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Influence of balanced fertilization on productivity, economics and soil fertility of rice –rice (*Oryza sativa* L.) cropping system under southern deccan plateau of Telangana

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ABSTRACT

On farm studies were conducted during kharif and rabi seasons for four consecutive years from 2013-14 to 2016-17 in 24 farmer's fields each year in unified Warangal district of Telangana state to study and demonstrate the influence of balanced fertilization on rice-rice 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 farmers practice. Balanced application of recommended dose of NPK (120-60-40 kg ha^{-1}) along with $ZnSO_4$ (50 kg ha^{-1}) to rice-rice cropping system recorded significantly higher mean grain (5.10 t ha^{-1} and 5.84 t ha^{-1}) and straw yield (6.46 t ha^{-1} and 7.49 t ha^{-1}) during both kharif and rabi seasons. Over the years, maximum System Rice Grain Equivalent yields (12.19 t ha^{-1}), higher gross (Rs 1 64, 590 ha^{-1}) and net returns (Rs 90,260 ha^{-1}) were also recorded with recommended NPK+ $ZnSO_4$. In addition to improvement in the fertility status of soil, higher sustainable yield index during both kharif (0.47) and rabi (0.71) seasons and per day system productivity (33.40 kg ha^{-1}day^{-1}) were recorded with recommended dose of NPK+ $ZnSO_4$.

***Keywords**:* Balanced fertilization, gross returns, net returns, soil fertility, system equivalent yield

Rice-rice is a major cropping sequence grown in an area of 14.15 lakh ha in Telangana state under bore well source of irrigation eco system. 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 (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-rice cropping systems with set of nutrient combinations treatments for continuous four years.

MATERIALS AND METHODS

On-farm experiments were conducted during *kharif* and *rabi* seasons of 2013-14, 2014-15, 2015-16 and 2016-17 in peasant's fields of Hanam konda (Vanamala kanparthi and Tekulagudem villages), Station ghanpur (Rajavaram and Chinna pendyala villages), Dharma sagar (Dharmapuram village) and Wardhannapeta (Kadarigudem villages) mandals of the then Warangal district, situated in Central Telangana Zone of southern deccan plateau of Telanagana. 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 8.08 and non saline (EC- 0.36 dSm^{-1}) in nature. Fertility status indicated that the soils were medium in organic carbon (0.67%), low in available N (190 kg ha^{-1}), high in available P (44.23 kg ha^{-1}) and medium in available K (285.74 kg ha^{-1}).

The experiment was conducted with seven treatments *viz*., control (no fertilizer), recommended N, NP, NK, NPK, NPK+Zn SO_4 and farmers practice. In farmers practice nitrogen dose is ranged from 125 kg ha^{-1} to 160 kg ha^{-1} with mean dose of 148 kg ha^{-1}. Phosphorous dose is ranged from 50 kg ha^{-1} to 100 kg ha^{-1} with mean dose of 85 kg ha^{-1}. K level is ranged from 0 to 30 kg ha^{-1} with

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Table 1: Grain and straw yield of rice during *kharif* season as influenced by different NPK combinations

Treatment	Grain yield (t ha^{-1})					Straw yield (t ha^{-1})					System rice grain equivalent yield (t ha^{-1})	Sustainable yield index (SYI)
	2013 -14	2014 -15	2015 -16	2016 -17	Pooled Mean	2013 -14	2014 -15	2015 -16	2016 -17	Pooled Mean		
Control	3.52	2.42	2.77	2.80	2.87	4.67	3.79	4.17	3.49	4.03	3.24	0.21
N	4.90	2.92	3.72	3.44	3.74	5.99	4.49	5.05	4.10	4.91	4.25	0.34
NP	5.23	3.26	3.88	3.63	4.00	6.39	4.75	5.29	4.44	5.22	4.6	0.38
NK	5.70	3.47	4.20	3.74	4.28	6.94	4.93	5.58	4.57	5.50	4.94	0.39
NPK	5.97	3.92	4.71	4.27	4.72	7.30	5.32	6.20	5.10	5.98	5.39	0.52
NPK + Zn SO_4	6.54	4.23	4.98	4.67	5.10	7.77	5.88	6.62	5.58	6.46	5.80	0.47
Farmers practice	5.50	4.11	4.83	4.53	4.74	6.45	5.45	6.67	5.67	6.06	5.41	0.48
SEm(±)	**0.29**	**0.11**	**12.2**	**0.08**	**0.15**	**0.37**	**0.20**	**0.13**	**0.12**	**0.20**		
LSD(0.05)	**0.85**	**0.32**	**0.36**	**0.25**	**0.45**	**1.07**	**0.60**	**0.37**	**0.35**	**0.60**		

Table 2: Grain and straw yield of rice during *rabi* season as influenced by different NPK combinations

Treatment	Grain yield (t ha^{-1})					Straw yield (t ha^{-1})					System rice grain equivalent yield (t ha^{-1})	Sustainable yield index (SYI)
	2013 -14	2014 -15	2015 -16	2016 -17	Pooled Mean	2013 -14	2014 -15	2015 -16	2016 -17	Pooled Mean		
Control	2.57	3.01	3.34	2.34	2.82	3.5	3.91	4.66	5.49	4.39	3.1	0.39
N	3.13	4.00	4.61	2.61	3.59	4.05	4.85	5.29	6.04	5.06	3.97	0.45
NP	3.78	4.39	4.92	3.92	4.25	4.41	5.23	5.99	6.89	5.63	4.58	0.57
NK	4.28	4.86	5.23	4.23	4.65	5.07	6.01	6.78	7.99	6.46	5.12	0.6
NPK	5.04	5.82	6.4	5.4	5.67	5.88	7	7.96	9.14	7.49	6.02	0.58
NPK + Zn SO_4	5.38	6.13	6.38	5.48	5.84	6.21	6.81	7.98	8.97	7.49	6.39	0.71
Farmers practice	4.07	5.46	5.91	4.91	5.09	5.02	6.77	7.68	8.6	7.02	5.69	0.54
SEm(±)	**0.34**	**0.10**	**0.12**	**0.09**	**0.17**	**0.36**	**0.19**	**0.11**	**0.11**	**0.17**		
LSD(0.05)	**1.00**	**0.31**	**0.37**	**0.27**	**0.49**	**1.06**	**0.57**	**0.34**	**0.32**	**0.51**		

mean dose of 20 kg ha^{-1}. Gross and net plot areas were $10m^2 \times 10\ m^2$ and $9m^2 \times 9m^2$. The data were statistically analyzed in RBD with each farmer's field as one replication. Popular varieties of rice *viz*., BPT 5204 (long duration) and MTU 1010 (short duration) were grown as test cultures during *kharif* and *rabi* respectively. Recommended dose of fertilizer to rice crop was 120:60:40 of NPK and 120:60:40:50 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 (30-35 days during *kharif* and 25-30 days during *rabi*). Irrigation, weed, pest and disease management was done as per recommendations of PJTSAU(Professor Jayashnkar Telangana State Agricultural University). Mean total of 40 and 60 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 (1984). 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 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

Table 3: Productivity and profitability of rice-rice cropping sequence as influenced by different NPK combinations

Year/Treatment	Control	N	NP	NK	NPK	NPK+ Zn SO_4	Farmers practice
Productivity (kg ha^{-1})							
System Rice Grain Equivalent Yield **(t ha^{-1})**	6.34	8.22	9.18	10.06	11.41	12.19	11.10
System per day productivity (kg ha^{-1} day^{-1})	17.37	22.52	25.15	27.56	31.26	33.40	30.41
Cost of Cultivation (₹ x10^3 ha^{-1})							
2013-14	59.00	61.39	67.19	63.90	69.55	74.04	75.20
2014-15	59.57	62.21	67.47	64.42	69.98	74.43	75.18
2015-16	60.05	63.02	67.76	64.94	70.51	74.82	75.40
2016-17	59.58	62.69	67.80	64.98	70.03	74.63	75.37
Pooled	59.55	62.33	67.55	64.56	70.02	74.48	75.29
Gross returns (₹ x10^3 ha^{-1})							
2013-14	85.40	112.10	127.04	140.50	154.20	168.29	144.19
2014-15	83.38	105.87	116.52	126.97	148.78	157.51	147.02
2015-16	98.19	134.06	141.12	151.40	178.35	182.20	172.04
2016-17	77.05	91.20	113.53	120.11	145.14	150.95	141.76
Pooled	86.00	110.81	124.55	134.75	156.62	164.74	151.25
Net returns (₹ x10^3 ha^{-1})							
2013-14	26.40	50.71	59.85	76.61	84.65	94.25	68.99
2014-15	23.81	43.67	49.05	62.55	78.80	83.08	71.84
2015-16	38.14	71.04	73.36	86.46	107.84	107.38	96.64
2016-17	17.47	28.51	45.73	55.13	75.11	76.32	66.39
Pooled	26.45	48.48	57.00	70.19	86.60	90.26	75.97
B:C ratio							
2013-14	1.45	1.83	1.89	2.20	2.22	2.27	1.92
2014-15	1.40	1.70	1.73	1.97	2.13	2.12	1.96
2015-16	1.64	2.13	2.08	2.33	2.53	2.44	2.28
2016-17	1.29	1.45	1.67	1.85	2.07	2.02	1.88
Pooled	1.44	1.78	1.84	2.09	2.24	2.21	2.01

Table 4: Post harvest soil nutrient status as influenced by NPK combinations (pooled data of 4 years)

Treatment	Organic carbon (%)	Avail N (kg ha^{-1})	Avail P (kg ha^{-1})	Avail K (kg ha^{-1})
Control	0.64	185.9	36.6	275.7
N	0.66	192.7	40.2	282.2
NP	0.68	189.1	44.7	280.8
NK	0.71	190.3	42.8	296.3
NPK	0.70	193.0	43.5	307.4
NPK+Zn SO_4	0.70	193.4	45.6	310.4
Farmers practice	0.71	187.5	45.2	276.4
SEm(±)	**0.02**	**1.2**	**0.5**	**1.8**
LSD (0.05)	**0.06**	**3.5**	**1.4**	**5.2**

application of recommended dose of NPK+$ZnSO_4$ (4.23 to 6.54 t ha^{-1}) and lowest were recorded in control (2.42 to 3.52 t ha^{-1}). Mean grain yield over years was significantly higher with application of recommended dose of NPK+$ZnSO_4$ (5.10 t ha^{-1}) than NK, NP, N and control. However, the treatments recommended NPK (4.72) and farmers practice (4.74) also registered on par average grain yield to that of NPK+ $ZnSO_4$. Straw yield also followed similar trend as that of grain with higher straw yields over years (5.58 to 7.77 t ha^{-1}) and mean straw yield (6.46 t ha^{-1}) with application of recommended dose of NPK+$ZnSO_4$. Rice grain equivalent yield (grain + grain equivalent of straw) was also with recommended dose of NPK+$ZnSO_4$ (5.80 t ha^{-1}). Sustainable yield index (SYI) was higher with recommended dose of NPK (0.52) followed by farmer's practice (0.48) and recommended dose of NPK+$ZnSO_4$ (0.47). Control treatment registered lowest SYI (0.21). Percent increase in grain yield with the application of recommended dose of NPK+$ZnSO_4$ was 77.7, 36.3, 21.5, 19.1, 8.0 and 7.5 over control, N, NP, NK, NPK and farmers practice respectively.

Productivity of rice during *rabi* season

During *rabi* season, rice grain yield was significantly higher in recommended dose of NPK+$ZnSO_4$ (5.84 t ha^{-1}) and was ranging from 5.38 to 6.38 t ha^{-1} over years (Table 2). Recommended NPK also recorded on par grain yield (5.67 t ha^{-1}) with that of recommended dose of NPK + $ZnSO_4$ and both the treatments were superior over farmers practice (5.09 t ha^{-1}) and rest of the treatments. Grain yield in unfertilized treatment was ranging from 2.34 to 3.34 t ha^{-1} over years. The increase in grain yield of rabi rice with recommended dose of NPK+$ZnSO_4$ was 107, 62.6, 37.4, 25.5, 2.9 and 14.7 percent higher over the control, N, NP, NK, NPK and farmers practice correspondingly. Straw yield also followed similar trend as that of grain with higher mean straw yield (7.49 t ha^{-1}) in treatments recommended dose of NPK+$ZnSO_4$ and recommended dose of NPK. Rice grain equivalent yield was also with recommended dose of NPK+$ZnSO_4$ (6.39 t ha^{-1}) was followed by recommended dose of NPK (6.02 t ha^{-1}). Higher Sustainable yield index was recorded with recommended dose of NPK+$ZnSO_4$ (0.71) and was followed by recommended dose of NK (0.60) and recommended NPK (0.58).

System productivity

Productivity of rice-rice system (Table 3) was higher in recommended dose of NPK+$ZnSO_4$ (12.19 t ha^{-1}) and was followed by recommended dose of NPK (11.41 t ha^{-1}) and farmers practice (11.10). Application of recommended dose of NPK+$ZnSO_4$ increased the grain yield to the tune of 92.3, 48.3, 32.8, 21.2, 6.8 and 9.8 percentage over control, recommended N, NP, NK, NPK and farmers practice. Per day productivity was also higher with recommended dose of NPK+$ZnSO_4$ (33.40 kg ha^{-1} day^{-1}) followed by NPK (31.26 kg ha^{-1} day^{-1}) and farmers practice (30.41 kg ha^{-1} day^{-1}). Lowest per day productivity was recorded in control (17.37 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 (0.61 PPM) in Zn, the application of this scarce nutrient helped rice-rice cropping system to record 5.1 to 8.0 percent higher yields over recommended NPK alone. The results are in agreement with Ravisankar *et al.* (2014), Hiremath *et al.* (2016) and shinde *et al.* (2015). 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.

Profitability of rice-rice system

Among the different treatments tested cost of cultivation was highest (Rs 75290 ha^{-1}) with farmer's practice and was lowest in control (Table 3). Recommended dose of NPK+ZnSO4 resulted in higher gross (Rs 164740 ha^{-1}) and net return (Rs 902600 ha^{-1}) with a cost of cultivation of Rs. 74480 ha^{-1} and was followed by recommended dose of NPK with Rs 156620 ha^{-1} of gross returns and Rs 86600 $ha^{-1}$of net returns. However, Benefit Cost ratio was higher in recommended dose of NPK (2.24) due to less cost of cultivation (Rs 70020 ha^{-1}) when compared with recommended dose of NPK+$ZnSO_4$ (2.21). In farmers practice the cost of cultivation was high when compared to other NPK combinations but the productivity was lesser than recommended NPK with or without $ZnSO_4$, hence resulted lower net returns and B:C ratio. Likewise 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. Singh *et al.* (2017) also confirmed that application of recommended quantity of nitrogen, phosphorus and potassium together with supplementation of location specific deficient micronutrient enhanced marginal returns in cereal based cropping systems.

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 4). 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), Dibaba (2014), Kumar and Hiremath (2016).

It is concluded that in rice-rice cropping systems, application of NPK+$ZnSO_4$ (120-60-40+50 kg ha^{-1}) is recommended to obtain higher grain yield, net returns and to preserve the soil fertility under southern deccan plateau of Telangana.

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