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AGRONOMIC FORTIFICATION THROUGH ZINC AND IRON APPLICATION: A VIABLE OPTION TO IMPROVE THE PRODUCTIVITY OF FODDER MAIZE

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SUMMARY

Zinc and iron both are extensively used to improve the productivity and quality of fodder maize, which ultimately helps in alleviate their deficiency in animals. To find out zinc and iron requirement of fodder maize a field experiment was conducted during *spring* season of 2020 at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The soil of the experimental field was sandy loam in texture, neutral in reaction, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potassium. The experiment was laid out in FRBD design with four zinc levels [No $ZnSO_4$, 20 kg/ha $ZnSO_4$ (basal dose), 25 kg/ha $ZnSO_4$ (basal dose) and 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS] and four iron sprays at 30 DAS [No $FeSO_4$, 0.5% foliar spray of $FeSO_4$, 1% foliar spray of $FeSO_4$ and 1.5% foliar spray of $FeSO_4$] and replicated thrice. Results shows that growth parameters and yield of fodder maize in spring season were significantly influenced due to zinc and iron management effects. Growth parameters like no of leaves/plant, leaf length, leaf breadth, plant height and LAI and yield of spring planted fodder maize were recorded highest with application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS. Similarly foliar spray of 1 % $FeSO_4$ at 30 DAS recorded better growth parameters and significantly higher yield of fodder maize. Application of 1 % foliar spray of $FeSO_4$ at 30 DAS recorded significantly higher green and dry fodder yield. However the difference in dry fodder yield with application of 0.5%, 1% and 1.5% foliar spray of $FeSO_4$ at 30 DAS was not significant. The crude protein content was recorded highest with foliar spray of 1.5% $FeSO_4$ at 30 DAS. Application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS in spring planted fodder maize resulted in 36.43 % higher green fodder yield and 36.35 % higher dry matter yield over control. Similarly application of 1% foliar spray of $FeSO_4$ at 30 DAS resulted in 12.68% higher green fodder yield and 12.70 % higher dry matter yield over control.

Key words : Fodder maize, LAI, crude protein content, Zinc and iron effect

In India, lower productivity of cattle is mainly due to unavailability of quality feed and fodder, improper nutrition, inadequate health-care and management. At present, the country faces a net deficit of 36% green fodder, 11% dry crop residues and 44% concentrate feed ingredients. Thus, any attempt towards enhancing feed availability and economizing the feed cost would result in increased margin of profits to livestock owners. The solution therefore, lies in increasing quality fodder production on limited space and time. Maize, a member of the family Poaceae and it is a multi-utility cereal, commonly known as queen of cereals due to its wider adaptability under diverse agro-ecological conditions and highest genetic potential. The maize grain is enriched with necessary nutrients as it contains 72% starch, 10% protein, 4.8% oil, 8.5% fibre, 3% sugar and 1% ash. It is a C_4 plant and is capable of utilising solar radiation more efficiently even at higher radiation intensity. Being a rich source of protein for livestock, sufficient quantities of soluble sugars make it critical for proper ensiling (Kumar *et al.*, 2020). Maize produces good quality herbaceous fodder with high palatability.

Micronutrients are involved in the key physiological processes of photosynthesis and respiration (Mengel *et al.,* 2001) and their deficiency can impede these vital physiological processes thus limiting yield gain. Among various micronutrients, zinc plays a crucial role in quality of fodder crops. Direct linkages between available micronutrient in the soil and their contents in forage and fodders have been widely studied and clearly established and it's also common in case of zinc (Jat *et al.,* 2014). Zinc is essential for animals, plants and human nutrition, thus opportunities for simultaneously addressing the deficiencies by applying them as supplemental fertilizer to crops, benefiting both farmers (better yields) and consumers (micronutrient-enriched food/fodder).

Zinc is one element, which is found to be acutely deficient in many geographical zones of India (Ramana *et al*., 2003; Garg *et al*., 2005; Udar *et al*., 2003). Most of the feed ingredients, particularly straws, were unduly low in Zn content (17.80 ppm). Zinc content was found below the critical level (30 ppm) in most of the crop residues and needed to be supplemented @ 80 ppm in the total ration (Arora, 1981) of animals, to overcome its deficiency. According to ICAR-IISS, Bhopal, across the states more than 50% samples of soil tested were found deficient in zinc; while in Haryana state this digit reached up to 65%. Deficiency of zinc in soil will lead to poor fodder yield as well as quality. Since, zinc is also a major nutrient in animal nutrition; if we properly manage its deficiencies in soil the problem associated with lower level of zinc in animals can be rectified. Iron is a necessary element that take place in several redox states, eagerly accepting and donating electrons, which confer the ability to function as a cofactor for numerous plant proteins that contribute in key metabolic pathways (Briat *et al*., 2007). Zinc and iron are important nutrients for both plants and human and their deficiency in soil is a worldwide concern.

Zinc and iron can be applied in different way such as foliar spray, soil application (sprayed over soil surface or applied in soil) and seed application method. With this hypothesis, the current study was planned to access limited information about scheduling and dose of zinc and iron application for better quality and yield of fodder maize in spring season of Hisar.

MATERIALS AND METHODS

A field experiment was carried out during *spring* season of 2020 at Agronomy Research Area of CCS Haryana Agricultural University, Hisar. The purpose of this experiment was to analyze the influence of zinc and iron management effects on performance of fodder maize in spring season The experiment was laid out in FRBD design with four zinc levels [No $ZnSO_4$, 20 kg/ha $ZnSO_4$ (basal dose), 25 kg/ha $ZnSO_4$ (basal dose) and 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS] and four foliar sprays of iron at 30 DAS [No $FeSO_4$, 0.5% $FeSO_4$, 1% $FeSO_4$ and 1.5% $FeSO_4$] replicated thrice. The climate of Hisar (29°10' N latitude and 75° 46' E longitude at an elevation of 215.2 m above mean sea level) is sub-tropical, semi-arid with an average annual rainfall of around 450 mm of which, 70-80 per cent is received during monsoon period *i.e.*, July to September and the rest is received in showers of cyclic rains during the winter and spring seasons. The Soil nitrogen and phosphorus status before sowing was 122 kg N and

TABLE 1

Zinc and iron management effects on growth attributes of spring planted fodder maize

Treatment	Plant height (cm)			Leaf length (cm)		
	45 DAS	90 DAS	At harvest	45 DAS	90 DAS	At harvest
Zinc levels						
No $ZnSO_4$	32	129	144	19.04	71.63	89.92
20 kg/ha $ZnSO_4$ (basal dose)	34	146	152	23.66	74.22	92.41
25 kg/ha $ZnSO_4$ (basal dose)	42	153	159	24.13	77.42	95.84
25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS	41	164	166	25.35	78.27	97.66
CD at 5 %	1.75	3.03	1.96	1.31	3.75	4.98
Iron spray at 30 DAS						
No $FeSO_4$	35	143	147	20.90	71.15	89.85
0.5% foliar spray of $FeSO_4$	37	148	153	22.29	75.56	94.3
1% foliar spray of $FeSO_4$	38	152	166	25.86	78.52	96.83
1.5 % foliar spray of $FeSO_4$	39	149	156	23.13	76.31	94.85
CD at 5 %	1.75	3.03	1.96	1.31	3.75	4.98

16.45 kg P_2O_5 /ha respectively, while organic carbon, pH and available K were 0.44, 7.7 and 371 kg/ha, respectively, before sowing in February, 2020. Experimental field was prepared thoroughly by two ploughings and one planking, followed by pre-sowing irrigation. Fodder maize variety 'African tall' was sown on 3rd February, 2020 and harvested manually on 20th May, 2020. The recommended dose of nitrogen and phosphorus were applied to all the treatments, of which full dose of phosphorus and half nitrogen were applied at sowing time and remaining half nitrogen were top dressed as urea at 30 days after sowing. At the time of top dressing of urea, fertilizer was broadcasted and care was taken so that the fertilizers were mainly applied on targeted crop rows only. As per the treatments, application of $ZnSO_4$ and $FeSO_4$ were done. To achieve uniform soil application of $ZnSO_4$, it was dissolved in water and then sprayed in the plots as per treatments as basal dose. While for treatments having foliar spray of zinc, 1% solution of $ZnSO_4$ were made and sprayed at 45 DAS. Similarly, 0.5 %, 1% and 1.5% solution of $FeSO_4$ were made and sprayed as per the treatments. The other agronomic practices like irrigation, insect-pests control and weed control measures were done as per recommended package of practices of CCS HAU, Hisar. All growth parameters and yield attributes of the crop were recorded on randomly selected tagged plants. The maize crop was harvested at 50 % flowering stage. The plant samples were collected at crop harvest and analyzed for quality parameters by standard procedure. Fresh green fodder yield recorded and plant samples collected at harvest were dried in hot air oven at 60°C for 48 h. These oven-dried samples of plants were ground to pass through 40 mesh sieve in a Macro-Wiley Mill and used for chemical analysis. The leaf area was measured at 60, 90 DAS and at harvest stage with sampling by measuring the five leaves from three plants in each plot. The total leaf area was computed using a potable leaf area analyzer LI-3000C (LI-COR, USA).

RESULT AND DISCUSSION

Effect on growth attributes

The critical analysis of data in Table 1 reveal that growth parameters like plant height and leaf length of spring planted fodder maize at different growth stages were significantly influenced by varying zinc and iron levels. Plant height of fodder maize at all the stages increased significantly with increase in zinc application. Significantly taller plants at 45, 90 DAS and at harvest were recorded with application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS. Similar trend were noticed in leaf length of maize which also increased significantly with increased doses of zinc. Application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS being at par with of 25 kg/ ha $ZnSO_4$ (basal dose) recorded significantly higher leaf length at all the three stages of crop growth.

A close perusal of the data in Table 1 on plant height of spring planted fodder maize reveal that application of 1% foliar spray of $FeSO_4$ at 30 DAS recorded significantly taller plants at 45, 90 DAS and at harvest. However, the difference in plant height with application of 1% and 1.5 % foliar spray of $FeSO_4$ at

TABLE 2

Zinc and iron management effects on no. of leaves/plant, dry matter accumulation and leaf breadth of spring planted fodder maize

Treatment	No of Leaves/ plant			Dry matter accumulation (kg/ha)		Leaf breadth (cm)
	45 DAS	90 DAS	At harvest	60 DAS	90 DAS	
Zinc levels						
No $ZnSO_4$	5.62	9.11	10.54	1110	4604	7.04
20 kg/ha $ZnSO_4$ (basal dose)	5.69	10.55	11.58	1232	5740	7.25
25 kg/ha $ZnSO_4$ (basal dose)	5.73	11.37	12.50	1621	6647	7.35
25 kg/ha $ZnSO_4$ (basal dose)+1% foliar spray at 45 DAS	5.80	11.57	13.02	1793	7934	7.56
CD at 5 %	N.S.	0.25	0.52	251	995	0.32
Iron spray at 30 DAS						
No $FeSO_4$	5.51	10.33	10.98	1113	4700	6.92
0.5% foliar spray of $FeSO_4$	5.68	10.61	11.71	1339	5336	7.28
1.0% foliar spray of $FeSO_4$	5.86	10.89	12.92	1749	8280	7.59
1.5 % foliar spray of $FeSO_4$	5.79	10.77	12.03	1555	6609	7.41
CD at 5 %	N.S.	0.25	0.52	251	995	0.32

30 DAS is not significant. Application of 1% foliar spray of $FeSO_4$ at 30 DAS being at par with 1.5% foliar spray of $FeSO_4$ recorded significantly higher leaf length of spring planted fodder maize at all the three growth stages.

Data presented in Table 2 revealed that growth parameters like number of leaves/plant at 90 DAS and at harvest, dry matter accumulation at 60 and 90 DAS and leaf breadth of spring planted fodder maize were recorded significantly higher with application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS. This may be attributed to significant role of zinc in protein synthesis and nitrogen metabolism in the plants. Number of leaves /plant at 45 DAS was not influenced significantly due to varying zinc and iron application.

Among various iron levels application of 1% foliar spray of $FeSO_4$ at 30 DAS being at par with 1.5 % foliar spray of $FeSO_4$ recorded significantly higher number of leaves/plant at 90 DAS and at harvest, dry matter accumulation at 60 and 90 DAS and leaf breadth of spring planted fodder maize. With the application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS there was 7.38 per cent increase in leaf breadth over no zinc application. Similarly, with the application of 1% foliar spray of $FeSO_4$ at 30 DAS there was 9.68 per cent increase in leaf breadth over no iron spray. Better growth attributes of maize due to application of Zinc and iron might be due to the fact that Iron and zinc play an important role on photosynthesis process of higher plants based on the fact that they are involved in metabolism reactions and catalyzing reaction. The positive and encouraging effect of zinc fertilization on growth of corn was also reported by Kumar (2013). The positive and encouraging effects of Zn fertilization on fodder yields of corn has also been observed by Kumar *et al.* (2017).

Effect on leaf area index

Leaf area index is an important parameter of photosynthesizing surface of plant and has pronounced effect on crop growth and yield. Leaf area ratio indicates the size of assimilatory surface area in relation to total dry matter accumulation. A close look of the data in Table 3 and Fig. 1 on LAI of spring planted fodder maize reveal that among various zinc levels application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 60 DAS being at par with of 25 kg/ ha $ZnSO_4$ (basal dose) recorded significantly higher leaf area index of spring planted fodder maize at 60, 90 DAS and at harvest. The lowest value of leaf area index was obtained with no zinc application.

Application of 1% foliar spray of $FeSO_4$ at 30 DAS recorded significantly higher LAI at 60, 90 DAS and at harvest. However the difference in LAI with application of 1% and 1.5 % foliar spray of $FeSO_4$ at 60, 90 DAS and at harvest is not significant. This positive effect of zinc and iron application might be due to the more vegetative growth and development of maize plant resulting in more dry matter accumulation and leaf area index.

TABLE 3

Zinc and iron management effects on LAI, yield and quality of spring planted fodder maize

Treatment	LAI			Green fodder yield (q/ha)	Dry Fodder yield (q/ha)	Crude protein content (%)
	60 DAS	90 DAS	At harvest			
Zinc levels						
No $ZnSO_4$	2.02	3.65	5.43	339.42	87.09	9.35
20 kg/ha $ZnSO_4$ (basal dose)	2.34	3.98	5.59	390.17	100.00	9.66
25 kg/ha $ZnSO_4$ (basal dose)	2.47	4.16	6.20	434.25	111.40	9.81
25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray at 45 DAS	2.68	4.33	6.35	463.08	118.75	9.90
CD at 5 %	0.31	0.46	0.72	7.91	2.11	0.36
Iron spray at 30 DAS						
No $FeSO_4$	1.97	3.45	5.36	377.83	96.96	9.46
0.5% foliar spray of $FeSO_4$	2.33	4.03	5.72	415.42	106.65	9.64
1% foliar spray of $FeSO_4$	2.67	4.49	6.47	425.75	109.28	9.78
1.5 % foliar spray of $FeSO_4$	2.54	4.15	6.02	407.92	104.34	9.84
CD at 5 %	0.31	0.46	0.72	7.91	2.11	0.36

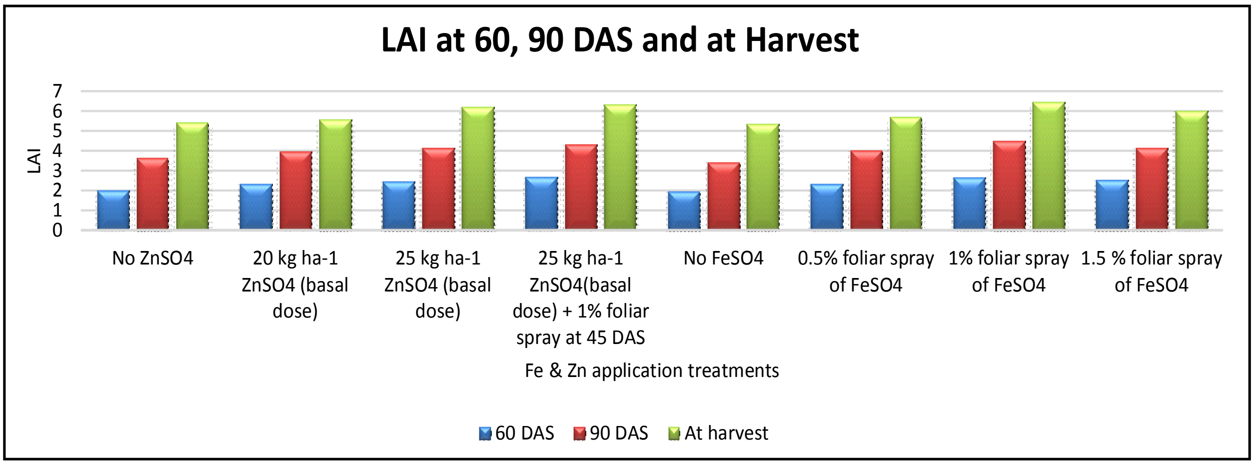

Fig. 1. Zinc and iron management effects on LAI at 60, 90 DAS and at harvest of spring planted fodder maize.

Effect on fodder yield

The results showed that the application of the both the micronutrients significantly influence maize green and dry fodder yield in spring season. Green fodder yield significantly increased from 339.42 q/ha to 463.08 q/ha and dry fodder yield from 87.09 q/ha to 118.75 q/ha with the application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS over control. Application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS had a significant increase of 36.43% higher green fodder yield than no zinc application. Among various iron sprays, highest green fodder yield was recorded with the application of 1% foliar spray of $FeSO_4$ which was 12.68% greater than the control (Table 3). It might be due better yield attributing character and This increase in the green fodder yield of maize may be attributed to the increased plant height, leaf length, breadth, numbers of leaves, leaf area index and higher dry matter accumulation with zinc and iron application which is consistent with the finding of (Manzeke *et al.,* 2014) that showed the significant effect of using zinc as a supplement fertilizer. Similar results for grain yield of maize were also reported by Bender *et al.,* 2013).

In the present investigation, highest dry fodder yield of maize was recorded with the application of foliar spray of 1.5% $FeSO_4$ at 30 DAS. However, the difference in dry fodder yield with application of 0.5%, 1% and 1.5% foliar spray of $FeSO_4$ at 30 DAS is not significant. The dry fodder yield was 36.3%, 18.75% and 6.59 % higher with application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS as compared to no Zinc, 20 kg/ha $ZnSO_4$ (basal dose) and 25 kg/ha $ZnSO_4$ (basal dose), respectively. Similarly, application of 1% foliar spray of $ZnSO_4$ at 45 DAS resulted in 12.70% higher dry fodder yield than control. Mugenzi *et al.* (2018) also revealed that application of Zn, Fe and their combination had a significant effect on the grain yield of maize. Significant improvement in green and dry fodder yield of maize over control was reported by Kumar *et al.* (2017) for all the zinc treatment with the highest green and dry fodder yield (pooled basis) with 20 kg/ha $ZnSO_4$ as basal dose which was at par with 10 kg/ha $ZnSO_4$ as basal dose + 0.5 foliar spray of $ZnSO_4$ at 30 DAS and 2 sprays of 0.5% $ZnSO_4$ at 30 and 45 DAS.

Effect on crude protein content (%)

A close look of the data in Table 3 reveal that lowest value of crude protein content of spring planted fodder maize was obtained with no iron and zinc application. Increasing application of $ZnSO_4$ and $FeSO_4$ resulted in significantly higher value of crude protein content of maize. Among various zinc levels, application of 25 kg/ha $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS and among various iron sprays application of 1.5% foliar spray of $FeSO_4$ at 30 DAS recorded significantly higher crude protein content of spring planted fodder maize. These results imply that the use of Zn and Fe might be an alternative way to improve fodder maize quality in regions with Zn and Fe deficiency. Kumar and Ram (2021) reported that Zn enrichment method combining soil addition and foliar spraying is the best one to improve the quality of maize fodder, and thus can be a good way to introduce Zn into animal nutrition. But, Mugenzi *et al.* (2018) revealed that application of Zn, Fe and the combination Zn-Fe as supplement on basal fertilizer had no significant influence on the grain of crude protein content of maize however, the treatments of Zn_{12} +

Fe_{18} and Zn_{18} + Fe_{12} had the higher concentration of crude protein, with 17% and 18% compared to the control treatment, respectively.

CONCLUSION

Overall, the study suggests that zinc (25 kg ha^{-1} $ZnSO_4$ (basal dose) + 1% foliar spray of $ZnSO_4$ at 45 DAS) and iron fertilization (1% foliar spray of $FeSO_4$ at 30 DAS) of fodder maize can enhance not only green and dry fodder yield but also improve quality of fodder maize in spring season.

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