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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON FODDER QUALITY AND NUTRIENT UPTAKE OF FODDER MAIZE (*Zea mays* L.)

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ABSTRACT

A field experiment was conducted during *kharif* 2021 at the Agricultural College Farm, Bapatla, Andhra Pradesh, to evaluate the effect of integrated nutrient management on fodder quality and nutrient uptake of fodder maize. The experiment was laid out in a factorial randomized block design with three replications using African tall fodder maize. Four manure and fertilizer combinations, *viz*., 100% inorganic recommended dose of nitrogen (RDN), 75% inorganic RDN + 25% N through FYM, 75% inorganic RDN + 25% N through vermicompost and 75% inorganic RDN + 25% N through poultry manure, were combined with four biofertilizer and micronutrient treatments. The latter comprised control, liquid biofertilizer consortia, biofertilizer consortia + soil application of $ZnSO_4$ and $FeSO_4$, and biofertilizer consortia + foliar application of $ZnSO_4$ and $FeSO_4$. Integrated nutrient management significantly influenced crude protein, crude fibre and total ash contents. Among manure and fertilizer treatments, 75% inorganic RDN + 25% N through poultry manure recorded the highest crude protein (8.20%) and total ash content (9.11%), while crude fibre was lowest (26.29%). Among biofertilizer and micronutrient treatments, foliar application of $ZnSO_4$ and $FeSO_4$ with biofertilizer consortia recorded the highest crude protein (8.70%) and ash content (9.44%) and the lowest crude fibre (24.66%). Nitrogen, zinc and iron contents and their uptake were significantly enhanced by integrated nutrient management. At harvest, the highest N, Zn and Fe uptake under manure and fertilizer treatments was recorded with poultry manure integration, while foliar Zn and Fe application recorded the highest uptake among biofertilizer and micronutrient treatments. Significant interaction effects were observed for crude protein yield and N, Zn and Fe uptake at harvest, with A_4B_4 generally recording the highest values. The study indicated that partial substitution of inorganic nitrogen with poultry manure combined with biofertilizer consortia and foliar Zn and Fe was effective in improving fodder quality and nutrient accumulation in fodder maize.

***Key words*:** Fodder maize; integrated nutrient management; crude protein; zinc; iron

Introduction

Fodder maize (*Zea mays* L.) is an important cereal fodder crop because of its high biomass production, palatability and suitability for feeding livestock. However, maintaining high fodder quality along with adequate biomass production requires balanced and efficient nutrient management. Nitrogen is particularly important because it contributes to protein synthesis and influences

the nutritive value of forage. Continuous dependence on inorganic fertilizers may not adequately maintain soil fertility, whereas integration of organic sources with inorganic fertilizers can improve nutrient availability and crop performance.

Organic manures such as farmyard manure (FYM), vermicompost and poultry manure provide nutrients gradually and may improve nutrient-use efficiency and soil nutrient availability. Poultry manure is a nutrient-rich organic source and can complement inorganic nitrogen fertilization. Earlier studies reported improvements in fodder quality and nutrient uptake through integrated application of organic and inorganic nutrient sources. Kumar and Sharma (2002) reported improvement in fodder quality with FYM, nitrogen and Azospirillum, while Godara *et al.*, (2012) observed improved crude protein yield in oat under integrated nutrient management. Micronutrients such as zinc and iron are also important for plant metabolism and nutrient utilization. Zinc is involved in several enzymatic and metabolic processes, while iron plays an important role in electron transport, chlorophyll formation and several enzyme systems. Biofertilizers can further contribute to nutrient availability and plant nutrition. Studies have shown improvements in nutrient uptake and fodder quality through the combined use of biofertilizers and micronutrients (Meena *et al.*, 2011; Bhoya *et al.*, 2013).

Despite the importance of integrated nutrient management in fodder crops, information on the combined influence of organic nitrogen sources, biofertilizer consortia and Zn and Fe application on fodder quality and nutrient accumulation in fodder maize is comparatively limited. Therefore, the present study was undertaken to evaluate the effect of integrated nutrient management on fodder quality and N, Zn and Fe content and uptake of fodder maize.

Materials and Methods

Experimental site

The experiment was conducted during *kharif* 2021 at the Agricultural College Farm, Bapatla, Andhra Pradesh. The experimental soil was sandy loam, neutral in reaction (pH 6.83), with low organic carbon (0.47%) and available nitrogen (156.80 kg ha^{-1}), medium available P_2O_5 (20.00 kg ha^{-1}) and K_2O (236.00 kg ha^{-1}), and low available Zn (0.49 mg kg^{-1}) and Fe (2.60 mg kg^{-1}).

Experimental design and treatments

The experiment was conducted in factorial randomized block design with three replications. African tall fodder maize was sown at 30 × 10 cm spacing. The experiment consisted of 16 treatment combinations.

Table 1: Effect of integrated nutrient management on fodder quality at harvest.

Treatment	Crude protein (%)	Crude fibre (%)	Total ash (%)
A_1	7.24	29.13	8.31
A_2	7.69	27.91	8.63
A_3	8.01	27.14	8.89
A_4	8.20	26.29	9.11
SEm±	0.17	0.48	0.20
CD (P=0.05)	0.50	1.39	0.58
B_1	6.70	31.91	7.93
B_2	7.37	28.79	8.33
B_3	8.38	25.11	9.24
B_4	8.70	24.66	9.44
SEm±	0.17	0.48	0.20
CD (P=0.05)	0.50	1.39	0.58
A × B	NS	NS	NS

Factor A: Manures and fertilizers

A_1 : 100% inorganic RDN

A_2 : 75% inorganic RDN + 25% N through FYM

A_3 : 75% inorganic RDN + 25% N through vermicompost

A_4 : 75% inorganic RDN + 25% N through poultry manure

Factor B: Biofertilizers and micronutrients

B_1 : Control

B_2 : Soil treatment with liquid biofertilizer consortia

B_3 : B_2 + soil application of $ZnSO_4$ @ 25 kg ha^{-1} + $FeSO_4$ @ 10 kg ha^{-1}

B_4 : B_2 + foliar spray of 0.2% $ZnSO_4$ + 0.5% $FeSO_4$ at 20 and 40 DAS

Quality analysis

Plant samples collected at harvest were initially shade dried and subsequently oven dried at 65°C. The samples were powdered using a Wiley mill and passed through a 40-mesh sieve. Crude fibre was estimated by the acid-alkali digestion method. Crude protein was calculated as

Supplementary Table 1: Interaction effect of different treatments on nitrogen uptake of forage maize at harvest.

Manures & fertilizers	Nitrogen uptake (kg ha^{-1})			
	Biofertilizers and micronutrients			
	B_1	B_2	B_3	B_4
A_1	66.91	84.41	100.66	108.55
A_2	71.40	88.44	114.79	124.06
A_3	76.02	94.63	137.15	150.70
A_4	81.75	98.41	142.89	160.31
SEm±	6.12			
CD (P=0.05)	17.67			

Table 2: Effect of integrated nutrient management on quality yields at harvest.

Treatment	CPY	CFY	TAY
A_1	563.32	2226.20	645.89
A_2	622.94	2210.44	698.47
A_3	716.39	2342.52	790.64
A_4	755.26	2331.25	830.42
SEm±	19.08	53.57	20.84
CD (P=0.05)	55.10	NS	60.19
B_1	462.63	2195.67	547.35
B_2	571.70	2231.15	647.83
B_3	774.20	2300.14	852.24
B_4	849.39	2383.46	918.01
SEm±	19.08	53.57	20.84
CD (P=0.05)	55.10	NS	60.19
A × B	S	NS	NS

CPY: Crude protein yield (kg ha^{-1}); CFY: Crude fibre yield (kg ha^{-1}); TAY: Total ash yield (kg ha^{-1})

nitrogen content × 6.25, while total ash was determined by the dry-ashing method.

Nutrient analysis

Nitrogen concentration was determined by the micro-Kjeldahl method. For Zn and Fe estimation, plant samples were digested using HNO_3 :$HClO_4$ in a 9:4 ratio, and Zn and Fe concentrations were determined using an atomic absorption spectrophotometer. Nutrient uptake was calculated from nutrient concentration and dry matter production.

Statistical analysis

The data were analyzed using Fisher's analysis of variance appropriate to the factorial randomized block design. Significance was tested using the F-test at the 5% probability level and critical difference was calculated for significant effects.

Results and Discussion

Fodder quality

Integrated nutrient management significantly influenced crude protein, crude fibre and total ash contents, whereas the interaction between the two factors was non-significant. Among manure and fertilizer treatments, A_4 recorded the highest crude protein content (8.20%) and total ash content (9.11%), while the lowest values were recorded with A_1 (7.24 and 8.31%, respectively). Crude fibre showed the opposite trend, with the highest value in A_1 (29.13%) and the lowest in A_4 (26.29%). Among biofertilizer and micronutrient treatments, B_4 recorded the highest crude protein (8.70%) and total ash (9.44%) and the lowest crude fibre (24.66%). B_1 recorded the lowest crude protein (6.70%) and ash (7.93%) and highest crude fibre (31.91%).

Table 3: Interaction effect on crude protein yield at harvest.

Manures & fertilizers	B_1	B_2	B_3	B_4
A_1	418.17	527.58	629.12	678.41
A_2	446.23	552.74	717.44	775.35
A_3	475.14	591.41	857.17	941.85
A_4	510.96	615.07	893.05	1001.94
SEm±	38.15			
CD (P=0.05)	110.19			

The improvement in crude protein under organic nitrogen integration may be associated with greater nitrogen availability and uptake. Similar responses have been reported in fodder crops under integrated nutrient management (Kumar and Sharma, 2002; Godara *et al*., 2012; Iqbal *et al*., 2014). The lower crude fibre under A_4 and B_4 indicates improvement in fodder quality. The increase in ash content under integrated nutrient management may be associated with greater mineral nutrient accumulation (Meena *et al*., 2013; Asif *et al*., 2020).

Quality yields

Crude protein yield and total ash yield were significantly affected by both factors. Crude fibre yield, however, was not statistically significant for either factor or their interaction. Numerically, A_4 recorded the highest crude protein yield (755.26 kg ha^{-1}) and total ash yield (830.42 kg ha^{-1}), while B_4 recorded 849.39 and 918.01 kg ha^{-1}, respectively.

Supplementary Table 2: Interaction effect of different treatments on zinc uptake of forage maize at harvest.

Manures & fertilizers	Zinc uptake (g ha^{-1})			
	Biofertilizers and micronutrients			
	B_1	B_2	B_3	B_4
A_1	85.01	151.02	179.16	188.81
A_2	129.48	153.92	194.64	203.17
A_3	133.44	166.72	226.51	250.12
A_4	144.06	172.23	234.12	257.85
SEm±	8.09			
CD (P=0.05)	23.37			

Supplementary Table 3: Interaction effect of different treatments on iron uptake of forage maize at harvest.

Manures & fertilizers	Iron uptake (g ha^{-1})			
	Biofertilizers and micronutrients			
	B_1	B_2	B_3	B_4
A_1	357.20	595.40	690.82	734.46
A_2	502.93	621.19	757.57	810.41
A_3	523.64	657.34	939.03	1066.31
A_4	552.83	665.16	1013.93	1124.09
SEm±	50.03			
CD (P=0.05)	144.51			

Table 4: Nutrient concentration of fodder maize at harvest as influenced by integrated nutrient management.

Treatment	N (%)	Zn (mg kg^{-1})	Fe (mg kg^{-1})
A_1	1.04	1.10	1.16
A_2	1.10	1.19	1.23
A_3	1.14	1.24	1.28
A_4	1.19	1.27	1.31
SEm±	0.03	0.56	2.47
CD (P=0.05)	0.08	1.61	7.13
B_1	0.96	1.02	1.07
B_2	1.10	1.15	1.18
B_3	1.28	1.32	1.34
B_4	1.14	1.30	1.39
SEm±	0.03	0.56	2.47
CD (P=0.05)	0.08	1.61	7.13
A × B	NS	NS	NS

The interaction for crude protein yield was significant. The highest crude protein yield (1001.94 kg ha^{-1}) was obtained with A_4B_4, while the lowest (418.17 kg ha^{-1}) was recorded with A_1B_1. The higher crude protein yield under integrated treatments was associated with improved nitrogen nutrition and greater fodder biomass.

Nutrient concentration and uptake

Nutrient concentration and uptake at harvest were markedly influenced by the integrated nutrient management treatments. The response was evident for nitrogen (N), zinc (Zn) and iron (Fe), with Factor A and Factor B treatments generally showing a progressive improvement in nutrient status. The interaction between the two factors was significant for nutrient uptake at harvest.

Nutrient concentration

At harvest, A_4 recorded the highest concentration of N (1.31%), Zn (22.17 mg kg^{-1}) and Fe (91.20 mg kg^{-1}) among the Factor A treatments. The corresponding lowest values were observed under A_1, with 1.16% N, 19.24 mg kg^{-1} Zn and 75.78 mg kg^{-1} Fe. Among the Factor B treatments, B_4 recorded the highest N (1.39%), Zn (23.05 mg kg^{-1}) and Fe (95.78 mg kg^{-1}) concentrations, whereas B_1 recorded the lowest values (1.07%, 17.78 mg kg^{-1} and 70.04 mg kg^{-1}, respectively). The A × B interaction was non-significant for the individual nutrient concentrations.

Nutrient uptake

Nutrient uptake showed a clear response to integrated nutrient management. Under Factor A, the highest uptake of N (120.84 kg ha^{-1}), Zn (202.06 g ha^{-1}) and Fe (839.00 g ha^{-1}) was recorded with A_4, while A_1 recorded the lowest values of 90.13 kg ha^{-1}, 151.00 g ha^{-1} and 594.47 g ha^{-1}, respectively. Among Factor B treatments, B_4 recorded the highest N uptake (135.90 kg ha^{-1}), Zn uptake (224.99 g ha^{-1}) and Fe uptake (933.82 g ha^{-1}), whereas B_1 recorded the lowest values. The A × B interaction was significant at harvest. The A_4B_4 combination recorded the highest uptake of N (160.31 kg ha^{-1}), Zn (257.85 g ha^{-1}) and Fe (1124.09 g ha^{-1}), while A_1B_1 recorded the lowest values (66.91 kg ha^{-1}, 85.01 g ha^{-1} and 357.20 g ha^{-1}, respectively). The higher nutrient uptake under A_4B_4 can be attributed to the combined effect of improved nutrient availability and a better nutritional environment for crop growth. (Note: Interaction tables of nutrient uptake given in supplementary Tables 1, 2 and 3).

Table 5: Nutrient uptake of fodder maize at harvest as influenced by integrated nutrient management.

Treatment	N uptake (kg ha^{-1})	CFY (g ha^{-1})	TAY (g ha^{-1})
A_1	90.13	151.00	594.47
A_2	99.67	170.30	673.03
A_3	114.62	194.19	796.58
A_4	120.84	202.06	839.00
SEm±	3.06	4.05	25.02
CD (P=0.05)	10.20	13.50	83.43
B_1	74.02	123.00	484.15
B_2	91.47	160.97	634.77
B_3	123.87	208.61	850.34
B_4	135.90	224.99	933.82
SEm±	3.06	4.05	25.02
CD (P=0.05)	10.20	13.50	83.43
A × B	S	S	S

Conclusion

Integrated nutrient management substantially improved the nutritive quality and nutrient accumulation of fodder maize. Among manure and fertilizer treatments, 75% inorganic RDN + 25% N through poultry manure (A_4) consistently produced higher crude protein and total ash contents and greater N, Zn and Fe uptake, while reducing crude fibre concentration. Among biofertilizer and micronutrient treatments, biofertilizer consortia combined with foliar application of 0.2% $ZnSO_4$ and 0.5% $FeSO_4$ at 20 and 40 DAS (B_4) was most effective at harvest. Significant interaction effects were observed for crude protein yield and N, Zn and Fe uptake at harvest, with A_4B_4 generally recording the highest values. Thus, partial substitution of inorganic nitrogen with poultry manure together with biofertilizer consortia and foliar Zn and Fe application can be considered an effective integrated nutrient management strategy for improving fodder quality and nutrient accumulation in fodder maize under the conditions of the experiment.

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