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Bio-Fortification of Annual Cereal Fodder Crops for Enhancing Zinc and Iron Content

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Abstract

A field experiment was conducted during *kharif,* 2021 at Regional Agricultural Research Station, Tirupati, Acharya N.G. Ranga Agricultural University with an objective to study the response of fodder crops to the application of Zinc and iron. The results revealed that highest number of leaves per plant (14.1), green fodder yield of 38,699 kg/ha, net returns of Rs 46,224/ha and B:C ratio of 2.49 was recorded with fodder maize African tall variety compared to fodder sorghum. Among the different levels of Zinc and Iron, significantly highest green fodder yield of 44,257 kg/ha was recorded with application of 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS with net returns of Rs 57,547/ha and B:C ratio of 2.86 followed by application of 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS with net returns of Rs 50,426/ha and B:C ratio of 2.63. Higher crude protein of 8.5% and 8.4% was realized with higher levels of micro nutrient application i.e., 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS and 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS respectively. Highest zinc content of 50 ppm was recorded with application of 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS and higher iron content of 178 ppm was recorded with application of 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS. Lowest green fodder yield of 30,938 kg/ha, net returns of Rs 31,150/ha, with low Iron (36 ppm) and Zinc (14 ppm) content was recorded with control.

Key words : *Fodder crops, bio-fortification, green fodder, crude protein, foliar application.*

Introduction

Indian soils are deprived of micro nutrients led to low crop yields. At present about 48.1 percent of Indian soils are deficient in Zinc and 11.2 percent in Iron. Zinc and iron deficiencies are an important soil fertility constraint to crop production. There has been significant nutrient depletion from agricultural soils and existing fertilizers primarily supply plant nutrients and not necessarily with the nutrients that are essential to humans and animals eating the plants. Application of micro nutrients through fertilizers in nutrient deficient soils will have positive effect on yield improvement. Agronomic bio-fortification is a process of either enriching existing macronutrient fertilizers with the nutrients lacking from human/animal diets and supplying these to our food/fodder crops in order to increase the concentrations of these elements in the human diet/animal feed. The goal of different methods of fortification is to increase the nutritional quality of crops to improve animal and inturn human nutrition. Agronomic bio-fortification through micronutrient enriched fertilizers could have a significant impact on the global problem of micronutrient malnutrition. Adequate fertilization in terms of primary, secondary and micro-nutrients is essential to ensure the quantity and quality of green fodder. Zinc and iron play an important role in crop nutrition and thought to be necessary for plant development and production, as their role in plant auxins bio-synthesis, oxidation reduction reactions, plant nitrogen metabolism, formation of chlorophyll, respiration, chief enzyme system and photosynthesis in plants. In this context, the experiment was conducted to know the response of fodder crops to the application of Zinc and Iron.

Materials and Methods

A field experiment was conducted during *kharif*-2021 at RARS, Tirupati of ANGRAU campus, Andhra Pradesh. The soil was sandy clay loam in texture with low organic carbon (0.39%) and available nitrogen (207 kg ha^{-1}), high in available phosphorus (58 kg ha^{-1}) and medium in available potassium (278 kg ha^{-1}). A total of 14 treatments consist of two main plot treatments as fodder crops M_1 – Fodder Maize (var. Africantall), M_2 – Fodder Sorghum (var. SSV 74) and the seven sub plot treatments of different levels of Zinc and Iron application i.e. S_1 – Control, S_2 - 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS; S_3 - 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS; S_4 - 10 kg $ZnSO_4$ +10 kg $FeSO_4$ /ha as basal + 1% $ZnSO_4$ 1 % $FeSO_4$ as foliar spray at 45 DAS; S_5 - 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS; S_6- 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS; S_7 - 20 kg $ZnSO_4$ +20 kg $FeSO_4$ /ha –as basal + 1% $ZnSO_4$ 1% $FeSO_4$ as foliar spray at 45 DAS. The experiment was laid out in spilt plot design replicated thrice. The recommended dose of 90 kg nitrogen in the form of urea was applied in two splits half at basal and remaining half at 30 DAS whereas 40 kg P_2O_5 and 40 kg K_2O ha^{-1} were applied at the time of sowing. The crop was sown at 30 cm x 10 cm spacing and thinning was carried out at 10 days after sowing with one seedlinghill^{-1}. The crop was harvested at 50% flowering stage for fodder purpose. All the quality

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parameters and nutrient concentrations were estimated by following standard procedures.

Results and Discussion

Growth, yield and quality : The results of experiment conducted during *kharif* -2021on fodder crops under different levels of zinc and iron revealed that growth parameters viz., plant height did not show any significant difference either with fodder crops or with different levels of application of zinc and iron at 45 days after sowing (Table-1). The plant height was significantly differed at harvest and recorded highest with fodder sorghum (253.9 cm) and lowest with fodder maize (225.1 cm). All the levels of zinc and iron application recorded significantly highest plant height compared to control. Highest plant height of 263.9 cm recorded with 10 kg $FeSO_4$ /haas basal + 1% $FeSO_4$ foliar spray at 45 DAS and lowest height of 193.3 cm recorded with control. Same trend was followed with respect to number of leaves per plant. Significantly highest number of leaves per plant was recorded with fodder maize at 45 days after sowing (10.1) and at harvest (14.1) and lowest with fodder sorghum 8.7 & 12.2 respectively. Different levels of zinc and iron application did not show any significant difference with respect to number of leaves per plant at 45 days after sowing, however significant difference was observed at harvest. All the levels of application recorded significantly higher number of leaves per plant than control and highest was noticed with 10 kg $FeSO_4$ /haas basal + 1% $FeSO_4$ foliar spray at 45 DAS (14.7) and lowest with control (12.1). The results were in consonance with (1).

Significantly the highest green fodder yield of 38,699 kg/ha was recorded with African tall fodder maize variety compared to fodder sorghum SSV-74 (35,604 kg/ha). With regard to application of different levels of zinc and iron, significantly highest green fodder yield of 44,257 kg/ha was recorded with application of 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS (Table-1). Next best green fodder yield was with application of 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS and recorded green fodder yield of 40,710 kg/ha. The next best treatment is 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS (38,348 kg/ha), fb combined application of 10 kg $ZnSO_4$ & 10 kg $FeSO_4$+ 1% $ZnSO_4$ and 1% $FeSO_4$foliar spray at 45 DAS (36,951kg/ha). (2) observed that combined micronutrients through soil + foliar application resulted in significantly higher grain, stover and biological yields. Next best green fodder yield of 35,523 kg/ha recorded with 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS. Significantly lowest green fodder yield of 30,938 kg/ha recorded with control. Similar results of yield advantage in maize have been reported by (4). Zinc plays a vital role in stomatal regulation and it creates ionic balance in plant system resulting in reduction of less water tension and regulates various physiological processes like carbohydrates and protein synthesis

Quality parameters Viz., crude protein and crude fibre were not significantly influenced among fodder crops however crude protein was significantly influenced by different levels of Zinc and Iron application (Table-1). Significantly highest crude protein of 8.5% was recorded with 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS, however comparable with 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS which resulted in 8.4% and combined application of 10 kg $ZnSO_4$ & 10 kg $FeSO_4$ + 1% $ZnSO_4$&1% $FeSO_4$ foliar spray at 45 DAS (8.2%). Remaining levels of Zinc and Iron application were comparable with control which recorded lowest crude protein of 7.4%. crude fibre was not significantly differed with different levels of Zinc and Iron application. These results are in concurrence with (3).

Economics : Among the fodder crops, highest economics were realized with fodder maize which recorded Rs 77,398/ha of gross returns compared to fodder sorghum (Rs 71,208/ha). Same trend was observed with net returns and B:C ratio i.e., Rs 46,224/ha with fodder maize and Rs 40,095/ha with fodder sorghum; 2.49 with fodder maize and 2.29 with fodder sorghum respectively (Table-2). With regard to zinc and iron levels, highest gross returns of Rs 88,514/ha along with net returns of Rs 57,547/ha and B: C ratio of 2.86 was realized with 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS. Next highest gross returns of Rs 81,420/ha along with net returns of Rs 50,426/ha and B: C ratio of 2.63 was realized with 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar sprays at 45 DAS. Combined application of lower levels i.e., 10 kg $ZnSO_4$& 10 kg $FeSO_4$+ 1% $ZnSO_4$ &1% $FeSO_4$ foliar spray at 45 DAS recorded highest gross returns of Rs 73,902/ha along with net returns of Rs 42,665/ha and B: C ratio of 2.37 compared to higher levels of combined application i.e., 20 kg $ZnSO_4$ and 20 kg $FeSO_4$ + 1% $ZnSO_4$ and 1% $FeSO_4$ foliar spray at 45 DAS which recorded gross returns of Rs 66.464/ha along with net returns of Rs 34,888/ha and B: C ratio of 2.10. Lowest gross returns of Rs 61,876/ha, net returns of Rs 31,150/ha and B: C ratio of 2.01 was realized control. Similar results were reported by (4, 5, 6).

Micro nutrient concentration : Zinc and iron concentrations in fodder crops did not differ significantly but significantly influenced by levels of application (Table-3). Significantly highest iron concentration of 178 ppm was recorded with application of 20 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS fb combined application of 20 kg $ZnSO_4$ and 20 kg $FeSO_4$+ 1% $ZnSO_4$

Table-1 : Growth, yield and quality of fodder crops influenced by varied levels of zinc and iron Application.

Treatment	Plant height (cm) at 45 DAS	Plant height (cm) at harvest	No. of leaves /plant at 45 DAS	No. of leaves /plant at harvest	Green fodder yield (kg/ha)	Crude protein (%)	Crude fibre (%)
Fodder crops							
Maize (African tall)	125.1	225.1	10.9	14.1	38699	8.2	34.6
Sorghum (SSV 74)	140.1	253.9	8.7	12.2	35604	7.9	35.4
SE(m) ±	5.46	7.62	0.25	0.25	309	1.2	2.9
C.D (P=0.05)	NS	23.4	1.4	1.3	1881	NS	NS
Zinc and Iron levels							
S_1-Control	112.8	193.3	9.5	12.1	30938	7.4	35.6
S_2-10 kg $ZnSO_4$ /ha –as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	139.0	249.5	9.9	14.1	40710	7.9	35.9
S_3-10 kg FeSO4 /ha–as basal + 1% $FeSO_4$ foliar spray at 45 DAS	145.4	263.9	10.2	14.7	44257	8.1	36.4
S_4-S_2 + S_3	137.9	241.3	9.6	13.7	36951	8.2	36.2
S_5-20 kg $ZnSO_4$/ha –as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	132.5	240.6	9.3	13.4	35523	8.4	37.4
S_6-20 kg FeSO4 /ha –as basal + 1% $FeSO_4$ foliar spray at 45 DAS	136.9	247.8	9.8	13.4	38348	8.5	36.9
S_7-S_5 + S_6	121.6	235.4	9.2	13.1	33232	8.0	36.8
SE(m) ±	8.02	11.4	0.37	0.49	565	1.4	3.2
C.D (P=0.05)	NS	26.1	NS	1.2	1650	0.7	NS
Factor C at ZI	18.5	NS	NS	NS	2333	NS	NS
Factor ZI at C	35.2	NS	NS	NS	2718	NS	NS

Table-2 : Economics of fodder crops influenced by varied levels of zinc and iron application.

Treatment	Grossreturns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
Fodder crops			
Maize (African tall)	77398	46224	2.49
Sorghum (SSV 74)	71208	40095	2.29
Zinc and Iron levels			
S_1-Control	61876	31150	2.01
S_2-10 kg $ZnSO_4$/ha –as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	81420	50426	2.63
S_3-10 kg $FeSO_4$/ha–as basal + 1% $FeSO_4$ foliar spray at 45 DAS	88514	57547	2.86
S_4-S_2 + S_3	73902	42665	2.37
S_5-20 kg $ZnSO_4$ /ha – as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	71046	39869	2.28
S_6-20 kg $FeSO_4$ /ha – as basal + 1% $FeSO_4$ foliar spray at 45 DAS	76696	45569	2.46
S_7-S_5 + S_6	66464	34888	2.10

and 1% $FeSO_4$ foliar spray at 45 DAS (169 ppm). Next best was with 20 kg $ZnSO_4$/ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS (152 ppm), fb 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 DAS (139 ppm). The lowest iron concentration was recorded with control (36 ppm). With respect to Zinc, significantly highest zinc concentration of 50 ppm was recorded with application of 20 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS fb 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 DAS (45 ppm), combined application of 20 kg $ZnSO_4$ & 20 kg $FeSO_4$+ 1% $ZnSO_4$ & 1% $FeSO_4$ foliar spray at 45 DAS (43 ppm). Remaining levels of Zinc and Iron application were comparable among them but significantly superior over control which recorded lowest zinc content (36 ppm) and iron content (14 ppm). Similar findings were reported by (7, 8).

Conclusions

Application of 10 kg $FeSO_4$ /ha as basal + 1% $FeSO_4$ foliar spray at 45 days after sowing or 10 kg $ZnSO_4$ /ha as basal + 1% $ZnSO_4$ foliar spray at 45 days after sowing in micro nutrient deficient soils proved to be an effective method for enhancing fodder yield and fortification of micro nutrients in fodder crops which inturn helps in cyclic process of micro nutrients from fodder crops to livestock and to humans.

Table-3 : Iron and zinc concentration of fodder crops at harvest influenced by varied levels of zinc and iron application.

Treatment	Fe (ppm)	Zn (ppm)
Fodder crops		
Maize (African tall)	122	48
Sorghum (SSV 74)	115	42
SE(m) ±	12	10
C.D (P = 0.05)	NS	NS
Zinc and Iron levels		
S_1-Control	36	14
S_2-10 kg $ZnSO_4$ /ha – as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	106	45
S_3-10 kg $FeSO_4$ /ha – as basal + 1% $FeSO_4$ foliar spray at 45 DAS	139	32
S_4- S_2 + S_3	125	38
S_5-20 kg $ZnSO_4$ /ha – as basal + 1% $ZnSO_4$ foliar spray at 45 DAS	152	50
S_6-20 kg $FeSO_4$ /ha – as basal + 1% $FeSO_4$ foliar spray at 45 DAS	178	33
S_7- S_5 + S_6	169	43
SE(m) ±	15	16
C.D (P = 0.05)	28	7
Factor C at ZI	NS	NS
Factor ZI at C	32	12

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