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Impact of Fertilizer Doses with Zinc and Nitrogen on the Growth of Maize (*Zea mays* L.) varieties

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Abstract

A field experiment was conducted during the Kharif season of 2024 at Vivekananda Global University, Jaipur, to evaluate the impact of varying nitrogen and zinc fertilizer doses on the growth performance of maize (Zea mays L.) under semi-arid conditions. The experiment comprised nine treatments involving different recommended doses of fertilizers (RDF) combined with soil and foliar application of zinc sulfate, laid out in a randomized block design. The results indicated significant effects of nitrogen and zinc application on key growth parameters, including plant population, plant height, days to 50% tasseling, and days to 75% maturity. The highest plant population and maximum plant height were recorded with 125% RDF combined with foliar-applied zinc sulfate (T9), demonstrating the superiority of foliar application at higher nutrient levels. T9 also showed the earliest tasseling, whereas the earliest maturity was observed under lower nutrient doses (T2 and T1), suggesting a trade-off between growth vigor and crop duration. The findings highlight that integrated application of nitrogen and zinc, particularly through foliar feeding, optimizes maize growth and development, contributing to improved productivity in semi-arid agro-ecosystems.

Keywords: Maize (Zea mays L.), Nitrogen, Zinc sulfate, Foliar application, Recommended dose of fertilizers (RDF), Randomized Block Design (RBD)

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Introduction

Maize is one of the most important food and cash crop. It is a low-priced commodity but a valuable source of all the nutrients. Maize is the third most important cereal crop in the world [1]. Maize (*Zea mays* L.), a major cereal crop native to Central America, is highly productive and nutritionally valuable. It is also known as the queen of cereals, globally occupies the 1st rank in productivity among cereals with 5.82 t/ha, followed by 4.66 t/ha of rice and 3.55 t/ha of wheat during 2019 [2]. Maize, being a C4 plant, is physiologically more efficient with higher per-day productivity. In India, it is the third most important cereal, grown widely across states like Karnataka, Madhya Pradesh, and Rajasthan. Nitrogen (N) is a key limiting nutrient that significantly boosts maize growth and yield, while zinc (Zn) plays a vital role in enzymatic functions and plant development. Both nutrients are essential, but their combined application in maize is not well explored. Hence, a study was undertaken to assess the effects of nitrogen and zinc—via soil and foliar application—on maize growth, yield, and economic returns.

Materials and Methods

A field experiment was carried out during the Kharif season of 2024 at the Research Farm, Vivekananda Global University, Jagatpura, Jaipur, and Rajasthan. The site lies in a semi-arid region with a subtropical climate, and the soil was sandy loam with medium fertility.

The climate during the study was typical for the region, with high temperatures ranging from 35°C to 45°C and minimums around 25°C to 30°C in the early season ideal for maize germination. Rainfall was erratic, although the region normally receives around 600 mm annually during the monsoon (July to October). Frequent dry spells meant actual usable rainfall for the crop was lower than average. Relative humidity increased during the monsoon, ranging between 60% to 85% in the mornings, supporting crop growth but also raising the risk of pest and disease attacks. Sunshine hours averaged 6–9 hours per day, which is favorable for photosynthesis in C4 crops like maize. The experiment was laid out in a Randomized Block Design (RBD) with nine treatments and three replications. Each plot consisted of 6 rows, spaced 45 cm apart, and each plant was spaced 15 cm within a row. The test variety of maize used in the study was DHM 117.

Field operations included land preparation, fertilizer application (120:60:40 N: P_2O_5: K_2O kg/ha), sowing, thinning, irrigation, and harvesting. Zinc was applied either as a soil amendment before sowing or as a foliar spray at critical crop stages. Observations were recorded for growth parameters (plant height, population, tasseling, and maturity), Data were statistically analyzed using ANOVA, and treatment differences were determined based on significance at the 5% probability level, following the procedures of [3].

Result and Discussion

Plant population

The analysis of plant population revealed significant differences among treatments ($F = 8.484$; $P < 0.001$), indicating an impact of nitrogen and zinc application on crop establishment and survival. The highest plant population was recorded in Treatment 9 (22.07 plants/m²), where 125% RDF and foliar application of ZnSO4 were used. This indicates improved germination and early seedling vigor under optimal nutrient conditions. Treatments 6, 7, and 8 also showed high plant population values (~21.33–21.37 plants/m²), signifying the benefit of foliar zinc application even at moderate RDF levels. The lowest plant population was observed in Treatment 1 (15 plants/m²), i.e., the control without any additional zinc or nitrogen, highlighting the critical role of nutrients in enhancing crop stand. These findings align with the results of [4-6], who also reported that optimal application of nitrogen and zinc significantly enhances plant population, germination rate, and early seedling vigor in maize this directly contributes to higher yield potential as shown in **Table 1** and **Figure 1**.

Table 1 Effect of Nitrogen and zinc doses on plant population after germination of maize

Treatments	Recommended doses	30 DAS	60 DAS	At harvest
T1 (Control)	100	87	88	86
T2	50% RDF+ZnSO4 (Recommended)	86	89	85
T3	75% RDF+ZnSO4(Soil application)	90	95	92
T4	100% RDF+ZnSO4(Soil application)	98	99	96
T5	125% RDF+ZnSO4)(Soil application)	97	96	97
T6	50% RDF+ZnSO4(Foliar application)	96	98	99
T7	75% RDF+ZnSO4(Foliar application)	95	94	96
T8	100% RDF+ZnSO4(Foliar application)	98	96	97
T9	125% RDF+ZnSO4(Foliar application)	99	98	98

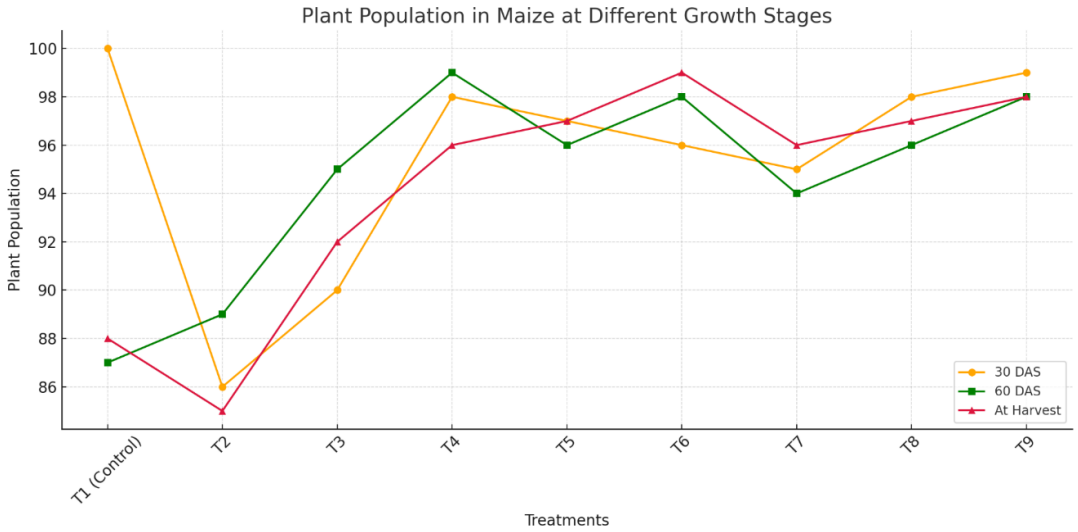

Figure 1 Effect of Treatments on Plant population (plants m²) in *Kharif* Maize

Plant height

The analysis of plant height across different treatment combinations of nitrogen and zinc revealed significant differences ($F = 17.916$; $P < 0.001$), indicating a strong influence of nutrient management on vegetative growth as shown in **Table 2** and **Figure 2**. [4] found that plant height increased significantly with increasing nitrogen levels, with the tallest plants observed at 300 kg N/ha, supporting the influence of nitrogen on vegetative growth. The maximum plant height of 115.88 cm was observed in Treatment 9 (125% RDF + ZnS_4 foliar application), which was significantly superior to the rest of the treatments. This suggests that a higher dose of nutrients, particularly when applied foliar, promotes better shoot elongation and overall growth. These observations are consistent with the findings of [4, 5], who reported that increasing nitrogen levels and the use of foliar-applied nutrients significantly enhance plant height in maize due to improved chlorophyll synthesis, nutrient mobility, and vegetative growth.

Table 2 Effect of Nitrogen and zinc doses on plant height (cm) in maize

Treatments	Recommended doses	30 DAS	60 DAS	At harvest
T_1 (Control)	100	81.65	89.67	85.6
T_2	50% RDF+$ZnSO_4$ (Recommended)	71.52	75.19	72.5
T_3	75% RDF+$ZnSO_4$(Soil application)	113.76	98.6	110.5
T_4	100% RDF+$ZnSO_4$(Soil application)	104.54	110.5	110
T_5	125% RDF+$ZnSO_4$)(Soil application)	115.68	112.6	108.72
T_6	50% RDF+$ZnSO_4$(Foliar application)	94.22	102.4	78.75
T_7	75% RDF+$ZnSO_4$(Foliar application)	86.43	84.6	81.78
T_8	100% RDF+$ZnSO_4$(Foliar application)	85.97	82.5	82.79
T_9	125% RDF+$ZnSO_4$(Foliar application)	127.74	110.71	109.2

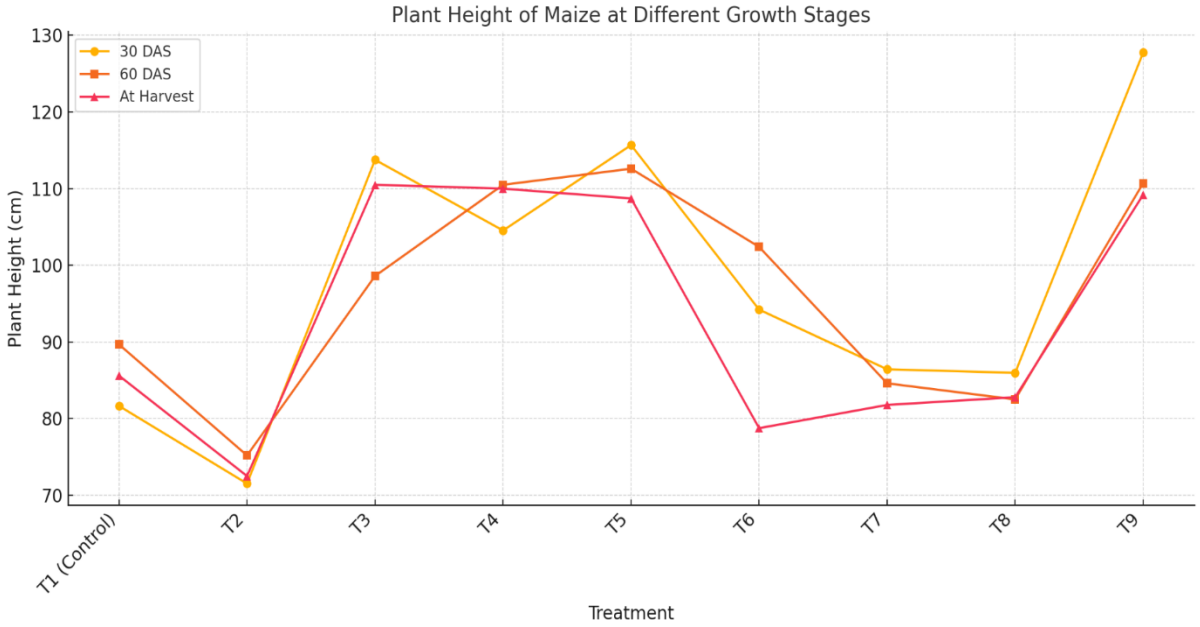

Figure 2 Effect of Nitrogen and zinc doses on plant height (cm) on maize

Days to 50% tasseling

A perusal of data presented in **Table 3** and **Figure 3** revealed that the days to 50% tasseling in maize varied significantly across treatments. Treatment T9 (125% RDF + ZnSO4 foliar application) recorded the earliest tasseling with an average

of 50.67 days, indicating faster crop development under high nutrient availability. Conversely, T5 (125% RDF + ZnSO4 soil application) showed the longest time to tasseling (57.67 days), likely due to delayed vegetative-to-reproductive transition. Treatments T3, T2, and T1 also recorded relatively earlier tasseling (52.67–54.67 days), while T4, T6, and T7 ranged from 55–56.33 days. These results suggest that nutrient dose and mode of zinc application notably influence the physiological maturity and flowering onset in maize.

Table 3 Showing the effect of nitrogen and zinc on days to 50% tasseling

Treatments	Recommended doses	30 DAS	60 DAS	At harvest
T_1 (Control)	100	54	56	54
T_2	50% RDF+$ZnSO_4$ (Recommended)	53	54	54
T_3	75% RDF+$ZnSO_4$(Soil application)	52	53	53
T_4	100% RDF+$ZnSO_4$(Soil application)	57	55	56
T_5	125% RDF+$ZnSO_4$)(Soil application)	58	57	58
T_6	50% RDF+$ZnSO_4$(Foliar application)	57	56	56
T_7	75% RDF+$ZnSO_4$(Foliar application)	56	55	54
T_8	100% RDF+$ZnSO_4$(Foliar application)	54	55	53
T_9	125% RDF+$ZnSO_4$(Foliar application)	51	50	51

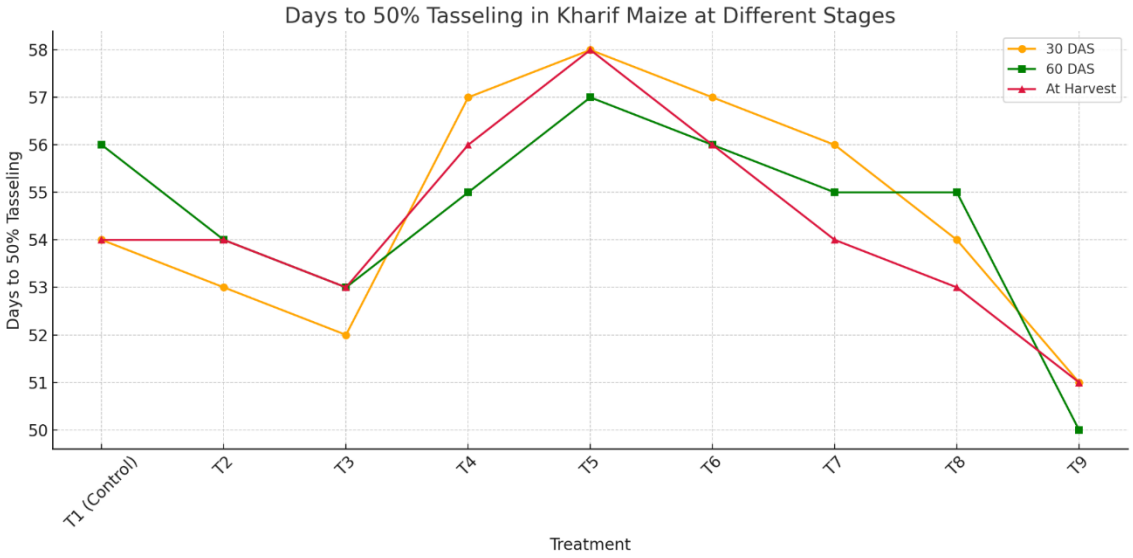

Figure 3 Graphical representation of the effect of nitrogen and zinc on days to 50% tasseling

Days to 75% maturity

The data presented in **Table 4** the data on days to 75% maturity among various maize treatments, showed considerable variation, indicating the influence of nitrogen and zinc application on crop duration. Earliest maturity was recorded in T2 (50% RDF + ZnSO4 recommended) and T1 (Control), which reached 75% maturity in ~97.0 and 98.3 days, respectively. These treatments had relatively lower nutrient availability, which may have led to shorter crop durations [5]. As shown in **Figure 4**, T3 (75% RDF + ZnSO4 soil application) and T9 (125% RDF + ZnSO4 foliar application) also exhibited earlier physiological maturity, with average durations of ~99.0 days, suggesting that even moderate to high input levels can maintain timely maturity depending on application method. The latest maturity was observed in T7 (75% RDF + ZnSO4 foliar) and T8 (100% RDF + ZnSO4 foliar), with average days of 108.3 and 109.7, respectively. This delay may be attributed to enhanced vegetative growth due to improved nutrient availability via foliar feeding, which prolonged the reproductive phase.

Table 4 Showing the effect of nitrogen and zinc on days to 75% maturity

Treatments	Recommended doses	30 DAS	60 DAS	At harvest
T_1 (Control)	100	96	101	98
T_2	50% RDF+$ZnSO_4$ (Recommended)	97	95	99
T_3	75% RDF+$ZnSO_4$(Soil application)	97	101	99
T_4	100% RDF+$ZnSO_4$(Soil application)	100	105	104
T_5	125% RDF+$ZnSO_4$)(Soil application)	109	105	106
T_6	50% RDF+$ZnSO_4$(Foliar application)	98	101	103
T_7	75% RDF+$ZnSO_4$(Foliar application)	110	108	107
T_8	100% RDF+$ZnSO_4$(Foliar application)	110	108	111
T_9	125% RDF+$ZnSO_4$(Foliar application)	98	99	101

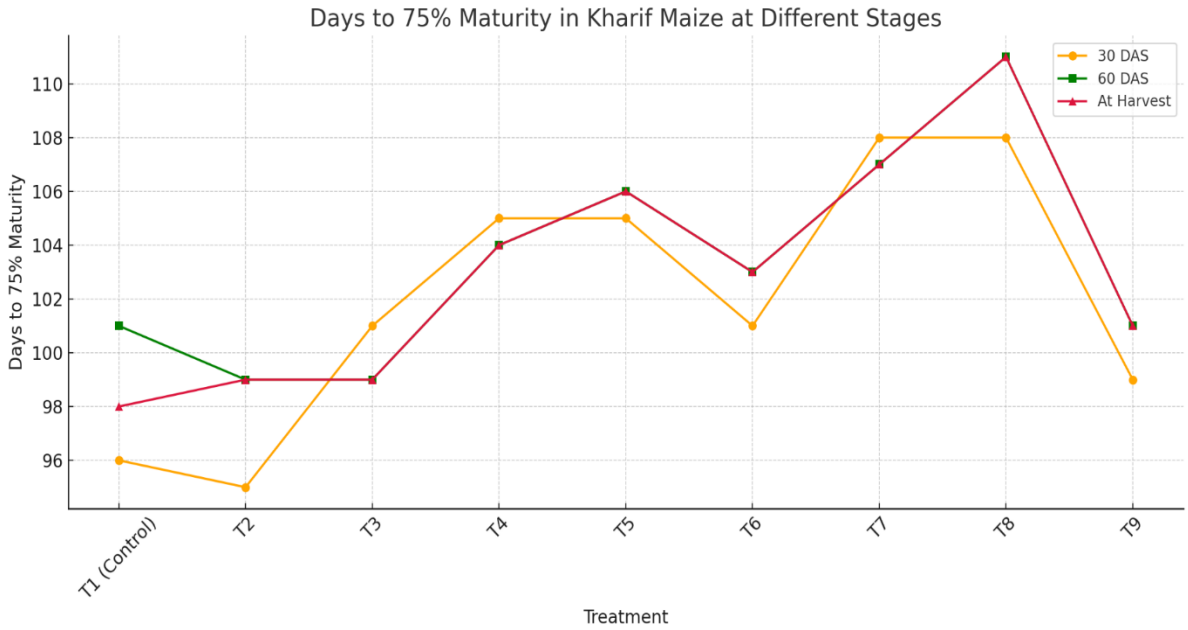

Figure 4 Graphical representation of showing effect of nitrogen and zinc on days to 75% maturity

Conclusion

The study revealed that combined nitrogen and zinc application significantly influenced plant population, plant height, days to 50% tasseling, and days to 75% maturity in maize. The highest plant population and plant height were observed under 125% RDF with foliar-applied $ZnSO_4$ (T9), highlighting the advantage of higher nutrient doses and foliar zinc for better crop establishment and vegetative growth. T9 also showed the earliest tasseling, while the earliest maturity occurred in T2 and T1 with lower nutrient inputs. These findings indicate that optimal nitrogen coupled with zinc application, particularly through foliar methods, enhances maize growth, development, and potentially yield.

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