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GROWTH AND YIELD RESPONSES OF MAIZE (*ZEA MAYS* L.) AS DETERMINED THROUGH NUTRIENT OMISSION TECHNIQUE

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ABSTRACT

A field experiment was conducted at Main Maize Research Station farm, Anand Agricultural University, Godhra, Gujarat during consecutive two *kharif* seasons of 2022 and 2023 to study the effect of nutrient omission on growth and yield of maize (*Zea mays* L.). The experiment was laid out in Randomized Block Design with 3 replications. The fourteen treatments on nutrient omission *viz.*, control (T_1), 160 kg N ha^{-1} (T_2), 20 kg P_2O_5 kg ha^{-1} (T_3), $N_{160}P_{20}$ kg ha^{-1} (RDF) (T_4), $N_{160}P_{20}K_{60}$ kg ha^{-1} (T_5), $N_{160}P_{20}S_{20}$ kg ha^{-1} (T_6), $N_{160}P_{20}Zn_5$ kg ha^{-1} (T_7), $N_{160}P_{20}Fe_{10}$ kg ha^{-1}(T_8), $N_{160}P_{20}K_{60}S_{20}$ kg ha^{-1} (T_9), $N_{160}P_{20}K_{60}Zn_5$kg ha^{-1}(T_{10}), $N_{160}P_{20}K_{60}Fe_{10}$ kg ha^{-1} (T_{11}), $N_{160}P_{20}K_{60}S_{20}Zn_5$ kg ha^{-1} (T_{12}), $N_{160}P_{20}K_{60}S_{20}Fe_{10}$ kg ha^{-1} (T_{13}) and $N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$ kg ha^{-1} (T_{14}) were studied. The maize variety GAWMH 2 was grown for two consecutive *kharif* seasons. The treatment $N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$ kg ha^{-1} (T_{14}) resulted in higher plant height at 60 DAS (203 cm) and at harvest (217 cm), cob length (17.13 cm), cob girth (13.82 cm), seed index (24.67 g), grain yield (5231 kg ha^{-1}) and stover yield (9728 kg ha^{-1}). Further, the treatments with omission of major nutrients, namely T_2:$N_{160}P_0$ (-P) and T_3: N_0P_{20} (-N) were significantly inferior in the performance of all growth and yield attributes of maize as compared to Recommended Dose of Fertilizer (T_4). Similarly the treatments with omission of micronutrients, namely T_{12} (-Fe) and T_{13} (-Zn) were also significantly lower in growth and yield attributes compared to all nutrient treatment T_{14} ($N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$ kg ha^{-1}). The grain and stover yield increased 21.69 and 27.29% in T_{14} treatment as compared to RDF (NP). The lowest grain and stover yield (3316 and 5434 kg ha^{-1}) were recorded in control treatment (T_1). The grain and stover yield increased with the stepwise addition of different nutrients in combination with nitrogen and phosphorus over application of RDF (NP only) with the increasing trend is as followed: NP <NP+Fe <NP+Zn <NP+S <NP+K <NPK+Fe <NPK+Zn <NPK+S <NPKS+Fe <NPKS+Zn <NPKSZn+Fe. The findings indicated that adequate application of the four primary nutrients (nitrogen, phosphorus, potassium and sulphur) along with two micronutrients (zinc and iron) was essential for attaining optimum growth and yield of maize.
***Keywords*:** Growth, maize, nitrogen, omission plot, phosphorous, potassium, yield.

Introduction

Maize (*Zea mays* L.) is an important cereal crop esteemed for its outstanding productivity and adaptability to various environmental conditions and significant role in both and human and animal diets, making it known as the "Queen of Cereals". It is utilized as food and animal feed while also serving as a raw material for various industries, including those producing protein, starch, oil, pharmaceuticals, food sweeteners, alcoholic beverages, cosmetics, biofuel etc. Nutritionally, maize is high in carbohydrates (70%) and contains about 10% of protein and 4% of oil (Jat *et al.*, 2019) and thus, crop has the potential to overcome hunger with ensuring food and nutritional security

(Grote *et al*., 2021). Maize is also an importance not only for its great adaptability to diverse conditions but also for its high responsiveness to improved management practices, especially irrigation and fertilization. In India, maize is placed in third position among the cereals in terms of its importance after rice and wheat (Mahapatra *et al*., 2018 and Suganya *et al*., 2020). Maize is mainly grown in *kharif* season which covers about 80% of the total area of maize cultivation in India (Lalfakzuali and Sharma, 2021). Maize was cultivated on 208.23 million ha in the world, yielding 124 million tonnes at a productivity level of 5.96 t ha^{-1} (FAOSTAT, 2023). In India, area, production and productivity of maize are 11.24 million hectares, 37.67 million tonnes and 3351 kg ha^{-1} respectively (Anonymous, 2023). Maize crop occupied 4.05 lakh hectares, with a production of 90.94 lakh tonnes and the average yield 2244 kg ha^{-1} was in the Gujarat state during 2023-24 (Anonymous, 2023).

Current fertilizer recommendations are largely generalized, focusing mainly on nitrogen, phosphorus and potassium, rather than targeted, site-specific nutrient management (Singh *et al*., 2020). Since maize hybrids respond well to added nutrients, adequate and balanced fertilization is essential to maximize yield.

Evaluating soil fertility is essential for ensuring adequate and balanced fertilization for high crop productivity. A nutrient omission trial helps identify the most limiting nutrients for crop growth. If a particular nutrient is excluded while all others are supplied at appropriate levels and the plants exhibit poor growth, the omitted nutrient is considered a limiting factor. On the other hand, if a nutrient is omitted but plant growth remains healthy, then that nutrient is not a limiting factor for crop production. Keeping the above facts in view, a field experiment was conducted to study the effects of i.e., effect of major and micro nutrients on growth and yield of maize using nutrient omission plot technique (NOPT).

Materials and Methods

The field experiment was carried out at the Main Maize Research Station, Anand Agricultural University, Godhra, Gujarat (INDIA) during *kharif* 2022 and 2023 with maize (var. GAWMH 2). The experimental field is situated at an elevation of 157 meters above mean sea 22° 47'N latitude, 73° 39'E longitude level. During the crop period of the experimentation, the average maximum temperature was ranged 21.5 and 28.5°C. The crop received a rainfall of 579 mm. The soil of experimental field was loamy sand in texture with pH 7.67, organic carbon 0.43%, soil available N, P and K status 208, 46 and 235 kg ha^{-1}, and available S, Zn and Fe status 8.76, 0.88 and 5.90 mg kg^{-1}, respectively. The experiment was laid out in randomized block design with three replications. The treatments were T_1: Control, T_2:$N_{160}P_0K_0S_0Zn_0Fe_0$, T_3:$N_0P_{20}K_0S_0Zn_0Fe_0$, T_4:$N_{160}P_{20}K_0S_0Zn_0Fe_0$, T_5:$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$, T_6:$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$, T_7:$N_{160}P_{20}K_0S_0Zn_5Fe_0$, T_8:$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$, T_9:$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$, T_{10}:$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$, T_{11}:$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$, T_{12}:$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$, T_{13}:$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$, T_{14}:$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$. Calculated amount of N, P, K, S, Zn and Fe were supplied through urea, DAP/ Orthophosphoric acid, muriate of potash, bentonite, zinc chloride and iron chloride, respectively. Recommended dose of nitrogen was applied through urea in four equal splits (one fourth at basal, one fourth at 4^{th} leaf stage, one fourth at 8^{th} leaf stage and one fourth at tasseling (flowering stage.). The whole quantity of recommended dose of phosphorus, potassium, sulphur, zinc and iron were applied as basal at time of sowing. The net plot size was 5 m × 3.6 m. The seeds of maize were sown in a row x plant spacing of 60cm x 20cm.To maintain the planting geometry; thinning was done at 15 DAS. The weed growth was suppressed by hand weeding as and when required. The data on cob length, cob girth, seed index, grain and stover yield were recorded at harvest. The growth parameters (plant height) was measured periodically and analysed statistically.

Results and Discussion

Effect of nutrient omission on growth parameters

Plant population

The nutrient omission had no significant effect on plant population (Table 1) at both the stage.

Plant height of maize

The plant height recorded at 30 DAS showed no significant variation due to nutrient omission treatments. However, plant height at 60 DAS showed a significant effect across treatments in both years and in the pooled data (Table 2). Among all treatments, the higher plant height (203.33, 201.67 and 202.50cm) at 60 DAS was observed with the application of T_{14} treatment during both the years and pooled result, respectively, In contrast, the lowest plant height (157.33, 147.67 and 152.50cm) was recorded in the control treatment (T_1) treatment during both the years and in pooled analysis. Omission of nitrogen (T_3) and phosphorus (T_2) resulted in comparatively lower plant heights (166.50 cm and 160.17 cm, respectively) in pooled analysis, which is highlighting the critical role of nitrogen in vegetative growth. The application of all nutrients likely enhanced cell division and metabolic activities within the plant system, leading to improved plant growth. Similar findings were reported by Sahu *et al.* (2017), Sushma and Sao (2018) and Lalfakzuali and Sharma (2021). Maximum plant height at harvest was recorded in T_{14} treatment with values of 218.00, 216.67, 217.33 cm in 2023, 2022 and in pooled result, respectively (Table 4.2). Similarly, Atnafu *et al.* (2021) and Kumar *et al.* (2022) found that the treatment receiving dose of nutrients ($T_{1:}$ $N_{100}P_{100}K_{100}$) resulted in production of taller plants of maize, which signifies the nitrogen plays a vital role in node elongation and growth of meristematic part in plants.

Number of cobs per net plot and Number of cobs per plant

The findings indicate that nutrient omission had no significant effect on number of maize cobs per net plot and number of cobs per plant (Table 4)

Effect of nutrient omission on yield parameters

Cob length

The result reveal (Table 4) that application of treatment T_{14} gave significant higher cob length during both the years. It was statistically at par with treatments T_{12}, T_{13}, T_9 and $T_{10.}$ The cob length increased by 20.14 and 44.96% in the all-nutrient-applied treatment (T_{14}) over RDF (T_4) and the control treatment (T_1), respectively. The highest cob length development may be attributed to enhanced photosynthetic activity resulting from an adequate supply of nitrogen and phosphorus. This finding aligns with the results of Ahmad *et al.* (2018) and Kumar *et al.* (2022), who reported a significant increase in cob length with higher applications of nitrogen and phosphorus. Whereas, lower cob length observed with the control treatment (T_1). The cob length reduction observed in the control treatment compared to treatment T_{14} was 31.07%. The cob length reduction due to omission of nitrogen and phosphorus were 9.96 and 3.19% as compared to RDF (T_4) and 25.05 and 19.42% as compared with treatment T_{14}. A similar finding was reported by Joshi *et al.* (2016), Getinet *et al.* (2022) and Ray *et al.* (2020), who found that lower cob lengths were obtained in the control treatment (T_1) and nitrogen omission treatments.

Cob girth

Data presented in (Table 4) revealed that application of T_{14} treatment gave significant higher cob girth during both the year and in pooled result, which was statistically at par with the T_{12}, T_{13}. The cob length increased by 17.37 and 28.93% in the all-nutrient-applied treatment (T_{14}) over RDF (T_4) and the control treatment (T_1), respectively. The availability of essential nutrients from NPKS fertilizers promotes improved cellular activities, increased cell division, enlargement and luxuriant growth. This observation was in line with the results of Baharvand *et al.* (2014), who reported that the ear diameter of maize increased with higher application rates of chemical fertilizers. Getinet *et al.* (2022) was also found that higher ear diameter was recorded with NPKSZn treatment. Whereas, lower cob length observed with the control treatment (T_1) during both the years and in pooled results, however it was at par with T_3 (N omission) and T_2 (P omission) treatments in pooled results. The cob girth reduction due to omission of nitrogen and phosphorus were 4.77 and 2.14% as compared to RDF (T_4) and 18.88 and 16.64% as compared with treatment T_{14}. The cob girth reduction observed in the control treatment compared to treatment T_{14} was 22.44%. The similar findings were reported by Ahmad *et al.* (2018), Ray *et al.* (2020) Getinet *et al.* (2022) and Kumar *et al.* (2022), who observed that ear diameter was lower in the control treatment (T_1) and nitrogen omission treatments.

Shelling percentage and seed index

The findings indicated that nutrient omission had no significant effect on shelling percentage of maize. Application of treatment T_{14} resulted significantly higher seed index (Table 5) during both the year and in pooled result, However, it was at par with T_{12} and T_{13} treatments. These results are in line with the study reported by Hargilas (2019) and Gangaiah (2019). The highest test weight was recorded in the SSNM treatment, followed by SSNM-K, SSNM-P and national-RDF. However, it was lower in the control treatment, with the lowest test weight observed in the nitrogen omission treatment. Lower seed index was reported by control treatment (T_1).

Effect of nutrient omission on yield

Grain yield of maize

Among the different treatments studied, significantly higher grain yield was observed under application of T_{14} during both the years as well as in pooled results (Table 6). However, it was statistically similar with treatments T_{12}, T_{13}, T_9, T_{10}, T_{11} and T_5. Treatment T_{14} showed increases of grain yield 57.72% compared to the control treatment (T_1) and 21.69% compared to the RDF.

Significantly lower grain yield recorded with T_1 treatment it was at par with T_3 treatment. The lowest yield from the control treatment (T_1) plot indicates that the soil was unable to supply a sufficient amount of nutrients while the lower yield of N-omitted plots indicates that application cannot be substituted by any other nutrient and has the highest contribution to maize yield. The yield reduction in nitrogen omitted plot was 29.75% over all nutrients given treatment (T_{14}). This confirms that N is the most limiting nutrient for maize production. It could be due to the effect of nitrogen on chlorophyll formation, photosynthesis and assimilated production because N stress reduces crop photosynthesis by reducing leaf area development and leaf photosynthesis rate by accelerating leaf senescence thereby reducing the final yield Diallo *et al.* (1997).

The per cent grain yield increased with the stepwise addition of different nutrients in combination with nitrogen and Phosphorus over application of RDF (NP only) with the increasing trend are as followed: NP < NP+Fe (2.06%) < NP+Zn (2.50%) < NP+S (7.12%) < NP+K (9.65%) < NPK+Fe (11.36%) < NPK+ Zn (12.92%) < NPK+S (14.50%) < NPKS+Fe (15.29%) < NPKS+Zn (18.76%) < NPKSZn+Fe (21.69%).

The maximum grain yield reduction were found in the control treatment (T_1), nitrogen omission and phosphorus omission treatments by 22.85, 14.52 and 6.20%, respectively, compared to the recommended dose of fertilizers (RDF). Omission of N caused greater reduction in grain yield, followed by P omission, when compared with 100% RDF. The second most yield-limiting nutrient followed by nitrogen was phosphorus. Phosphorus omitted treatments gave lower yield as compared to other treatments except control treatment (T_1) and N-omitted plots, its mean that P deficiency also limits maize yield. Its deficiency is a common crop growth and yield-limiting factor in unfertilized soils and affects leaf growth dynamics in maize (Ibrikci *et al.*, 2005; Rehman *et al.*, 2011). The present result revealed that P-omitted plots showed reduced maize growth characters compared to NPKSZnFe treated plots and 22.91% yield reduction was indicating that the soil might be unable to supply sufficient amount of P that is required for proper growth and development of plants.

Ghosh *et al.* (2021) observed that application of major mineral fertilizer had a noticeable increase in grain yield over control treatment (T_1) or nutrient omitted plots, this might be due to the relatively higher response of maize to N and its role in protein formation, a constituent of chlorophyll and involvement in carbohydrate utilization which resulted in higher grain yield. The similar findings were reported by Prusty *et al.* (2020), Getinet *et al.* (2022) and Afrida and Tampubolon (2022).

Stover yield of maize

The result revealed that the stover yield (Table. 6) significantly increased under treatment T_{14} and it was statistically at par with the treatments T_{12}, T_{13}, T_9 and T_{10} while, significant lower stover yield of maize was observed with control treatment (T_1). Application of T_{14} treatment increased stover yield by 79.01 and 27.29% over control treatment (T_1) and RDF based on pooled result, respectively. While the stover yield was reduced by 14.93% in T_3 (nitrogen omission) treatment and 7.68% in T_2 (phosphorus omission) treatment compared with NP (RDF) treatment T_4 based on pooled data. The per cent stover yield increased with the stepwise addition of different nutrients in combination with nitrogen and Phosphorus over application of RDF (NP only) with the increasing trend are as followed: NP <NP+Fe (3.79%) <NP+Zn (4.06%) < NP+S (5.73%) < NP+K (8.85%) <NPK+Fe (12.10%) <NPK+Zn (14.99%) < NPK+S (16.24%) <NPKS+Fe (19.13%) <NPKS+Zn (21.62%) <NPKSZn+Fe (27.29%).

The omission of N (PK fertilizer regime) resulted in lower crop growth and relative growth rates and lower biomass production and grain yields than other treatments. This could have been due to the crucial role of N during growth and reproduction that was impaired under low supply – N is heavily involved in vital metabolic, biochemical and physiological processes right from germination to maturity, Andrade *et al.*, (2003), Sangoi *et al.* (2008) and Khan *et al.* (2013). The omission of P (application NK fertilizer regime) nutrient was also observed to cause a reduction in maize performance in this study. This could have been due to the impaired root development and energy production under inadequate phosphorus supply, Uchida (2000) and Fageria, *et al.* (2008). Similar results have also been reported by Suriya *et al.* (2000) and Segda *et al.* (2005). Sahu *et al.* (2017) reported a decrease in straw yield of rice with omission of N, P, K and S. Similar result was reported by Nunes *et al.* (1996) and Acharya *et al.* (2020) that biomass production increased with increasing nitrogen level.

Table 1: Effect of nutrient omission on plant population

Treatment No.	Treatments	Plant population/net plot					
		Initial			At harvest		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	90	90	90	86	86	86
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	86	87	86	81	83	82
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	93	84	89	89	81	85
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	88	95	92	84	90	87
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	86	85	86	81	81	81
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	94	88	91	89	83	86
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	90	85	87	86	81	83
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	89	88	89	85	82	84
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	85	87	86	80	81	81
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	87	88	88	83	83	83
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	93	90	91	88	85	87
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	89	88	89	85	81	83
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	89	97	93	85	89	87
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	90	88	89	86	84	85
T	S. Em±	3.4	5.0	3.0	2.4	4.1	2.4
	C. D. at 5 %	NS	NS	NS	NS	NS	NS
Y	S. Em±	-	-	1.4	-	-	1.1
	C. D. at 5 %	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	4.3	-	-	3.4
	C. D. at 5 %	-	-	NS	-	-	NS
C.V.%		6.62	9.88	8.40	4.92	8.49	6.91

Table 2: Effect of nutrient omission on plant height at 30 DAS, 60 DAS and at harvest of maize

Treatment No.	Treatments	Plant height (cm)								
		30 DAS			60 DAS			at harvest		
		2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	Control	69.33	72.33	70.83	157	148	153	172	162	167
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	78.67	80.67	79.67	171	162	167	185	176	181
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	77.33	78.00	77.67	165	155	160	180	169	175
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	80.00	83.33	81.67	171	167	169	185	181	183
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	82.33	85.00	83.67	186	181	183	201	195	198
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	82.00	84.33	83.17	185	178	182	201	189	195
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	81.67	84.00	82.83	183	176	179	200	189	195
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	81.33	83.33	82.33	177	172	175	191	186	189
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	84.67	85.67	85.17	198	195	197	213	209	211
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	83.00	85.67	84.33	195	194	194	209	209	209
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	82.67	85.67	84.17	186	182	184	204	197	201
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	86.33	86.00	86.17	200	201	201	215	214	215
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	85.33	85.67	85.50	199	198	199	213	211	212
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	91.00	91.33	91.17	203	202	203	218	217	217
T	S. Em±	4.85	4.66	3.36	7	8	5	6	10	6
	C. D. at 5 %	NS	NS	NS	20	25	15	18	30	17
Y	S. Em±	-	-	1.58	-	-	2.56	-	-	2.85
	C. D. at 5 %	-	-	NS	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	4.75	-	-	7.67	-	-	8.55
	C. D. at 5 %	-	-	NS	-	-	NS	-	-	NS
C.V.%		10.26	9.64	9.95	6.36	8.20	7.31	5.31	9.36	7.55

Table 3: Effect of nutrient omission on number of cobs per net plot

Treatment No.	Treatments	Number of cobs net plot			Number of cobs per plant		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	93	92	93	1.08	1.07	1.08
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	89	92	91	1.11	1.11	1.11
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	97	91	94	1.10	1.12	1.11
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	93	99	96	1.11	1.10	1.11
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	90	92	91	1.11	1.14	1.13
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	99	94	97	1.11	1.14	1.12
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	95	91	93	1.11	1.13	1.12
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	94	91	92	1.10	1.11	1.10
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	90	92	91	1.12	1.14	1.13
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	92	95	94	1.11	1.14	1.12
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	98	94	96	1.10	1.11	1.10
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	94	92	93	1.10	1.14	1.12
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	93	101	97	1.10	1.13	1.11
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	96	95	96	1.12	1.14	1.13
T	S. Em±	3	4	2	0.02	0.02	0.01
	C. D. at 5 %	NS	NS	NS	NS	NS	NS
Y	S. Em±	-	-	1	-	-	0.01
	C. D. at 5 %	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	3	-	-	0.02
	C. D. at 5 %	-	-	NS	-	-	NS
C.V.%		5.26	7.46	6.45	2.74	3.48	3.14

Table 4: Effect of nutrient omission on cob length and cob girth

Treatment No.	Treatments	Cob length (cm)			Cob girth (cm)		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	13.57	10.07	11.82	10.70	10.73	10.72
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	14.18	13.43	13.80	11.30	11.74	11.52
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	13.73	11.94	12.84	10.97	11.46	11.21
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	14.58	13.93	14.26	11.63	11.91	11.77
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	15.72	15.17	15.45	12.23	12.63	12.43
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	14.98	15.06	15.02	12.03	12.60	12.32
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	14.88	14.73	14.80	11.90	12.47	12.18
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	14.63	14.62	14.63	11.80	12.23	12.02
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	16.85	15.77	16.31	12.43	12.83	12.63
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	16.32	15.56	15.94	12.39	12.80	12.60
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	15.97	15.21	15.59	12.33	12.73	12.53
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	17.18	16.09	16.64	12.77	13.56	13.16
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	16.98	15.93	16.46	12.63	13.13	12.88
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	17.53	16.73	17.13	13.70	13.93	13.82
T	S. Em±	0.55	0.68	0.44	0.51	0.46	0.34
	C. D. at 5 %	1.59	1.99	1.24	1.48	1.35	0.98
Y	S. Em±	-	-	0.21	-	-	0.16
	C. D. at 5 %	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	0.62	-	-	0.49
	C. D. at 5 %	-	-	NS	-	-	NS
C.V.%		6.10	8.13	7.13	7.31	6.42	6.87

Table. 5: Effect of nutrient omission on shelling percentage and seed index

Treatment No.	Treatments	Shelling (%)			Seed index (g)		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	71.63	74.71	73.17	20.13	18.93	19.53
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	72.81	77.40	75.11	21.50	20.13	20.82
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	74.96	75.59	75.28	20.73	19.37	20.05
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	75.15	77.20	76.17	21.63	20.53	21.08
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	74.77	76.17	75.47	21.90	21.53	21.72
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	73.85	78.17	76.01	21.87	21.47	21.67
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	73.34	75.46	74.40	21.80	21.30	21.55
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	76.23	77.57	76.90	21.57	20.93	21.25
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	74.56	74.03	74.29	23.63	22.17	22.90
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	75.20	74.87	75.03	22.80	21.80	22.30
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	74.49	75.71	75.10	22.77	21.70	22.23
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	75.99	74.80	75.39	24.73	22.90	23.82
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	74.28	74.56	74.42	23.87	22.47	23.17
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	75.75	75.91	75.83	25.23	24.10	24.67
T	S. Em±	2.72	2.29	1.78	0.86	0.88	0.61
	C. D. at 5 %	NS	NS	NS	2.50	2.56	1.74
Y	S. Em±	-	-	0.84	-	-	0.29
	C. D. at 5 %	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	2.51	-	-	0.87
	C. D. at 5 %	-	-	NS	-	-	NS
C.V.%		6.33	5.22	5.79	6.63	7.13	6.87

Table 6: Effect of nutrient omission on grain yield of maize

Treatment No.	Treatments	Grain yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	3350	3282	3316	5707	5161	5434
T_2	$N_{160}P_0K_0S_0Zn_0Fe_0$	4049	4015	4032	7387	6723	7055
T_3	$N_0P_{20}K_0S_0Zn_0Fe_0$	3700	3649	3675	6787	6215	6501
T_4	$N_{160}P_{20}K_0S_0Zn_0Fe_0$	4412	4185	4299	7933	7351	7642
T_5	$N_{160}P_{20}K_{60}S_0Zn_0Fe_0$	4778	4649	4714	8566	8070	8318
T_6	$N_{160}P_{20}K_0S_{20}Zn_0Fe_0$	4668	4542	4605	8338	7821	8080
T_7	$N_{160}P_{20}K_0S_0Zn_5Fe_0$	4528	4283	4406	8278	7626	7952
T_8	$N_{160}P_{20}K_0S_0Zn_0Fe_{10}$	4502	4272	4387	8328	7535	7932
T_9	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_0$	4998	4846	4922	9248	8519	8883
T_{10}	$N_{160}P_{20}K_{60}S_0Zn_5Fe_0$	4977	4731	4854	9183	8391	8787
T_{11}	$N_{160}P_{20}K_{60}S_0Zn_0Fe_{10}$	4906	4668	4787	8879	8254	8566
T_{12}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_0$	5212	4998	5105	9615	8974	9295
T_{13}	$N_{160}P_{20}K_{60}S_{20}Zn_0Fe_{10}$	5016	4896	4956	9396	8812	9104
T_{14}	$N_{160}P_{20}K_{60}S_{20}Zn_5Fe_{10}$	5307	5155	5231	9945	9510	9728
T	S. Em±	267	297	200	544	473	360
	C. D. at 5 %	775	864	567	1580	1375	1022
Y	S. Em±	-	-	94	-	-	170
	C. D. at 5 %	-	-	NS	-	-	NS
Y X T	S. Em±	-	-	282	-	-	510
	C. D. at 5 %	-	-	NS	-	-	NS
	C.V.%	10.04	11.60	10.82	11.21	10.52	10.91

Conclusion

The findings indicated that application of T_{14} significantly enhanced plant height at 60 DAS and at harvest. The T_{14} treatment also produced a significantly higher cob weight, cob length and cob girth and seed index, higher grain and stover yield. The yield increased in treatment T_{14} over control and RDF was 57.72 and 21.69%. Significantly lower grain yield recorded with T_1 treatment. The maximum grain yield reduction were found in the control, nitrogen omission and phosphorus omission treatments by 22.85, 14.52 and 6.20%, respectively, compared to the recommended dose of fertilizers (RDF). Omission of N caused greater reduction in grain yield, followed by P omission, when compared with 100% RDF. The increased in treatment T_{14} stover yield by 79.01 and 27.29 % as compared to the control and RDF, respectively, The stover yield decreased by 28.89, 14.93 and 7.68% in the control, nitrogen omission and phosphorus omission treatments, respectively, compared to the recommended dose of fertilizers (RDF-NP). The grain and stover yield increased with the stepwise addition of different nutrients in combination with nitrogen and phosphorus over application of RDF (NP only) with the increasing trend is as followed: NP < NP+Fe < NP+Zn < NP+S < NP+K < NPK+Fe < NPK+Zn < NPK+S < NPKS+Fe < NPKS+Zn < NPKSZn+Fe.

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