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Effect of different levels of Zinc (Zn) and Iron (Fe) on growth and yield of maize (*Zea mays* L.) in Central Uttar Pradesh

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Abstract

The present study entitled “Effect of Different Levels of Zinc (Zn) and Iron (Fe) on Growth and Yield of Maize (*Zea mays* L.) in Central Uttar Pradesh” was carried out during the kharif season of 2025 to assess the effectiveness of Zn (Zn) and Iron (Fe) applied through different application methods viz., soil application, foliar application and seed priming, on plant growth, productivity and economic profitability of maize. The experiment was conducted at the Crop Research Field, Department of School of Advance Agriculture Sciences and Technology, Chhatrapati Shahu Ji Maharaj University, Kanpur (U.P.). The field was laid out in randomised complete block design (RCBD) with three replications and it was comprised with ten treatment combination including untreated control (T₁), Zn @ 10 kg/ha, soil application (T₂), Zn @ 5g/l, foliar application (T₃), Zn @ 20 g/kg seed, seed priming (T₄), Fe@10 kg/ha, soil application (T₅), Fe @ 5 g/l, foliar application (T₆), Fe @ 20 g/kg seed, seed priming (T₇), Zn @ 10 kg/ha + Fe @ 10kg/ha, soil application (T₈), Zn @ 5 g/l + Fe @ 5 g/l, foliar application (T₉), Zn @ 20 g/kg seed + Fe @ 20 g/kg seed, seed priming (T₁₀). The result revealed that growth attributing characters viz., Plant height (178.3cm), No. of leaves (12.5), Dry matter accumulation (256.3g/plant), as well as yield-attributing and yield parameters, viz., No. of cobs/plant (3.8), No. of grain/cob (504.6), grain yield (74.3 q ha⁻¹), Stover yield (95.2 kg/ha⁻¹), Harvest Index(51.1%) was superior under the combined soil application of Zn @ 10 kg/ha + Fe @ 10 kg/ha (T₈) compared with the untreated control, which recorded comparatively lower growth and yield performance.

Keywords: Zinc, iron, Maize, growth, yield, seed priming, foliar application and soil application

Introduction

Maize (*Zea mays* L.) occupies a prominent position among cereal crops and is widely consumed as a staple food in many parts of the world. Despite its importance as an energy source, the nutritional quality of maize grain can be limited by inadequate levels of essential micronutrients, particularly zinc (Zn) and iron (Fe). It is cultivated in more than 165 countries on an area of 177 million hectare with a production of 875 million tonnes and productivity of 5 tonnes per ha⁻¹ (Yadav *et al.*, 2014) ^[16]. The maximum area under maize cultivation is in the United States (35.4 million ha) followed by China (35 million ha) and Brazil (14.2 million hectare), respectively. India ranks fourth in maize acreage in the world (Yadav *et al.*, 2014) ^[16].

Major states, which grow maize, are Karnataka, Maharashtra, Andhra Pradesh, Bihar Tamil Nadu, Madhya Pradesh and Rajasthan. Together these states account for more than 80% of the total share in the country in term of both area and production. Since 1950, area under maize has increased from 3.31 to 9.0 million ha and production from 1.73 million tonnes to 24.4 million tonnes in 2013-14 (IIMR, 2015). The increase has been very rapid in the last 10 years because of increase in productivity and expansion of area due to spread of its cultivation in Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu (IIMR, 2015). India earns foreign exchange worth rupees 2500 to 3000 crores annually by exporting only maize grain of 2.5 to 3.0 million tonnes and it contributes 400 billion rupees toward national gross domestic product (IIMR, 2015).

Regular consumption of maize with insufficient amounts or low bioavailability of these minerals may increase the risk of micronutrient deficiencies among populations that depend strongly on maize-based foods. Enhancing the accumulation of Zn and Fe in maize grain through bio

fortification offers a promising approach to improve the nutritional value of the crop. The presence of genetic variability for micronutrient accumulation in maize provides an opportunity to identify and utilize superior germplasm in breeding programmes. Combining genetic improvement with suitable agronomic practices may further enhance mineral accumulation and bioavailability in maize grain, thereby supporting efforts toward improved food and nutritional security.

Zinc (Zn) and iron (Fe) are vital micronutrients that play important roles in maintaining human health, growth, and physiological functions. Inadequate intake of these nutrients can result in micronutrient malnutrition and is associated with various health disorders. Cereals constitute a major component of the diet in many developing regions of Asia and Africa and can provide up to 75% of the total dietary energy in some populations.

In addition to spraying, micronutrients may be used as a pre-sowing treatment. Priming is the simplest method to hydrate seeds in order to improve germination and seedling emergence in many crop species. Osmo priming is a pre-sowing treatment that consists of seed incubation in an osmotic solution, such as with microelements. Environmental and Experimental Biology ISSN 2255-9582 Main root length, dry weight and leaf area of groundnut were significantly affected by seed treatment with calcium and zinc (Geeta *et al.*, 1996). Seed priming with zinc can improve crop emergence, seedling establishment and seed metabolism (Farooq *et al.*, 2012) [4].

Maize has a much smaller genetic range in grain concentrations of Zn and Fe, limiting the utility of selection-based bio fortification (Ortiz-Monasterio *et al.*, 2007; Maqbool and Beshir, 2018) [12, 10]. These studies also showed that foliar application of Zn, Se or I were more effective compared with soil applications for increasing grain concentrations (Wang *et al.*, 2012; Zou *et al.*, 2012; Wang *et al.*, 2013; Cakmak *et al.*, 2017) [14, 18, 15, 2]. Compared with foliar application of Zn alone, foliar spray of Zn plus nitrogen (N) further improves Zn concentration and Zn bioavailability in wheat grain and flour, indicating a promising strategy for Zn fortification of wheat (Li *et al.*, 2015) [9]. Recently, several studies showed that foliar spray of a mixture of micronutrient solution containing simultaneously Zn, Se, and/or Fe to wheat and rice grown in different countries greatly increased grain concentrations of Zn, Se and I (Zou *et al.*, 2019; Prom-u-thai *et al.*, 2020; Naeem *et al.*, 2022) [17, 13, 11]. However, little information is available regarding the effects of foliar spraying a mixture of micronutrients in solution on grain concentrations and bioavailability in maize.

Materials and Methods

Experimental Site

A field experiment titled “Effect of Different Levels of Zinc (Zn) and Iron (Fe) on Growth and Yield of Maize (*Zea mays* L.) in Central Uttar Pradesh” was conducted during kharif season 2025. This study was carried out at Crop Research Farm, Department of Agronomy, School of Advanced Agriculture Sciences and Technology, Chhatrapati Shahu Ji Maharaj University, Kanpur, Uttar Pradesh. The experimental location represents the Central Plain Zone of Uttar Pradesh, longitude 80.263065 and latitude 26.499183. The soil was slightly alkaline, with a pH of 7.7 and an electrical conductivity of 0.65 dS/m. The soil contained 0.36% organic carbon. Available Nitrogen (228kg/ha) and phosphorus (14.25kg/ha), potassium (264kg/ha), Iron (5.85ppm), Zn (0.72ppm) where maize is commonly grown during the rainy season under monsoonal conditions. The seeds of hybrid BSIM2007 maize variety having good germination rate were used as plant material. There was use the Zn and Fe

application in three way (seed priming, foliar application and soil application) to find out the Fe and Zn availability and cover the deficiency in the crop research farm.

Description of experiments

To study the effect of soil, foliar and seed priming method of Iron (Fe) and Zinc (Zn) levels on growth and yield of maize. The experimental consists of three factors with 10 treatment i.e., T₁ (Control), T₂ (Zn₁₀kg/ha) soil application, T₃ (Zn₅g/l) foliar application, T₄ (Zn₂₀g/kg seed) seed priming, T₅ (Fe₁₀kg/ha) soil application, T₆ (Fe₅g/l) foliar application, T₇ (Fe₂₀g/kg seed) seed priming, T₈ (Zn₁₀kg/ha + Fe₁₀kg/ha) soil application, T₉ (Zn₅g/l + Fe₅g/l) foliar application, T₁₀ (Zn₂₀g/kg seed + Fe₂₀g/kg seed) seed priming, use by randomized block design (RBD) in experimental site. Everything was done in three replication and this experiment duration measured at 30, 60 and DAS. Analysis of variance (ANOVA) was performed to assess the significance of treatment effects at the 5% probability level. The significance of the F-test was determined, and treatment means were compared using the critical difference (CD) test at the 5% level of significance, following the procedure described by Gomez and Gomez.

Results and Discussion

Plant height (cm)

At harvest, the same trend was maintained, with T₈ producing the tallest plants (178.3cm), followed by T₉ (177.3cm), while T₁ recorded the minimum plant height (155.2cm). The enhanced plant height under combined Zn and Fe application may be attributed to their complementary roles in chlorophyll synthesis, enzyme activation, photosynthesis and nutrient metabolism, promoting cell division, elongation and assimilate production. Soil application likely ensured sustained micronutrient availability and uptake throughout crop growth. Overall, combined Zn and Fe application, particularly through soil application, produced superior plant growth, indicating the benefits of balanced micronutrient nutrition. Kumar *et al.*, (2023) [8], Jat *et al.*, (2022) [6], and Ariraman *et al.*, (2022) [1], have reported similar effect.

No. of leaves

At 60 DAS, the maximum number of leaves per plant (12.5) was recorded with T₈ (Zn@10kg/ha+Fe@10kg/ha, soil application), which was closely followed by T₉ (Zn@5g/l+ Fe@ 5g/l, foliar application) with 12.4 leaves per plant. The treatment T₁₀ (Zn @20g/kg seed+ Fe@ 20g/kg seed, seed priming) also resulted in a comparatively greater number of leaves (11.8per plant). Among the treatments involving individual nutrient application, T₂ (Zn @10kg/ha, soil application) and T₅ (Fe @10 kg/ha, soil application) recorded an identical value of 11.2 leaves per plant, followed by T₃ (Zn @5g/l, foliar application) with 10.8 leaves per plant. The minimum number of leaves per plant (9.5) was registered under T₁ (Control). This was followed by T₇ (Fe@20g/kg seed, seed priming) and T₄ (Zn@20g/kg seed, seed priming) which produced 9.8 and 10.1 leaves per plant, respectively. Adequate Zn and Fe nutrition enhances metabolic activity, leaf initiation, root development and nutrient-use efficiency, resulting in greater leaf production and sustained vegetative growth. Dudhat *et al.*, (2026) [3] and Ariraman *et al.*, (2022) [1], reported similar improvements in maize growth following soil, foliar and seed application of Zn and Fe.

Dry matter accumulation (g/m²)

At harvest, the maximum biomass accumulation (256.3g/plant) was obtained with T₈, followed by T₉ (254.7g/plant) and T₁₀

(252.4g/plant). Among the individual nutrient treatment, T₂ and T₅ recorded 245.5 and 243.7g/plant, respectively while the minimum dry matter accumulation (206.2 g/plant) was observed under T₁. The increased dry matter accumulation may be attributed to improved Zn and Fe availability and uptake, which enhanced root growth, chlorophyll formation, photosynthetic activity and enzymatic processes. Zn promotes enzyme activation, protein synthesis and carbohydrate metabolism, while

iron is essential for chlorophyll formation and electron transport. Improve micronutrient nutrition their by enhanced photosynthetic production and translocation, resulting in greater dry matter accumulation. These findings are consistent with those of M. Krishnaraj (2020)^[7], Kumar *et al.*, (2023)^[8], and Jat *et al.*, (2022)^[6], who reported increased dry matter production in maize following Zn and Fe application.

Table 1: Effect of Zinc and Iron application different levels at harvest stage and no. of leaves at 60 days on the growth parameters of maize

Treatment	Plant Height (cm)	No. of leaves/plant	Dry matter accumulation(g/plant)
T ₁ : Control	155.2	9.5	206.2
T ₂ : Zn@10kg/ha, soil application	169.7	11.2	245.5
T ₃ : Zn @5g/l, foliar application	164.8	10.8	231.6
T ₄ : Zn@20g/kg seed, seed priming	159.6	10.1	229.3
T ₅ : Fe@10kg/ha, soil application	167.4	11.2	243.7
T ₆ : Fe@5g/l, foliar application	162.7	10.4	226.4
T ₇ : Fe@20g/kg seed, seed priming	157.9	9.8	222.4
T ₈ : Zn @ 10kg/ha + Fe @ 10kg/ha, soil application	178.3	12.5	256.3
T ₉ : Zn@5g/l+Fe@5g/l, foliar application	177.3	12.4	254.7
T ₁₀ : Zn @20g/kg seed + Fe@ 20 g/kg seed, seed priming	176.7	11.8	252.4
SEM ±	5.71	0.37	7.67
CD (P=0.05)	16.83	1.10	22.64

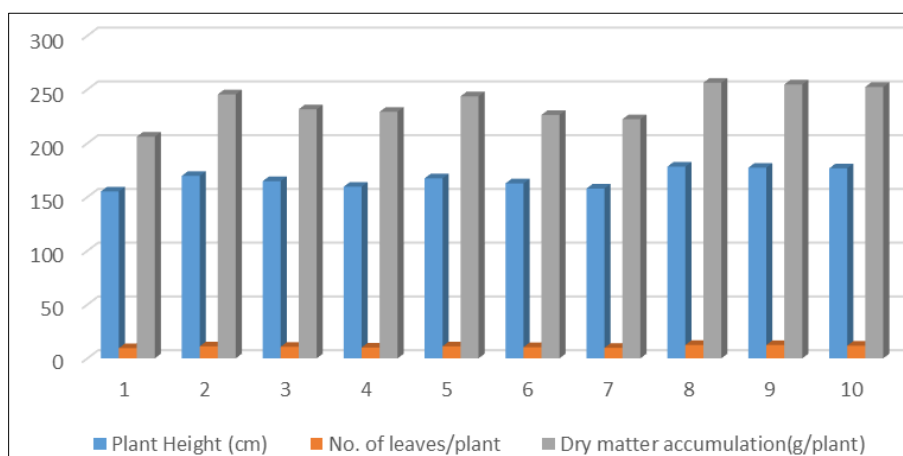


Fig 1: Effect of Zn and Fe application different levels at harvest stage and no. of leaves at 60 day on the growth parameters of maize

Yield Attributes & Yield

No. of cob/plant, No. of Grain/Cob, Grain Yield (q/ha), Stover Yield (q/ha), Harvest Index (%). The highest number of cobs per plant (3.8) was recorded under T₈ (Zn@10kg/ha+Fe@10 kg/ha, soil application), followed by T₉ (Zn@5g/l +Fe@5g/l, foliar application) with 3.7 cobs per plant and T₁₀ (Zn@ 20g/kg seed +Fe @20g/kg seed, seed priming) with 3.4 cobs per plant. Among the treatment receiving individual Zn or Fe application, T₂ (Zn@10 kg/ha, soil application) and T₅ (Fe@ 10kg/ha, soil application) recorded an identical value of 2.8 cobs per plant. The minimum number of cobs per plant (2.3) was observed under T₁ (Control).

The highest number of grains cob⁻¹ (504.6) was registered under T₈ (Zn @ 10 kg ha⁻¹ + Fe @ 10 kg ha⁻¹ pollen development, fertilization, cob formation and grain filling, resulting in longer cobs and more grain cobs⁻¹. Seed priming likely supported early seedling establishment, while foliar application improved nutrient availability during reproductive growth. Overall, integrated Zn and Fe application enhanced physiological efficiency and yield formation in maize, supporting the findings of Dudhat *et al.*, (2026)^[3], Jat *et al.*, (2022)^[6] and M Krishnaraj (2020)^[7]. Soil application, followed by T₉ (Zn @ 5 g l⁻¹ + Fe @ 5 g l⁻¹, foliar application) with 488.4 grains cob⁻¹ and T₁₀ (Zn @ 20 g kg⁻¹

seed + Fe @ 20 g kg⁻¹, soil application), followed by T₉ (Zn @ 5 g l⁻¹ + Fe @ 5 g l⁻¹, foliar application) with 488.4 grains cob⁻¹ and T₁₀ (Zn @ 20 g kg⁻¹ seed + Fe @ 20 g kg⁻¹ seed, seed priming) with 463.2 grains cob⁻¹. Among the individual applications, T₂ (Zn @ 10 kg ha⁻¹, soil application) recorded 420.8 grains cob⁻¹, followed by T₅ (Fe @ 10 kg ha⁻¹, soil application) with 406.6 grains cob⁻¹. The minimum number of grains cob⁻¹ (330.7) was recorded under T₁ (Control).

The highest grain yield (74.3q/ha) was obtained with T₈ (Zn@10 kg/ha+Fe@10kg/ha, soil application) followed by T₉ (zn@5g/l + Fe@5g/l, foliar application) with 63.5q/ha and T₁₀ (Zn@20g/kg seed + Fe@20g/kg seed, seed priming) with 55.4q/ha. Among the individual nutrient treatment, T₂ (Zn@10 kg/ ha, soil application) recorded 54.3 q/ha, closely followed by T₅ (Fe@10kg/ha, soil application) with 54.2 q/ha. The minimum grain yield (38.3q/ha) was registered under T₁ (Control).

The maximum Stover yield (95.2q/ha) was recorded under T₉ (Zn@5g/l + Fe @5g/l, foliar application), followed by T₇ (Fe@20g/kg seed, seed priming) with 94.6q/ha and T₁ (Control) with 94.3 q/ha. Treatment T₁₀ (Zn@20g/kg seed + Fe @20 g/kg seed, seed priming) produced 82.2 q/ha, whereas T₆ (Fe@5g/L, foliar application) and T₅ (Fe@10 kg/ha, soil application) recorded 77.3 and 77.0 q/ ha respectively. The lowest Stover yield

(52.0q/ha) was observed under T₂ (Zn@10kg/ha, soil application).

The highest harvest index (51.1%) was recorded under T₂ (Zn@10kg/ha, soil application) closely followed by T₈ (Zn@10kg/ha + Fe @10kg/ha, soil application) with 51.0%. Treatment T₃ (Zn@5g/l, foliar application) recorded a harvest index of 41.9%, followed by T₅ (Fe@10kg/ha, soil application) with 41.3%. The lowest harvest index (28.9%) was observed under T₁ (Control). Overall, the combined application of Zn and Fe enhanced grain production considerably, with T₈ producing the maximum grain yield where as T₉ resulted in the highest

biological and stover yields.

The combined application of Zn and Fe through the most effective method resulted in superior yield attributes, whereas the control recorded the lowest values (table 2.). The response could be attributed to improved Zn and Fe availability and uptake, which enhanced root growth, chlorophyll synthesis, photosynthetic activity and assimilate production. Zinc contributes to enzyme activation, protein synthesis and reproductive growth, while iron plays a key role in chlorophyll formation and electron transport. Improved nutrient supply during critical growth stages may have promoted better

Table 2: Effect of Zinc and Iron on different application at yield attributes of maize

Treatment	No. of cob/plant	No. of Grain/cob	Grain yield (q/ha)	Stover yield(q/ha)	Harvest Index (%)
T ₁ : Control	2.3	330.7	38.3	94.3	28.9
T ₂ : Zn@10kg/ha, soil application	2.8	420.8	54.3	52.0	51.1
T ₃ : Zn@5g/l, foliar application	2.6	395.2	48.3	66.9	41.9
T ₄ : Zn@20g/kg seed, seed priming	2.4	347.6	41.2	67.9	37.8
T ₅ : Fe@10kg/ha, soil application	2.8	406.6	54.2	77.0	41.3
T ₆ : Fe@5g/l, foliar application	2.5	352.4	45.0	77.3	36.8
T ₇ : Fe@20g/kg seed, seed priming	2.4	345.2	40.1	94.6	29.8
T ₈ : Zn@10kg/ha+Fe@10kg/soil application	3.8	504.6	74.3	71.4	51.0
T ₉ : Zn@5g/l+Fe@5g/l, foliar application	3.7	488.4	63.5	95.2	40.0
T ₁₀ : Zn@20g/kgseed+Fe@20g/kg seed, seed priming	3.4	463.2	55.4	82.2	40.2
SEM ±	0.1	14.12	1.84	2.60	0.25
CD(P=0.05)	0.3	41.65	5.43	7.68	1.00

The economic performance of maize was considerably influenced by the application of zinc and iron through different methods. The cost of cultivation increased slightly with soil and foliar application because of the additional expenditure on micronutrient fertilizers and their application, while seed priming involved comparatively lower input costs. However, the increase in input cost was more than compensated by the improvement in crop productivity and monetary returns. Among the treatments, the combined soil application of Zn @ 10 kg ha⁻¹ + Fe @ 10 kg ha⁻¹ (T₈) recorded the highest gross return (₹194,814.8 ha⁻¹), net return (₹138,804.8 ha⁻¹) and B:C ratio (2.5), followed by combined foliar application of Zn + Fe (T₉), which recorded a gross return of ₹173,935.2 ha⁻¹, net return of ₹119,275.2 ha⁻¹ and B:C ratio of 2.2 (fig.2). The superior economic performance of T₈ was mainly due to the greater yield obtained under balanced Zn and Fe nutrition, which resulted in higher monetary returns

despite the relatively higher cost of cultivation. These findings were associated with Deepak *et al.*, (2025) and Krishnaraj (2020) [7].

The higher profitability may be due to the combined effect of zinc and iron on plant growth, chlorophyll formation, photosynthesis, enzyme activity and nutrient use, which improved grain and stover yield. Soil application supplied nutrients throughout crop growth, while foliar application provided nutrients during critical growth stages. Seed priming had lower cultivation costs but also gave lower returns. Among individual treatments, soil application of Fe @ 10 kg ha⁻¹ (T₅) recorded the highest economic performance, with a gross return of ₹147,583.9 ha⁻¹, net return of ₹93,073.9 ha⁻¹ and B:C ratio of 1.7. Overall, combined zinc and iron application, particularly through soil, improved the economic returns of maize. These findings are consistent with Dudhat *et al.* (2026) [3], Jat *et al.* (2022) [6] and Ariraman *et al.* (2022) [1].

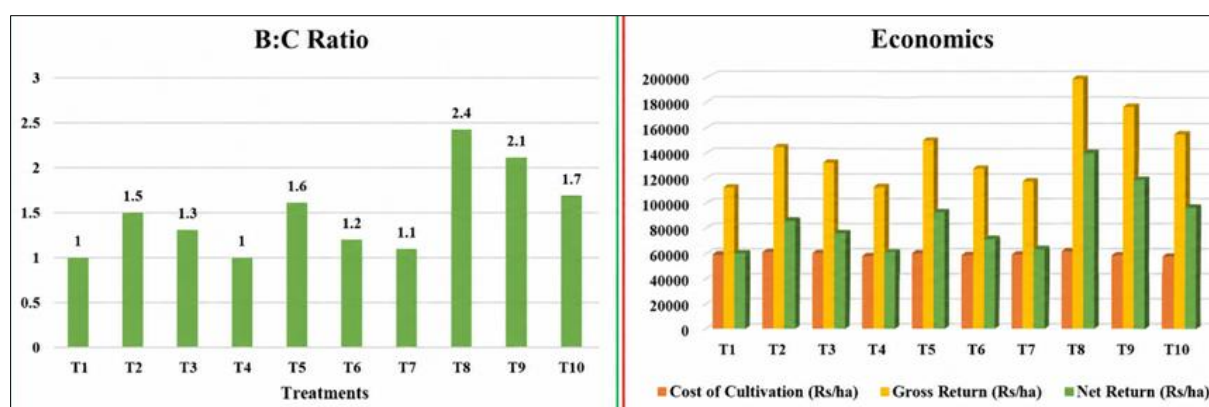


Fig 2: Effect of Zn and Fe application on economics of maize

Conclusion

Based on the findings of the present investigation, it can be concluded that the combined application of zinc and iron had a positive influence on the growth and yield of maize under the Central Plain Zone of Uttar Pradesh. Among the treatments

evaluated, T₈, comprising Zn @ 10 kg ha⁻¹ and Fe @ 10 kg ha⁻¹ through soil application, resulted in higher grain yield and economic returns. Therefore, the hybrid BSIM2007, when supplied with Zn @ 10 kg ha⁻¹ and Fe @ 10 kg ha⁻¹ through soil application, may be considered a suitable nutrient management

practice for achieving higher productivity and profitability of maize. Soil application of zinc and iron showed a more favourable effect on the growth and yield of maize compared with seed priming and foliar application.

Limitations

The study was conducted at a single location during one Kharif season and used only one maize hybrid (BSIM2007). Therefore, the results may not be applicable to all locations, seasons, or maize hybrids. The experiment mainly evaluated the effects of Zinc and iron application methods on maize growth and yield. Long-term effects on soil nutrient status, nutrient use efficiency and soil fertility were not studied. Further experiments at different locations and over several seasons are needed to confirm these results under different agro-climatic conditions.

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Competing Interests

Authors have declared that no competing interest exist.

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