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Fodder maize yield and its quality as influenced by soil and foliar application of zinc and iron

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Abstract
Micronutrients deficiencies are often referred to as "hidden Hunger" because affected individuals may not show immediate signs on malnutrition, yet their health is compromised over the long term. Major biofortification done through genetical approach manipulation done through agronomical practices and micronutrient containing fertilizers. Among these three-fodder maize fortification done through agronomical approach, zinc and iron has vital role in biofortification micronutrient fertilization application by soil and foliar application. This strategy entails increasing the accumulation of target nutrients like zinc and iron in edible plant tissues by fertilization or other stimulation. The aim of the present study was evaluated fodder yield and quality of fodder maize as influenced by soil and foliar application of zinc and iron during *Kharif* season of 2019 and 2020. The treatment were T_1: 0 kg $ZnSo_4$/ha (control), T_2: 10 kg $ZnSo_4$/ha as basal + 1% $ZnSo_4$ foliar spray at 45 DAS, T_3: 10 kg $FeSo_4$/ha as basal + 0.5% $FeSo_4$ foliar spray at 45 DAS, T_4: 10 kg $ZnSo_4$ +10 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS, T_5: 20 kg $ZnSo_4$/ha as basal +1% $ZnSo_4$ foliar spray at 45 DAS, T_6: 20 kg $FeSo_4$/ha as basal + 0.5% $FeSo_4$ foliar spray at 45 DAS and T_7: 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS. An experiment was laid out in Randomized block design with three replications. Soil application of $ZnSo_4$ and $FeSO_4$ @ 10 kg/ha *fb* foliar application of 1.0% $ZnSo_4$ and 0.5% $FeSO_4$ treatment reported higher growth and yield attributes like periodical plant height, number of leaves at harvest, leaf stem ratio and green fodder yield. Response of zinc and iron fortification treatment on dry matter and crude protein content, crude protein yield and neutral detergent fiber were found to be non-significant. Soil and foliar application of Zn and Fe on fodder maize improved Zn and Fe content in plant and soil over control (No micronutrient application) treatment.

Keywords: Biofortification, iron, fortification, green fodder yield, zinc and dry matter yield, crude protein yield, nutrient content and uptake

Introduction

In the Agricultural system, agriculture is considering a main source of income and rearing dairy animals as a secondary source of income in a rural area of our country. Through dairy farming provides large amount of organic matter for primary sector, which helps to improves physicochemical properties of soil. Due to modern urbanization and drastically increasing world population damage soil health and finally effect on human health. Among the women, preschool children and young youth facing problem of micronutrients malnutrition's or hidden hunger due to low dietary intake, non-balance food, especially zinc and iron micronutrients. More than one third population facing risk from micronutrients specially zinc and iron.

Animal husbandry is become a significant sector in Indian agriculture. Farmers always favour maize for generating high-quality maize-cob silage for feeding cattle during lean fodder production seasons for optimal milk production (Kumar *et al.*, 2019[a]) [10]. Malnutrition is one of the important problems which affect the overall human productivity costing huge economic losses to the nations (Kumar *et al.*, 2019[b]) [11]. Reduce micronutrient deficiency like zinc and iron among rural and urban population by enhancing targeted micronutrient attention though agronomical intervention. One of the most important techniques in the sustainable production of nutritious and nutrient-dense food and feed is agronomic biofortification of field crops with micronutrients. (Grujcic *et al*., 2021) [5]. Maize, being a C_4 plant and versatile in nature adopted to various Agro-climatic condition (Ariraman *et al.*, 2022) [1].

Zinc, iron, boron and manganese are common essential micronutrients that are part of the photosynthesis, chlorophyll formation, nucleic acid, protein synthesis, N-fixation and other biochemical pathways. For increasing zinc and iron, agronomical manipulation is a quick and faster approach to increase concentration of targeted elements. The deficiency of Zn in Indian soils is expected to increase to 63% by the year 2025 as more areas of marginal land are brought under intensive cultivation without adequate micronutrient fertilization (Tripathi *et al*., 2009) [16]. The right source and mode of application is very important for the corrections of deficiencies (Singh *et al.*, 2021) [15]. Zinc is a vital micronutrient for human health. Zinc is known as the "metal of life" because it performs a wide range of critical tasks. Zinc is a fundamental plant vitamin that helps plants with protein synthesis, glucose metabolism, and heat stress resistance (Tsonev and Cebola lidon, 2012 [17] and Cobot *et al.*, 2019 [3]). Zinc is necessary for the functioning and structural integrity of up to 10% of the proteins in biological systems. Zinc is essential for cell reproduction, hormone synthesis, immune system function, and electrolyte homeostasis enzyme activation, photosynthesis, and protein synthesis. Zinc deficiency can lead to stunted growth and reduced yields. Iron is a key component of chlorophyll, which is essential for photosynthesis. Iron deficiency can result in yellowing of leaves (chlorosis) and decreased plant growth.

When maize fodder boosted with Zn and Fe is fed to animals, it improves fodder quality and, as a result, milk quality, increases Zn content in milk, and reduces the risk of infectious illnesses. Dairy cattle nutrition is highly affected by Zn, Fe and Se presence in the feed, because these micronutrients have crucial role in different metabolic processes. Recent research on the foliar and soil treatment of Zn and Fe demonstrated that agronomic biofortification is effective in reducing these micronutrient deficiencies. So, agronomic bio-fortification is a holistic approach to eliminate micronutrient deficiency in food crops through agronomic practices by means of soil and foliar application. Both zinc (Zn) and iron (Fe) are essential micronutrients that play crucial roles in plant growth and development. Here's how soil and foliar application of zinc and iron can affect fodder maize yield and quality.

Material and Method

The field experiment was conducted for two consecutive years during the *kharif* seasons of 2019 and 2020 at Main Forage Research Station, Anand Agricultural University, Anand (Gujarat) India (30°56′ N, 75°52′ E, 247 m above mean sea level). Weather parameters according to standard meteorological week are presented in fig.1. The soil of the experimental field was loamy sand in texture, low in organic carbon (0.28%) and medium in available phosphorus (35.12 kg/ha) and available potash (280.00 kg/ha) with slightly alkaline (pH 7.46) in reaction. The experiment was arranged in randomized block design with three replications, consisting of seven treatments *viz.* T_1: 0 kg $ZnSo_4$/ha (control), T_2: 10 kg $ZnSo_4$/ha as basal + 1% $ZnSo_4$ foliar spray at 45 DAS, T_3: 10 kg $FeSo_4$/ha as basal + 0.5% $FeSo_4$ foliar spray at 45 DAS, T_4: 10 kg $ZnSo_4$ +10 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS, T_5: 20 kg $ZnSo_4$/ha as basal +1% $ZnSo_4$ foliar spray at 45 DAS, T_6: 20 kg $FeSo_4$/ha as basal + 0.5% $FeSo_4$ foliar spray at 45 DAS and T_7: 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS. Recommended dose of fertilizer (80-40-0 NPK kg/ha) to fodder maize crop was applied with 50 percent of nitrogen and 100 percent of phosphorus as a basal in the form of urea and Single Super Phosphate (SSP) and muriate of potash (MOP), respectively and remaining 50 percent of nitrogen was applied at 30 DAS. Zinc and iron were applied as a soil application as well as foliar application (0.5 percent of zinc and iron as per treatment at 45 DAS) in the form of $ZnSO_4$ and $FeSO_4$, respectively at 45 DAS to respective treatments. Tag five plants in each net plot area for measuring growth and yield attributing characters as per standard protocol. For proximate analysis collected 500 g green plant sample from each plot and follow standard process for quality analysis (Table 1). The data collected from the experiment during crop growth period were subjected to statistical analysis (Randomized Block Desing) as described by Gomez and Gomez (1984) [7].

Quality analysis of green fodder

Fodder Dry matter percentage

Dry matter percentage was determined by using the following formula.

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

Dry matter yield (q/ha) was calculated by dry matter% 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 (Estefan *et al*., 2013) [4].

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 expressed in q/ha.

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

Table 1: Following are different methods for green fodder proximate analysis)

Sr. No.	Parameters	Method adopted
1	Neutral detergent fibre (%)	Forage fibre analysis US method (Goering and Vansoest 1975) [7]
2	Acid detergent fibre (%)	Forage fibre analysis US method (Goering and Vansoest 1975) [7]
3	Crude protein content (%)	Kjeldhl's method (Jackson 1973) [9]
4	Total micronutrients Zn, Fe, Mn, Cu	Wet Digestion (HNO_3: $HClO_4$- 4:1) (Atomic Absorption Spectrophotometry) (Jackson 1973) [9]

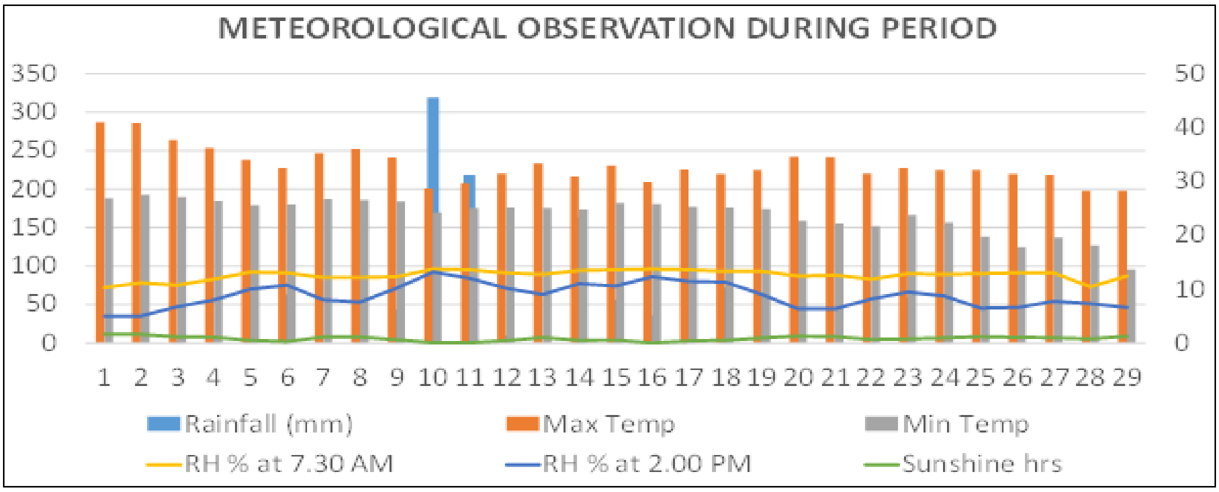

Fig 1: Meteorological observation during growth period

Results and Discussion

Plant stands per meter row length, plant height at 30 DAS and number of leaves (Table 2) of fodder maize was found to be non-significant due to various treatments. It means uniform germination of seed in each experimental plot. Application of 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS (T_7) reported significantly higher plant height (163.87 and 238.37 cm at 45 DAS and at harvest, respectively). Increasing height may be related to an increase in the plant's photosynthetic capacity, which is responsible for the generation of fresher biomass, dry matter, and its distribution throughout the plant. Another reason to increase growth parameters *i.e* plant height and number of leaves (Table 2) might be due to use of Zn and Fe, as zinc and nitrogen have a synergistic effect on plant growth and development (Rajkumar and Shivkumar, 2021) [13]. Leaf stem ratio is most important parameter in fodder crops for better yield performance, it is also directly related with higher green fodder, An application of 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS (T_7) noted higher leaf stem ratio (1.185%). The growth parameters have a direct relationship with green fodder yield through photosynthetic activity, fresh biomass production and dry matter accumulation. A strong linear and positive relation between growth parameters and yield was established. Increase in the yield attributes could be due to continuous supply of organically chelated micronutrients (Zn and Fe) to the crop. Zn and Fe are part of the photosynthesis, assimilation, and translocation of photosynthates from source (leaves) to sink.

Perusal of data presented in Table 2 and fig.2 revealed that application of 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS (T_7) treatment reported significantly the highest green fodder (407 q/ha), it was 8.24% higher over treatment T_4 (10 kg $ZnSo_4$ +10 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS). Minimum green fodder (306 q/ha) was reported in treatment T_1 (0 kg $ZnSo_4$/ha) than rest of treatments. Increase in yield was due to improved availability of micronutrients (Zn and Fe) which could be attributed to the formation of stable organometallic complexes of micronutrients with organic matter, especially during the enrichment process to last for a longer time and release the nutrients slowly in the soil system in such a way that the nutrients are protected from fixation and made available to the plant root system throughout the crop growth (Nikhil Kumar and Salakinkop S.R. 2018) [12]. Low green yield (306 q/ha) with no application of RDF and micronutrients (Control). The fact that Fe is an advantageous part of several enzymes that favorably enhance the nutritional environment of the crop and ultimate production may be the cause of the increase in the parameter (Asif *et al.*, 2020) [2].

Zinc and iron micronutrients are taken parts in many physiological functions, their improper supply can badly affect crop growth and yield. Response of soil and foliar application of Zinc and iron on dry matter, protein content, crude protein yield and neutral detergent fiber were found to be non-significant during two-year experimentation on fodder maize. Data expressed (Table 3 and fig.2) significant changes in dry matter yield under different biofortification treatments (Fig.02). Dry matter yield ranging from 67.51 to 82.95 q/ha. Higher dry matter yield (82.95 q/ha) was reported in treatment T_7 (20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS) but it was not differed with treatment T_4 (10 kg $ZnSo_4$ +10 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS). High dry matter is the indicator of good quality forage. Zn and Fe improved dry matter yield of green fodder extended as compared to the sole application. Biofortification of Fe and Zn improved the yield and increased in yield might be due to their crucial role in photosynthesis, respiration, biological and physiological activities (Salih, 2013 [14] and Asif *et al*., 2020 [2])

Zinc and iron are two heavy metal micronutrients that perform critical functions in plants (Hagh *et al.*, 2016) [8]. As compared with soil initial data Zn (1.33 ppm) and Fe (3.66 ppm) content is increase in all treatments. Zinc and iron concentration in plants and soil nutrient status of fodder maize are considerably influenced by various zinc and iron treatments. Application of 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS(T_7) reported higher Zn content (167.77 ppm) and treatment T_4 (10 kg $ZnSo_4$ +10 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS) reported higher Fe Content (344.53 ppm). Treatment T_7 (20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 DAS) reported higher Zn content (2.61%) and Fe content (4.26%) than the rest of treatment (Table 3). Higher grain yield with Zn and Fe treatment might be linked to enhanced total dry matter production as a result of greater Zn and Fe absorption and translocation to reproductive organs. Zinc and iron uptake in fodder maize found to be significant by used of different treatments. Higher uptake of zinc (140.07 q/ha) and iron (285.43 q/ha) was reported in treatment T_7 (20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha as basal + 1% $ZnSo_4$ + 0.5% $FeSo_4$) than rest of treatments as well as control.

Table 2: Treatment response on growth, yield attributes, yield, and quality of fodder maize (Pooled of Two years)

Treat	Plant stands per meter row length	Plant height (cm)			No. of leaves per plant	Leaf stem ratio	GFY (q/ha)	DM%	CP%
		At 30 DAS	At 45 DAS	At harvest					
T_1	7.75	71.15	140.32^{d}	203.12^{e}	14	0.654^{a}	306^{e}	22.06	5.71
T_2	7.63	72.40	148.13^{c}	209.25^{d}	14	0.569^{a}	346^{d}	21.38	5.71
T_3	7.75	72.2	140.75^{d}	214.63^{c}	14	0.691^{a}	341^{d}	21.66	5.89
T_4	7.75	73.12	152.33^{b}	219.75^{b}	13	0.994^{a}	376^{b}	21.44	6.40
T_5	7.88	71.12	145.25^{c}	213.25^{cd}	14	0.901^{a}	345^{d}	22.95	5.31
T_6	8.00	71.80	146.15^{c}	222.5^{b}	14	0.895^{a}	362^{c}	20.51	5.43
T_7	8.37	76.90	163.87^{a}	238.37^{a}	16	1.185^{a}	407^{a}	20.42	6.14
S.Em ±	0.20	2.46	2.99	4.77	0.65	0.600	7.0	0.67	0.42

Table 3: Treatment response on quality, micronutrient content and uptake of fodder maize (Pooled of Two years)

Treat	DMY (q/ha)	CPY (q/ha)	NDF	Zn content		Fe content		uptake (q/ha)	
				In plant (%)	In soil (ppm)	In plant (%)	In soil (ppm)	Zn	Fe
Initial status	-	-	-	-	1.33	-	3.16	-	-
T_1	67.51^{d}	3.85	81.28	71.52^{f}	1.53^{c}	183.46^{d}	1.56^{d}	48.6^{e}	143.21^{d}
T_2	73.81^{c}	4.21	82.51	150.24^{d}	2.25^{ab}	247.48^{b}	2.01^{cd}	111.05^{d}	181.36^{c}
T_3	73.83^{c}	4.35	82.10	76.93^{e}	1.71^{c}	343.27^{a}	3.57^{ab}	56.08^{e}	242.75^{b}
T_4	80.55^{ab}	5.16	82.58	163.07^{b}	2.04^{bc}	346.93^{a}	3.39^{b}	131.45^{b}	276.22^{a}
T_5	79.18^{b}	4.18	83.99	155.06^{c}	2.33^{ab}	233.06^{c}	2.44^{c}	121.06^{c}	176.83^{c}
T_6	74.5^{c}	4.02	82.49	68.848^{f}	2.01^{bc}	343.82^{a}	4.11^{a}	51.68^{e}	251.65^{b}
T_7	82.95^{a}	5.12	83.79	167.77^{a}	2.61^{a}	344.53^{a}	4.26^{a}	140.07^{a}	285.43^{a}
S.Em ±	3.11	0.35	1.51	4.25	0.06	4.79	0.12	14.97	31.76

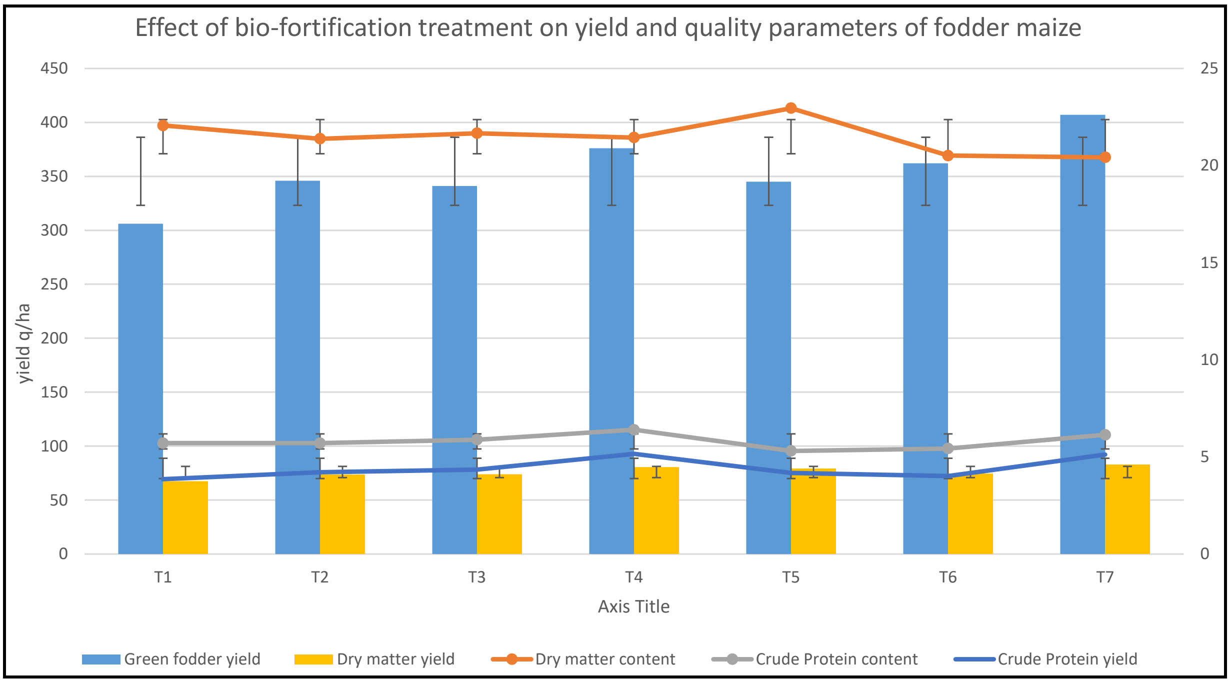

Fig 2: Effect of biofortification treatment on green fodder yield and quality parameters of fodder maize

Conclusion

To overcome malnutrition problems, agronomical biofortification offer best solution to escalating micronutrients. Foliar application of Zn and Fe sprays provide a practical and useful way to agronomically biofortify rice and maize with Zn and Fe. Agronomic biofortification offers long-term answers to the escalating micronutrient-related malnutrition problems. A practical and beneficial method for agronomic biofortification with Zn and Fe is the application of foliar sprays. Based on two years experimentation data, the yield and quality of fodder maize can be positively influenced by both soil and foliar application of zinc and iron, ensuring that these essential micronutrients are available in adequate amounts for optimal plant growth and development. Agronomical bio-fortification is a very good process to improve green fodder yield and quality of fodder maize. Significantly response on growth and yield parameters, green fodder yield, quality parameter, content and uptake of zinc and iron and post-harvest soil micronutrient status like zinc and iron found to be higher by application of 20 kg $ZnSo_4$ +20 kg $FeSo_4$/ha soil application *fb* 1% $ZnSo_4$ + 0.5% $FeSo_4$ foliar spray at 45 days after sowing.

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