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Ferti-fortification of zinc and iron on green fodder yield and quality of fodder maize

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Abstract

A field experiment was conducted during *kharif* 2025 at the Main Forage Research Station, Anand Agricultural University, Anand, Gujarat, to evaluate the effect of soil and foliar application of zinc and iron on growth, yield, quality, nutrient enrichment, and soil fertility status of fodder maize. The aim of the study was to evaluate the effect of soil and foliar application of Zinc and Iron on the growth and yields of fodder maize and to assess the enhancement of Zn and Fe content in fodder maize through soil and foliar application of Zn and Fe. The experiment was laid out in a Randomized Block Design (RBD) with three replications and ten treatments comprised of T₁- Control (RDF), T₂- RDF + ZnSO₄·7H₂O @ 25 kg/ha as a soil application, T₃ - RDF + FeSO₄·7H₂O @ 50 kg/ha as a soil application, T₄ - RDF + ZnSO₄·7H₂O @ 25 kg/ha + FeSO₄·7H₂O @ 50 kg/ha as a basal, T₅ - RDF + foliar application of 0.5% ZnSO₄ at 15 & 30 DAS, T₆ - RDF + foliar application of 0.5% FeSO₄ at 15 and 30 DAS, T₇ - RDF + foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄ at 15 & 30 DAS, T₈ - RDF + ZnSO₄·7H₂O @ 25 kg/ha as a basal *fb* 0.5% ZnSO₄ foliar application at 15 & 30 DAS, T₉ - RDF + FeSO₄·7H₂O @ 50 kg/ha as a basal *fb* 0.5% FeSO₄ at 15 & 30 DAS and T₁₀ - RDF + ZnSO₄·7H₂O @ 25 kg/ha + FeSO₄·7H₂O @ 50 kg/ha as a basal *fb* foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄ at 15 & 30 DAS. The recommended dose of fertilizers (80-40-00 kg NPK/ha) was applied uniformly to all treatments and fodder maize variety GFM-1 (Anand Tall) was used as the test crop. The treatment T₁₀ [RDF + ZnSO₄·7H₂O @ 25 kg/ha + FeSO₄·7H₂O @ 50 kg/ha as basal followed by 0.5% ZnSO₄ + 0.5% FeSO₄ foliar sprays at 15 and 30 DAS] recorded the highest plant height (209.73 cm), green fodder yield (402.90 q/ha), dry matter content (25.9%), dry matter yield (104.07 q/ha), crude protein content (5.38%), crude protein yield (5.61 q/ha), Zn content (23.04 mg/kg), Fe content (83.09 mg/kg), and their respective uptake values. The treatment also improved post-harvest soil DTPA-extractable Zn (0.55 mg/kg) and Fe (5.05 mg/kg). However, ADF, NDF and number of leaves per plant were not significantly affected. The study concluded that combined soil and foliar application of Zn and Fe along with RDF is an effective strategy for ferti-fortification of fodder maize, enhancing productivity, quality, micronutrient enrichment and soil fertility under loamy sand conditions of Anand, Gujarat.

Keywords: Ferti-fortification, maize, zinc, iron

Introduction

Agriculture and animal husbandry are closely linked in India, where livestock plays an important role in supporting rural livelihoods and crop production. Despite possessing only 2.3% of the world's land area and 4.2% of water resources, India supports about 15% of the global livestock population and 17% of the human population (Kumar *et al.*, 2012) ^[10]. However, fodder crops are often cultivated on marginal lands under poor management, resulting in low-quality forage. Only about 8.4 million hectares (5.23% of the total agricultural area) are devoted to fodder cultivation, which is insufficient to meet the growing feed requirements of livestock (Mohan *et al.*, 2017) ^[12]. Future projections indicate significant deficits in green and dry fodder by 2050, highlighting the need to improve fodder productivity through better resource management and crop integration (IGFRI, 2018) ^[4].

Maize (*Zea mays* L.), known as the “Queen of Cereals,” is an important dual-purpose crop used for both human consumption and animal feed. Fodder maize is highly valued due to its rapid growth, high biomass production, excellent palatability and nutritive value. It contains appreciable levels of crude protein, fiber fractions, cellulose and hemicellulose, making it a preferred fodder crop for dairy animals (Rupa *et al.*, 2021) ^[15]. In India, maize occupies more than 108 lakh

hectares, with the majority cultivated during the kharif season (ANGRAU, 2024).

Micronutrients, particularly zinc (Zn) and iron (Fe), are essential for plant growth, forage quality, and animal nutrition. Zinc is involved in numerous enzymatic activities, while iron plays a crucial role in photosynthesis, respiration, and chlorophyll synthesis. Zinc deficiency has become a widespread problem in Indian soils, affecting crop productivity and forage quality (Kumar *et al.*, 2024) ^[6]. Agronomic biofortification through soil and foliar application of Zn and Fe has emerged as an effective strategy to enhance the nutritional quality of crops and fodder. Studies have shown that zinc- and iron-enriched fodder improves forage quality, increases micronutrient concentration in animal feed, enhances milk quality, and reduces disease incidence in livestock (Kumar *et al.*, 2016; Patel and Rathod, 2024) ^[8, 13]. Although biofortification has been widely studied in food crops, limited information is available on forage crops. Therefore, agronomic biofortification of fodder maize with zinc and iron offers a promising, cost-effective approach to improve fodder productivity, nutritional quality, and livestock health, especially in regions with micronutrient-deficient soils.

Materials and Methods

Soil and climate of experiment location

The field experiment was conducted during the *kharif* season of 2025 at Main Forage Research Station, Anand Agricultural University, Anand (Gujarat) India (22°35' N and 72°55' E with a 45.1 m above mean sea level). During experiment period, mean weekly weather parameter was recorded at Department of Agricultural Meteorology, B.A. College of Agriculture and these standard meteorological week wise data are presented in Fig.1. The experimental soil was loamy sand in texture with good drainage and moisture retention capacity. Before sowing, composite soil sample was taken for physicochemical properties of soil (Table 1).

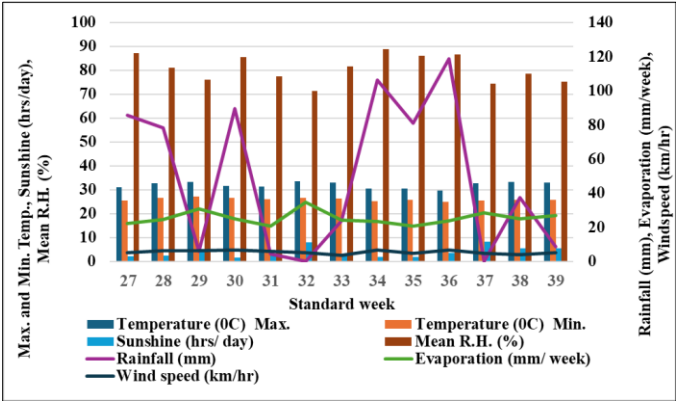


Fig 1: Mean weekly weather parameters noted throughout the growing season of the year 2025

Experimental analysis design and treatment details

The experiment was laid out in a Randomized Block Design (RBD) in *kharif* season with three replications and ten treatments. Net plot size is 2.4 × 4.0 m (9.6 m² area). Treatment details given below

T₁- Control (RDF),

T₂- RDF + ZnSO₄.7H₂O @ 25 kg/ha as a soil application,

T₃- RDF + FeSO₄.7H₂O @ 50 kg/ha as a soil application,

T₄- RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal,

T₅- RDF + foliar application of 0.5% ZnSO₄

T₆- RDF + foliar application of 0.5% FeSO₄

T₇- RDF + foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄

T₈- RDF + ZnSO₄.7H₂O @ 25 kg/ha as a basal *fb* 0.5% ZnSO₄ foliar application

T₉- RDF + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* 0.5% FeSO₄

T₁₀- RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄

The recommended dose of fertilizers (80-40-00 kg NPK/ha) was applied uniformly to all treatments. Recommended nitrogen and phosphorus were applied through urea and single super phosphate; half dose of nitrogen (40 kg/ha) and full dose of phosphorus (40 kg/ha) was applied as basal and remaining fifty percent nitrogen (40 kg/ha) was applied at 30 days after sowing. Soil application of 25 kg ZnSO₄ and 50 kg FeSO₄ applied as basal dose and foliar solution of 0.5% ZnSO₄ and FeSO₄ with 0.25% neutralized lime water at 15 and 30 days after sowing. For experiment purpose fodder maize (Gujarat Fodder Maize 1 Anand Tall) was used as the test crop and it was sown at 30 cm between two rows with seed rate 80 kg/ha. For uniform and better germination, after sowing immediate apply one irrigation. For healthy growth and reducing weed competition crop should be free from any type of weeds for the two-hand weeding and one interculture operation was carried out during crop growth period. Experiment field was ready through harrowing and planking after two cross cultivations. Uniform field level is required for better movement of irrigation in field and uniform germination. For growth and yield attributing character’s observation selected five random plants from net plot area. At milking phase fodder maize was harvested, first selected tag plant was harvested for recording necessary biometric observations afterwards produced was added to the net plot respectively. For proximate analysis purpose, collect fresh choup 500 g green plant sample from each plot according to standard process for quality analysis (Table 2). Field experiment was conducted in Randomized Complete Block Design. According to set of observation collect all data from net plot area and converted into mean data. The mean data of experiment was analysed through ANOVA technique for statistical analysis of Randomized Complete Block Design as described by Gomez and Gomez (1984).

Table 1: Soil physicochemical properties

Sr. No.	Properties	Value	Method
1	Soil pH (1:2.5, Soil: Water)	7.3	Potentiometric method (Jackson, 1973) ^[5]
2	EC (dS/m) at 25°C (1:2.5, Soil: Water)	0.23	Conductivity meter method (Jackson, 1973) ^[5]
3	Organic carbon (%)	0.36%	Chromic acid wet oxidation method (Walkley and Black, 1934)
4	Available N (kg/ha)	172	Alkaline KMnO ₄ method (Subbiah and Asija, 1956)
5	Available P ₂ O ₅	28	Olsen’s method, Spectrophotometric (Olsen <i>et al.</i> , 1954)
6	Available K ₂ O	216.12	Flame photometric method (Jackson, 1973) ^[5]
7	DTPA extractable Fe (mg/kg)	2.49	Atomic Absorption Spectrophotometric Method Lindsay and Norvell (1978) ^[11]
8	DTPA extractable Zn (mg/kg)	0.44	

Table 2: Different methods used for green fodder proximate analysis

Sr. No.	Parameters	Method Used
1	Neutral detergent fiber (%)	Forage fiber analysis US method (Goering and Van Soest 1975) ^[3]
2	Acid detergent fiber (%)	Forage fiber analysis US method (Goering and Van Soest 1975) ^[3]
3	Crude protein content (%)	Kjeldahl's digestion method (Jackson 1973) ^[5]
4	Total micronutrient Zn and Fe	Atomic Absorption Spectrophotometric Method (Piper 2019) ^[14]
5	DTPA Zn and Fe	Atomic Absorption Spectrophotometric Method (Lindsay and Norvell 1978) ^[11]

Proximate analysis of green fodder

Fodder Dry matter percentage

Dry matter percentage was determined by using the following formula.

$$\text{Dry matter content \%} = \frac{\text{Dry matter}}{\text{Fresh weight (g)}} \times 100$$

Dry matter yield (q/ha) was calculated by dry matter 5 and fresh fodder yield of maize.

Fodder Crude protein content (%)

Analysis of crude protein content was done through a digestion process. Nitrogen was calculated from the amount of acid that was used in titration. Then the reading was multiply with 6.25 to obtain crude protein percentage (Jackson (1973) ^[5]).

Fodder Crude protein yield (q/ha)

The crude protein yield was estimated by multiplying crude protein% with dry matter yield by employing the formula given below and express in q/ha.

$$\text{Crude protein yield (q/ha)} = \frac{\text{Dry matter yield (q/ha)} \times \text{CP \%}}{100}$$

Nutrient uptake (kg/ha)

Following formula was used to calculate nutrient uptake by fodder maize

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{Dry matter yield (kg/ha)}}{100}$$

Results and Discussion

Effect of different treatment on growth attributes and growth of fodder maize was found significant (Table-3). A perusal of the data in Table 3 indicates that the different treatments had a non-significant effect on the plant population at 15 DAS and the number of leaves per plant. This confirms that the plant population remained uniform across and not found treatment effects on plant population.

Data reported in Table 3 revealed that periodical plant height of fodder maize as significantly influenced by different treatments. According to mean value, plant height at 30 DAS was not significantly affected by the different treatments later on higher plant at 45 DAS (127.47 cm) and at harvest (209.73 cm) was noted in treatment T₁₀ (RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄) than rest of treatments except treatment T₃ (RDF + FeSO₄.7H₂O @ 50 kg/ha as a soil application), T₄ (RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal), T₅ (RDF + foliar application of 0.5% ZnSO₄), T₆ (RDF + foliar application of 0.5% FeSO₄) and T₈ (RDF + ZnSO₄.7H₂O @ 25 kg/ha as a basal *fb* 0.5% ZnSO₄ foliar application) at 45 DAS (Range of height from 127.47 to 90.47 cm) whereas at harvest (Range of height from 209.73 to 159.02 cm), treatment T₁₀ (RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄) remain at par

with treatment T₃ (RDF + FeSO₄.7H₂O @ 50 kg/ha as a soil application), T₄ (RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal), T₅ (RDF + foliar application of 0.5% ZnSO₄), T₇ (RDF + foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄), T₈ (RDF + ZnSO₄.7H₂O @ 25 kg/ha as a basal *fb* 0.5% ZnSO₄ foliar application) and T₉ (RDF + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* 0.5% FeSO₄). The minimum plant height (90.47 and 159.02 cm) was observed under the control treatment (T₁) at 45 DAS and at harvest. The improvement in plant height may be due to the combined application, which improves the availability and supply of balanced nutrients. The application of nitrogen drives rapid vegetative growth, accelerating cell division and elongation, which leads to longer internodes and increased leaf area. It also promotes robust early-stage root development, allowing the plant to absorb more water and soil nutrients. Furthermore, these nutrients are essential for energy transfer (ATP), enzyme activation, hormone function, and chlorophyll synthesis. Together, they ensure that macro-nutrients (such as N and P) are efficiently utilized, preventing stunting or nutrient lockout.

Combined application of recommended dose of fertilizer along with zinc and iron micronutrition application through soil and foliar application lead to improve in economical yield. Data presented in Table 3 indicated that application of 100% (80-40-0 NPK kg/ha) + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha + 0.5% ZnSO₄ + 0.5% FeSO₄ (T₁₀) recorded the higher green fodder yield (402.90 q/ha), which remained statistically at par with T₄ (379.31 q/ha) and T₉ (345.43) which is significantly superior over the remaining treatments (Table 3). The lowest green fodder yield (300.28 q/ha) was recorded under the control treatment (T₁). Comparison with control treatment (T₁) treatment T₁₀ recorded 34.17% higher green fodder yield. Combined application of Zn and Fe along with foliar sprays significantly improved growth and yield of fodder maize. optimizing plant growth hormones, maximizing chlorophyll synthesis, and improving nutrient absorption through dual-delivery pathways (Kumar *et al.*, 2017, 2018 and Adesh *et al.*, 2021) ^[9, 7, 1].

The combined application of zinc and iron along with recommended dose of macro nutrients significantly improved fodder quality, nutrient concentration, nutrient uptake, and micronutrient status in soil (Table 4-6). In connection to dry matter content (25.9%) and dry matter yield (104.07 q/ha) were recorded under T₁₀ (soil application of ZnSO₄ and FeSO₄ along with foliar spray of ZnSO₄ and FeSO₄), it was 64.10% higher than control (T₁). Enhanced dry matter accumulation may be attributed to improved photosynthetic activity, chlorophyll synthesis, and nutrient utilization resulting from adequate Zn and Fe supply (Sewhag *et al.*, 2022) ^[16]. Zinc (Zn) is critical for the synthesis of tryptophan, an amino acid that serves as a precursor to auxins (growth hormones). Zinc promotes rapid cell division and stem elongation. Iron (Fe) is an absolute requirement for the synthesis and maintenance of chlorophyll molecules. It acts as a structural component in the electron transport chain (cytochromes), ensuring maximum solar energy conversion. Phosphorus drives energy storage and transfer via adenosine triphosphate (ATP). Along with zinc, it stimulates extensive root development, allowing the plant to absorb more water and nutrients.

Furthermore, zinc acts as a vital structural component and activator of enzymes, such as tryptophan synthetase, which are responsible for protein biosynthesis. Without adequate zinc, protein synthesis suffers significantly.

Crude protein (5.38%) and crude protein yield (5.61 q/ha) of fodder maize was reported higher in treatment T₁₀ (80-40-0 NPK kg/ha) + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha + 0.5% ZnSO₄ + 0.5% FeSO₄) than rest of treatments (Table-4). In case of crude protein yield, treatment T₁₀ was statistically at par with treatment T₂ (RDF + ZnSO₄.7H₂O @ 25 kg/ha as a soil application), T₃ (RDF + FeSO₄.7H₂O @ 50 kg/ha as a soil application), T₄ (RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha as a basal), T₇ (RDF + foliar application of 0.5% ZnSO₄ + 0.5% FeSO₄), T₈ (RDF + ZnSO₄.7H₂O @ 25 kg/ha as a basal *fb* 0.5% ZnSO₄ foliar application) and T₉ (RDF + FeSO₄.7H₂O @ 50 kg/ha as a basal *fb* 0.5% FeSO₄). Increase in crude protein content in fodder maize may be attributed to the combined application of nutrients, which work synergistically to maximize chlorophyll production, amino acid synthesis, and nitrogen assimilation. Zinc activates the carbonic anhydrase enzyme, accelerating carbon fixation and creating the carbon skeletons required for protein synthesis. Meanwhile, iron serves as a critical structural component of nitrate reductase and nitrite reductase enzymes, which convert absorbed nitrate into ammonium. Together, zinc and iron enhance root growth and metabolic activity, thereby increasing the plant's capacity to absorb soil-applied nitrogen. Neutral detergent fiber (NDF) measures the overall plant cell wall components to predict how much forage an animal can consume, whereas acid detergent fiber (ADF) measures the highly indigestible parts to estimate the overall energy value of the feed. Response of different treatments

on acid detergent fiber and neutral detergent fiber was found non-significant (Table-4).

Micronutrient enrichment of fodder maize was markedly enhanced by Zn and Fe fertilization. Treatment T₁₀ (80-40-0 NPK kg/ha) + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha + 0.5% ZnSO₄ + 0.5% FeSO₄) recorded higher Zn content (23.04 mg/kg), Zn uptake (239.69 g/ha), Fe content (83.09 mg/kg), and Fe uptake (865.43 g/ha). The increased nutrient concentration and uptake were primarily due to greater nutrient availability and higher biomass production under integrated soil and foliar application (Patel and Rathod 2024) ^[13]. Application of 80-40-0 NPK kg/ha) + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha + 0.5% ZnSO₄ + 0.5% FeSO₄ (T₁₀) noted significantly higher value of S content (0.14%) and uptake (14.21 g/ha). The improvement in sulphur content likely resulted from the balanced application of all targeted nutrients.

Similarly, DTPA-extractable Zn (0.55 mg/kg) and Fe (5.05 mg/kg) in soil were significantly improved under T₁₀ (Table 3), indicating the beneficial residual effect of micronutrient fertilization. Overall, the integrated application of ZnSO₄ and FeSO₄ through soil and foliar methods proved most effective in enhancing fodder yield, quality, biofortification, nutrient uptake, and soil micronutrient status in fodder maize. The results are in accordance with the those of findings reported by Patel and Rathod (2024) ^[13].

Digestibility is an important parameter for measurement of the animal feed nutritive value. In present study there are different digestibility parameter was calculated (Table 6). DMI varies from 1.53 to 1.59%, DMD range from 58.58 to 61.41%, TDN range from 51.11 to 55.80%, RFV is range from 69.94 to 75.42% and RFQ is range from 64.01 to 71.79%.

Table 3: Effect of treatment on growth attributes, yield attributes and green fodder yield of fodder maize

Tr	Plant population per meter row length at 15 DAS	Plant height (cm)			No. of leaves per plant	Green Fodder yield (q/ha)
		At 30 DAS	At 45 DAS	At harvest		
T ₁	11.13	76.13	90.47	159.02	10.7	300.28
T ₂	11.20	74.80	105.80	175.39	11.9	314.90
T ₃	11.67	76.80	108.20	181.70	12.3	318.67
T ₄	11.40	71.73	122.00	208.41	12.0	379.31
T ₅	11.40	74.60	111.53	185.38	10.6	319.55
T ₆	11.73	75.33	110.67	165.59	12.0	300.35
T ₇	11.43	77.60	115.23	187.99	12.8	326.06
T ₈	11.93	77.93	99.53	189.50	12.4	329.13
T ₉	11.67	79.47	101.57	192.90	12.5	345.43
T ₁₀	12.17	80.80	127.47	209.73	13.2	402.90
S. Em. ±	0.50	3.55	6.62	10.37	0.54	21.36
CD =0.05	NS	NS	19.68	30.82	NS	68.33

Table 4: Effect of different treatments on proximate analysis of fodder maize

Tr	Dry matter (%)	Dry matter yield (q/ha)	Crude protein (%)	Crude protein yield (q/ha)	Acid detergent fiber (%)	Neutral detergent fiber (%)
T ₁	21.0	63.10	4.14	2.61	38.92	78.58
T ₂	22.6	71.29	4.88	3.49	37.04	77.07
T ₃	23.3	74.10	4.97	3.68	37.43	78.02
T ₄	24.8	94.08	5.02	4.72	36.96	78.35
T ₅	25.1	79.62	4.25	3.43	37.68	78.36
T ₆	24.9	74.81	4.57	3.44	38.03	78.36
T ₇	24.1	78.67	4.82	3.79	37.47	76.53
T ₈	24.3	79.79	4.97	3.97	37.38	78.82
T ₉	23.9	82.65	4.77	3.95	37.62	77.49
T ₁₀	25.9	104.07	5.38	5.61	35.28	75.99
S. Em. ±	0.89	5.21	0.20	0.30	1.69	3.69
CD =0.05	2.66	15.47	0.60	0.90	NS	NS

Table 5: Effect of different treatments on proximate analysis of fodder maize

Tr	Zinc content (mg/kg)	Zinc uptake (g/ha)	Fe Content (mg/kg)	Iron uptake (g/ha)	S content (mg/kg)	S uptake (g/ha)
T ₁	18.03	114.35	59.70	376.87	0.09	5.70
T ₂	21.20	150.79	66.00	470.41	0.13	9.03
T ₃	19.58	143.72	70.22	527.27	0.11	8.19
T ₄	22.19	209.18	75.72	712.25	0.13	12.19
T ₅	21.70	172.32	65.64	533.13	0.11	8.44
T ₆	19.40	144.44	76.62	571.00	0.11	8.50
T ₇	20.49	161.36	72.22	568.20	0.11	8.66
T ₈	22.07	175.36	66.68	536.36	0.10	8.26
T ₉	20.03	165.13	79.47	656.47	0.12	9.65
T ₁₀	23.04	239.69	83.09	865.43	0.14	14.21
S. Em. ±	0.93	14.08	4.04	55.82	0.01	0.74
CD =0.05	2.76	41.83	12.03	165.85	0.02	2.20

Table 6: Effect of different treatment on soil micronutrient status and nutritional indices

Tr	DTPA Zn (mg/kg)	DTPA Fe (mg/kg)	Available sulphur (mg/kg)	DMI (%)	DMD (%)	TDN (%)	RFV (%)	RFQ (%)
Initial	0.44	2.49	10.56					
T ₁	0.37	2.90	10.87	1.54	58.58	51.11	69.94	64.01
T ₂	0.47	3.54	10.70	1.57	60.05	53.53	73.16	68.50
T ₃	0.38	3.73	11.89	1.54	59.74	53.03	71.33	66.38
T ₄	0.46	4.22	12.06	1.53	60.11	53.63	71.38	66.79
T ₅	0.49	3.55	10.67	1.54	59.55	52.71	70.82	65.70
T ₆	0.40	4.10	11.01	1.53	59.27	52.25	70.33	64.95
T ₇	0.45	4.22	11.14	1.57	59.71	52.98	72.62	67.59
T ₈	0.51	3.45	11.98	1.53	59.78	53.10	70.84	65.86
T ₉	0.42	4.47	11.86	1.56	59.60	52.79	72.24	67.17
T ₁₀	0.55	5.05	12.57	1.59	61.41	55.80	75.42	71.79
S. Em. ±	0.02	0.24	0.63	0.07	1.34	2.22	3.52	3.88
CD =0.05	0.09	0.78	NS	0.23	4.20	6.97	11.13	12.20

Conclusion

The combined application of zinc and iron significantly improved the growth, yield, quality, nutrient content and nutrient uptake of fodder maize. Treatment T₁₀ [RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha + 0.5% ZnSO₄ + 0.5% FeSO₄] recorded the highest values for plant height, dry matter content, crude protein content, crude protein yield and Zn and Fe content and uptake, remaining statistically at par with T₄ [RDF + ZnSO₄.7H₂O @ 25 kg/ha + FeSO₄.7H₂O @ 50 kg/ha]. However, ADF, NDF, number of leaves per plant and available sulphur in soil were not significantly affected by the treatments. Overall, soil application of ZnSO₄.7H₂O @ 25 kg/ha and FeSO₄.7H₂O @ 50 kg/ha (T₄) proved to be the most economical and effective treatment for zinc and iron Ferti-fortification, enhancing fodder productivity, quality, nutrient enrichment and soil micronutrient status under the loamy sand conditions of Anand, Gujarat.

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Conflicts of Interest

The authors declare no competing financial interests or personal relationships that could influence or bias the findings reported in this paper.

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