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

Abstract:

This field experiment was carried out 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, 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.) known as "Queen of cereals" is considered one of the most important food grains in India after rice and wheat, it ranks fifth and third in area and production respectively in our country. "Though it is consumed all over the country but it is a staple food of people in hilly and sub mountain area of North India. It is extensively grown in Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh etc". **(Dayanand and Jain, 1994).**

Maize is mostly grown in India during the rainy (kharif) and winter (rabi) seasons. Under the zaid season, maize can also be grown. "Maize is gaining immense importance on account of its potential uses in manufacturing starch, plastics, rayon, adhesive, dye, resins, boot polish etc. and due to this large uses it is rightly called a Miracle crop and also known as ˛Queen of cereals' due to its high potential yield". (Lokadal and Sreekanth, 2018). "It has great potential to meet the food demands of living beings which collectively include both humans and animals. Nutrient composition of maize includes crude protein 7.6%, crude fibre 2.3%, crude fat 3.6%, starch 63.8%, Total sugar 1.7%, Gross energy 3840 kcal/kg". (Afzal et al., 2017). In India, maize occupied 9.2 million hectares in 2018-19, with an average productivity of 2965 kg/ha and a yield of 27.8 million t (ICAR-IIMR, 2019-2020). The acreage of maize cultivation is increasing in Odisha as the state produced 0.73 million t of maize with a productivity of 2886 kg/ha from 0.25 million ha of area (GoO, 2020).

"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" **(Saleem *et al.* 2011).**

"One of the most prevalent elements in the crust of planet Earth is silicon (Si). Si has been demonstrated to be advantageous for plant growth even though it isn't recognised as an essential element for higher plants" [7]. "Si plays a critical role in enhancing crops' resilience to biotic and abiotic stresses, including disease and pest resistance, reduction of toxicities from heavy metals like Al, Mn, and Fe, tolerance to salinity and drought conditions, and reduction of freezing stress" [8]. "By lowering leaf transpiration and the velocity of water flow in the xylem vessel, the addition of Si to maize can improve water use efficiency" [10]. "Benefits of si in maize have been linked to its impact on increasing effective leaf area, photosynthetic efficiency, and population quality, as well as delay of leaf senescence" [11]. "As optimum photosynthesis increases yield and production, it is a determining factor for crop growth and development. Photosynthesis is also the most fundamental and important physiological process directly associated to maize yield, especially at developmental stages" [13]. "Raising photosynthetic capability can result in a 50% increase in crop yield potential" [14].

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". (Bevara et. Al., 2022) 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, higher plant height (193.66 cm) was observed in treatment 9 [B_3 (100 ppm) + Si_3 (700 ppm)]. However, treatment 8 [B_2 (75 ppm) + Si_3 (700 ppm)] (192.21 cm) was significantly at par with treatment 9.

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. 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 observed in treatment 9 B_3 (100 ppm) + Si_3 (700 ppm) However treatment 6. [B_2 (75 ppm) + Si_3 (700)] (12.6) was significantly at par with treatment 9

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 maximum plant dry weight (93.61 g/plant) was observed in treatment 9 [B_3 (100 ppm) + Si_3 (700 ppm)] (92.45 g/plant). However, treatment 8 [B_3 (100 ppm) + Si_2 (500 ppm)] was statistically at par with the treatment 9.

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). "**Boron might have attributed to the favorable influence on plant metabolism and biological process activity and their stimulating effect on photosynthetic pigments and enzyme activity which in turn encouraged vegetative growth resulting in higher dry weight". **(Parasa *et al.*, 2023).**

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.
silicon, increased the synthesis of carbohydrates and that might have increased the sink size and capacity. Similar results are obtained by **Lokadal A and Sreekanth B.**

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 observed in treatment 9 {B_3 (100 ppm) + Si_3 (700 ppm)] However, the treatment 6 [B_2 (75 ppm) + Si_3 (700 ppm)] (3.26) number of cobs/plant was significantly at par with treatment 9.

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 9 [B_3 (100 ppm) + Si_3 (700 ppm)]. However the treatment 6 [B_2 (75 ppm) + Si_3 (700 ppm)] (20.29 cm) was significantly at par with treatment 9.

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 observed in treatment 9 [B_3 (100 ppm) + Si_3 (700 ppm)] However treatments 6 [B_2 (75 ppm) + Si_3 (700 ppm)] (15.43) was significantly at par with treatment 9.

Silicon resulted in carbohydrates synthesis from photosynthetic activity for longer period might have resulted in efficient translocation of food material into the sink (grain) thereby increased the number of filled grains percentage. Similar results are obtained by **Lokadal. A and Sreekanth B**

No. of grains/cob

The maximum number of grains/cob (534.26) was observed in treatment 9 [B_3 (100 ppm) + Si_3 (700 ppm)]. However, both treatments 6 B_2 (75 ppm) + Si_3 (700 ppm) (525.41) and treatment 8 [B_3 (100 ppm) + Si_2 (500 ppm)] (520.95) was statistically at par with treatment 9.

"Boron also enhances chlorophyll content in leaf and there by bio mass and phosynthates production is increased, which are effectively transferred towards the roots for its development and to provide required energy for nutrient uptake this uptake results in higher biological yields". **Aluri *et al.*, (2021). "**silicon resulted in carbohydrates synthesis from photosynthetic activity for longer period might have resulted in efficient translocation of food material into the sink (grain) thereby increased the number of filled grains percentage". Similar results are obtained by **Lokadal. A and Sreekanth B**

Seed index (g)

B_3 (100 ppm) + Si_3 (700 ppm) treatment has recorded highest seed index value (30.76 g). However, both treatments 6 [B_2 (75 ppm) + Si_3 (700 ppm)] (29.86 g) and treatment 8 [B_3 (100 ppm) + Si_2 (500 ppm)] (29.36 g) was statistically at par with the treatment 9.

"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).** "silicon application might have improved and enhanced the photosynthetic activity resulting in higher density of grain by improving the translocation and accumulation of carbohydrates and other macro and micro molecules also increased in number of filled grains and influenced the biomass of grains, and ultimately grain weight increased". Similar results are obtained by **Lokadal. A and Sreekanth B**

Grain yield (t/ha)

The higher yield was observed in treatment 9 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.

"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)**. silicon application might have increased photosynthetic activity of plant resulting in more formation of carbohydrates and more uptakes of other nutrients which resulted in higher grain yield. Similar results are obtained by **Choudhary et al.**

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. silicon application might have resulted in more utilization of solar radiation, moisture and nutrients since silicon provides more erectness to plant for efficient utilization of solar radiation resulting in better stover yield. Similar results are obtained by **Singh *et al.*** "Boron also enhances chlorophyll content in leaf and there by bio mass and phosynthates production is increased, which are effectively transferred towards the roots for its development and to provide required energy for nutrient uptake this uptake results in higher biological yields". **Aluri *et al.*, (2021).**

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

Aluri Manoj Kumar., C. Umesha and Gorla Venkata Raju (2022). Effect of Phosphorus and Boron Levels on Growth and Yield of Chickpea (*Cicer arietinum* L.). International Journal of Plant & Soil Science 34(21): 266-271, 2022; Article no. IJPSS.89045.

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

Afzal, U.S., Anjum, M.M., Usman, H., Khan, M., Iqbal, O.M. and Khan, K. (2017). Seed yield performance of different maize (*Zea mays* L.) genotypes under agroclimatic conditions of Haripur. International Journal of Environmental Sciences and Natural Resources, 5: 97-102.

Choudhary R, Sharma SK, Choudhary RS, Yadav SK, Jat G, Singh Hari et al. Effect of silicon fertilization on wheat productivity and profitability in Southern Rajasthan. Indian J Agri Sci. 2022;92(4):500-4.

Covshoff, S. and J. M. Hibberd, "Integrating C4 photosynthesis into C3 crops to increase yield potential," Current Opinion in Biotechnology, vol. 23, no. 2, pp. 209–214, 2012.

Dayanand, Jain OP. Rabi maize cultivation for enhanced production. India Fm. 1994;43(10):11-12.

E. Epstein, "Silicon," Annual Review of Plant Biology, vol. 50, pp. 641–664, 1999.

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

GoO (2020). 5-decades of Odisha agriculture statistics. Directorate of Agriculture and Food Production, Government of Odisha, India. pp. 46.

ICAR - IIMR (2019-20). Director's report: ICAR – Indian Institute of Maize Research, PAU Campus, Ludhiana, Punjab, India.

Lokadal A, Sreekanth B. Effect of soil application of silicon on growth and yield attributes of rice (*Oryza sativa* L.). Int J Curr Microbiol Appl Sci. 2018;7(11): 838-44.

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.

M. Ahmed, M. Asif, and Fayyaz-ul-Hassan, "Resilience of physiological attributes of wheat (*Triticum aestivum* L.) to abiotic stresses," Scientific Research and Essays, vol. 7, no. 35, pp. 3099–3106, 2012.

M. H. Gharineh and A. Karmollachaab, "Effect of silicon on physiological characteristics wheat growth under water-deficit stress induced by PEG," International Journal of Agronomy and Plant Production, vol. 4, no. 7, pp. 1543–1548, 2013.

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.

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.

Singh KK, Singh K, Singh R, Singh Y, Singh CS. Response of nitrogen and silicon levels on growth, yield and nutrient uptake of rice (*Oryza sativa* L.) Oryza. 2006;43(3):220-3.

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-

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.

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

Bevara Asirinaidu, Joy Dawson, Bevara

Anasuyamma and Peruru Sasidhar. Effect of nitrogen and boron on growth and yield of Mustard (Brassica juncea L.) The Pharma Innovation Journal 2022; 11(4): 1176-1179

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)	CGR (g/m^2/day)
1	B_1 (50 ppm) + Si_1 (300 ppm)	174.1	10.9	84.36	9.23
2	B_1 (50 ppm) + Si_2 (500 ppm)	178.31	11.2	86.65	10.76
3	B_1 (50 ppm) + Si_3 (700 ppm)	179.57	11.5	87.38	11.02
4	B_2 (75 ppm) + Si_1 (300 ppm)	183.69	11.8	89.53	10.83
5	B_2 (75 ppm) + Si_2 (500 ppm)	186.93	12.2	90.79	11.06
6	B_2 (75 ppm) + Si_3 (700 ppm)	192.21	12.6	92.45	11.94
7	B_3 (100 ppm) + Si_1 (300 ppm)	184.54	12	90.67	10.77
8	B_3 (100 ppm) + Si_2 (500 ppm)	188.12	12.3	91.12	11.51
9	B_3 (100 ppm) + Si_3 (700 ppm)	193.66	12.8	93.61	11.94
10	Control (RDF 120:60:40 Kg/ha)	171.76	10.8	82.25	8.95
	F Test	S	S	S	S
	SEm (±)	0.81	0.1	0.65	0.39
	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	Cob length (cm)	Rows/Cob	Grains/cob	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)
1	B_1 (50 ppm) + Si_1 (300 ppm)	1.8	15.18	14.57	487.5	26.2	5.91	12.13
2	B_1 (50 ppm) + Si_2 (500 ppm)	2	15.8	14.5	489	26.6	6.01	12.8
3	B_1 (50 ppm) + Si_3 (700 ppm)	2.3	16.44	14.2	498.2	26.8	6.02	12.96
4	B_2 (75 ppm) + Si_1 (300 ppm)	2.5	16.58	14.5	503.4	26.7	6.11	13.33
5	B_2 (75 ppm) + Si_2 (500 ppm)	2.9	17.86	14.83	517	29.1	6.31	13.76
6	B_2 (75 ppm) + Si_3 (700 ppm)	3.2	20.29	16.23	527.8	29.8	6.82	14.26
7	B_3 (100 ppm) + Si_1 (300 ppm)	2.6	17.26	14.67	511.1	27.1	6.18	13.73
8	B_3 (100 ppm) + Si_2 (500 ppm)	3	18.31	15.83	524.2	29.3	6.61	13.86
9	B_3 (100 ppm) + Si_3 (700 ppm)	3.4	20.94	16.43	534.2	30.7	6.98	14.73
10	Control (RDF 120:60:40 Kg/ha)	1.6	14.82	13.1	484	26.1	5.46	11.46
	F Test	S	S	S	S	S	S	S
	SEm (±)	0.08	0.75	0.25	2.92	0.48	0.06	0.38
	CD (P=0.05)	0.24	2.23	0.74	8.67	1.42	0.18	1.11