Influence of Zinc and Gibberellic Acid on Growth and Yield of Maize

(*Zea mays* L.)

Abstract

A field experiment was carried out during *kharif* season of 2022 on Maize crop at Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.), to study the "Influence of Zinc and Gibberellic acid on growth and yield of Maize (*Zea mays* L.)" The treatments consisted of 3 levels of Zinc (Soil application 20 kg/ha, Foliar application 0.5% and Soil application 10 kg/ha + Foliar 0.25%) and Foliar application of Gibberellic Acid (50, 100 and 150 ppm) and a control. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and each were replicated thrice. The results revealed that treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) with combination of GA_3 at 150 ppm produced higher plant height (187.73 cm), more dry weight (184.05 g), maximum number of cobs per plant (1.60), maximum number of rows per cob (14.67), maximum number of grains per row (26.33), test weight (215.78 g), higher grain yield (6.76 t/ha), higher stover yield (13.80) and higher harvest index (32.87%). Similarly, maximum gross return (2,18,280.00 INR/ha), net return (1,49,997.00 INR/ha) and highest B:C ratio (2.20) was also recorded in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) with combination of GA_3 at 150 ppm.

Keywords: Maize; Zinc; Gibberellic Acid; Growth ; Yield; kharif.

INTRODUCTION:

"Maize or corn (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. The wider adaptability and high yield potential of maize and its utility as food, feed and forage crop signifies the importance of maize. The plant (*Zea mays* L.) is a monoic annual plant which belongs to maideas tribe and the grass family of *gramineae*, and their cells have 2n chromosomes. Maize is the third most important crop after wheat and rice and is grown in more countries than any other crop in the world. Maize is a heat climate plant, aleven though in India, it's far grown in nearly all of the states representing 21 exceptional agro-ecological areas and in all of the 3 crop seasons- *kharif* (June-October), *rabi* (November- April) and *zaid* (February- May)" **National Academy of Agricultural Research Management (2013).** "The major maize producing countries are USA, China, Brazil, Argentina, Mexico, South Africa, Yugoslavia and India. Among the maize growing countries, India rank 4th in area and 7th in production, representing around 4% of the world maize area and 2% of total production. In India, area, production and productivity of maize is 9.76 mha, 26.14 mt and 26.80 kg ha-1 respectively" **(Anonymous, 2017).**

"Amongst the cereals, maize is a rich source of essential nutrients needed by both human beings and animals. The nutritional value of maize is high. With respect to the nutritive values, 100 g of maize are found to be rich in 89.1% moisture, 1.9 g protein, 0.2 g fat, 0.06 g ash, 8.2 mg carbohydrate, 28 mg calcium, 86 mg phosphorus and 11 mg ascorbic acid" **(Kumar *et al*. 2018)**. Maize protein, "Zein" is rich in tryptophan and lysine, the two essential amino acids. As it's far a potential crop in India, it occupies essential area as meals (25%), fowl feed (49%) animal feed (12%), business merchandise usually starch (12%), brewery (1%) and seed (1%). (**Das *et al*. 2009).** Maize has tremendous market potential not only in India but also in the international market. It has also enormous potential to provide food security, nutritional security and income to maize growers. Maize qualifies as potential crop for doubling farmer's income. By growing maize farmers save 90% of water, 70% of power compared to paddy.

"Zinc is an essential element for higher plants, and its importance in agriculture is increasingly being recognized. Low zinc availability in soil is common worldwide, and zinc deficiency leads to reductions in crop. Maize is one of the crops most sensitive to zinc deficiency" (**Mattiello *et al.* 2015**). "Zinc deficiency has increased from 44% to 48%, and is expected to further increase up to 63% by 2025 in India. Zinc deficiency in maize is known as "White bud". Zinc is most crucial among the micronutrients that take part in plant growth and development due to its catalytic action in metabolism of almost all crops" (**George *et al*. 2002**). "Zinc play a key role in pollination and seed set processes; so that their deficiency can cause decrease in seed formation and subsequent yield reduction. Zinc is important in photosynthesis and respiration, and zinc deficiency decreases the photosynthetic rate, chlorophyll content, activity of carbonic anhydrase, and protein biosynthesis". [25] "Soil applied zinc is effective in enhancing the grain yield where as zinc concentration in grain improves via foliar spray of zinc fertilizer. Based on particular studies, (**Mortvedt *et al*. 1991**) is of the view that soil and foliar application of zinc enhances the yield of crops". Therefore application of zinc fertilizer may be an important measure for improving the yield and quality of maize. Zinc is now being reported as third most limiting nutrient elements in crop production after N and P.

"PGR's are being used extensively in agriculture for the growth and development of various crops. 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. PGR in the form of foliar spray at the flowering stage helps in improving physiological efficiency along with crop productivity. Dwarfing depends upon gibberellins deficiency and dwarfing gene effects on gibberellins biosynthesis. So, by applying gibberellic acid on dwarf maize mutant, they showed normal growth after hormone treatment. In addition, long stems have more bioactive gibberellins than short stems" (**Naghashzadeha *et al*. 2009**). "Gibberellic acid regulates several plant metabolisms processes, such as stem elongation, leaf expansion, seed germination, flower induction, and fruit development" (**Sun *et al*. 2010**). "Specifically, in corn, gibberellic acid is reported to promote good seed germination performance" **(Pan *et al*. 2017).** In maize, GA_3 application caused a remarkable increase in total chlorophyll contents.

MATERIALS AND METHODS:

A field experiment was conducted during *kharif* season 2022 at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj (U.P). The soil of the experimental field was sandy loam in texture, nearly neutral in soil reaction (pH 7.6), organic carbon level in medium condition (0.87%), medium available N (225 kg/ha), high in available P (41.8 kg/ha) and medium available K (261.2 kg/ha). The treatment consisted of three levels of zinc viz. Soil application 20 kg/ha, Foliar application 0.5%, Soil application (10 kg/ha) + Foliar 0.25%) and Foliar application of Gibberellic Acid (50, 100 and 150 ppm). The experiment was laid out in randomized block design with ten treatments, each were replicated thrice and was laid out with the different treatments allocated randomly in each replication. The treatment combinations are T_1- Soil application of Zinc (20 kg/ha) + GA_3 50 ppm, T_2 - Soil application of Zinc (20 kg/ha) + GA_3 100 ppm, T_3- Soil application of Zinc (20 kg/ha) + GA_3 150 ppm, T_4- Foliar application of Zinc (0.5%) + GA_3 50 ppm, T_5- Foliar application of Zinc (0.5%) + GA_3 100 ppm, T_6- Foliar application of Zinc (0.5%) + GA_3 150 ppm, T_7- Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 50 ppm, T_8- Soil application of Zinc (10 kg/ha)+ Foliar (0.25%)+ GA_3 100 ppm, T_9- Soil application of Zinc (10 kg/ha)+ Foliar (0.25%)+ GA_3 150 ppm, T_{10}- Control N:P:K 120:60:40 kg/ha. All agronomic practices are followed as per requirements and in order during the crop period. During the course of the experiment, random sampling technique was adopted for recording the observations on various morphological characters of the plant .The frequency of observations and the parameter on which the observations were taken are divided into pre – harvest (pertaining to growth attributes) and post-harvest (relating to yield attributes, quality parameter, soil parameter and economics) and was examined accordingly. Experimental data collected was subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level.

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)

At 100 DAS, the significantly higher plant height (187.73 cm) [Table 1] was recorded in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm over all the other treatments. However, plant height in treatment 6 with Foliar application of zinc (0.5%) + GA_3 150 ppm (186.06 cm), treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (186.45 cm) and treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (187.50 cm) was found to be statistically at par with treatment 9. From the data, it is evident that the plant height at 40, 60, 80 and 100 DAS significantly increased due to increase in levels of zinc and change in methods of application of zinc from soil application and foliar application. Among the micronutrients, the combined application of zinc both as soil application and foliar spray significantly increased the plant height in all stages. Similar findings were reported by **Chand *et al*. (2017)**. "The increase in plant height maybe the balanced application of zinc along with NPK fertilizer, as many researchers state that zinc is involved in a number of physiological processes of plant growth and metabolism". **Panneerselvam *et al*. (2014).**

Plant dry weight (g/plant)

At 100 DAS, the significantly higher dry weight (184.05 g/plant) [Table 1] was recorded in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm over all the other treatments. However, dry weight in treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (181.97 g/plant) was found to be statistically at par with treatment 9. The increase in yield could be attributed to proper supply of Zn upto harvesting stages in soil which might have led to increased photosynthetic activity for longer period and their beneficial effect on metabolism of plants thereby finally increased dry matter accumulation. Similar findings were reported by **Singh *et al*. (2021)**. "Further increase in dry weight with the application of gibberellic acid GA_3 as foliar spray, promotes cell proliferation in plant developmental stages due to their own metabolism regulation and promotes the development of cells by increasing turgour pressure and it also activates different enzymes and has a positive effect on plant growth and dry matter accumulation". **Islam *et al*. (2014)**.

Yield parameters

No of cobs/plant

The data revealed that maximum number of cobs (1.60) [Table 2] was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 6 with foliar application of zinc (0.5%) + GA_3 150 ppm (1.40), treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (1.46) and treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (1.53) was found to be statistically at par with treatment 9. The zinc application to maize is a factor affecting positively its yielding potential. The yield forming effect of this nutrient prevailed in early stages of maize growth resulting in high number of cobs/plant. Similar result has also been reported by **Humtsoe *et al*. (2018).**

No of rows/plant

The data revealed that the maximum Number of row /cob (14.67) [Table 2], was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 8 with Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 100 ppm (14.40) was found to be statistically at par with treatment 9. Number of grain rows per cob directly affects the number of grains per cob and ultimately grain yield of maize. The study showed that foliar application of zinc at anthesis produced the maximum number of grains per cob. The results are in accordance with **Ehsanullah *et al*. (2015).** Further the foliar application of growth hormones at 4-5 leaf stage has mostly affected the strength of physiological sources so that improves yield attributes of plants such as number of rows/cob. Similar results have been reported by **Ghodrat *et al.* (2012)**

No of grains/row

The data revealed that maximum Number of grains/row (26.33) [Table 2], was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (25.73) and treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (26.06) was found to be statistically at par with treatment 9. Higher chlorophyll content contributed to the increase in the number of grains per row that resulted from the application of zinc, and this appears to have had a positive impact on photosynthetic activity, the synthesis of metabolites and growth-regulating substances, oxidation and metabolic activities, and ultimately better crop growth and development that increased yield attributes. Das et al. (2020) have reported similar findings. The plant growth regulators also increase mobilization of reserve food materials to the developing sink through increases in hydrolyzing and oxidizing enzyme activities and lead to yield increases. Earlier studies by Anjum et al. (2017) and Thuc et al. (2021) revealed findings that were comparable.

Test weight

The data revealed that the maximum Test Weight (215.78 g) [Table 2], was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (215.21 g) was found to be statistically at par with treatment 9. The results exhibited that thousand grain weight was significantly affected by Zn application because Zn stimulates metabolic processes in seed. The amount of grains might have been accommodated by expanding the cob, which would have provided enough room for each grain to develop. This would have resulted in higher test weight and higher grain weight per cob. These outcomes are consistent with what Shahab et al. (2016) and Kumar et al. (2019) found. Gibberellin produce centers in plants are: stem terminal, root active parts, young leaves, growing fruit and particularly, growing seeds. The micronutrient combination of Zinc (10 kg/ha+0.25%)+ GA_3 significantly increased the 1000 grain weight and this might be due to constant supply of micronutrients and growth regulator during critical phases of the crop growth.

Grain Yield

The data revealed that maximum Grain Yield (6.76 t/ha) [Table 2] was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + $GA_3$150 ppm. However treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (5.93) and treatment 8 with Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 100 ppm (6.34 t/ha) was found to be statistically at par with treatment 9. The increase in grain yield maybe due to the adequate supply of Zn both as soil and foliar application during the various growth stages of the plant, which might have led to increased photosynthetic activity for longer period and their beneficial effect on metabolism of plants thereby, increasing dry- matter accumulation. The results are in conformity with **Shahab *et al*.(2016).** Further increase in the yield in response to the foliar application of GA_3 150 ppm, might be due to the reduction in flower and fruit drop, increase in vegetative growth, fruit length and fruit thickness. Similar results have also been reported by **Singh *et al*. (2018)**

Stover yield

The data revealed that the maximum Stover Yield (13.80 t/ha) [Table 2] was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (12.92) and treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (13.45) was found to be statistically at par with treatment 9. The increase in stover yield might be due to application of plant growth regulators as it increase mobilization of reserve food materials to the developing sink through increases in hydrolyzing and oxidizing enzyme activities and lead to yield increases as well as stover yield. Similar results were obtained by **Ramesh *et al*.(2019).**

Harvest index (%)

The data revealed that the maximum harvest index (32.87%) [Table 2] was observed in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm. However treatment 7 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 50 ppm (31.45%) and treatment 8 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 100 ppm (32.00%) was found to be statistically at par with treatment 9. The probable reasons for recording maximum growth and yield were recorded in treatment 9 with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) + GA_3 150 ppm, might be due to higher mineralization potential of Zinc + GA_3 enabling it to actively and quickly release its nutrients for plant uptake and use.

ECONOMICS

The result showed that [Table 3] maximum gross return (2,18,280.00 INR/ha), net return (1,49,997.00 INR/ha) and B:C ratio (2.20) was recorded in treatment 9 with Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 150 ppm. The probable reasons for recording maximum net returns (1,49,997.00 INR/ha) and maximum benefit cost ratio (2.20), might be due to the higher yields and net returns associated with the respective treatments.

CONCLUSION

In the light of the above study, it is concluded that (Treatment 9) with Soil application of Zinc (10 kg/ha) + Foliar (0.25%) along with Foliar application of GA_3 (150 ppm) performed better in terms of growth and yield as compared to other treatments. Significantly higher plant height, dry weight, maximum number of cobs per plant, number of rows per cob, number of grains per row , test weight, grain yield, stover yield and harvest index . Maximum gross return, net return and B:C ratio was also recorded in treatment 9. The conclusion drawn are based on one season data only which requires further confirmation for recommendation.

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Table 1. Effect of Zinc and Gibberellic acid on growth parameters of Maize.

	Treatment combinations	At 100 DAS	
		Plant height (cm)	**Dry weight (g/plant)**
1.	Soil application of Zinc (20 kg/ha) + GA_3 50ppm	182.63	170.29
2.	Soil application of Zinc (20 kg/ha) + GA_3 100ppm	183.20	172.41
3.	Soil application of Zinc (20 kg/ha) + GA_3 150ppm	183.94	172.90
4.	Foliar application of Zinc (0.5%) + GA_3 50ppm	184.47	173.19
5.	Foliar application of Zinc (0.5%) + GA_3 100ppm	185.27	176.96
6.	Foliar application of Zinc (0.5%) + GA_3 150ppm	186.06	178.04
7.	Soil application of Zinc (10 kg/ha)+ Foliar(0.25%) + GA_3 50ppm	186.45	179.61
8.	Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 100ppm	187.50	181.97
9.	Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 150ppm	187.73	184.05
10.	Control N:P:K 120:60:40 kg/ha	173.86	165.42
	F test	S	S
	SEm(±)	1.13	1.42
	CD (p = 0.05)	2.34	2.93

Table 2: Effect of Zinc and Gibberellic acid on yield attributes and yield of Maize.

	Treatment combinations	Number of Cob/Plant	Number of rows / cob	Number of grains /row	Test Weight (g)	Grain Yield (t/ha)	Stover Yield (t/ha)	Harvest index (%)
1.	Soil application of Zinc (20 kg/ha) + GA_3 50 ppm	1.20	12.4	22.56	205.32	3.63	9.52	27.60
2.	Soil application of Zinc (20 kg/ha) + GA_3 100 ppm	1.26	12.67	22.86	208.1	3.96	10.06	28.21
3.	Soil application of Zinc (20 kg/ha) + GA_3 150 ppm	1.33	12.93	23.32	206.88	4.36	10.82	28.72
4.	Foliar application of Zinc (0.5%) + GA_3 50 ppm	1.26	13.07	24.36	209.16	4.39	11.56	27.60
5.	Foliar application of Zinc (0.5%) + GA_3 100 ppm	1.37	13.2	24.86	211.03	4.90	11.83	29.25
6.	Foliar application of Zinc (0.5%) + GA_3 150 ppm	1.40	13.47	25.26	212.52	5.33	12.10	30.05
7.	Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 50 ppm	1.46	14.00	25.73	213.26	5.93	12.92	31.45
8.	Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 100 ppm	1.53	14.40	26.06	215.21	6.34	13.45	32.00
9.	Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 150 ppm	1.60	14.67	26.33	215.78	6.76	13.80	32.87
10.	Control N:P:K 120:60:40	1.06	12.4	21.96	204.47	3.13	8.50	26.91
	F test	S	S	S	S	S	S	S
	SEm(±)	0.09	0.23	0.48	0.96	0.57	0.64	0.77
	CD (p = 0.05)	0.20	0.47	1.00	1.99	1.18	1.32	1.60

Table 3: Effect of Zinc and Gibberellic acid on economics of Maize.

Treatment combinations	Total cost of Cultivation (INR)	Gross return (INR/ha)	Net Return (INR/ha)	Benefit cost ratio (B:C)
1. Soil application of Zinc (20 kg/ha) + GA_3 50 ppm	65,784.00	1,31,980.00	66,196.50	1.01
2. Soil application of Zinc (20 kg/ha) + GA_3 100 ppm	67,034.00	1,41,700.00	74,666.50	1.11
3. Soil application of Zinc (20 kg/ha) + GA_3 150 ppm	68,284.00	1,54,220.00	85,936.50	1.26
4. Foliar application of Zinc (0.5%) + GA_3 50 ppm	65,609.00	1,59,940.00	94,331.50	1.44
5. Foliar application of Zinc (0.5%) + GA_3 100 ppm	66,859.00	1,71,010.00	1.04,152.00	1.56
6. Foliar application of Zinc (0.5%) + GA_3 150 ppm	68,109.00	1,80,640.00	1,12,532.00	1.65
7. Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 50 ppm	65,784.00	1,97,180.00	1,31,397.00	2.00
8. Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 100 ppm	67,034.00	2,08,270.00	1,41,237.00	2.11
9. Soil application of Zinc (10 kg/ha)+ Foliar (0.25%) + GA_3 150 ppm	68,284.00	2,18,280.00	1,49,997.00	2.20
10. Control N:P:K 120:60:40 kg/ha	63,834.00	1,31,500.00	67,667.00	1.06