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Effect of boron application and plant growth regulator on growth and yield of maize (*Zea mays* L.)

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Abstract
The field experiment was conducted during Kharif 2021 at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.36%), available N (171.48 kg/ha), available P (15.2 kg/ha) and available K (232.5 kg/ha). The treatment consisted of three sources of boron (soil application of 1kg/ha, foliar application 25ppm and soil application 0.5kg/ha + foliar application 15ppm) and the three levels of plant growth regulator (GA1 50ppm, GA2 100ppm and GA3 150ppm) and one control plot respectively. The experiment was laid out in Randomized Block Design with Ten treatments each replicated thrice on the basis of one year experimentation. The treatments which are T1:Control, T2: Soil application Boron 1kg/ha + GA3 50ppm, T3: Soil application Boron 1kg/ha + GA3 100ppm, T4: Soil application Boron 1kg/ha + GA3 150ppm, T5: Foliar application Boron 25ppm + GA3 50ppm, T6: Foliar application Boron 25ppm + GA3 100ppm, T7: Foliar application Boron 25ppm + GA3 150ppm, T8: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm, T9: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm, T10: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm are used. The results showed that application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm was recorded significantly higher plant height (185.99 cm), Plant dry weight (187.82 g/plant), Crop growth rate (7.18 g/m2/day), Cobs/plant (1.34), Seeds/row (29.36), Row/cob (14.73), Seed yield (7.70 t/ha), Stover yield (12.28 t/ha), Test weight (215.73 g), Harvest index (38.55%), gross returns (Rs. 1,23,200/ha), net return (Rs. 82,416.31/ha) and benefit cost ratio (2.02) as compared to other treatments.

Keywords: Boron, foliar, GA3, soil, yield

Introduction

Maize (*Zea mays* L.) is a cereal crop and it is called as "queen of cereals" and "non-tillering plant". Maize is one of the three major world food crops, is recognized as the "golden food" because of its high grain yield and nutrition value, and plays a very important role in the daily calorie intake of humans. Maize is the third most important crop in India after rice and wheat. In the world, India's ranks 5th in acreage and 8th in production of maize (USDA 2018) [22], Maize or corn serves as a basic raw material to thousands of industrial products that may include oil, starch, alcoholic beverages, pharmaceutical, food sweeteners, cosmetic, gum, textile, package and paper industries. Corn is good for digestion due to its fiber content and corn may prevent diabetes and hypertension. The nutritional value of maize is high as it contains 72% starch, 10% protein, 8.5% fibre, 4.8% oil, 3.0% sugar and 1.7% ash (Hokmalipour, *et al.*, 2010) [9], The starch in maize can be hydrolysed and enzymatically treated to produce syrups, particularly high fructose corn syrup, and a sweetener; and also fermented and distilled to produce grain alcohol. Grain alcohol from maize is traditionally the source of Bourbon whiskey (Mohammadi *et al.*, 2012) [14], The major maize producing countries are USA, China, Brazil, Argentina, Mexico, South Africa, Yugoslavia and India**.** In India, Maize is emerging as third most important cereal crop after rice and wheat that occupies an area of 9.60 million ha with the production of 27.15 million tonnes, having average productivity of about 2.8 tonnes/ha Boron application improves growth, and enhances stress tolerance in plants and improves grain production (Hussain *et al.*, 2012) [10], World-wide Boron deficiency is more extensive then the any other plant micro nutrient deficiency (Gupta 1979) [7], Boron deficiency caused sterility in maize, in sufficient levels of available boron soil reduce crop yield, impair grain quality, and increase the susceptibility of crops to diseases. Boron is considered as an essential element for plant growth and development, sexual reproduction in plant is more sensitive to B deficiency, then vegetative growth (Ahmad *et al.*, 2009) [1], The main function of Boron relate to cell wall strength and development, cell division, fruit and seed development sugar transport and hormone development. Boron deficiency depresses commercial corn yield primarily through grain set failure. Boron deficiencies are usually apparent on the new leaves of maize since it is during the development of new tissue that nutrients are most required (Reid *et al.*, 2004) [17], Boron deficiency inhibits root elongation through limiting of cell enlargement and enlargement and cell division in the growth zone of root tips and that in severe boron deficiency cases, root growth is ceases due to the death of root tips, (Dell *et al.*, 1997) [5], Maize has been previously considered to have a relatively low boron (B) requirement compared with other cereals (Martens *et al.*, 1991) [13], Gibberellins induce flowering in long-day plants which require chilling. The heading was delayed by addition of gibberellic acid (GA) to the root zone in super-dwarf rice (Frantz *et al.*, 2004) [6], Gibberellins are probably one of the growth regulators that have a significant effect on flowering. Dwarfing depends upon gibberellin deficiency and dwarfing gene effects on gibberellin biosynthesis. So, by applying gibberellic acid on dwarf maize mutant, they showed normal growth after hormone treatment. In addition, long stems have more bioactive gibberellin than short stems (Naghashzadeha *et al.*, 2009) [15], Plant growth hormones so far have been emerged as “magic chemicals” that could increase agricultural production at an unprecedented rate and help in removing and circumventing many of the barriers imposed by genetics and environment. Spraying different concentration of gibberellic acid over the plans at 3-4 leaf growth stage increased seed yield and yield components in soybean (Azizi *et al.*, 2012) [4],

Materials and Methods

This experimental trial was carried out during *Kharif* 2021 at Crop Research Farm (CRF), Department of Agronomy, Sam Higginbottom University of Agriculture, Technology & Sciences (SHUATS), Prayagraj (U. P) located at 25˚39”42” North latitude, 81˚67”56” East longitude and 98 m altitude above the mean sea level. The experiment laid was out in Randomized Block Design consisting of Ten treatments which are T1:Control, T2: Soil application Boron 1kg/ha + GA3 50ppm, T3: Soil application Boron 1kg/ha + GA3 100ppm, T4: Soil application Boron 1kg/ha + GA3 150ppm, T5: Foliar application Boron 25ppm + GA3 50ppm, T6: Foliar application Boron 25ppm + GA3 100ppm, T7: Foliar application Boron 25ppm + GA3 150ppm, T8: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm, T9: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm, T10: Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm replicated thrice to determine the Effect of Boron Application and Plant Growth Regulators on Growth and Yield of Maize. The soil of the trail plot was sandy loam in texture nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.36%), available N (171.48 kg/ha), medium in available P and K (15.2 kg/ha and 232.5 kg/ha respectively). The nutrient sources used in the research plot were urea, DAP and MOP to fulfill the requirements of nitrogen, phosphorous and potassium. The recommended dose of 120 kg N, 60 kg P2O5, 40 kg K2O/ha. Between the period of germination to harvest several plant growth parameters were recorded at equal intervals and after harvest several yield parameters were recorded. In growth parameters plant height (cm), dry weight (g/plant), Crop growth rate (g/m2/day) and Relative growth rate (g/g/day) were recorded and yield parameters like cobs/plant, row/cob, seeds/row, test weight (g), seed yield (t/ha), stover yield (t/ha) and Harvest index (%) were recorded and statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design (Gomez, K. A. and Gomez, A. A. 1984).

Result and Discussion

Growth parameters of maize

Plant height (cm)

As shown in Table 1 significantly highest plant height (185.99 cm) was recorded in the treatment T10 with Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm over all the other treatments. However, the treatments with application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (185.61 cm) which were found to be at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm as compared to all the treatments. With the increase in levels of boron and change in methods of application of boron from soil application and foliar application, the plant height gradually increased, which might be attributable to greater photosynthetic activity and chlorophyll synthesis due to boron fertilization resulting into better vegetative growth. Gibberellic acid have a regulatory function are produce the shoot apex primary in the leaf primordial and root system stimulates stem growth dramatically and also stimulates cell division, cell elongation and enzyme secretion, which eventually increased the plant height. The improvement in plant height was due to interaction of both boron and GA3 application to Maize crop. Similar results were reported by Tahir *et al*. (2012) [20], and Keykha *et al*. (2014) [13],

Dry weight (g)

Treatment T10 with Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm was recorded with significantly maximum dry weight (187.82 g/plant) over all the treatments. However, the treatments with Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm (185.45 g/plant) and Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (186.13 g/plant) which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm. Dry weight was increased significantly with increasing levels of Boron. As boron generally influences cell division and nitrogen absorption from the soil might enhanced plant growth which reflects in terms of plant dry weight. These findings are in harmony with those obtained by Singh *et al*. (2015). GA3 promotes cell proliferation in plant developmental stages due to their own metabolism regulation and promotes the development of cells by increasing turgor pressure and it also activates different enzymes and has a positive effect on plant growth and dry matter accumulation. The results were found in accordance with Islam *et al*. (2014) [12],

Crop growth rate (g/m2/day)

Treatment T10 with Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm was recorded with significantly highest Crop growth rate (7.18 g/m2/day) at 80 DAS- At harvest over all the treatments. However, the treatments with Foliar application Boron 25ppm + GA3 150ppm (6.74 g/m2/day), Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm (7.24 g/m2/day) and Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (7.09 g/m2/day) which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm. The dry matter yield increase in the Boron suggests that it was one of the limiting nutrients in the soils. This indicates that, at this level, the soil boron was further improved with better boron nutrition leading to high dry matter production which in turn increases CGR. These results are in agreement with the findings of Siddiqui *et al.* (2009).

Relative Growth rate (g/g/day)

During 80 DAS-At harvest, there was no significant difference among the treatments. However, highest Relative growth rate (0.0063 g/g/day) was recorded with the treatment Control and Soil application Boron 1kg/ha + GA3 100ppm whereas, minimum Relative growth rate (0.0056 g/g/day) was recorded with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm

Effect on yield and yield attributes of Maize

Significantly Maximum Cobs/plant (1.34) was recorded with the treatment T10 of application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm over all the treatments. However, the treatments Foliar application Boron 25ppm + GA3 150ppm (1.27), Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm (1.29) and Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (1.31) which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm**.** The increase in number of cobs/plant due to the soil and foliar application of Boron and positive effect of boron may be due to key role in plant metabolism and in the synthesis of nucleic acid Tahir *et al*. (2012) [20], Significantly maximum Seeds/row (29.36) was recorded with the treatment T10 of application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm over all the treatments. However, the treatments Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (28.82) which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm. Application of boron to maize crop generally improves cob growth by synthesizing tryptophan and axon. The enhancement effect on seeds/pod and pods/plant attributed to the favorable influence of the Boron application to crops on nutrient metabolism, biological activity and growth parameters and hence, applied boron resulted in taller and higher enzyme activity which in turn encourage more seeds/row and cobs/plant. The application of GA3 along with boron helped in increase the number of seeds per row of cob. Similar findings have been reported earlier by Anjum *et al*. (2017) [2], and Thuc *et al*. (2021) [21], significantly highest Row/cob (14.73) was recorded with the treatment T10 of application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm over all the treatments. However, the treatments Foliar application Boron 25ppm + GA3 150ppm (13.85), Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm (14.12) and Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm (14.36) which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm. Increase in this attribute by foliar spray might be due to the involvement of the sprayed and soil application of boron in enzyme activation, membrane integrity, chlorophyll formation, Stomatal balance and starch utilization at early stages which enhanced accumulation of assimilate in the grains resulting in heavier grains and applications accelerated the plant growth along with cell division and contributed to the increase of dry matter per unit area and accordingly increased seed weight. These results are in agreement with the findings of Asif *et al.* (2013) [3], significantly highest Harvest index (38.55%) was recorded with the treatment T10 application of Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm over all the treatments. However, the treatments with (37.57%) in Foliar application Boron 25ppm + GA3 100ppm (38.02%) in Foliar application Boron 25ppm + GA3 150ppm, (38.44%) in Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm and (38.08%) in Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm which were found to be statistically at par with treatment T10 Soil application 0.5kg/ha + Foliar (15ppm) + GA3.

Table 1: Effect of Boron application and Plant growth regulators on growth parameters of Maize.

		Plant height(cm)	Dry weight(g/plant)	Crop growth rate(g/m2/day)	Relative growth rate(g/g/day)
1.	Control	180.87	171.25	5.33	0.0063
2.	Soil application Boron 1kg/ha + GA3 50ppm	181.66	174.57	5.68	0.0060
3.	Soil application Boron 1kg/ha + GA3 100ppm	182.04	175.71	5.74	0.0063
4.	Soil application Boron 1kg/ha + GA3 150ppm	182.90	177.54	5.89	0.0060
5.	Foliar application Boron 25ppm + GA3 50ppm	183.82	179.44	6.10	0.0060
6.	Foliar application Boron 25ppm + GA3 100ppm	183.75	181.19	6.43	0.0060
7.	Foliar application Boron 25ppm + GA3 150ppm	184.45	183.08	6.74	0.0060
8.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm	184.72	185.45	7.24	0.0060
9.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm	185.61	186.13	7.09	0.0060
10.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3 150ppm	185.99	187.82	7.18	0.0056
	S. EM (±)	0.35	0.83	0.21	0.00

Table 2: Effect of Boron application and Plant growth regulators on Yield attributes and Yield of Maize

	Treatments	Cobs /Plan	Seeds/ row	Row/cob	Seed Yield (t/ha)	Stover Yield t/ha)	Test weight (g)	Harvest Index (%)
1.	Control	1.08	24.13	11.11	4.64	8.88	201.69	34.33
2.	Soil application Boron 1kg/ha + GA3 50ppm	1.15	25.55	12.44	5.12	9.50	204.36	35.03
3.	Soil application Boron 1kg/ha + GA3 100ppm	1.17	25.87	12.74	5.47	9.84	205.25	35.70
4.	Soil application Boron 1kg/ha + GA3 150ppm	1.20	26.53	12.98	5.91	10.24	208.49	36.56
5.	Foliar application Boron 25ppm + GA3 50ppm	1.24	26.79	13.28	6.13	10.56	209.55	36.72
6.	Foliar application Boron 25ppm + GA3 100ppm	1.25	27.26	13.53	6.53	10.86	210.95	37.57

7.	Foliar application Boron 25ppm + GA3 150ppm	1.27	27.89	13.85	6.89	11.23	211.85	38.02
8.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3 50ppm	1.29	28.06	14.12	7.17	11.48	213.65	38.44
9.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3 100ppm	1.31	28.82	14.36	7.49	11.99	214.83	38.08
10.	Soil application 0.5kg/ha + Foliar (15ppm) + GA3150ppm	1.34	29.36	14.73	7.70	12.28	215.73	38.55
	S. EM (±)	0.03	0.30	0.30	0.09	0.10	0.55	0.42
	CD (P = 0.05)	0.08	0.89	0.88	0.27	0.31	1.64	1.24

Conclusion

Based on the findings of the investigation it may be concluded that the treatment with Boron 0.5kg/ha + Foliar (15ppm) + GA3 150ppm performed exceptionally in all growth, yield parameters and in obtaining seed yield of Maize. Hence, Boron 0.5kg/ha + Foliar (15ppm) + GA3 150ppm is beneficial under Uttar Pradesh Conditions

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