Effect of Foliar Application of Boron and Silicon on Growth and Yield of Maize (*Zea mays L.)*

Abstract:

The field experiment was conducted during *Zaid* season 2022 at experimental field of Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology& Sciences, Prayagraj and Uttar Pradesh, India. The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH7.3), low in organic carbon (0.48%), available nitrogen (230 kg/ha), available phosphorus (13.60 kg/ha) and available potassium (215.4 kg/ha).. Ten treatments, each replicated three times, were used in the one-year experiment, which was set up using a randomised block design. The results of the study showed that the treatment B3 (100 ppm) + Si3 (700 ppm) significantly increased plant height (193.66 cm), the number of leaves per plant (12.83), the dry weight of the plant (93.61 g/plant), and yield attributes such as the number of cobs per plant (3.4), the length of the cob (20.94 cm), the number of rows per cob (15.6), and the number of grains per cob (534.2). The yield parameters of Seed index (30.7), Grain yield (6.98 t/ha), and Straw yield (14.73 t/ha) were considerably greater with the same treatment B3 (100 ppm) + Si3 (700 ppm).

Keywords: *Maize, Boron, Silicon, growth, yield.*

Introduction:

Maize (*Zea mays* L.) is one of the most important and versatile crop belonging to family poaceae. It is the world's third primary cereal crop after wheat and rice grown mostly all over the world for the production of food, feed and fodder. Globally, maize is known as queen of cereals because of its highest genetic yield potential. Apart from this, maize is an important industrial raw material and provides large opportunity for value addition. It has attained a position of industrial crop globally as 83% of its production in the world is used in feed, starch and bio-fuel industries. Further, using maize directly or indirectly more than 3000 products are being made providing a wide opportunity for value addition

Maize is mostly grown in India during the rainy (kharif) and winter (rabi) seasons. Under the zaid season, maize can also be grown. In India, 80% of the acreage used for growing maize is used during the kharif season, 10% during the rabi season, and the remaining 20% during the zaid season. More than 70% of the area used for growing kharif maize is rainfed, and both biotic and abiotic stressors are frequently present. Approximately 47% of the maize grown in India is used as chicken feed. The remaining product is utilised for a variety of reasons, including 13% for food and livestock feed, 12% for industrial usage, 14% for the starch industry, 7% for processed foods, and 6% for export and other uses.

Boron (B) is a compulsory indispensable element for normal growth of higher plants and its availability in soil and irrigation water is an important determinant of agricultural production **(Saleem *et al*. 2011).** 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. B deficiency causes different effects on very diverse processes in vascular plants such as root elongation, indole acetic acid oxidase activity, sugar translocation, carbohydrate metabolism, nucleic acid synthesis, and pollen tube growth **(Goldbach and Wimmer, 2007; Saleem *et al*. 2011).** B has a critical role in growing tissues. Actually boron deficiency decreases or inhibits the growth of both vegetative and reproductive plant parts **(Dell and Hung, 1997).**

Silica is known as the second most abundant element in earth crust. Silicon concentrations in plants range from 0.1% (similar to Phosphorous and Sulfur) to more than 10% of whole plant dry matter **(Epstein, 1999).** Silicon was reported to reduce the hazardious effects of various abiotic and biotic stresses including salt stress, metal toxicity, drought stress, radiation damage, various pests and diseases caused by both fungi and bacteria, nutrients imbalance, high temperature and freezing **(Ma, 2004).** Silicon restored the hormonal balances to a level comparable with non-stressed plants and stimulated the production of hormones involved in stress adaptation (abscisic, salicylic, and jasmonic acids) **(Narges, 2018)**. Si promotes the growth of various higher plants **(Zhu *et al.* 2004).**

Materials and Methods:

In order to study the two micronutrients with foliar spray, Boron and Silicon were taken. The experiment was conducted at during *Zaid* 2022, at Crop Research Farm, Naini Agricultural Institute, SHUATS, Prayagraj. The experimental site of the study is geographically located at 25.28^{o}N latitude, 81.54^{o}E longitude and 98 m altitude above the mean sea level (MSL). The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and deep. Pre- sowing soil samples were taken from a depth of 15 cm with the help of an auger. The composite samples were used for the chemical and mechanical analysis. The treatments consist of foliar spray of two micronutrients Boron at (50, 75, 100ppm), Silicon (300, 500, 700ppm). The experiment was laid out in randomized block design with ten treatments each replicated thrice and control i.e., recommended N, P and K (120:60:40 kg/ha).

Results and Discussions:

Growth parameters

Table.1 Pertaining the details of effect of Boron and silicon on growth attributes of Maize.

Plant height (cm)

At harvest maximum plant height (193.66 cm) was observed with the treatment B_3 (100 ppm) + Si_3 (700 ppm) which was significantly superior over all the treatments except with the treatment B_2 (75 ppm) + Si_3 (700 ppm) with plant height (192.21 cm).

Application of boron and silicon might have favoured the overall growth of the plant. These micronutrients help the crop in a positive way to achieve higher growth attributes. Application of silicon might have increased the chlorophyll content and other factors that are directly proportionate to the growth of the plant. Poaceae family species like maize accumulate large amounts of Si and its application to these crops ensured better growth **(Mitani and Ma, 2005)**. Boron might have played important role in the cell structure and also in materialization of cell in plants which ultimately leads to better growth. Increasing concentrations of both boron and silicon significantly affected the growth and also plant height. Findings of present research are well in agreement with that **Gong *et al.* (2005).**

Number of leaves

At Harvest, maximum no. of leaves/plant (12.83) was recorded with application of B_3 (100 ppm) + Si_3 (700 ppm) which was significantly superior over all the treatments. B_2 (75 ppm) + Si_3 (700 ppm) treatment with number of leaves/plant (12.6) was found to be at par with the treatment B_3 (100 ppm) + Si_3 (700 ppm).

Micronutrients play an important role in the lifecycle of the plants. Especially, the elements like silicon and boron enhance the growth of the plants. Application of silicon to the maize might have increased the number of leaves per plant. Similar findings have been reported by **Qadir *et al*. (2013).**

Dry weight (g)

At harvest higher plant dry weight (93.61 g/plant) was recorded with the treatment B_3 (100 ppm) + Si_3 (700 ppm). However, the plant dry weight (92.45 g/plant) recorded with the treatment B_3 (100 ppm) + Si_2 (500 ppm) and was statistically at par with the treatment B_3 (100 ppm) + Si_3 (700 ppm).

Increase of plant dry weight in the initial stages of crop is gradual and later on from 40 DAS the plant dry weight showed significant increase. This is due to better source and sink capacity developed due to better dry matter production with the application of boron and silicon. Silicon especially, increases the photosynthetic efficiency and thus leads to the production of photosynthates reflected in better growth and ultimately in higher dry accumulation. The maximum plant dry weight might have been achieved by the maximum plant height, number of leaves/plant and stem girth and etc., These findings are in harmony with those obtained by **Marngar and Dawson (2017).**

Crop growth rate (g/m^2/day)

During the interval of 60 - at harvest there is no significant variation of crop growth rate in the genotypes due to the reduction in the growth of the plant. The crop growth rate trend is depicted in the Fig 1.

Relative growth rate(g/g/day)

During 60 - 80 DAS interval there was more reduction in relative growth rate when compared with the other two intervals. This is due to the crop maturity and no further vegetative growth. There was a declining trend recorded with all the treatments. Relative growth rate decreased steadily due to lower dry matter accumulation with the advancement of the crop growth stages. These results were in match up with those reported by **Akhtar *et al.* (2018).**

Yield attributes:

Table. 2 Pertaining the details of effect of Boron and silicon on yield attributes and yield of Maize.

Number of cobs/plant

The maximum number of cobs/plant (3.46) was recorded with the treatment B_3 (100 ppm) + Si_3 (700 ppm), which was significantly superior over all the treatments. However, the treatment B_2 (75 ppm) + Si_3 (700 ppm) with (3.26) number of cobs/plant was found to be statistically at par with the treatment B_3 (100 ppm) + Si_3 (700 ppm).

Number of cobs/plant is a genetical aspect and micronutrients may or may not influence largely regarding this aspect. Boron helps in the flower formation and development which indirectly involves in the cob formation and hence boron plays an important role in formation of more number of cobs per plant. These results are in close conformity with the results reported by **Wasaya *et al.* 2017**.

Length of the cob (cm)

The maximum length of the cob (20.94 cm) was recorded with the treatment B_3 (100 ppm) + Si_3 (700 ppm) which was significantly superior over all the treatments. However, the treatment B_2 (75 ppm) + Si_3 (700 ppm) with the cob length (20.29 cm) was found to be statistically at par with B_3 (100 ppm) + Si_3 (700 ppm)

The probable reason for longer cob length at a higher level of silicon and boron could be due to optimum utilization of solar light, higher assimilated production and its conversion to starches resulted in higher ear length. These findings were similar to the results reported by **Tahira *et al.* (2018).**

No. of rows/cob

The maximum number of rows/cob (15.6) was recorded with the application of B_3 (100 ppm) + Si_3 (700 ppm) which was significantly superior over all the treatments except with the application of B_2 (75 ppm) + Si_3 (700 ppm) which achieved (15.43) number of rows/cob.

Boron and Silicon application might have influenced the greater production of metabolites and their translocation to various sinks especially the productive structures. This might be the reason for the maximum number of rows in a cob. These results are in agreement with the findings reported by **Adnan and Hafiz (2020).**

No. of grains/cob

The maximum number of grains/cob (534.26) was recorded with the treatment B_3 (100 ppm) + Si_3 (700 ppm) which was significantly superior over all the treatments. However, the treatments B_2

(75 ppm) + Si_3 (700 ppm) with the number of grains/plant (525.41) and B_3 (100 ppm) + Si_2 (500 ppm) with number of grains/plant (520.95) were at par with the treatment B_3 (100 ppm) + Si_3 (700 ppm).

Many factors are responsible to affect grains/cob such as rate of fertilizer application, micronutrient application, number of irrigations and soil fertility status etc., Growing conditions like air and soil temperature, soil water status and nutritional status in addition to weather change might also impact this yield attributing character. Similar findings were reported by **Wasaya *et al*., (2017).**

Seed index (g)

B_3 (100 ppm) + Si_3 (700 ppm) treatment has recorded highest seed index value (30.76 g). However, the treatments B_2 (75 ppm) + Si_3 (700 ppm) with the seed index value (29.86 g) and B_3 (100 ppm) + Si_2 (500 ppm) with seed index value (29.36 g) were at par with the treatment B_3 (100 ppm) + Si_3 (700 ppm).

Seed index is influenced by both environmentally and genetically. Nutrient intake, irrigation, grain filling pattern and other factors influence the seed index in the maize crop. Application of the micronutrients i.e., Boron and Silicon might also have influenced the seed index in a positive way. Boron has effect on the many functions of the plant such as hormone movement, flowering and fruiting process and pollen germination specially its influences on the directionality of pollen tube growth **Robbertse *et al*., (1990).** Grains weights, yield parameters and B accumulation in barley grains were significantly increased under Boron concentrations. These results are in agreement with the findings of **El-Feky *et al*., (2012)**

Grain yield (t/ha)

The higher yield with the treatment B_3 (100 ppm) + Si_3 (700 ppm) is due to the yield attributes like number of grains per cob, length of the cob (cm) and seed index (g) of the seeds which were significantly higher. The highest grain yield was correlated with longer cob, growth duration, partitioning higher crop growth rate and grain cob weight ratio.

The higher increase in the yield has been reported to be associated with the absorption of macro and micro nutrients by maize crop. Application of Silicon and Boron improved the growth attributes of the maize crop which directly affects the yield and yield attributes in a positive way. Boron as essential micronutrient plays an important role in increasing pollen grains germination and pollen tube enlargement, fruit set% and finally the yield. It is responsible for stimulating cell division, biosynthesis and translocation of sugars, water and nutrient uptake and IAA biosynthesis **(Ahmed et al., 2009).** These results were supported by the findings of **Salim 2014**.

Stover yield (t/ha)

The higher stover yield with the B_3 (100 ppm) + Si_3 (700 ppm) is due to the higher significant values in the growth attributes like plant height (cm), number of leaves per plant and the dry weight of the plant. In general, taller plants with more stem girth and more number of leaves tend to produce more stover yield per unit area due to the higher dry matter accumulation etc. However, due to the higher plant dry weight with the treatment B_3 (100 ppm) + Si_2 (500 ppm), higher stover yield was recorded. This result is mainly due to the application of silicon and boron as they influence the growth of the plant at cellular level by maintaining the better and firm cell structure and better photosynthetic activity and etc., these results were supported by the findings of **Ahmed *et al.* 2008.**

Harvest index (%)

Maximum harvest index (32.76%) was recorded with the treatment B_1 (50 ppm) + Si_1 (300 ppm). The lowest harvest index (31.08%) was recorded with treatment B_2 (75 ppm) + Si_3 (700 ppm).

CONCLUSION

From the observations, it was concluded that with the combination of Boron (100ppm)+ Silicon(700ppm) in treatment no. 9 significantly recorded higher in all the growth and yield attributes and can be recommended to farmers.

REFERENCES

Saleem M., Khanif, Y.M., Ishak, F., Samsuri, A.W. and Hafeez, B. (2011). Importance of Boron for Agriculture Productivity. *International Research Journal on Agricultural Science and Soil Science*, **1**(8): 293-

Narges, M., Markus, W., Frank, W., Brigit, H., Uwe, L. and Neumann, G. (2018). Silicon Improves Chilling Tolerance during Early Growth of Maize by Effects on Micronutrient Homeostasis and Hormonal Balances. *Frontiers in Plant Science,* **9**: 420.

Gong, H.J., Chen, K.M., Chen G.C., Wang S.M. and Zhang C. L. (2005). Silicon alleviates oxidative damage of wheat plants in pots under drought. *Plant Sciences,* **169**:313–321

Qadir, J., Awan, M.S., Baloch, I.H., Shah, M.A. and Nadim, N. (2013). Application of micronutrients for yield enhancement in rice. *International Journal of Plant Sciences and Biology,* **4**: 45-76.

Marngar, E. and Dawson, J. (2017). Effect of biofertilizers, levels of nitrogen and zinc on growth and yield of hybrid maize (Zea mays L.). *International Journal of Current Microbiology and Applied Sciences*, **6**(9): 3614-3622.

Akhtar, M., Mosleh, U. and Hossain, I. (2018). Study on the Growth and Yield Potential of Promising Wheat Genotypes under Modified Agronomical Practices. *World Journal of Research and Review*, **6**(1): 41-49.

Wasaya, A., Shabir, M.S., Hussain, M., Ansar, M., Aziz, A., Hassan, W. and Ahmad, I. (2017). Foliar Application of Zinc and Boron Improved the Productivity and Net Returns of Maize Grown under Rainfed Conditions of Pothwar Plateau. *Journal of Soil Science and Plant Nutrition*, **17**(1): 33-45

Adnan, M. and Bilal, H.M.(2020). Role of Boron Nutrition on Growth, Phenology and Yield of Maize (*Zea Mays* L .) Hybrids. *Open Access Journal of Biogeneric Science & Research*, **4**(5)-2020.

Tahira, M., Shehzada, W., Sarwarab, M.A., Sajid, H. and Imranb, M. (2018). Efficacy of Boron as Foliar Feeding on Yield and Quality Attributes of Maize (*Zea mays* L.). *Pakistan Journal of Scientific and Industrial Research*, **61B**(1) 9-14.

El-Feky, S.S., El-Shintinawy F.A., E.M. Shaker and H.A. Shams. (2012). Effect of elevated boron concentrations on the growth and yield of barley (*Hordeum vulgare* L.) and alleviation of its toxicity using different plant growth modulators. *Australian Journal of Crop Science*, **6**(12): 1687-1695.

Ahmed, W., Niaz, A., Kanwal, S. and Rahmatullah, A. (2009). Role of boron in plant growth. *Journal of Agricultural Research*, **47**(3): 329-338.

Salim, B. M. Effect of Boron and Silicon on Alleviating Salt Stress in Maize. (2014). *Middle East Journal of Agriculture Research*, **3**(4): 1196 - 1204.

Ahmed A.H., Harb E.M., Higazy M.A and Morgan H. (2008). Effect of Silicon and Boron Foliar Applications on Wheat Plants Grown under Saline soil Conditions. *International Journal of Agricultural Research,* **3**(1): 1-26.

Table 1. Effect of Boron and Silicon on Growth and Growth Attributes of Maize

S. No.	Treatments	Plant height (cm)	Number of Leaves/Plant	Plant dry weight (g/Plant)	CGR (g/m^2/day) during 20-4 DAS	RGR (g/g/day) during 20-40 DAS
1	B_1 (50 ppm) + Si_1 (300 ppm)	174.1	10.9	84.36	9.23	0.064
2	B_1 (50 ppm) + Si_2 (500 ppm)	178.31	11.2	86.65	10.76	0.085
3	B_1 (50 ppm) + Si_3 (700 ppm)	179.57	11.5	87.38	11.02	0.086
4	B_2 (75 ppm) + Si_1 (300 ppm)	183.69	11.8	89.53	10.83	0.079
5	B_2 (75 ppm) + Si_2 (500 ppm)	186.93	12.2	90.79	11.06	0.077
6	B_2 (75 ppm) + Si_3 (700 ppm)	192.21	12.6	92.45	11.94	0.079
7	B_3 (100 ppm) + Si_1 (300 ppm)	184.54	12	90.67	10.77	0.073
8	B_3 (100 ppm) + Si_2 (500 ppm)	188.12	12.3	91.12	11.51	0.078
9	B_3 (100 ppm) + Si_3 (700 ppm)	193.66	12.8	93.61	11.94	0.084
10	Control (RDF 120:60:40 Kg/ha)	171.76	10.8	82.25	8.95	0.066
	F Test	S	S	S	S	NS
	SEm (±)	0.81	0.1	0.65	0.39	0
	CD (P=0.05)	2.4	0.29	1.94	1.16	-

Table 2. Effect of Boron and Silicon on yield and yield attributes of Maize

S. No.	Treatments	Cobs/Plant	Length of Cob (cm)	Rows/Cob	Grains/cob	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1	B_1 (50 ppm) + Si_1 (300 ppm)	1.8	15.18	14.57	487.5	26.2	5.91	12.13	32.76
2	B_1 (50 ppm) + Si_2 (500 ppm)	2	15.8	14.5	489	26.6	6.01	12.8	31.95
3	B_1 (50 ppm) + Si_3 (700 ppm)	2.3	16.44	14.2	498.2	26.8	6.02	12.96	31.7
4	B_2 (75 ppm) + Si_1 (300 ppm)	2.5	16.58	14.5	503.4	26.7	6.11	13.33	31.55
5	B_2 (75 ppm) + Si_2 (500 ppm)	2.9	17.86	14.83	517	29.1	6.31	13.76	31.48
6	B_2 (75 ppm) + Si_3 (700 ppm)	3.2	20.29	16.23	527.8	29.8	6.82	14.26	32.36
7	B_3 (100 ppm) + Si_1 (300 ppm)	2.6	17.26	14.67	511.1	27.1	6.18	13.73	31.08
8	B_3 (100 ppm) + Si_2 (500 ppm)	3	18.31	15.83	524.2	29.3	6.61	13.86	32.29
9	B_3 (100 ppm) + Si_3 (700 ppm)	3.4	20.94	16.43	534.2	30.7	6.98	14.73	32.14
10	Control (RDF 120:60:40 Kg/ha)	1.6	14.82	13.1	484	26.1	5.46	11.46	32.29
	F Test	S	S	S	S	S	S	S	NS
	SEm (±)	0.08	0.75	0.25	2.92	0.48	0.06	0.38	0.68
	CD (P=0.05)	0.24	2.23	0.74	8.67	1.42	0.18	1.11	-