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Balanced Fertilization in Rice-Maize Cropping System to Improve the Productivity, Economics and Soil Fertility Status in North Coastal Zone of Andhra Pradesh, India

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ABSTRACT

On farm studies were conducted during kharif and rabi seasons for two consecutive years from 2019-20 to 2020-21 in 24 farmers fields each year in Vizianagaram district of Andhra Pradesh state to study and demonstrate the importance of balanced fertilization on rice-maize cropping system. The seven treatments consists of control, recommended N alone, recommended N and P, recommended N and K, recommended N, P and K, recommended NPK+ $ZnSO_4$ and farmer's practice. Balanced application of recommended dose of NPK (80-60-50 kg ha^{-1}) along with $ZnSO_4$ (50 kg ha^{-1}) to rice and recommended dose of NPK (200-80-80 kg ha^{-1}) to maize in rice-maize cropping system recorded significantly higher mean grain (5287 kg ha^{-1} and 7172 kg ha^{-1}) and straw yield (7389 kg ha^{-1} and 9284 kg ha^{-1}) during both kharif and rabi seasons. Over the years, maximum System Rice Grain Equivalent yields (8676 kg ha^{-1}), higher gross (Rs 2,16,611 ha^{-1}) and net returns (Rs 1,36,579 ha^{-1}). In addition to improvement in the fertility status of soil, higher sustainable yield index (1.07) and per day system productivity (54.76 kg $ha^{-1}day^{-1}$) were recorded with recommended dose of NPK+ $ZnSO_4$.

***Key words**: Balanced fertilization, Rice-maize cropping system, Soil fertility, System equivalent yield, Yross returns, Net returns*

Introduction

Rice-maize is a major cropping sequence grown in an area of 5.21 lakh ha in Andhra Pradesh state under bore well source of irrigation ecosystem. In India, grain yields have been improved for the past three decades in cereal based irrigated intensified agriculture with cultivation of high yielding varieties and enhanced usage of chemical fertilizer. The cereal production in the India increased by five times where as fertilizer consumption increased by 322 times since green revolution implies low fertilizer use efficiency (Rajendra Prasad, 2009). In cereal based cropping systems, the soil available reserves of carbon and NPK are shoveled heavily. Especially a deficit of about 10 M t of NPK is estimated in the recent past for the estimated NPK requirement of 30 M t every year. Further, subsidized availability coupled with instant response of N fertilizers prompted indiscriminate N and P applications to cereals and habituated application of DAP and low or ignoring of K resulted in nutrient imbalance. Decreasing of factor productivity or response ratio to 6 kg is another alarming situation. Further, continuous mining of secondary and micro nutrients are seldom replenished. In post green revolution era multiple nutrient deficiencies including micro nutrients is one of the important problems making systems unsustainable (Jat *et al.,* 2016). Moreover, deficiency of Zn is very frequent in rice-based cropping system with no or little application of Zn fertilizer (Saha *et al.,* 2015). In view of these facts, a participatory research was carried out in farmer's fields to quantify the productivity potential of Rice-Maize cropping systems with set of nutrient combinations treatments for continuous two years.

Materials and Methods

On-farm experiments were conducted during *kharif* and *rabi* seasons of 2019-20 and 2020-21 in farmers fields of Saluru (Mettavalasa, Regapuvalasa and Gangannadoravalasa Villages) and Makkuva (Chimidivalaasa, Kodipeddavalasa and Yerrasamanthalavalasa Villages) mandals of the Vizianagaram district, situated in North Coastal Zone of East Coast plains and Hills of Andhra Pradesh. Every year the study was conducted in 24 farmer's fields selecting four farmers in each village. The mean initial physical and chemical properties of soils indicated that soils are sandy clay loams in texture and slightly alkaline reaction with pH of 7.08 and Neutral (EC- 0.16 dS/m) in nature. Fertility status indicated that the soils were medium in organic carbon (0.52%), low in available N (172.20 kg ha^{-1}), high in available P (24 kg ha^{-1}) and high in available K (304 kg ha^{-1}).

The experiment was conducted with seven treatments *viz*., control (no fertilizer), recommended N, NP, NK, NPK, NPK+$ZnSO_4$ and farmer's practice. In farmers practice Nitrogen, Phosphorous and Potash fertilizers applying with doses of 76, 42 and 38 kg ha^{-1} in case of Rice and 154, 74 and 52 kg ha^{-1} in case of Maize. Gross and net plot areas were 10m × 10 m and 9m × 9m. The data was statistically analyzed in RBD with each village as one replication consists of average four farmers in that village. In rice popular variety MTU-1121 (Medium duration) and in maize popular hybrid Syngenta NK-6127 (Medium Duration) were grown as test cultures during *kharif* and *rabi* respectively. Recommended dose of fertilizer to rice crop was 80:60:50:50 of NPK and 200:80:80:00 of NPK and Zn SO_4 for *kharif* and *rabi* seasons respectively. Urea, SSP, MOP and Zn SO_4 were used as source for NPK and Zn. Nitrogen was applied in three equal splits at basal, active tillering and panicle initiation stages. While, entire P_2O_5 was applied as basal and K_2O was applied in 2 equal splits as basal and at panicle initiation. Entire $ZnSO_4$ was applied as basal. Rice crop was transplanted after attaining sufficient age of nurseries (25-30 days during *kharif*). In case of Maize, Nitrogen was applied in four equal splits at basal, 20DAS, 40 DAS and 60 DAS. While, entire P_2O_5 was applied as basal and K_2O was applied in 2 equal splits as basal and at 60 DAS initiation along with nitrogenous fertilizer. The $ZnSO_4$ was applied as basal in rice is sufficient for Maize crop. Irrigation, weed, pest and disease management was done as per recommendations of Acharya N.G.Ranga Agricultural University. Mean total of 6 and 8 irrigations were given to *kharif* and *rabi* respectively.

Every season, the data on grain and straw yields were recorded at harvest. The data was analyzed statistically by the standard procedure outlined by Gomez and Gomez (1976). Initial and after harvest soil samples were analyzed for available N P and K. Soil organic carbon was determined by the Walkley–Black method (Nelson and Sommers, 1982), available N by Alkaline permanganate method (Subbaiah and Asija, 1956), available P by Olsen's extractant method (Olsen *et al*., 1954) and available K by extracting with neutral normal ammonium acetate and using Flame photometer (Jackson, 1967).

Results and Discussion

Productivity of rice during *kharif* season

During all the years of study, highest grain yields during *kharif* season (Table 1) were recorded with application of recommended dose of NPK+$ZnSO_4$ (5287 kg ha^{-1}) and lowest were recorded in control (3124 kg ha^{-1}). Mean grain yield over years was significantly higher with application of recommended dose of NPK+$ZnSO_4$ (5287 kg ha^{-1}) than NK, NP, N and control. Straw yield (Table 1) also followed similar trend as that of grain with higher straw yield (7389 kg ha^{-1}) with application of recommended dose of NPK+$ZnSO_4$. Percent increase in grain yield with the application of recommended dose of NPK+$ZnSO_4$ was 69, 35, 22, 15.82, 7 and 12 over control, N, NP, NK, NPK and farmers practice respectively.

Productivity of Maize during *rabi* season

During *rabi* season, maize grain yield was significantly higher in recommended dose of NPK+$ZnSO_4$ (7172 kg ha^{-1}) (Table 1) followed by recommended NPK (6460 kg ha^{-1}) and farmers practice (5982 kg ha^{-1}) and found superior over rest of the treatments. Grain yield in unfertilized treatment was 2769 kg ha^{-1}. The increase in grain yield of rabi maize with recommended dose of NPK+$ZnSO_4$ was 159, 77, 50, 31, 11 and 20 percent higher over the control, N, NP, NK, NPK and farmers practice correspondingly. Straw yield (Table 1) also followed similar trend as that of grain with higher mean straw yield (9284 kg ha^{-1}) in treatments recommended dose of NPK+$ZnSO_4$ was followed by recommended dose of NPK (8384 kg ha^{-1}).

System Productivity and sustainability Yield Index

Productivity of rice-maize system (Table 1) was higher in recommended dose of NPK+$ZnSO_4$ (13963 kg ha^{-1}) and was followed by recommended dose of NPK (12718 kg ha^{-1}) and farmers practice (11921 kg ha^{-1}). Application of recommended dose of NPK+$ZnSO_4$ increased the system productivity to the tune of 116, 58, 39, 25, 10 and 17 percentage over control, recommended N, NP, NK, NPK and farmers practice. Per day productivity was also higher with recommended dose of NPK+$ZnSO_4$ (54.76 kg ha^{-1} day^{-1}) followed by NPK (49.87 kg ha^{-1} day^{-1}) and farmers practice (46.75 kg ha^{-1} day^{-1}). Lowest per day productivity was recorded in control (25.39 kg ha^{-1} day^{-1})

Higher yields with recommended dose of NPK during both the seasons and in turn system productivity may be ascribed to improvement of P in better root development and therewith absorption of N, whereas K is involved in N hesperidins in cereals. Further, experimental soil sites were marginally deficient (0.58 PPM) in Zn, the application of this scarce nutrient helped rice-maize cropping system to record 7 to 7.5 percent higher yields over recommended NPK alone. The results are in agreement

Table 1. Grain and straw yield of Rice and Maize in Rice-Maize Cropping System as influenced by different NPK combinations

Treatment	Pooled (2019-20 & 2020-21) Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		System Rice Grain Equivalent Yield (t ha^{-1})	System Productivity (t ha^{-1})	Production efficiency (kg ha^{-1} day^{-1})	Sustainable Yield Index (SYI)
	Paddy	Maize	Paddy	Maize				
Control	3124	2769	4362	3587	3350	6474	25.39	0.37
N	3916	4059	5444	5306	4910	8826	34.61	0.59
NP	4309	4766	5987	6253	5765	10074	39.51	0.70
NK	4565	5472	6324	7128	6619	11184	43.86	0.81
NPK	4903	6460	6931	8384	7815	12718	49.87	0.95
NPK + Zn SO_4	5287	7172	7389	9284	8676	13963	54.76	1.07
Farmers practice	4685	5982	6597	7731	7236	11921	46.75	0.88
SEm(±)	68.75	57.96	94.99	80.46				
CD(0.05)	198.59	167.41	274.37	232.41				
CV	3.82	2.70	3.78	2.89				

Table 2. Productivity and Profitability of rice-rice cropping sequence as influenced by different NPK combinations

Treatment	Rice (pooled 2019-20 & 2020-21)				Maize (pooled 2019-20 & 2020-21)				Rice-Maize System for both the years			
	Gross Returns	COC	Net Returns	BC Ratio	Gross Returns	COC	Net Returns	BC Ratio	Gross Returns	COC	Net Returns	BC Ratio
Control	55961	29080	26881	0.92	46847	32018	14829	0.46	102808	61098	41710	0.68
N	70750	30074	40676	1.35	68811	34585	34226	0.99	139561	64659	74902	1.16
NP	77409	33315	44094	1.32	81363	35786	45577	1.27	158772	69101	89671	1.30
NK	82119	32663	49456	1.51	92904	36922	55982	1.52	175023	69585	105438	1.52
NPK	86883	34253	52630	1.54	109813	42100	67713	1.61	196696	76353	120343	1.58
NPK + Zn SO_4	95101	36670	58431	1.59	121510	43362	78148	1.80	216611	80032	136579	1.71
Farmers practice	84780	33691	51089	1.52	101229	39741	61488	1.55	186009	73432	112577	1.53

with Ravisankar *et al.* (2014), Hiremath *et al.* (2016) and shinde *et al.* (2015). Raghuveer singh *et al.* (2017) also concluded that application of recommended quantity of nitrogen, phosphorus and potassium together with supplementation of location specific deficient micronutrient is essential for realizing higher production, in major food production systems of the country.

Rice grain equivalent yield (Table 1) was higher also with recommended dose of NPK+$ZnSO_4$ (8676 kg ha^{-1}). Sustainable yield index (SYI) was higher with recommended dose of NPK+$ZnSO_4$ (1.07) followed by NPK(0.95) and farmer's practice (0.88). Control treatment registered lowest SYI (0.37).

Higher Sustainable yield index was recorded with recommended dose of NPK+$ZnSO_4$ (1.07) and was followed by recommended NPK (0.95) and farmers practice (0.88).

Profitability of rice-maize system

Recommended dose of NPK+$ZnSO_4$ resulted in higher gross income in rice and maize are Rs 95101 ha^{-1} and Rs 121510 ha^{-1} respectively (Table 2) and net return (Rs 58431 ha^{-1} and Rs 78148 ha^{-1}) with a cost of cultivation of Rs. 36670 ha^{-1} and Rs. 43362 ha^{-1} and was followed by recommended dose of NPK with Rs 86883 ha^{-1} and Rs 109813 ha^{-1} of gross returns and Rs 52630 ha^{-1} and Rs 67713 ha^{-1} of net returns. Among the different treatments tested cost of cultivation was highest (Rs 36670 ha^{-1} and Rs 43362 ha^{-1}) with NPK+$ZnSO_4$ and was lowest in control in rice and maize crops respectively.

Benefit Cost ratio was higher in recommended dose of NPK+$ZnSO_4$ (1.71) when compared to all other treatments. In control, though cost of cultivation was less due to no fertilizer application, this treatment recorded lesser grain yield and net benefit was also the lowest. These results are in agreement with findings of Sharma *et al.* (2011). Hiremath and Hosamani (2015) in their study on maize-chickpea system stated that recommended dose of NPK along with $ZnSO_4$ recorded significantly higher net returns and benefit cost ratio than other treatments. Raghuveer singh *et al.* (2017) also confirmed that application of recommended quantity of nitrogen, phosphorus and potassium together with supple-

Table 3. Nutrient Uptake in Paddy as influenced by NPK combinations (Pooled data of 2 years-2019-20 & 2020-21)

Treatment	N Grain (kg ha^{-1})	P Grain (kg ha^{-1})	K Grain (kg ha^{-1})	N Straw (kg ha^{-1})	P Straw (kg ha^{-1})	K Straw (kg ha^{-1})
Control	32.19	8.21	12.88	24.01	5.52	56.33
N	42.63	10.83	16.60	24.09	7.17	70.51
NP	46.62	12.20	17.62	31.28	8.17	78.35
NK	49.25	12.55	21.30	33.26	8.62	83.57
NPK	54.56	13.96	22.80	35.86	9.46	92.62
NPK+Zn SO_4	58.73	14.97	24.32	39.47	9.72	96.48
Farmers practice	51.05	13.02	20.86	33.43	8.91	87.60
SEm(±)	0.88	0.17	0.38	0.57	0.15	1.41
CD(0.05)	2.55	0.51	1.12	1.66	0.43	4.08
CV	4.52	3.57	4.90	4.47	4.53	4.28

Table 4. Nutrient Uptake in Maize as influenced by NPK combinations (Pooled data of 2 years-2019-20 & 2020-21)

Treatment	N Grain (kg ha^{-1})	P Grain (kg ha^{-1})	K Grain (kg ha^{-1})	N Straw (kg ha^{-1})	P Straw (kg ha^{-1})	K Straw (kg ha^{-1})
Control	30.92	6.43	11.96	17.13	5.08	34.11
N	46.97	9.88	18.56	25.75	7.85	53.59
NP	57.11	12.77	22.06	31.38	9.57	64.05
NK	65.43	14.59	26.62	36.60	10.82	78.03
NPK	80.77	17.99	32.08	43.74	13.70	95.86
NPK+Zn SO_4	93.64	20.68	35.75	49.23	16.10	110.29
Farmers practice	70.54	15.35	28.02	38.53	11.46	79.63
SEm(±)	0.89	0.55	0.38	0.60	0.25	1.04
CD(0.05)	2.59	1.61	1.10	1.75	0.74	3.02
CV	3.45	9.82	3.73	4.28	5.93	3.48

Table 5. Post harvest soil nutrient status as influenced by NPK combinations (Pooled data of 2 years-2019-20 & 2020-21)

Treatment	pH	Organic carbon (%)	Avail N (kg ha^{-1})	Avail P (kg ha^{-1})	Avail K (kg ha^{-1})	E C (ds/m)
Before	7.08	0.52	172.20	24.00	304.00	0.16
Control	6.46	0.52	186.40	66.14	252.24	0.14
N	6.02	0.48	204.24	61.67	244.22	0.17
NP	6.54	0.46	194.42	102.24	232.24	0.15
NK	6.36	0.47	196.42	58.48	268.00	0.16
NPK	6.24	0.52	192.34	92.46	267.33	0.15
NPK+ Zn SO_4	6.62	0.57	197.54	97.20	272.33	0.16
Farmers practice	6.24	0.52	201.49	86.52	264.33	0.17
SEm(±)	0.03	0.012	1.50	0.28	1.62	0.003
CD(0.05)	0.12	0.031	4.42	0.82	4.64	0.013
CV	**1.54**	**5.49**	**1.87**	**5.36**	**1.52**	**6.14**

mentation of location specific deficient micronutrient enhanced marginal returns in cereal based cropping systems.

Nutrient Uptake

Recommended dose of NPK+$ZnSO_4$ recorded significantly higher nutrient uptake in both grain and straw and was followed by recommended dose of NPK in both rice and maize for NPK nutrients.

Soil nutrient status after harvest

Post harvest analysis indicated higher status of organic carbon and available N, P, K with application of recommended dose of NPK+$ZnSO_4$ followed by NPK over other treatments (Table 5). Balanced application of NPK results in better root and shoot growth and build up the soil fertility over a period. Gangwar *et al.* (2014) reported that the continuous use of under and less number of nutrients to soil erodes the nutrient base and effects the productivity. In higher doses of fertilizers application significant improvement in soil fertility status after harvest was reported by Hile *et al.*, (2007); Jain *et al.*, (2012), Dechassa Hirpa Dibaba (2014); Mohan Kumar and Hiremath (2016).

It is concluded that in rice-maize cropping systems, application of NPK+$ZnSO_4$ 80-60-50-50 kg ha^{-1} and 200-80-80 respectively are recommended to obtain higher grain yield, net returns and to preserve the soil fertility under East coast plains and hills of Andhra Pradesh.

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