Nitrogen Use Efficiency and Production Efficiency of Rice Under Rice-Pulse Cropping System with Integrated Nutrient Management

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Abstract

Studies on effect of Integrated Nutrient Management (INM) in rice and cumulative and residual effects of Integrated Nutrient Management of *kharif* rice on performance of *rabi* green gram were conducted at Regional Agricultural Research Station, Anakapalle during kharif and rabi 2009 and 2010. Rice was grown in *kharif* with 12 treatments, consisting of INM practices (where 50 % or 75 % recommended NPK were integrated with vermicomposts prepared from sugarcane trash, weeds, vegetable waste and rice straw), recommended fertilizer dose and control. During rabi, greengram was grown by dividing above plots into two, one receiving 50 % recommended chemical fertilizers and the other without any fertilizers. Grain and seed yields of rice and green gram were higher with INM practices, specially when vegetable market waste compost was applied. Production efficiency of rice increased with reduced chemical fertilizer levels and highest production efficiency was recorded with 50 % chemical fertilizers integrated with vermicomposts over 75 % chemical fertilizers integrated with vermicomposts. The nitrogen use efficiency with application of 75 % chemical fertilizers + weed vermicompost @ 2.5 tha^{-1} was better than other combinations closely followed by 50 % RDF + 50 % prathista organics. Lowest production efficiency was recorded with 100 % chemical fertilizers alone. Highest profitable treatment in both the crops and in both fertilizer and without fetilizer effects was 75 % chemical fertilizers + vegetable market waste vermicompost @ 2.5 tha^{-1}.

Key words: INM, rice, greengram, production efficiency, yield, benefit cost ratio

It is widely recognized that neither use of organic manures alone nor chemical fertilizers can achieve the sustainability of the yield under the modern intensive farming. Contrary to detrimental effects of inorganic fertilizers, organic manures are available indigenously which improve soil health resulting in enhanced crop yield. However, the use of organic manures alone might not meet the plant requirement due to presence of relatively low levels of nutrients. Therefore, in order to make the soil well supplied with all the plant nutrients in the readily available form and to maintain good soil health, it is necessary to use organic manures in conjunction with inorganic fertilizers to obtain optimum yields. Among Rice based cropping systems rice-pulse cropping system is one of the most important cropping systems in Andhra Pradesh With the advantage of considerable area under rice fallow system and retreating monsoon, pulse crop (greengram) fits into the system and is preferred by the farming community of Andhra Pradesh as a second crop after rice. Declining trend in productivity observed in several long term experiments all over India in these crops (Reddy *et al.* 2004). Hence, the present investigation of involving vermicomposts obtained from various organic residues integrated with inorganic fertilizers was taken up to study the production effeciency, productivity, nitrogen use effeciecny and benefit cost ratio under rice-pulse cropping system.

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Materials and Methods

A field experiment was conducted during *kharif* and *rabi* 2009 and 2010 consecutively on rice-greengram cropping system at Regional Agricultural Research Station, Anakapalle. The initial soils were neutral in soil reaction (pH 7.22) with non saline conductivity (0.210 dSm^{-1}). The organic carbon content was 0.51 % and the available nitrogen content was low (241 kg ha^{-1}), available phosphorus was medium in status (27.45 kgha^{-1}) and potassium content was high (309 kg ha^{-1}). There were 12 treatments of integrated nutrient management imposed on rice crop.

Vermicompost preparation: The cane trash and paddy straw obtained during harvest of sugarcane and rice crops were collected. The main weed species available in sugarcane field i.e (*Cyperus rotundus,Cynodon dactylon, Cleome viscosa, Commalina bengalensis* and *Trianthema portulacastrum*) were collected from the field and the vegetable market waste was collected from Anakapalle vegetable markeThese organic residues were shade dried for few days and cut into small pieces. The organic residues were spread in the pit (6.0 x 1.0 x 0.6 m) up to 6″ height and 5 % dung slurry was uniformly distributed on the top of the organic residues sufficient to wet the surface. Over this layer another layer of organic residues was spread followed by spraying of dung slurry uniformly. This process was repeated till the spread of the organic residues 6″ above the top of the pit. After partial decomposition of organic residues (attained in 15 days) the earthworms (*Eisenia foetida)* were released @ 1 kg (around 1000 worms) per 1 ton organic residues in to the bed by making holes at the top of the bed on four corners and centre of the pit. Throughout the composting process, sufficient moisture was maintained i.e. at 50 percent of maximum water holding capacity of a material. The matured vermicompost samples were collected for laboratory analysis and field application.

Vermicomposts obtained from different organic residues viz., cane trash, weeds, vegetable market waste and rice straw @ 2.5 t ha^{-1} along with different levels of (50 % and 75 %) nitrogen chemical fertilizers were used to evaluate their efficiency under integrated nutrient management in rice. certified organic manures supplied by M/s Prathista Industries Ltd., Hyderabad, viz., Suryamin (20 % N) for N supplement, Biophos (20 % P_2O_5) and Biopotash (14 % K_2O) for P & K supplements, Biozinc (12 % Zn) for zinc supplement were tested together along with other INM treatments (Table 1). The main treatments include T_1- 50 % RDF + 2.5 t ha^{-1} cane trash compost, T_2-50 % RDF + 2.5 t ha^{-1} weed compost, T_3-50 % RDF + 2.5 t ha^{-1} vegetable market waste compost, T_4-50 % RDF + 2.5 t ha^{-1} rice straw compost, T_5-75 % RDF + 2.5 t ha^{-1} cane trash compost, T_6-75 % RDF + 2.5 t ha^{-1} weed compost, T_7-75 % RDF + 2.5 t ha^{-1} veg.market waste compost, T_8-75 % RDF + 2.5 t ha^{-1} rice straw compost, T_9-100 % RDF T_{10}- Control, T_{11}: 100 % Prathista organic manures and T_{12}: 50% RDF + 50% Prathista organic manures. During rabi, each plot was divided into two halves and 50 % recommended dose of chemical fertilizers of greengram i.e 10 and 20 kg N and P ha^{-1} were applied to one half, while the crop in the other half was studied under the residual effect. The maximum and minimum temperatures recorded during rice crop growth period were 37.8 and 19.6^{o}C, respectively. The weather parameters are quite favourable for crop growth. Grain and seed samples at harvesting stage were collected, oven dried and ground. The total nitrogen content (%) in the dried plant sample was determined by microkjeldahl distillation method (Piper, 1966). The diacid extract (9:4 nitric acid : perchloric acid) was used for analysis of total phosphorus, potassium and micronutrients in plant samples. Concentration of nutrient was multiplied by yield for calculation of nutrient uptake. The Production effeciency of rice for two years was calculated by using formula Production Effeciency = Grain yield in treated plot-grain yield in control/ N uptake in treated plot- N uptake in control plot. Nitrogen Use Efficiency = N uptake in treated plot- N uptake in control plot / Fertilizer nitrogen applied and Benefit cost ratio was calculated as gross returns accrued divided by total cost incurred. All the parameters were analysed in a randomized block design (for rice) and split plot design (for greengram) to list the variance of different treatments at 5 per cent level of significance (Rao, 1983).

Results and Discussion

Grain yield and seed yield of rice and greengram

Results revealed that the grain yield (Table 3) of rice varied from 2.60 (absolute control) to 5.85 t ha^{-1} (75 % RDFN + vegetable market waste vermicompost @ 2.5 t ha^{-1}). Significantly higher grain yield was recorded when 25 % N substituted through vegetable market waste vermicompost, which was on par with weed vermicompost. Regarding greengram all the fertilizer treatments recorded higher seed yields than their respective treatments for without fertilizers. In both the sub plots the treatment which received 75 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1} during preceding rice crop recorded higher seed yields of greengram than other treatments, and it was on par with T_6, T_{11} and T_{12}. The difference in seed yields between fertilizer and without fertilizer effects was 0.86 q ha^{-1}. The treatment with 100 % RDF for preceding rice and 50 % RDF for *rabi* greengram (cumulative effect) exhibited slight redurction in yield in second year than first year of study. In both fertilizer and without fertilizer treatments yield reduction was observed in 100 % RDF and absolute control treatment in second year than first year, However in all the INM treatments, seed yield increased during second year compared to first year in both the sub plots. The higher grain and seed yields of rice and greengram with integrated use of different vermicomposts and chemical fertilizers might be attributed to higher availability of macro and micro nutrients and facilitating uptake by plants resulting in better growth and dry matter production and also occurrence of different beneficial microorganisms, presence of growth promoting substances, hormones, enzymes, antibiotics etc., in vermicompost. Similar results were reported by Barik *et al.* (2008) and Datta and Singh (2010). Among different INM treatments, 75 % RDFN in combination with different vermicomposts @ 2.5 t ha^{-1} (T_5 to T_8) recorded significantly higher yields compared to 50 % RDFN in combination with different vermicomposts @ 2.5 t ha^{-1} (T_1 to T_4). This could be due to high availability and utilization of nitrogen by the crop from inorganic source (fertilizer) whereas release of nitrogen from organic source may not be full during the crop growth period. These findings are in conformity with Singh *et al.* (2005) and Pandey *et al.* (2007).

Production Efficiency

Production efficiency was relatively higher with INM treatments during second year over first year and it was just reverse in 100 % chemical fertilizer treatment (Table 2). Higher production efficiency was obtained with integrated use of chemical fertilizers with vermicomposts than chemical fertilizers alone. This could be because of prolonged supply of nitrogen as a results of minerailization (Reddy *et al.* 2004). Among INM treatments, highest production efficiency was recorded when 50 % chemical fertilizers were integrated with vermicomposts compared to 75 % chemical fertilizers plus vermicomposts.Conjunctive use of organics along with inorganics sets a congenial soil environment with consistent supply of nutrients over the crop period by enhancing the crop growth which results in high production effeciency (Singh *et al.* 2005).

Nitrogen use efficiency

Among different treatments, the nitrogen use efficiency with application of 75 % RDFN + weed vermicompost @ 2.5 tha-1 was better than other combinations and it was closely followed by 50 % RDF + 50 % prathista organics (Table 2). Nitrogen use efficiency (NUE) was more in second year compared to first year which could be due to continuous supply of nitrogen and also due to residual effects. Nitrogen use efficiency was more in integrated treatments over inorganic treatment.

Due to application of vermicompost in lowland rice, the activity of beneficial microbes and colonization of micorhizal fungi increased, which play an important role in mobilization of nutrients and thereby leading to better availability of nutrients facilitating uptake by plants resulting in high nitrogen use efficiency (Chakravorti and Samantaray, 2006). Among different vermicomposts (cane trash, weeds, vegetable market waste and rice straw vermicomposts) used in the study, rice responded favourably to the addition of vegetable market waste and weed vermicomposts as a partial substitute of chemical nitrogen fertilizer compared to application of other vermicomposts. This might be due to the rate of decomposition and C/N ratio of the organic manures, which decide the availability of nutrient (Singh *et al.* 2008).

Benefit-cost ratio (BCR) in rice -greengram cropping system under integrated nutrient management

***Kharif* rice**

The gross returns were more in INM treatments compared to 100 % chemical fertilzers and absolute control plots. Among different INM treatments, the plot which received 75 % RDFN + vegetable market waste vermicompost @ 2.5 t ha^{-1} recorded maximum gross returns of Rs. 58,793/- with a benefit cost ratio of 2.81 (Table 4). Higher returns from INM treatments than 100 % chemical fertilizers is due to reduction in cost of cultivation, vermicompost is prepared in the farm itself (assuming production cost is 0.50 paise kg^{-1} only). The treatment with 75 % RDFN + vegetable market waste vermicompost @ 2.5 t ha^{-1} was most profitable (BCR = 2.81) and least profitable is absolute control i.e T_{10} (BCR=1.65).

***Rabi* greengram**

Cost of cultivation was slightly lower in all the unfertilized treatments compared to fertilized treatments. Among all treatments, $T_{7,}$ i.e 75 % RDFN + VMW VC @ 2.5 t ha^{-1} added to preceding rice was profitable with gross returns, net returns and BC ratio of Rs. 25,736 & Rs. 23,142 and Rs.18,861&16,992 and 3.85 & 3.76 under fertilizer and un fertilizer treatments, respectively. Highest profitable treatment in both cumulative and residual effects was T_7 (3.85 and 3.76) followed by T_6 (3.73 and 3.64) and least profitable is absolute control i.e T_{10} (2.08 and 1.64).

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Table 1: Nutrient composition of different organic manures used in the study

Treatment	Total macronutrients (%)			Total micronutrients (mg kg^{-1})			
	N	P	K	Zn	Fe	Mn	Cu
Cane trash vermicompost	1.14	0.46	1.61	61	294	32	28
Weed vermicompost	1.88	1.01	1.31	81	365	67	36
Veg. market waste vermicompost	2.11	1.22	1.45	89	412	98	57
Paddy straw vermicompost	1.12	0.43	1.64	58	284	36	24
Suryamin	20	-	-	-	-	-	-
Biophos	-	20	-	-	-	-	-
Biopotash	-	-	14	-	-	-	-
Bizinc	-	-	-	12 %	-	-	-

Table 2: Effect of INM on productivity, production efficiency and nitrogen use efficiency of rice

Treatments	Grain yield (tha^{-1})			Production efficiency		Nitrogen Use Efficiency	
	2009	2010	Mean	2009	2010	2009	2010
T_1: 50 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	4.4	5.2	4.80	64.5	69.1	33.5	40
T_2: 50 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	4.6	5.4	5.00	56.1	63.7	34.9	39.3
T_3 : 50 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	4.8	5.6	5.20	54.8	59.7	37.2	43.6
T_4: 50 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	4.3	5.0	4.65	67.0	70.1	30.7	35.9
T_5: 75 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	5.0	5.6	5.30	57.0	61.7	40.2	42.7
T_6: 75 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	5.2	6.0	5.60	56.2	58.2	37.5	44.7
T_7 : 75 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	5.5	6.2	5.85	56.6	59.9	39.8	43.8
T_8: 75 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	4.8	5.5	5.15	54.8	60.0	38.4	42.9
T_9: 100 % chemical fertilizers	4.6	4.8	4.70	60.4	57.8	33.1	34
T_{10} : Absolute control	2.8	2.4	2.60	-	-	-	-
T_{11}: 100 % Prathista organic manures	5.2	6.0	5.60	57.6	60.5	40.9	42.7
T_{12}: 50% RDF + 50% Prathista organic manures	5.4	6.2	5.80	57.4	59.9	44.9	44.2
Mean	4.7	5.3	5.00				
S.Em$\pm$	0.14	0.18	0.15				
CD (0.05)	0.38	0.44	0.42				
CV (%)	7.4	7.2	-				

Table 3: Cumulative and residual effects of INM of *kharif* rice on seed yield (qha^{-1}) of *rabi* greengram

Treatments	Seed yield					
	2009			2010		
	50 % RDF	0 % RDF	Mean	50 % RDF	0 % RDF	Mean
T_1: 50 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	7.41	6.85	7.13	7.92	7.15	7.54
T_2: 50 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	7.83	7.07	7.45	8.15	7.36	7.76
T_3 : 50 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	8.05	7.11	7.58	8.41	7.69	8.05
T_4: 50 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	7.37	6.64	7.01	7.85	7.01	7.43
T_5: 75 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	7.89	7.16	7.53	8.1	7.67	7.89
T_6: 75 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	8.21	7.20	7.71	8.65	7.88	8.27
T_7 : 75 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	8.52	7.69	8.11	8.84	7.92	8.38
T_8: 75 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	7.8	7.04	7.42	8.05	7.33	7.69
T_9: 100 % chemical fertilizers	7.51	6.70	7.11	7.4	6.02	6.71
T_{10} : Absolute control	4.84	3.75	4.30	4.54	3.05	3.80
T_{11}: 100 % Prathista organic manures	8.23	7.46	7.85	8.45	7.52	7.99
T_{12}: 50% RDF + 50% Prathista organic manures	8.38	7.35	7.87	8.6	7.8	8.20
Mean	7.67	6.83	7.25	7.91	7.03	7.47
CD (0.05)						
M	0.555			0.569		
S	0.384			0.394		
MxS	0.709			0.728		
CV (%)	6.8			5.9		

Treatments	Rice	Greengram	
		50 % RDF	0 % RDF
T_1: 50 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	2.37	3.40	3.37
T_2: 50 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	2.47	3.54	3.48
T_3 : 50 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	2.56	3.65	3.57
T_4: 50 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	2.29	3.37	3.29
T_5: 75 % RDFN + cane trash vermicompost @ 2.5 t ha^{-1}	2.55	3.54	3.57
T_6: 75 % RDFN + weed vermicompost @ 2.5 t ha^{-1}	2.69	3.73	3.64
T_7 : 75 % RDFN + vegetable market waste vermicompost @ 2.5 tha^{-1}	2.81	3.85	3.76
T_8: 75 % RDFN + paddy straw vermicompost @ 2.5 t ha^{-1}	2.48	3.51	3.46
T_9: 100 % chemical fertilizers	2.20	3.30	3.07
T_{10} : Absolute control	1.65	2.08	1.64
T_{11}: 100 % Prathista organic manures	2.76	3.70	3.61
T_{12}: 50% RDF + 50% Prathista organic manures	2.92	3.76	3.65

Table 4: Benefit-Cost ratio in rice -greengram cropping system under Integrated Nutrient Management