Hameed *et al.* (2012) who reported that increasing level of boron increased the grain weight of maize.

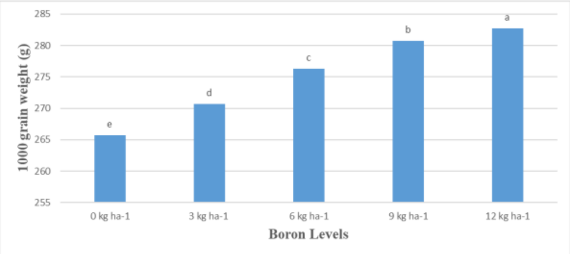

Fig. 3. Impact of boron levels on 1000 grain weight (g) of maize.

Grain yield (kg ha-1)

Statistical analysis of the data revealed that grain yield was significantly (P ≤0.05) affected by different boron levels (fig. 4). The maximum grain yield resulted by boron @ 12kg ha-1 while the minimum grain yield was received from treatment the control treatment. The similar results were obtained by Nasim *et al.* (2012) who reported positive response of maize to foliar application at the rate of 10 ppm.

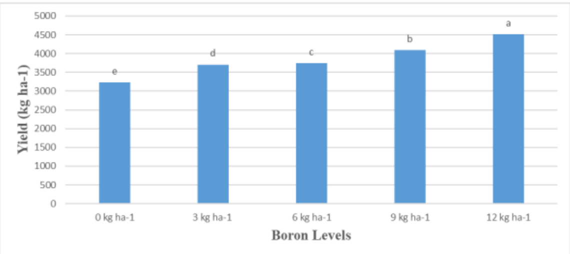

Fig. 4. Impact of boron levels on maize yield (kg ha-1).

Harvest index (%)

Harvest index is a ratio of grain yield to biological yield. Harvest index is most important parameter indicating photosynthetic efficiency of crop and transformation of photosynthates into economic yield. Harvest index was increased with increasing boron level (fig 5). The boron level of 12kg ha-1 produced significantly highest harvest index (32.68%) as compared to other levels of boron. However, the lowest harvest index was achieved (28.27%) from the plot where no boron was applied (control treatment). These results are confirmed by the findings of Hameed *et al.* (2012) who reported that increasing level of boron positively influenced the harvest index.

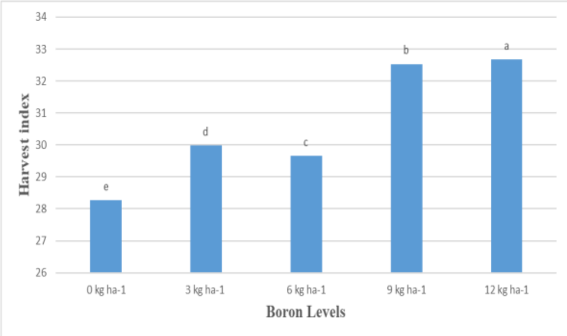

Fig. 5. Impact of boron levels on Harvest index of maize.

Conclusion

It is observed that application of boron @ 12kg ha-1 gave highest leaf area index, total dry matter (TDM) kg ha-1, plant height (cm), number of cobs per plant, cob diameter (cm), cob length (cm), number of grain rows per cob, number of grains per cob, 1000 grain weight (g), grain yield (kg ha-1) and harvest index (%). Therefore, it is concluded that application of boron @ 12kg ha-1 is best to get better maize production.

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