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Effect of nitrogen and zinc on growth and yield of popcorn (*Zea mays everta* L.)

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Abstract
A field experiment was conducted during *Rabi* season of 2023-24 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.). The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. The treatments consisted of 3 levels of Nitrogen (80 Kg/ha, 100 Kg/ha and 120 Kg/ha as Soil application) and 3 levels of Zinc (25 kg/ha soil application, 0.5% foliar application and 12.5 kg/ha soil application + 0.25% Foliar application) and a control (120:60:40 N-P-K kg/ha). The results revealed that application of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9) recorded maximum plant height (175.57 cm), dry weight (157.47 g), number of cobs/plant (1.60), number of grain rows per cob (15.33), number of grains per row (30.36), test weight (21.34 g), grain yield (3.78 t/ha), straw yield (10.20 t/ha) and harvest index (29.85%). It also recorded the maximum gross returns (1,60,319.00 INR/ha), net returns (1,14,755.00 INR/ha) and B:C ratio (2.51) were also recorded in the same treatment in popcorn.

Keywords: Popcorn, zinc, boron, growth, yield, and economics

1. Introduction
Popcorn (*Zea mays everta* Sturt.) is a popular and nutritious snack. The majority of global popcorn production is located in the United States. Popcorn cultivation in India is limited and production value is low, but usage and demand are increasing. Experimental results are still limited on cultivation methods for growing popcorn. In general, the cultural practices used to grow sunken corn can be used to grow popcorn, with some minor modifications. The global popcorn market size was estimated at USD 5.2 billion in 2021. The largest producers of popcorn globally are the United States, Argentina, and China. The United States, in particular, is known for producing a significant portion of the world's popcorn. However, compared to some other countries, popcorn production in India has traditionally been relatively low. The major popcorn-producing states in India include Maharashtra, Madhya Pradesh, and Karnataka. The production of popcorn in India has been increasing in recent years due to changing consumer preferences and the expansion of the snack food industry. The government has also taken initiatives to promote the cultivation of popcorn to boost its production. (FAO Stats).
Nitrogen is the key element in achieving consistently high yield in cereals. Nitrogen is the most common limiting nutrient for crop production and therefore adoption of good nitrogen management strategies often results in large economic benefit to the farmers. Not only genetic potential of hybrid, but also cultural practices such as nitrogen fertilizer rates and plant densities have important effects on popcorn yield**.** Nitrogen fertilizer is also one of the most important factors affecting plant growth and grain yield of corn hybrids (Russel and Balko, 1980). Nitrogen stress during flowering and grain filling stage results in kernel and ear abortion, accelerates leaf senescence, reduce photosynthesis and Kernal weight.
Maize is high nutrient demanding crop and sensitive to zinc supply as indicated by its high content in grain, as compared to other micronutrients. Zinc has several important functions in plants, including major roles in enzyme reactions, photosynthesis, DNA transcription and auxin activity. Zinc deficiency in crops is a common problem worldwide therefore, zinc malnutrition

has become a major health burden among the resource poor people. Application of Zn fertilizers could be a viable option to fulfill the crop demand for Zn and also to increase its content in grains. Deficiency of Zn in soil causes deficiency in crops and altogether this has become a problem all over the world with acute zinc deficiency ranges in arid to semi-arid regions of the world. Zinc is a trace element needed in small quantity but in critical concentrate. If the amount of available zinc is not adequate, plants will suffer with physiological stress. Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effect of short periods of plant and salt stress**.**

Moreover, the proper method of nutrient application can be another approach for better uptake and utilization of Zn. Amongst the different methods, the foliar spray of micronutrients is efficient for enhancement of crop productivity**.** This way of nutrient application is an easy and simple method for improvement of plant nutritional condition, as stated for maize and wheat Grzebisz *et al*., 2008) [10]. Reasons for effectiveness of foliar spray are simple due to its direct application to the leaves. Therefore, appropriate Zn application methods are important for optimal absorption and use. It can be used as a foliar spray or as a soil treatment. Though zinc applied to the soil promotes grain yield, its presence in the kernel was only enhanced by foliar spraying of zinc fertilizer. As a result, it is advised to use a combination of soil and foliar zinc applications to boost both kernel zinc content and yield. Adopting proper nutrient management and targeted nutrient application can help in mitigating deficiencies, promote better grain quality and productivity of maize. These abilities of the crop can be exploited and cultivated to get better results

Keeping in view the above facts, the present experiment was undertaken to find out the 'Effect of nitrogen and zinc on the growth and yield of popcorn'.

2. Materials and Methods

A field experiment was conducted during Rabi season of 2023-24 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.). The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. The treatments consisted of 3 levels of Nitrogen (80 Kg/ha, 100 Kg/ha and 120 Kg/ha as Soil application) and

3 levels of Zinc (25 kg/ha soil application, 0.5% foliar application and 12.5 kg/ha soil application + 0.25% Foliar application) and a control (120:60:40 N-P-K kg/ha). The results revealed that application of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9) recorded maximum plant height (175.57 cm), dry weight (157.47 g), number of cobs/plant (1.60), number of grain rows per cob (15.33), number of grains per row (30.36), test weight (21.34 g), grain yield (3.78 t/ha), straw yield (10.20 t/ha) and harvest index (29.85%). It also recorded the maximum gross returns (1,60,319.00 INR/ha), net returns (1,14,755.00 INR/ha) and B:C ratio (2.51) were also recorded in the same treatment in popcorn. Data recorded on different aspects of crop, *viz*., growth, yield attributes and yield were subjected to statistical analysis by analysis of variance method as described**.**

3. Results and Discussion

3.1 Growth Attributes

3.1.1 Plant height (cm)

The increased in plant height may be due to the interaction between nitrogen and zinc which works to promote optimal plant growth. This includes increased stem elongation and overall height due to enhanced metabolic activities and efficient nutrient uptake.

3.1.2 Plant Dry weight (g)

The increase in plant dry weight might be due to the combination of nitrogen and zinc which helps in promoting vigorous vegetative growth, while ensuring optimal nutrient uptake and utilization, enhancing overall biomass production. Stating application of zinc gave significant increase in dry matter production.

3.1.3 Crop Growth Rate (g/m2/day)

Higher crop growth rate (25.47 g/m2/day) was recorded with the application of 120 kg/ha Nitrogen and soil application of 25 kg/ha Zinc (Treatment 7), which was found to be statistically at par with all treatments. This might be due to the role of nitrogen and zinc which accelerates the growth rate of popcorn. The combination of nitrogen and zinc promotes cell division and elongation, promote nutrient uptake, leading to increased leaf area, stem length and overall biomass accumulation. Similar finding was also reported by Sarwar *et al*. (2012) [18].

3.1.4 Relative Growth Rate (g/g/day)

This increase in relative growth rate might be due to the combined effects of nitrogen and zinc which promotes rapid biomass accumulation and vegetative growth, while zinc ensures essential for sustained growth and development. Excessive nitrogen can sometimes interfere with zinc uptake or induce zinc deficiency symptoms.

3.2 Yield Attributes

3.2.1 Number of Cobs per plant

Number of cobs per plant (1.60) was significantly higher with the application of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9), while Treatment 7 and Treatment 8 were found to be statistically at par with the highest.

3.2.2 Number of grains per Cob

Number of grain rows per cob (17.20) was significantly higher with the application of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9), while Treatment 3 and Treatment 7 were found to be statistically at par with the highest.

3.2.3 Number of Grains per row

Number of grains per row recorded no significant difference among treatments. However maximum number of grains per row (30.36) was recorded with the application of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9), which was found to be statistically at par with all treatments.

3.2.4 Test weight (g)

The increased in the above given yield attributes might be due to the combination of nitrogen and zinc which supports vegetative growth and kernel development, while ensuring optimal reproductive growth and grain filling, contributing to improved number of cobs/plant, number of grain rows/cob, number of grains/row and test weight.

3.2.5 Grain yield (t/ha)

The increased in grain yield might be due to the combination of

nitrogen and zinc which promotes vigorous vegetative growth, increases leaf area for photosynthesis and enhances reproductive development, leading to more robust plants with higher yield potential. This ensures optimal conditions for plant growth and productivity. Similar finding was reported by Abunyewa and Quarshie (2004) [2].

3.2.6 Straw yield (t/ha)

The increased in straw yield might be due to the combination of nitrogen and zinc which helps in promoting robust vegetative growth. This includes taller plants with more extensive foliage and stems, resulting in higher biomass accumulation of straw components. Similar finding was reported by Ghodpage *et al.* (2008) [10].

3.2.7 Harvest Index (%)

This increase in harvest index might be due to the combination of nitrogen and zinc which helps in promoting overall plant vigor and biomass accumulation, while ensuring efficient nutrient uptake and utilization for grain filling. Together, they contribute to maximizing grain yield relative to straw yield, therefore improving the harvest index. Similar finding was reported by Kafle *et al*. (2022) [13].

3.3 Economics

The highest gross returns (1,60,319.00 INR/ha), the highest net returns (1,14,755.00 INR/ha) and benefit cost ratio (2.51) were recorded in treatment 9 (120 kg/ha Nitrogen + soil application of 12.5 kg/ha of Zinc along with foliar application of 0.25% Zinc) as compared to other treatments. The treatment of 120 kg/ha Nitrogen + soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc also recorded the maximum B:C ratio (2:51).

Table 1: Effect of nitrogen and zinc on the growth attributes of Popcorn

S. No.	Treatments Combinations	Plant height (cm)	Plant Dry Weight (g/plant)	CGR ($g/m^2/day$)	RGR (g/g/day)
1.	80 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	119.04	78.10	20.06	0.0598
2.	80 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	121.02	77.40	19.47	0.0588
3.	80 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	116.62	74.21	17.99	0.0548
4.	100 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	122.87	75.59	19.15	0.0597
5.	100 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	119.70	78.08	19.10	0.0558
6.	100 kg/ ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	126.35	82.35	20.42	0.0573
7.	120 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	127.23	79.05	19.72	0.0580
8.	120 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	126.09	82.64	20.54	0.0576
9.	120 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	129.20	96.03	24.34	0.0611
10.	Control: 120:60:40 N-P-K hg/ha	111.47	70.82	17.58	0.0574
	F-Test	S	S	S	NS
	S.Em±	3.368	2.902	1.146	0.003
CD (P=0.05)		10.006	8.623	3.403	-

Table 2: Effect of nitrogen and zinc on yield attributes of popcorn

S. No.	Treatments Combinations	Cobs/plant	Rows/cob	Grains/row	Test weight (g)
1.	80 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	1.32	13.92	25.32	19.29
2.	80 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	1.28	14.14	27.55	19.73
3.	80 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	1.39	14.46	27.92	20.39
4.	100 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	1.41	14.08	27.55	20.46
5.	100 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	1.45	14.21	26.01	21.07
6.	100 kg/ ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	1.38	14.19	28.47	20.84
7.	120 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	1.48	14.85	27.09	21.10
8.	120 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	1.53	14.10	27.60	20.69
9.	120 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	1.60	15.33	30.36	21.34
10.	Control: 120:60:40 N-P-K hg/ha	1.29	13.75	24.13	19.71
	F-Test	S	S	NS	S
	S.Em±	0.037	0.297	1.065	0.238
	CD (P=0.05)	0.111	0.882	-	0.709

Table 3: Effect of nitrogen and zinc on yield of popcorn

S. No.	Treatments Combinations	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
1.	80 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	2.72	6.52	29.48
2.	80 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	3.01	7.09	29.82
3.	80 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	2.86	6.98	29.05
4.	100 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	3.55	9.62	26.95
5.	100 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	3.05	8.24	27.05
6.	100 kg/ ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	3.17	9.02	26.03
7.	120 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	3.41	9.35	26.71
8.	120 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	3.55	9.78	26.67
9.	120 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	3.78	10.20	27.02
10.	Control: 120:60:40 N-P-K hg/ha	2.66	6.27	29.85
	F-Test	S	S	S
	S.Em±	0.062	0.250	0.507
	CD (P=0.05)	0.185	0.743	1.507

Table 3: Effect of nitrogen and zinc on economics of popcorn

S. No.	Treatments Combinations	Cost of cultivation (INR/ha)	Gross returns (INR/ha)	Net returns (INR/ha)	B:C ratio
1.	80 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	47225.00	112426.00	65201.00	1.38
2.	80 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	43102.47	124091.00	80989.00	1.87
3.	80 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	45163.00	118749.00	73585.00	1.62
4.	100 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	47425.00	150676.00	103251.00	2.17
5.	100 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	43302.47	129638.00	86335.00	1.99
6.	100 kg/ ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	45363.65	136329.00	90965.00	2.00
7.	120 kg/ha Nitrogen + 25 kg/ha Zinc (Soil app.)	47625.00	145084.00	97459.00	2.04
8.	120 kg/ha Nitrogen + 0.5% Zinc (Foliar app.)	43502.47	151503.00	108001.00	2.48
9.	120 kg/ha Nitrogen + 12.5 kg/ha (Soil app.) + 0.25% (Foliar app.)	45563.65	160319.00	114755.00	2.51
10.	Control: 120:60:40 N-P-K hg/ha	43500.00	109735.00	66235.00	1.52

4. Conclusion

It can be concluded that the crop sown at an application rate of 120 kg/ha Nitrogen and soil application of 12.5 kg/ha Zinc along with foliar application of 0.25% Zinc (Treatment 9) has recorded 2.51 B:C Ratio in popcorn.

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