Pedology and Environment 2024, 34 (02), 149-159
doi.org/10.47114/j.pedoenv.2024.dec 3

Studies on influence of zinc fortification on yields and quality of fodder maize

M. Shanti, R. Susheela, V. Chandrika, T. Shashikala, M.C. Patnaik And P. Surendra Babu

[1]*Agricultural College, Sircilla, Rajanna Sircilla Dist- 505301*
[2]*Agricultural College, Palem, Nagar Kurnool Dist -509381*
[3]*Agricultural Research Station, Utukur, Kadapa Dist-560037*
[4]*AICRP on Forage Crops & Utilization, ARI, Rajendranagar, Hyderabad-500030*
[5,6]*Coordinated Micronutrients Scheme, ARI, Rajendranagar, Hyderabad-500030*

Abstract : An experiment was conducted to study the effect of the fortification of a fodder maize variety. African Tall with micronutrient zinc through $ZnSO_4$ fertiliser application. The study involved fortification at different doses through soil application and foliar sprays at different stages of the crop. Green fodder yields were highest at 50 kg $ZnSO_4$ ha^{-1}, while Zinc content increased with increasing crop growth from knee high (18.9 mg kg^{-1}) to fodder harvest (37.9 mg kg^{-1}), with the highest concentration at soil application of 50 $ZnSO_4$ ha^{-1}. Zinc fortification of 23% was observed when 50 kg of $ZnSO_4$ was added through soil application, while soil application of 25 kg $ZnSO_4$ ha^{-1}, along with two foliar sprays at knee high and tasseling, showed on par yields. Foliar sprays complemented soil application, but exclusive foliar application failed to show an impact on yields. No significant effect of zinc was observed on quality parameters, viz., crude protein, acid detergent fibre or neutral detergent fibre. The crude protein content, though, did not vary significantly; the highest was observed when 50 kg of $ZnSO_4$. Zinc influenced Neutral detergent fibre at fodder harvest significantly; however, no particular trends were observed; zinc application did not affect acid detergent fibre at any stage of the crop.

Keywords: *fodder maize, zinc fortification, green fodder yields, crude protein, neutral detergent fibre, acid detergent fibre*

Introduction

Zinc is a very important micronutrient for human health. Zinc regulates metabolism and influences the multifaceted development of the body. It also influences the human immune system, as evident by its deficiency, which marks susceptibility to various pathogenic infections and diseases. International Zinc Nutrition Consultative Group (IZiNCG, 2004) of WHO indicated that zinc deficiency in children <5 years of age increased the risk of incidence for diarrhoeal disease, pneumonia, as well as malaria and supplements with zinc would hasten recovery (WHO, 2014). Wessells & Brown (2012) indicated that inadequate zinc in more than 25% population in South Asian countries, including India, would be an elevated public health concern. Micronutrient deficiencies of Zn and Fe are more prevalent in countries such as India, Pakistan, China, Iran, and Turkey. Zinc ranks fifth among the most important factors that affect life in developing countries (Cakmak, 2008). The present adversaries of zinc deficiencies are a result of consuming nutritionally deficient foods, such as milk and cereal, which are vital components in the diets of developing countries. Diet of

[*]**Corresponding author**: (Email:)

plant and animal origin, *viz.*, food grains, milk and meat, reflects the nutrient status of the soil on which they are grown. Singh and Behara (2011) analysed over three lakh soil samples across the country and found that 49 per cent of the soils were deficient in zinc. Additionally, several nutritional surveys on forage quality evaluation by IGFRI, Jhansi, have clearly indicated deficiencies of Ca, P, Cu, and Zn in lactating cows due to the feed and forage being served. Characteristics of a Zn deficiency in animals include loss of appetite, reduced growth and reproduction, and impaired health of bone and skin tissues. Forages neither contain all the minerals that animals require nor are they present in adequate quantity (Vargas & McDowell, 1997). Flaring up the situation, the use of high-analysis fertilisers, limited recycling of plant residues and a gap between removal and supplementation of secondary and micronutrients have resulted in widespread Zn deficiency. Often, fodders could not secure sufficient quantities of Cu, Zn, Se and Ca from soils, despite the fact that soils are well provided with these nutrients (Marijanusic et al., 2017), while grazing animals invariably exhibit Zn deficiency when soils and forages contain limited concentrations of Zn (Hill et al., 2019). This deficiency scenario needs to be alleviated by supplementing the plant with additional zinc, either directly or through the soil.

In combating the situation, two options are available to improve zinc concentration in body tissue: food fortification and pharmaceutical supplementation. While the latter comes with a cost, the former is more cost-effective. Biofortification is currently in vogue, with studies focusing on both genetic and agronomic fortification of cereals and other food grains. The investigation emphasised biofortification of zinc in fodder maize, which is one of the most important crops grown throughout the country during all seasons. It is a popular fodder crop that has a vast preference among the dairy community due to its photo-inhibitory nature, animal preference, adaptability, and forage quality, as well as its lack of antinutritional factors at any stage of its life. Besides, being supplied at a subsidised rate by the Department of Animal Husbandry of the State, it is the most preferred and widely grown fodder amongst the dairy community.

Materials and methods

A field experiment was conducted in the fields of the All-India Coordinated Research Project on Forage Crops and Utilisation at Rajendranagar, Hyderabad. Fodder maize was raised during the *rabi* season for two consecutive years. The soil of the experimental site was well-drained and a moderately deep sandy loam with a near-neutral pH of 7.8 and an electrical conductivity of 0.38 to 0.56 dS m^{-1}. The soil was low in organic carbon and available nitrogen but high in phosphorus and potassium status, with mean values ranging from 152 to 168 kg of N ha^{-1}, 33 to 36 kg of P ha^{-1}, and 344 to 448 kg of K ha^{-1}, respectively. The initial soil zinc concentration was 0.45 ppm in both fields. A total of 13 treatments were imposed in 3 replications in the field experiments. The treatments included different doses of zinc sulfate and various methods of application at different stages of crop growth. Zinc was applied in the form of zinc sulfate ($ZnSO_4.7H_2O$) @ 12.5, 25 and 50 kg ha^{-1} during the last ploughing as a basal application. Treatments included the application of zinc sulphate as a foliar spray at a 0.2 per cent concentration at the knee-high stage, tasseling stage, or both. Care was taken to ensure that the water spray was applied to other treatments that did not receive foliar zinc.

The detail of the treatments is given in Table 1. The state recommended fertiliser dose of N, P, K for fodder maize, i.e., 120: 60: 40 kg ha^{-1}, was adopted. Nitrogen was applied in 2 equal splits; the first split, including 50% of N, was applied at the last ploughing, and the second half at the knee-high stage of the crop. The entire dose of phosphorus and potash where applied during the last ploughing. Urea, single superphosphate and muriate of potash were used as sources of N, P, and K, respectively. Zinc sulphate (21% zinc) was used as a source of zinc. Care is taken that zinc is not applied with phosphorus fertiliser. The spacing adopted was 30 cm between rows and 10 cm between plants within a row. All the recommended practices for fodder maize were implemented. The crop was harvested at the early dough stage as recommended for fodder maize.

Representative samples of the crop were taken at the knee-high, tasseling, and harvest stages. Green

Table 1: Details of treatments

S.No	Treatments
1	T_1- Control
2	T_2- 25 kg $ZnSO_4$ soil
3	T_3- T_2+$ZnSO_4$ spray at knee high
4	T_4- T_2+$ZnSO_4$ at tasselling
5	T_5-T_2+Two sprays at knee high and tasselling
6	T_6- 12.5 kg $ZnSO_4$ soil
7	T_7-T_6+ spray at knee high
8	T_8- T_6+ onespray at tasselling
9	T_9- T_6+ two sprays at knee high and tasselling
10	T_{10}- Spray at knee high
11	T_{11}- Spray at tasselling
12	T_{12}- Two sprays at knee high and tasselling
13	T_{13}- 50 kg soil application of $ZnSO_4$

fodder yields were taken at the early dough stage of the crop as recommended for forage maize. Plant samples were shade-dried before being transferred to ovens for further drying to a constant weight, which took approximately 2-3 days. The samples were pounded in a Wiley mill and processed for analysis of zinc and other quality parameters following standard procedures. Zinc in the initial soil was estimated by the procedure described by Lindsay and Norwell (1978). In plants, the concentration of a di-acid mixture was estimated using an atomic absorption spectrophotometer (model Hitachi 170-30). Crude protein was estimated by estimating nitrogen content in the sample (Piper, 1966) and multiplying by 6.25. Other quality parameters, *viz.*, neutral detergent fibre and acid detergent fibre, were analysed as per the procedure described by Van Soest (1963).

The concentration of zinc was studied at the knee-high, tasseling and harvest stages, and the percentage fortification is calculated using the following formulaa:

$$\text{Percent fortification} = \frac{\text{Content of nutrient in treated plot - content of nutrient in control}}{\text{Content of nutrient in control (Maximum yield)}}$$

Statistical analysis of the data was done by applying the technique of analysis of variance for simple RBD (Panse & Sukhatme, 1989). A critical difference for examining treatment means and their significance was calculated at a 5% level of probability.

Results & Discussion

Yields

The two-year study also showed a significant response of zinc application on green fodder yields of fodder maize (Table 2). There were significant differences in GFY between treatments, with the highest yields in the treatment receiving 50 kg $ZnSO_4$ ha^{-1}. The treatments receiving 25 kg $ZnSO_4$ (with or without foliar sprays), 12.5 kg $ZnSO_4$ and exclusive foliar treatments recorded mean green fodder yields of 45.3, 42.1 and 38.9 t ha^{-1}, while the highest yields of 53.1 t ha^{-1} were recorded when 50 kg $ZnSO_4$ ha^{-1} was applied. This indicates that soil application performed better than foliar sprays, with better performance evident as the application of zinc to the soil increased up to 50 kg ha^{-1}. Although foliar sprays complemented soil applications, exclusive foliar applications failed to show an impact on yields. The best treatment showed an increment of 346 kg of fodder yield for every kilogram of $ZnSO_4$ applied. A sustainability index of 0.70 was obtained, which was derived from the mean, maximum yields, and standard deviation. These results are in conformity to those reported by Ahmed et al, 2014, who reported positive and significant influence of zinc on green fodder yield of maize. Mahdi et al. (2011), Sheraz *et al.* (2012) and Jamil *et al.* (2015) also reported increased GFY with increasing Zn application. An increase in green fodder yields of up to 10 and 20 kg ha^{-1} was also reported with the application of $ZnSO_4$ to soil by Kumar *et al.* in 2015 and 2017, respectively. Maximum accumulation of 13 kg ha^{-1} of zinc was reported by Wenger et al. (2002) in maize when grown on artificially zinc-enriched soil. Highest green fodder yields at 50kg $ZnSO_4$ ha^{-1} along with foliar application at 30 and 45 DAS were observed in African Tall (Sulthana, 2015). Increased zinc content in grain in seed crop of maize was reported by Pongde and Ghodpade (2014), Olusegun and Meki (2014) (in pot

Table 2: Effect of different levels of Zn and its mode of application on GFY, DFY, CPY and B:C ratio (pooled over two years)

S.No.	Treatments	GFY	DFY	CPY	B:C ratio
		(t ha^{-1})			
1	T_1- Control	35.8	5.15	0.40	2.56
2	T_2- 25 kg $ZnSO_4$ soil	45.4	6.68	0.56	3.05
3	T_3-T_2+Zn SO_4 spray at knee high	43.7	6.18	0.53	2.89
4	T_4-T_2+$ZnSO_4$ at tasselling	43.0	6.66	0.59	2.85
5	T_5-T_2+Two sprays at knee high and tasselling	49.0	7.12	0.61	3.16
6	T_6- 12.5 kg $ZnSO_4$ soil	40.5	6.22	0.52	2.78
7	T_7-T_6+ spray at knee high	39.1	5.78	0.45	2.65
8	T_8- T_6+ one spray at tasselling	43.9	6.85	0.58	2.97
9	T_9- T_6+ two sprays at knee high and tasselling	38.7	5.76	0.46	2.55
10	T_{10}- Spray at knee high	37.3	5.52	0.49	2.58
11	T_{11}- Spray at tasselling	41.0	5.90	0.50	2.84
12	T_{12}- Two sprays at knee high and tasselling	38.5	5.88	0.52	2.59
13	T_{13}- 50 kg soil application of $ZnSO_4$	53.1	8.86	0.83	3.40
	Mean	42.2	6.35	0.54	2.84
	s.d	4.88	0.94	0.11	0.26
	S.Em($\pm$)	1.56	0.90	0.07	
	CD (P 0.05)	5.1	2.66	0.22	

studies), Patil et al. (2016), Singh et al. (2017) (up to 10 kg $ZnSO_4$ ha^{-1}), Gajbhiye *et al.* (2018) (up to 25 kg $ZnSO_4$ ha^{-1}), Kachapur *et al. (*2019) (up to 15 kg $ZnSO_4$ ha^{-1}) and Muhammad et al. (2019) (up to 15 kg $ZnSO_4$ ha^{-1}).

Dry fodder yields were also influenced by the zinc application. All the treatments receiving soil application of zinc showed almost on par dry matter yields; however, the DFY of foliar treatments were on par with each other and with that of the control (Table 2). The highest dry folder yields of 8.86 tons per hectare were observed in the treatment that received 50 kg $ZnSO_4$ ha^{-1}. All the treatments receiving 25 kg of $ZnSO_4$ ha^{-1} were on par with the best treatment, indicating that performance with respect to DFY at 25 kg $ZnSO_4$ is commendable. The crude protein yield in treatment receiving 50 kg $ZnSO_4$ ha^{-1} and that which received 25 kg $ZnSO_4$ ha^{-1} along with two foliar sprays was found to be on par. No significant variations were observed in other treatments.

The nutrient use efficiency here was 13.1, 26.8 and 48.3 % when ZnSO4 was applied to soil at rates of 12.5, 25.0 and 50.0 kg ha^{-1}, respectively. On the contrary, the NUE of exclusive foliar treatments varied between 4.2 and 7.5%.

Zinc content

Zinc content of fodder maize varied with different stages of crop growth. As indicated in Table 3, at the knee-high stage, zinc content varied from 17.5 mg kg^{-1} to 20 mg kg^{-1}. Though no significant differences existed between the treatments, T_5, which received 25 kg $ZnSO_4$ ha^{-1} along with a spray at the knee-high stage of the crop, recorded the highest concentration of nutrients.

There was an increase in zinc concentration at tasseling over that of the knee-high stage, with values ranging between 24.2 and 28.6 mg kg^{-1}; however, differences between the treatments were insignificant. At harvest, i.e., at the early dough stage of fodder maize, these differences were significant, with the highest concentration of zinc in T13, which received 50 kg $ZnSO_4$ as basal. All treatments receiving 25 kg of $ZnSO_4$ ha^{-1}, with or without foliar sprays, recorded par values. Those treatments that received 12.5 kg $ZnSO_4$ ha^{-1} as basal recorded par values with a single foliar spray at knee-high or at the tasseling stage of the crop (Table 3). This indicates that a 12.5 kg basal application of $ZnSO_4$ ha^{-1} is equal to a single foliar spray either at the knee-high stage or at tasseling. Besides, it is important to observe that the zinc concentration in the treatment receiving 25 kg $ZnSO_4$ ha^{-1} + foliar spray at knee high is on par with the treatment that received 12.5 kg $ZnSO_4$ ha^{-1} + two foliar sprays. This highlights that the foliar sprays are indeed instrumental in increasing the zinc concentration of tissues.

The treatments that those receiving a single foliar spray, either at knee high or at tasseling, were on par with control, as well as with those treatments which received 12.5 kg $ZnSO_4$ ha^{-1} as basal, along with one spray either at knee high or at tasseling. Two foliar sprays always proved better than a single spray in this regard. The zinc content was highest (41.7 mg kg^{-1}) when $ZnSO_4$ was applied at 50 kg as a soil application, but all treatments that received 25 kg $ZnSO_4$ as basal along with one or two foliar sprays proved comparable. Jahiruddin *et al.* (2001) reported that, although no changes were observed in yield parameters, the concentration of zinc increased in plant tissues when corn was raised in zinc-fertilised soil. Kumar *et al.* (2017) reported 50.9% higher zinc content when 20 kg of $ZnSO_4$ ha^{-1} was applied over the control. Sulthana (2015) reported the highest zinc content in tissues at the time of fodder harvest in all treatments receiving 50 kg $ZnSO_4$ ha^{-1}. An increase in zinc content up to 48 mg kg-1 was observed by Salakinkop *et al.* (2019), when 20 or 25 kg Zn was applied either alone or through FYM.

Zinc fortification

With respect to zinc fortification at the knee-high stage, which ranged between 4.6 and 14.3%, it was observed that all the treatments receiving 25 and 50 kg $ZnSO_4$ ha^{-1} with or without foliar sprays were on par and recorded significantly higher fortification than the former. Similarly, treatments receiving 12.5 kg $ZnSO_4$ ha^{-1} as soil application (with or without foliar sprays) and those treatments receiving purely foliar sprays were on par with each other (Table 3). This indicates the importance of foliar spray in the management of zinc nutrition. It is important to observe that the fortification

Table 3: Effect of zinc application on zinc content and fortification at different stages of fodder maize (pooled over two years)

S.No	Treatments	Zn content (mg kg^{-1})			Zn fortification (%)		
		KH	Tass	Har.	KH	Tass.	Har.
1	T_1- Control	17.5	24.2	34.1	0	0	0
2	T_2- 25 kg $ZnSO_4$ soil	19.4	27.0	38.5	10.9	11.6	12.9
3	T_3-T_2+Zn SO_4 spray at knee high	19.4	27.2	39.1	10.9	12.4	14.7
4	T_4-T_2+$ZnSO_4$ at tasselling	19.7	27.7	40.3	12.6	14.5	18.2
5	T_5-T_2+Two sprays at knee high and tasselling	20.0	27.9	41.1	14.3	15.3	20.5
6	T_6- 12.5 kg $ZnSO_4$ soil	18.6	25.5	35.8	6.3	5.4	5.0
7	T_7-T_6+ spray at knee high	18.6	25.7	36.3	6.3	6.2	6.5
8	T_8- T_6+ one spray at tasselling	18.6	26.0	36.7	6.3	7.4	7.6
9	T_9- T_6+ two sprays at knee high and tasselling	18.7	26.2	37.7	6.9	8.3	10.6
10	T_{10}- Spray at knee high	18.3	25.5	36.1	4.6	5.4	5.9
11	T_{11}- Spray at tasselling	18.3	25.6	36.4	4.6	5.8	6.7
12	T_{12}- Two sprays at knee high and tasselling	18.4	27.1	38.8	5.1	12.0	13.8
13	T_{13}- 50 kg soil application of $ZnSO_4$	19.7	28.6	41.7	12.6	18.2	22.3
	Mean	18.9	26.5	37.9	7.8	9.4	11.3
	S.Em($\pm$)	0.68	0.56	0.90	1.68	2.08	2.24
	C.D (0.05)	NS	NS	2.62	3.42	5.76	6.24

KH- knee high stage, Tass.: tasseling stage, Har: harvest of fodder, early dough stage

was more than 100% in treatments receiving 25 kg $ZnSO_4$ ha^{-1} compared to those receiving exclusive foliar treatments or 12.5 kg $ZnSO_4$ ha^{-1} as soil application. Undisputedly, the highest fortification was observed with 50 kg $ZnSO_4$ ha^{-1}, soil application.

Similar trends were observed at the tasseling stage of the crop, with an average fortification percentage varying between 5.4 (single foliar spray at the knee-high stage) and 18.2 (only soil application at 50 kg $ZnSO_4$ ha^{-1}). Per cent fortification (means), however, steadily increased from knee high (7.8%) to fodder harvest (11.3%) through tasseling (9.4%). A high fortification rate of 22.3% was observed when zinc was applied to the soil at 50 kg $ZnSO_4$ ha^{-1}. Treatments receiving 25 kg $ZnSO_4$ as basal along with one or two sprays at knee high or tasseling were also found to be on

Table 4: Effect of different levels and mode of zinc application on quality at harvest of fodder (pooled over two years)

S.No.	Treatments	CP%			NDF%			ADF%		
		KH	Tass.	Har.	KH	Tass.	Har.	KH	Tass.	Har.
1	T_1- Control	15.0	9.8	7.8	35.6	41.5	43.6	26.5	35.9	38.2
2	T_2- 25 kg $ZnSO_4$ soil	15.1	10.2	8.4	35.4	40.4	41.8	25.5	35.5	38.6
3	T_3-T_2+Zn SO_4 spray at knee high	16.2	10.8	8.5	36.3	38.2	40.4	25.6	35.0	38.1
4	T_4-T_2+$ZnSO_4$ at tasselling	15.2	10.9	8.9	34.9	39.7	41.2	24.1	35.0	38.2
5	T_5-T_2+Two sprays at knee high and tasselling	17.5	9.6	8.5	35.8	39.5	44.8	25.2	35.9	39.5
6	T_6- 12.5 kg $ZnSO_4$ soil	15.7	11.2	8.4	34.9	39.7	41.8	27.1	35.7	37.8
7	T_7-T_6+ spray at knee high	18.1	10.3	7.8	36.2	38.7	39.6	27.1	34.6	35.9
8	T_8- T_6+ one spray at tasselling	16.2	11.3	8.5	36.0	40.0	43.3	26.8	36.5	38.8
9	T_9- T_6+ two sprays at knee high and tasselling	15.7	10.9	7.9	37.1	40.9	44.6	28.1	36.0	38.4
10	T_{10}- Spray at knee high	16.7	9.9	8.9	37.8	41.7	45.1	27.3	35.0	38.2
11	T_{11}- Spray at tasselling	17.1	11.1	8.5	36.5	40.7	42.1	27.8	35.1	36.6
12	T_{12}- Two sprays at knee high and tasselling	17.1	9.3	8.9	36.0	41.4	41.0	26.5	36.0	36.1
13	T_{13}- 50 kg soil application of $ZnSO_4$	16.1	10.6	9.4	35.5	40.2	41.2	27.1	35.2	37.0
	Mean	16.3	10.2	8.4	36.0	40.2	42.3	26.5	35.5	37.8
	S.Em ($\pm$)	0.64	0.81	0.36	0.38	0.94	0.81	1.10	0.98	1.02
	C.D	NS	NS	1.08	NS	NS	2.24	NS	NS	NS

par with the best treatment. There was a 158% increase in zinc fortification with an increase in soil application of $ZnSO_4$ from 12.5 to 25.0 kg ha^{-1}, and a 72% increase with an increase in zinc application from 25 kg ha^{-1} to 50 kg ha^{-1}, respectively. The importance of foliar spray was also proved by the above values.

Fodder Quality:

Crude protein content, neutral detergent fibre and acid detergent fibre, which are components of fibre expression, were analysed at the three stages of crop growth, viz., knee high, tasseling and harvest (Table 4).

No effect of zinc application was observed on the crude protein percentage at either the knee-high or tasseling stages of the crop. However, at harvest, the influence of zinc on crude protein content was evident, with the highest values observed in the 50 kg soil application of $ZnSO_4$ (Fig. 1). Little variations were observed between treatments with most of them being on par. It is important to observe that even the treatments receiving foliar application were on par with the best treatment; besides, treatments receiving 12.5 kg $ZnSO_4$ ha^{-1} were found to be on par with control. Jamil et al. (2015), found that application of Zn @10 kg ha^{-1} increased crude protein content of baby corn fodder. Kumar et al. (2017) also reported increased crude protein content up to 20 kg of $ZnSO_4$ ha^{-1}. However, contradictory results were reported by Sheraz et al. (2012), who indicated that crude protein content was unaffected by Zn application in maize.

The neutral detergent fibre (NDF) component was significantly influenced by the zinc application (Fig. 2). Nevertheless, no particular trends were observed with regard to treatmental variations in NDF. However, zinc did not appear to influence acid detergent fibre (ADF) at any stage of crop growth. (Fig. 3). Kumar et al. (2015) found that crude fibre was negatively influenced by Zn application, on the contrary, Dadhich and Gupta (2005) found that crude protein and crude fibre of fodder pearl

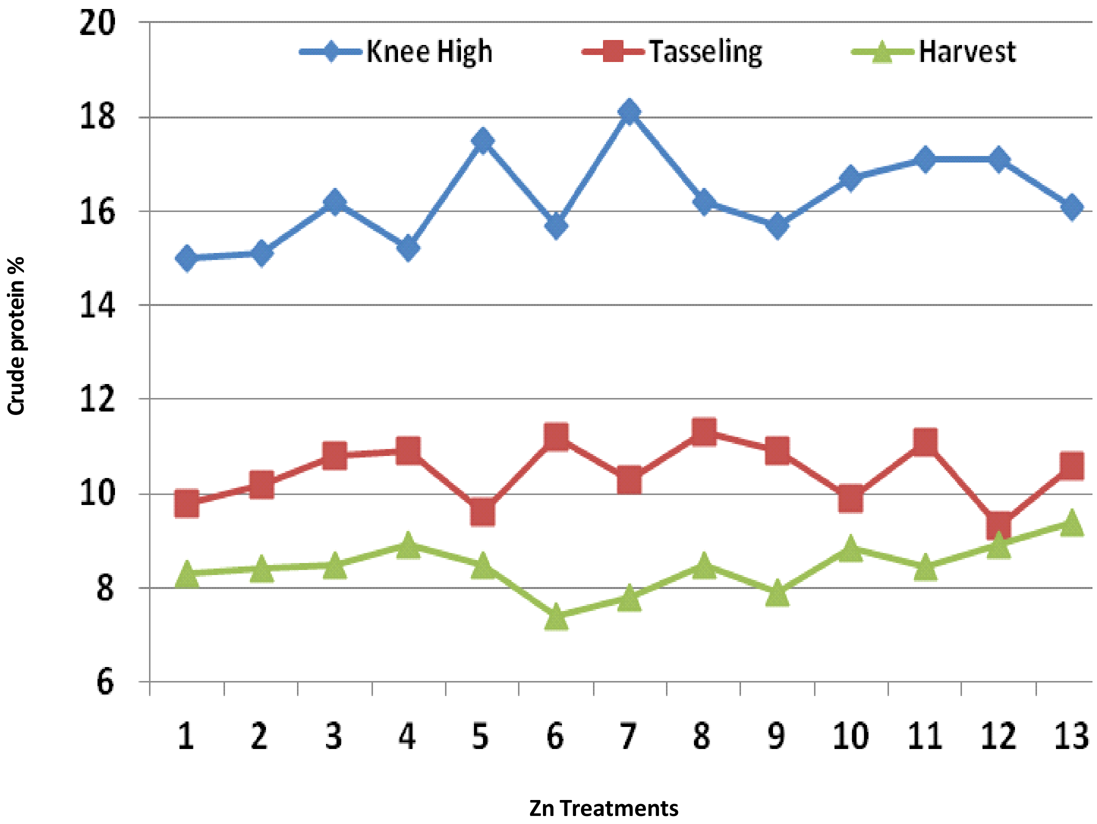

Fig. 1: Crude protein % of fodder maize at different stages of crop as influenced by zinc application

millet increasing by increasing zinc application upto 10 kg ha^{-1}.

Economics

Investment in zinc (ten kilograms of $ZnSO_4.7H_2O$, costing Rs. 700) reaped commendable returns in terms of green fodder yield, besides quality of fodder (Table 1). The B: C ratio varied between 2.56 and 3.4, with the highest values observed when 50 kg of $ZnSO_4$ was applied as a basal fertiliser, although 25 kg $ZnSO_4$ ha^{-1} to the soil, along with two foliar sprays, also

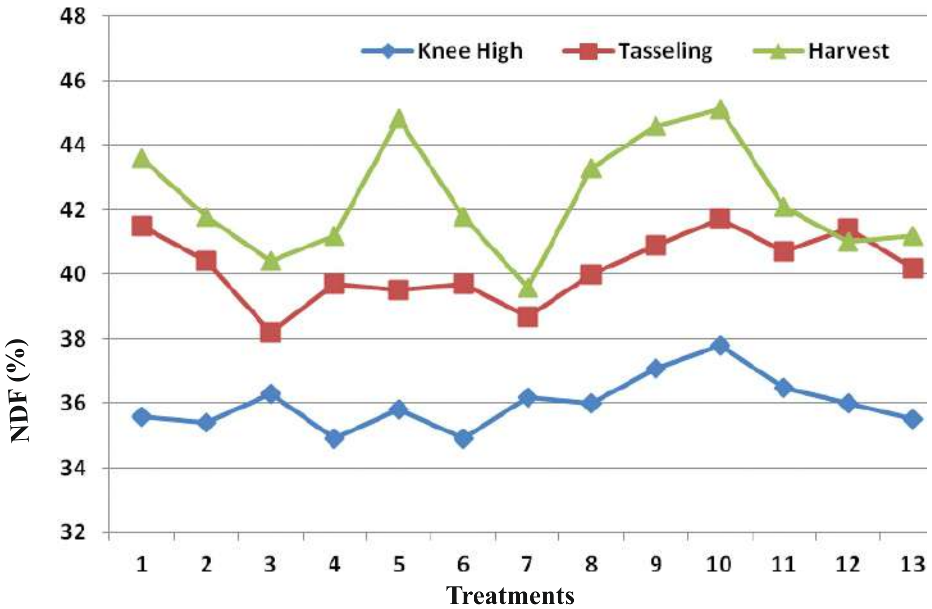

Fig. 2: Neutral detergent fibre % of fodder maize at different stages of crop as influenced by zinc application

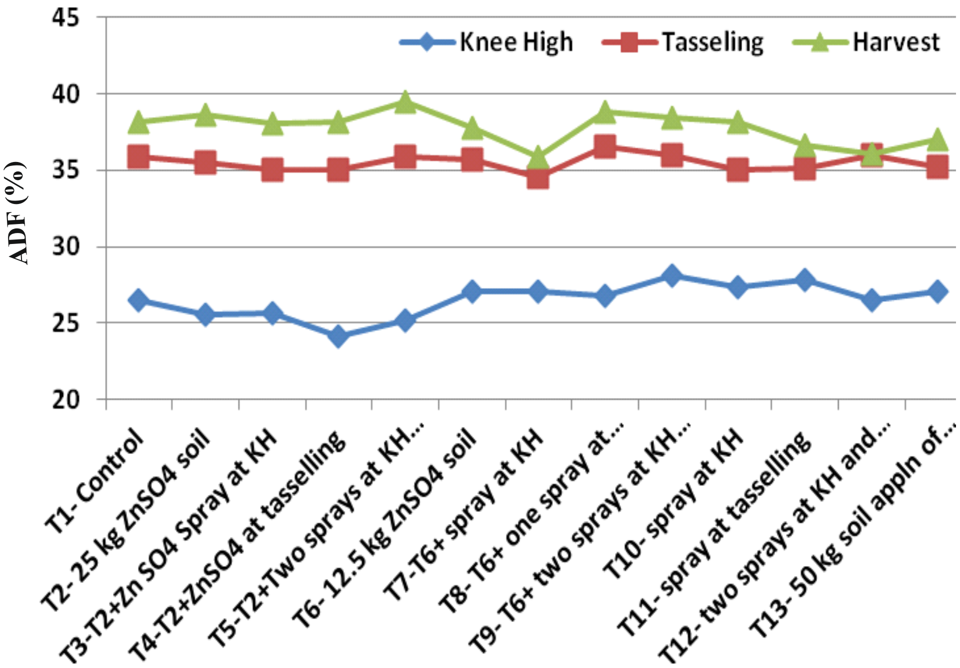

Fig. 3: Acid detergent fibre % of fodder maize at different stages of crops as influenced by zinc application

proved effective.

Conclusion:

Application of 50 kg $ZnSO_4$ ha^{-1} as basal or application of 25 kg $ZnSO_4$ ha^{-1} to soil along with two foliar sprays at knee-high and tasseling stages in zinc-deficient soils yielded good returns in terms of green fodder yield, besides quality fodder for livestock. Thus, fortification of fodder maize would improve milk standards and help overcome zinc deficiency, especially in children, adolescent girls, and lactating mothers, for a better country.

Acknowledgements:

The authors sincerely thank Principal Scientist & Head, Micronutrient scheme of University for financially supporting the research besides facilitating analysis.

References

Ahmed Muzaffar, Sun YingYing, Waseem Bashir, Shahbaz Khan, Sanaullah baloch, Yang Yang, Andul Haffez, Baloch, A. J. and Shabeer Ahmed (2014). Influence of integrated levels of potassium and zinc on the green fodder yield of maize (Zea mays L.) *Journal of Biology, Agriculture and Healthcare*, 4(25): 162-170

Cakmak I. (2008). Enrichment of cereal grains with zinc: Agronomic or genetic biofortification. *Plant and Soil*, 302: 1-17.

Dadhich L. K. and Gupta A. K. (2005). Effect of sulphur, zinc and planting patterns on yields and quality of fodder pearl millet (*Pennisetum glaucum*) *Indian Journal of Agricultural Sciences*,, 75(1): 49-51.

Gajbhiya P. N., Bulbule A. V. and Kumbhar C. T. (2018). Effect of Zinc fertilizer levels and application methods on zinc fractions and grain yield of maize *Internationlal Journal of Current Microbiology and Applied Sciences*, 7(11): 1-12.

Hill G. M. and Shannon M. C. (2019). Copper and Zinc Nutritional Issues for Agricultural Animal Production. *Biological of Trace Elements Research* 188**:** 148–159 https://doi.org/10.1007/s12011-018-1578-5

IZiNCG (2004). Assessment of the risk of zinc deficiency in populations and options for its control. Hotz C. and Brown K. H. (eds.), Food Nutrition Bulletin. 25: S91–S204.

Jahiruddin M., Harada H., Hatanaka T., Sunaga Y. and Dekker M. (2001). Adding boron and zinc to soil for improvement of fodder value of soybean and corn. *Communications in Soil Science and Plant Analysis,* 32(17&18): 2943-2951.

Jamil Moazzam, Abid Sajad, Maqshoof Ahmad, Fakhar-u-Zaman, M., Abbasi, G.H. and Muhammad Aeshad (2015). Growth, yield and quality of maize (*Zea mays*) fodder as affected by nitrogen-zinc interaction in arid climate. *Pakistan Journal of Agricultural Sciences*, 52(3): 637-743.

Kachapur R. M., Talekar S. C., Harlapur S. I. and Salakinkop S. R. (2019). Effect od soil and foliar supplementation with zinc and iron on yield and economics of maize (*Zea mays* L.) *Maize Journal* 8-1

Kumar Rakesh and Bohra, J. S. (2014). Taylor and Francis, Philadelphia, USA, *Archives of Agronomy and Soil Science,* 60(9): 1193-1206.

Kumar Rakesh, Bohra J. S., Kumawat N. and Singh A. K. (2015). Fodder yield, nutrient uptake and quality of baby corn (*Zea mays* L.) as influenced by NPKS and Zn fertilization. *Research on Crops*, 16(2): 243-249.

Kumar Rakesh, Singh M., Meena B. S., Ram H. Parihar C. M., Kumar Sourabh, Yadav M. R., Meena R. K., Kumar U. and Meena V. K. (2017). Zinc management effects on quality and nutrient yield of fodder maize (*Zea mays*). *Indian Journal of Agricultural Sciences*, 87(8): 1013-1017.

Lindsay W. L. and Norwell W. A. (1978). Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*, 42: 421-428.

Mahdi S. S., Hasan Badrul, Bhat R.A., Aziz M. A., Singh Lal, Faisal-ur-Rasool, Intikhab Aalum and Shibana Bashir (2011). Effect of nitrogen, zinc and seed rate on growth dunamics and yield of fodder maize (*Zea mays*) under temperate conditions. *Plant Archives*, 11(2): 965-971.

Marijanusic K., Manojlovic M., Bogdanovic D., Cabilovski R. and Lombnaes P. (2017). Mineral composition of forage crops in respect to dairy cow nutrition, *Bulgarian Journal of Agricultural Science,* 23(2): 204-212.

Muhammad Faran Khalid, Amjed Ali, Hasnain Waheed, Muhammad Ehsan Safdar, Muhahammad Mansoor Javaid, Muhammad Sikander Hayyat, Ali Raza, Naila Faerroq and Hafiz Haider Ali (2019). Exploring the role of zinc fertilization methods for agronomic bio-fortification and its impact on phenology, growth and yield characteristics of maize. *Universidade Estadual de Londrina*, 40(5S1): 2209-2222.

Olusegun A. Yerokun and Meki Chirwa (2014). Soil and foliar application of zinc to maize and wheat grown on a Zambian Alfisol *African Journal of Agricultural Research* , 9(11): 963-970.

Panse V. G. and Sukhatme P. V. (1989). 'Statistical Methods for Agricultural Workers', Indian Council of Agricultural Research, New Delhi.

Patil S. and Merwade M. N. (2016). Influence of micronutrient application methods on growth, yield and yield components of fodder maize (*Zea mays* L.) *Journal of Farm Sciences*, 29(2): 212-215.

Piper C. S. (1966). Soil and Plant Analysis: a laboratory manual of methods for the examination of soils and the determination of the inorganic constituents of plants.(Hans : Bombay).

Pongde S. M. and Ghodpade R. M. (2014). Impact of phosphorus and zinc application and their interactions on yield and uptake of nutrients by maize in Vertisols *International Journal of Forestry and Crop Improvement*, 5(1): 16-21.

Salakinkop S. R., Harlapur S. I., Kachapur R. M. and Talekar S. C. (2019). Effect of soil and foliar supplementation with zinc and iron onyield and economics of maize (Zea mays L.) *Maize Journal*, 8(1): 26-30.

Sheraz M. S., Hasan Badrul and Singh Lal (2012). Influence of seed rate, nitrogen and zinc on fodder maize (*Zea mays*) in temperate conditions of western Himalayas. *Indian Journal of Agronomy* 57(1): 85-88.

Singh M. V. and Behera S. K. (2011). AICRP be on micro and secondary nutrients and pollutant elements in soil and plants- A profile Research bulletin, 10, 1-57.

Singh S., Singh V. and Mishra P. (2017). Effect of NPK, boron and zinc on productivity and profitability of late sown *kharif* maize (*Zea mays* L.) in western Uttar Pradesh, India. *Annals of Agricultural Research*,, 38(3): 310-313.

Sulthana Shaik Mehtaz (2015). Agronomic fortification of fodder maize (*Zea mays* L.) with zinc. Thesis dissertation submitted to Acharya N.G. Ranga Agricultural University- Guntur.

Van Soest P. J. (1963). The use of detergents in the analysis of fibrous feed II. A rapid method for the determination of fibre and lignin. *Journal Association Annals of Chemistry*, 46: 829-835.

Vargas E. and McDowell L. R. (1997). Mineral deficiencies of cattle in Central America and the Caribbean, emphasizing Costa Rica. In: Proceedings of the International Conference on Livestock in the Tropics, University of Florida, Gainesville, Florida, May, 99−114.

Wenger K., Gupta S. K., Furrer G., Schulin R. and Kluwer (2002). Zinc extraction potential of two common crop plants, *Nicotina tabaccum* and *Zea mays Plant and Soil* 242-2,217-225.

Wessells K. R and Brown K. H. (2012). Estimating the global prevalence of Zinc deficiency: results based on zinc availability in national food supplies and prevalence of stunting. United States of America.

WHO ((2014). Integrated Management of Childhood Illness: distance learning course. World Health

Received: July 2024 *Accepted: September 2024*