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Effect of vermicompost and zinc application on yield attributes of kharif maize (*Zea Mays* L.)

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ABSTRACT

A two-year field experiment was conducted at the Students' Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, during the kharif seasons of 2024 and 2025 to evaluate the effect of vermicompost and zinc application on the yield attributes of hybrid maize (cv. Sweet Pearl). The experiment was laid out in a split-plot design with three replications. The main plots comprised three nutrient management treatments, viz. 100% RDNPK (M1), 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ (M2) and 50% RDNPK + vermicompost @ 6.0 t ha⁻¹ (M3), while the sub plots comprised five zinc treatments, viz. control (Z1), basal ZnSO₄ @ 25 kg ha⁻¹ (Z2), foliar nano Zinc @ 0.4% at 30 DAS (Z3), foliar ZnSO₄ @ 0.5% at 30 DAS (Z4) and foliar ZnSO₄ @ 0.5% at 30 and 45 DAS (Z5). On pooled basis, 50% RDNPK + vermicompost @ 6.0 t ha⁻¹ recorded the highest number of grains row-1 (35.18), cob weight (290.11 g) and grain weight cob-1 (139.71 g), which were 16.7, 8.6 and 10.3% higher, respectively, than 100% RDNPK, whereas the number of grain rows cob-1 was not significantly affected. Among the zinc treatments, basal application of ZnSO₄ @ 25 kg ha⁻¹ recorded the highest values for all four attributes (14.29 grain rows cob-1, 36.18 grains row-1, 288.65 g cob weight and 138.53 g grain weight cob-1) and was followed by two foliar sprays of 0.5% ZnSO₄; all zinc treatments were significantly superior to the control. The interaction of nutrient management and zinc application was non-significant for all attributes. Partial substitution of RDNPK with vermicompost @ 6.0 t ha⁻¹ together with zinc application, preferably as basal ZnSO₄ @ 25 kg ha⁻¹, therefore improved the yield attributes of hybrid maize.

Keywords: Maize, Vermicompost, Zinc sulphate, Nano zinc, Foliar spray, Yield attributes

1. Introduction

Maize (*Zea mays* L.), a monoecious cereal of the family Poaceae, is the third most important cereal crop of the world after wheat and rice (Awika, 2011) [1]. Because of its C₄ photosynthetic pathway and high genetic yield potential it is often called the "Queen of cereals" (Stalin *et al.*, 2016) [2] and it serves as food, animal feed and an industrial raw material. Maize is a heavy feeder of nutrients, and the continuous use of chemical fertilizers alone, without return of organic matter, can lead to declining soil organic carbon, nutrient imbalance and stagnating productivity in intensive maize-based systems. Long-term studies have shown that intensive maize-based cropping systems are showing signs of fatigue, proved by stagnating or declining crop productivity and soil quality. The implication of organic manures (OM) in crop production not only improves soil physiochemical properties but also increases crop productivity and is eco-friendly, cheap, readily available and a potential source of nutrients.

Integrated nutrient management, in which part of the chemical fertilizer is substituted by organic sources, is a sustainable way to sustain productivity while improving soil health. Vermicompost, produced by the action of earthworms on organic wastes, is a stabilised, finely divided material that supplies nutrients in plant-available forms, stimulates microbial activity and contains plant growth-promoting substances; its application has been shown to improve plant growth and yield of several crops (Atiyeh *et al.*, 2000; Arancon *et al.*, 2004) [4, 3]. Its use together with a reduced dose of chemical fertilizer is therefore attractive for maize.

Zinc is an essential micronutrient that activates a large number of enzymes and takes part in carbohydrate metabolism, protein synthesis and pollen formation (Kathula *et al.*, 2026) [5]. Zinc deficiency is the most widespread micronutrient disorder of cereals worldwide and maize is considered highly sensitive to it (Alloway, 2008; Cakmak, 2008) [6, 7]. Zinc can be supplied through the soil or as foliar sprays, and the efficiency of these methods differs with crop, soil and stage of application (Wasaya *et al.*, 2017; Rehman *et al.*, 2018; Cakmak *et al.*, 2018) [9, 10, 8]. Nano-formulations of zinc have also been proposed as an alternative to conventional ZnSO₄, but information on their performance relative to soil and foliar ZnSO₄ in maize is limited.

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The yield attributes, namely grain rows per cob, grains per row, cob weight and grain weight per cob, are the direct components through which nutrient management is expressed in final grain yield. The present investigation was therefore undertaken to study the effect of vermicompost combined with a reduced dose of RDNPK, and of different methods of zinc application, on the yield attributes of hybrid maize under the conditions of the Central Plain Zone of Uttar Pradesh.

2. Materials and Methods

2.1 Experimental site, soil and climate

The present investigated has been conducted at the Students’ Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, during the *kharif* seasons of 2024 and 2025. The Soil is clay loam in texture, near neutral (pH 7.4), medium in organic carbon (0.34%), with 197.45 kg ha⁻¹ available N, 13.75 kg ha⁻¹ available P and 156.2 kg ha⁻¹ available K. The experiment was laid out in a split-plot design with three replications. The main plots consisted of three nutrient management treatments: 100% RDNPK (M₁); 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ (M₂); and 50% RDNPK + vermicompost @ 6.0 t ha⁻¹ (M₃). The sub plots consisted of five zinc treatments: control without zinc (Z₁); basal application of ZnSO₄ @ 25 kg ha⁻¹ (Z₂); foliar spray of nano zinc @ 0.4% at 30 days after sowing (DAS) (Z₃); foliar spray of ZnSO₄ @ 0.5% at 30 DAS (Z₄); and foliar spray of ZnSO₄ @ 0.5% at 30 and 45 DAS (Z₅). Thus, there were 15 treatment combinations. The hybrid maize cultivar Sweet Pearl was sown at a spacing of 50 × 20 cm. The recommended dose of fertilizer (RDNPK) was 120:60:40 kg N, P₂O₅ and K₂O ha⁻¹; it was applied in full in M₁ and at half the rate (60:30:20 kg ha⁻¹) in M₂ and M₃. Vermicompost is applied in the soil 20 days before sowing of maize. Basal ZnSO₄ was applied at sowing, and foliar sprays were made with 0.5% at the different stages indicated for each treatment. The observation recorded number of grains row⁻¹, number of grains per rows, cob weight, grain weight

Statistical analysis

The data for each year and the pooled data of the two years were subjected to analysis of variance appropriate for a split-plot design (Gomez *et al.*, 1984) [11]. Treatment means were compared using the critical difference (CD) at the 5% level of probability, and non-significant differences are denoted as NS. Standard errors of the mean (SE_m±) are given in the tables.

3. Results and Discussion

The yield attributes of both years followed the same trend, and the values of 2025 were marginally higher than those of 2024 for every treatment. The results are therefore discussed on the basis of pooled data.

3.1 Grain rows cob-1

The data on the number of grain rows cob⁻¹ are presented in Table 1 and Fig. 1.

Effect of nutrient management. Nutrient management did not significantly influence the number of grain rows cob⁻¹ in either year or on pooled basis. The pooled values were 13.30, 13.79 and 14.03 under 100% RDNPK, 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ and 50% RDNPK + vermicompost @ 6.0 t ha⁻¹, respectively; the numerically highest value under M₃ was only 5.5% above M₁. The number of kernel rows is largely a genetically determined character that is fixed early during ear differentiation, which may explain why it responded little to the source of nutrients, so that replacing half of the RDNPK with vermicompost neither increased nor reduced it.

Effect of zinc application. Zinc application significantly increased the number of grain rows cob⁻¹ (CD 0.53 pooled). The lowest value was recorded in the control (12.12), and all zinc treatments were significantly superior to it: basal ZnSO₄ (14.29), foliar ZnSO₄ at 30 and

45 DAS (14.19), foliar ZnSO₄ at 30 DAS (14.05) and foliar nano Zn (13.89), an increase of 14.6–17.9% over the control. The four zinc treatments were at par with one another. The positive response may be due to the role of zinc in activating enzymes of carbohydrate metabolism and protein synthesis and in pollen formation, which favours ear development (Kathula *et al.*, 2026) [5]. The interaction (A × B) was non-significant.

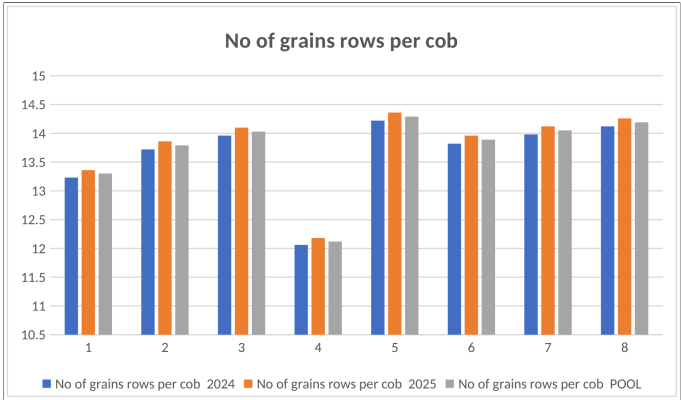


Figure 1. Effect of (A) nutrient management and (B) zinc application on number of grain rows cob⁻¹ of maize (pooled data of 2024 and 2025). Error bars show SE_m ±; VC = vermicompost.

3.2 Grains row-1

The data on the number of grains row⁻¹ are presented in Table 2 and Fig. 2.

Effect of nutrient management. Nutrient management had a significant effect on the number of grains row⁻¹. On pooled basis, 50% RDNPK + vermicompost @ 6.0 t ha⁻¹ produced the highest number of grains row⁻¹ (35.18), which was significantly higher than 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ (32.56) and 100% RDNPK (30.15); the increase over 100% RDNPK was 16.7%. Vermicompost releases nutrients slowly and in available forms, improves soil structure and water holding capacity and supplies growth-promoting substances (Atiyeh *et al.*, 2000 and Bhatt *et al.*, 2013) [4]. A more continuous supply of nutrients through silking and grain set may have reduced the number of unfilled kernel positions on the ear, giving more grains per row even though half of the chemical fertilizer had been replaced.

Table 1. Effect of nutrient management and zinc application on number of grain rows cob⁻¹ of maize

Treatment	2024	2025	Pooled
A. Nutrient management (main plot)			
100% RDNPK	13.23	13.36	13.30
50% RDNPK + vermicompost @ 3.0 t ha ⁻¹	13.72	13.86	13.79
50% RDNPK + vermicompost @ 6.0 t ha ⁻¹	13.96	14.10	14.03
SE _m ±	0.16	0.17	0.17
CD (p = 0.05)	NS	NS	NS
B. Zinc application (sub plot)			
Control	12.06	12.18	12.12
Basal ZnSO ₄ @ 25 kg ha ⁻¹	14.22	14.36	14.29
Foliar nano Zn 0.4% (30 DAS)	13.82	13.96	13.89
Foliar ZnSO ₄ 0.5% (30 DAS)	13.98	14.12	14.05
Foliar ZnSO ₄ 0.5% (30 & 45 DAS)	14.12	14.26	14.19
SE _m ±	0.18	0.18	0.18
CD (p = 0.05)	0.53	0.54	0.53

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Treatment	2024	2025	Pooled
Interaction (A × B)			
$SE_m \pm$	0.32	0.32	0.32
CD ($p = 0.05$)	NS	NS	NS

RDNPK = recommended dose of N, P and K (120:60:40 kg ha⁻¹); NS = non-significant.

Effect of zinc application. Zinc application significantly increased the number of grains row⁻¹ (CD 1.31 pooled). Basal application of ZnSO₄ @ 25 kg ha⁻¹ recorded the highest value (36.18), significantly higher than all other treatments, followed by foliar ZnSO₄ at 30 and 45 DAS (34.51) and at 30 DAS (33.50), which were at par with each other, and foliar nano Zn (32.16). The control recorded the lowest number (26.80); zinc application increased grains row⁻¹ by 20.0–35.0% over the control. Zinc is involved in pollen viability and in the metabolic processes that govern kernel set, and a better zinc supply therefore results in more fertilised, filled kernel positions (Kathula *et al.*, 2026) [5]. The advantage of the basal application may be due to the soil supplying zinc to the crop throughout the growth period, whereas foliar sprays supply it only at specific stages (Rehman *et al.*, 2018) [10]. The interaction was non-significant.

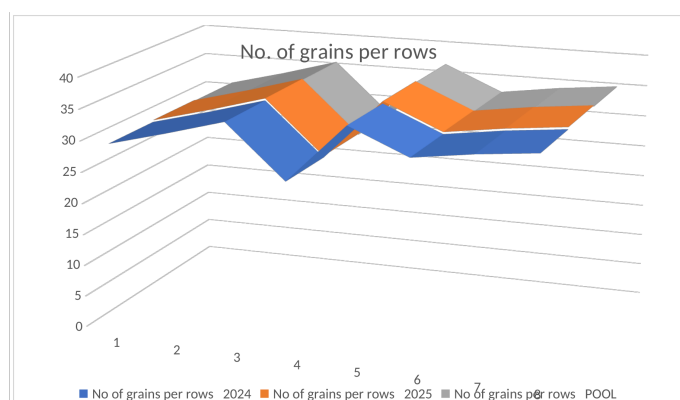


Figure 2. Effect of (A) nutrient management and (B) zinc application on number of grains row⁻¹ of maize (pooled data of 2024 and 2025). Error bars show $SE_m \pm$; VC = vermicompost.

3.3 Cob weight

The data on cob weight are presented in Table 3 and Fig. 3.

Effect of nutrient management. Cob weight was significantly influenced by nutrient management. The highest pooled cob weight (290.11 g) was recorded under 50% RDNPK + vermicompost @ 6.0 t ha⁻¹, which was significantly higher than 100% RDNPK (267.16 g) by 8.6% and at par with 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ (278.14 g). The later was also at par with 100% RDNPK. The heavier cobs under the higher vermicompost rate reflect the greater number of grains and the better grain filling recorded under the same treatment (Sections 3.2 and 3.4), consistent with the improved nutrient availability and soil conditions provided by vermicompost.

Table 2. Effect of nutrient management and zinc application on number of grains rows of maize

Treatment	2024	2025	Pooled
A. Nutrient management (main plot)			
100% RDNPK	30.00	30.30	30.15
50% RDNPK + vermicompost @ 3.0 t ha ⁻¹	32.40	32.72	32.56
50% RDNPK + vermicompost @ 6.0 t ha ⁻¹	35.00	35.35	35.18
$SE_m \pm$	0.38	0.39	0.39
CD ($p = 0.05$)	1.51	1.52	1.52
B. Zinc application (sub plot)			

Treatment	2024	2025	Pooled
Control	26.67	26.93	26.80
Basal ZnSO ₄ @ 25 kg ha ⁻¹	36.00	36.36	36.18
Foliar nano Zn 0.4% (30 DAS)	32.00	32.32	32.16
Foliar ZnSO ₄ 0.5% (30 DAS)	33.33	33.67	33.50
Foliar ZnSO ₄ 0.5% (30 & 45 DAS)	34.33	34.68	34.51
$SE(m) \pm$	0.45	0.45	0.45
CD ($p = 0.05$)	1.31	1.32	1.31

Interaction (A × B)

$SE_m \pm$	0.77	0.78	0.78
CD ($p = 0.05$)	NS	NS	NS

RDNPK = recommended dose of N, P and K (120:60:40 kg ha⁻¹); NS = non-significant.

Effect of zinc application. Zinc application significantly increased cob weight (CD 10.88 pooled). Cob weight was lowest in the control (253.50 g), and all zinc treatments were significantly superior to it: basal ZnSO₄ (288.65 g), foliar ZnSO₄ at 30 and 45 DAS (285.48 g), foliar ZnSO₄ at 30 DAS (283.78 g) and foliar nano Zn (280.93 g), i.e. 10.8–13.9% higher. The zinc treatments did not differ significantly among themselves, indicating that, for this character, soil application and foliar sprays of zinc were equally effective. Similar improvement in cob weight and other cob characters with zinc fertilisation has been reported in maize (Wasaya *et al.*, 2017; Saboor *et al.*, 2021) [9, 12]. The interaction was non-significant.

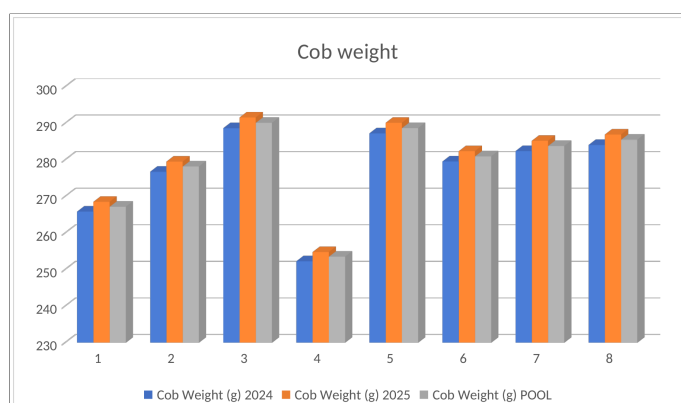


Figure 3. Effect of (A) nutrient management and (B) zinc application on cob weight (g) of maize (pooled data of 2024 and 2025). Error bars show $SE_m \pm$; VC = vermicompost.

3.4 Grain weight cob-1

The data on grain weight cob⁻¹ are presented in Table 4 and Fig. 4.

Effect of nutrient management. Grain weight cob⁻¹ increased significantly with the inclusion and the rate of vermicompost. On pooled basis, the highest value (139.71 g) was recorded under 50% RDNPK + vermicompost @ 6.0 t ha⁻¹, significantly higher than 50% RDNPK + vermicompost @ 3.0 t ha⁻¹ (133.13 g) and 100% RDNPK (126.63 g), the increase over 100% RDNPK being 10.3%. Because half of the RDNPK was replaced, this shows that vermicompost at 6.0 t ha⁻¹ more than compensated for the reduced chemical fertilizer, probably through a more balanced and sustained nutrient supply during grain filling (Atiye *et al.*, 2000 and Bhat *et al.*, 2013) [4].

Table 3. Effect of nutrient management and zinc application on cob weight (g) of maize

Treatment	2024	2025	Pooled
A. Nutrient management (main plot)			
100% RDNPK	265.83	268.49	267.16

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Treatment	2024	2025	Pooled
50% RDNPK + vermicompost @ 3.0 t ha ⁻¹	276.75	279.52	278.14
50% RDNPK + vermicompost @ 6.0 t ha ⁻¹	288.66	291.55	290.11
SE _m ±	3.31	3.35	3.33
CD (p = 0.05)	13.01	13.14	13.08
B. Zinc application (sub plot)			
Control	252.24	254.76	253.50
Basal ZnSO ₄ @ 25 kg ha ⁻¹	287.22	290.09	288.65
Foliar nano Zn 0.4% (30 DAS)	279.53	282.33	280.93
Foliar ZnSO ₄ 0.5% (30 DAS)	282.37	285.19	283.78
Foliar ZnSO ₄ 0.5% (30 & 45 DAS)	284.06	286.90	285.48
SE _m ±	3.71	3.75	3.73
CD (p = 0.05)	10.82	10.93	10.88
Interaction (A × B)			
SE _m ±	6.42	6.49	6.45
CD (p = 0.05)	NS	NS	NS

RDNPK = recommended dose of N, P and K (120:60:40 kg ha⁻¹); NS = non-significant.

Effect of zinc application. Zinc application significantly increased grain weight cob⁻¹ (CD 5.19 pooled). The highest value (138.53 g) was recorded with basal ZnSO₄, which was at par with foliar ZnSO₄ at 30 and 45 DAS (136.43 g) and at 30 DAS (134.37 g) and significantly higher than foliar nano Zn (131.94 g). All zinc treatments were significantly superior to the control (124.53 g), the increase ranging from 6.0 to 11.2%. The responses are in agreement with the findings of Wasaya *et al.* (2017) [9] and Saboor *et al.* (2021) [12] in maize, and with the view that zinc nutrition, whether through the soil or foliage, improves crop productivity and grain zinc status (Cakmak, 2008; Cakmak *et al.*, 2018) [7, 8]. The single spray of nano zinc @ 0.4% was the least effective of the zinc treatments for grains row⁻¹ and grain weight cob⁻¹, which suggests that one spray at this concentration supplied less zinc than the basal dose or two sprays of ZnSO₄. The interaction between nutrient management and zinc application was non-significant.

Table 4. Effect of nutrient management and zinc application on grain weight cob⁻¹ (g) of maize

Treatment	2024	2025	Pooled
A. Nutrient management (main plot)			
100% RDNPK	126.00	127.26	126.63
50% RDNPK + vermicompost @ 3.0 t ha ⁻¹	132.47	133.79	133.13
50% RDNPK + vermicompost @ 6.0 t ha ⁻¹	139.02	140.41	139.71
SE _m ±	1.58	1.59	1.59
CD (p = 0.05)	6.19	6.26	6.23
B. Zinc application (sub plot)			
Control	123.91	125.15	124.53
Basal ZnSO ₄ @ 25 kg ha ⁻¹	137.84	139.22	138.53
Foliar nano Zn 0.4% (30 DAS)	131.28	132.60	131.94
Foliar ZnSO ₄ 0.5% (30 DAS)	133.70	135.03	134.37
Foliar ZnSO ₄ 0.5% (30 & 45 DAS)	135.75	137.11	136.43
SE (m)±	1.77	1.79	1.78
CD (p = 0.05)	5.17	5.22	5.19
Interaction (A × B)			
SE _m ±	3.07	3.10	3.08

Treatment	2024	2025	Pooled
CD (p = 0.05)	NS	NS	NS

RDNPK = recommended dose of N, P and K (120:60:40 kg ha⁻¹); NS = non-significant.

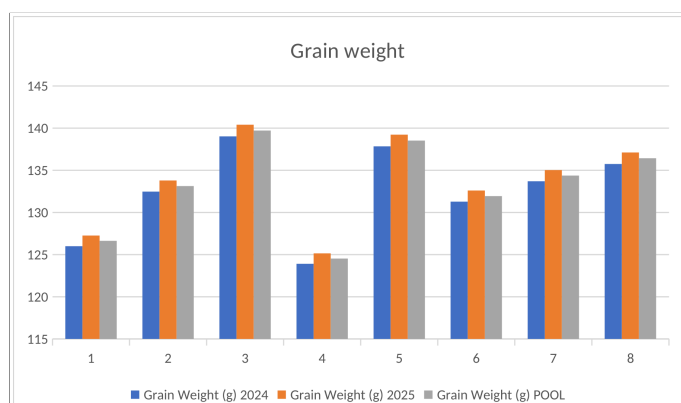


Figure 4. Effect of (A) nutrient management and (B) zinc application on grain weight cob⁻¹ (g) of maize (pooled data of 2024 and 2025). Error bars show SE_m ±; VC = vermicompost.

3.5 Interaction effects

The interaction between nutrient management and zinc application was non-significant for all four yield attributes in both years and on pooled basis. The effects of vermicompost and of zinc were therefore additive and independent: the benefit of zinc was obtained at every nutrient management level, and the benefit of vermicompost at every zinc level, so the two practices can be combined without any adverse interaction.

4. Conclusion

Replacing half of the recommended NPK by vermicompost @ 6.0 t ha⁻¹ gave significantly more grains row⁻¹, heavier cobs and higher grain weight cob⁻¹ than 100% RDNPK, without affecting the number of grain rows cob⁻¹. Among zinc treatments, basal application of ZnSO₄ @ 25 kg ha⁻¹ gave the highest values of all the yield attributes studied, and two foliar sprays of 0.5% ZnSO₄ at 30 and 45 DAS were the next best, at par with it for grain rows cob⁻¹, cob weight and grain weight cob⁻¹. A single foliar spray of nano Zn @ 0.4% was the least effective of the zinc treatments, although it was still better than no zinc. The two factors acted independently. It is concluded that 50% RDNPK + vermicompost @ 6.0 t ha⁻¹ together with basal ZnSO₄ @ 25 kg ha⁻¹ (or, where basal application is not possible, foliar ZnSO₄ @ 0.5% at 30 and 45 DAS) is the most favourable practice for improving the yield attributes of hybrid maize in the Central Plain Zone of Uttar Pradesh.

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