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Enhancement of rice productivity and nitrogen use efficiency through Bioactivator™ treated nitrogen fertilization

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ABSTRACT

Field studies during dry and wet season of 2011 and 2012 were made at research farm of DRR Rajendranagar to assess the role of bioactivator treated nitrogen (N) fertilization on enhancing the productivity and N use efficiency of rice. The mean data indicated that bioactivator treatment of urea at 75% recommended dose of N (RDN) and RDN (180 and 120 kg ha^{-1} in dry and wet seasons) has brought in 21.1 and 9.7 (dry seasons) and 12.7 and 5.3 % (wet seasons improvement in rice grain yield over no bioactivator treated N (3.08 and 3.70 t ha^{-1} in dry seasons and 5.53 and 6.01 t ha^{-1} in wet seasons). Marked activation of microbes (bacteria, fungi and actinomycetes) by bioactivator were seen when vermicompost was applied along with 50% RDN. Application of bioactivator treated RDN is recommended for realizing higher profits (Rs.10, 239 and 40,996) from rice crop.

Key words: *rice, nitrogen, bioactivator, economics*

Rice is the most important food crop of India that is grown on 42.6 million (m) ha (FAOSTAT, 2010) with a production of 104.4 million tonnes (m t) during 2012-13 (DES, 2013) contributing to 29.9% of total calorie needs (Timmer, 2010). The tremendous progress made in rice production in the country in past six decades has been ascribed to cultivation of short statured high yielding varieties under irrigated conditions with adequate fertilizer application and need based plant protection. As there is little scope for bringing additional area under cultivation, increased use of fertilizers is inevitable for attaining the future crop production goals. With an average consumption of 164.8 kg NPK fertilizers/ha in 2011 (DES, 2014) of which rice crop accounted for 29% NPK fertilizer consumption in 2010 (Heffer, 2013) in the country. Low nitrogen (N) use efficiency under irrigated conditions, which rarely exceeds 40% (Ladha *et al*., 2005 and Fageria *et al*, 2009) and high N application (81.7 kg ha^{-1}) is resulting in the N load in the environment. Hence, attempts were made since last decades to enhance the N use efficiency through use of modified N fertilizers (by treating urea with nitrification or urease inhibitors) or by altering the method and time of N fertilization that were quite successful in research farms but failed to reach the farmers' field. In recent times, some additives called fertilizer enhancers were explored for enhancing the N use efficiency like Bioactivator™ of Cytozyme Laboratories, Inc., USA. This proprietary microbial fermentation formulation mixed with urea fertilizer prior to its application was reported to increase the efficiency of N fertilizer by as much as 25% besides reducing the loss of fertilizer in the soil by stimulating specific microorganisms which convert mineral forms of N fertilizer into organic forms, reducing inefficiencies associated with both volatilization and leaching. In view of this, the present investigation was taken up with a view to explore the possibility of reducing the N fertilizer dose without compromising the rice yield by the application of Bioactivator.

MATERIALS AND METHODS

A fixed-plot field study was conducted for two consecutive seasons (Dry season 2011-12 and wet season 2012) at research farm of Directorate of Rice

Research, Rajendranagar, Hyderabad. The soil of the experimental site is clayey (Veritsol; Typic Pellustert) with 7.8 pH, EC 0.26 dS/m in 1:2.5 soil : water (Jackson, 1973) containing 0.65% organic carbon (Wakley and Black, 1943), 258 kg ha^{-1} $KMnO_4$ extractable N (Subbiah and Asija, 1956), 392 kg ha^{-1} NH_4OAC extractable K, and 18 kg ha^{-1} 0.5 M $NaHCO_3$ extractable P (Olsen *et al*., 1956). The experiment was laid out in randomized complete block design with four replications consisting of six treatments (Control *i.e.* no nitrogen, no bioactivator), recommended dose of nitrogen (100% RDN) *i.e.* 180 and 120 kg ha^{-1} during Dry and wet seasons, 100% RDN + bioactivator, 75% RDN, 75% RDN + bioactivator and 50% RDN through fertilizer + 25% RDN through vermicompost) + bioactivator were tested. Nursery raised seedlings {45 and 30 day old in dry season (MTU1010) and wet (PA6444) seasons} were transplanted at a spacing of 20 cm x 15 cm on 3rd February and 13th July 2012. The crop received 26 kg ha^{-1} of phosphorus (P) as single super phosphate (SSP) and 75 kg ha^{-1} of potassium (K) as muriate of potash (MOP) which were broadcasted uniformly before final puddling of field and incorporated into the soil. Nitrogen (N) was applied as per the treatments through prilled urea in three equal splits, each at transplanting and 15 and 40 days after transplanting (DAT) in dry and at transplanting, 30 and 60 DAT in wet season The bioactivator treatment was done by mixing 2 ml of bioactivator in one kg urea prior to application as per the suggested protocol. Bioactivator used in the study is a plant origin product obtained with multistage fermentation process and chemical treatment and is composed of 25% organic fraction, 14.3% mineral fraction (containing organically chelated complex nutrients) and 60.7% inert ingredients/ water. Vermicompost used in the study contained 1.0-2.0-2.0% N-P-K and was uniformly applied as per the treatments as basal along with SSP and MOP. Other management practices were followed as per the crop recommendation for irrigated transplanted conditions. Plant and soil samples were collected thrice, at 15 and 40 DAT in dry and 30 and 60 DAT in wet season (prior to N application) and also at the time of harvesting and analyzed for N content (Jackson, 1973). Growth observations were recorded periodically and yield attributes were recorded at the time of harvesting. Nitrogen uptake was obtained as product of nutrient concentration and yield (grain and straw). Agronomic N use efficiency (ANUE) was worked out as ratio of yield (yield in N applied treatment - yield in no N applied treatment in kg ha^{-1}) and amount of N (kg ha^{-1}) applied. Apparent recovery efficiency (RE) was worked as ratio of N uptake (N applied - control) to the nutrient applied. In the calculation of economics, minimum support price of rice grain i.e. Rs. 12,500/ton and rice straw Rs.1,500/ ton in both dry and wet seasons was used. The N fertilizer price (₹ kg^{-1}) of 12.93 is used. Phosphorus and potassium nutrients were used at a price (₹ kg^{-1}) of 48.13 and 29.38. Vermicompost was given a price of Rs. 3,000/ton. Bioactivator was used at a price of ₹ 0.95/ml. Net B:C ratio is worked out as ratio of net returns to the cost of cultivation. Microbial population was enumerated in the soil samples collected at 50 DAT (10 days after application of 2nd split of N) in dry seasonwhile in wet season it was determined thrice (at 10 days after every split of N application) *i.e*., at 10, 40 and 70 DAT. The analysis of variance (ANOVA) was done in RBD for various soil and plant observations. The significance of treatment differences was compared by critical difference (CD) at 5 per cent level of significance (P=0.05) and statistical interpretation of treatments was done as per Gomez and Gomez (1988).

RESULTS AND DISCUSSION

Plant height, yield attributes (panicles/m2, grains/ panicle), grain and straw yield of rice were significantly influenced by N fertilization with and without bioactivator during both the seasons (Table1). Plant height, the general indicator growth, was low in dry season which has produced rice crop plants that are shorter by 18.5 cm when compared with wet season (102.1 cm) probably due to different cultivars used and weather to which the crop is exposed to. All the N fertilized treatments being at par with each other during both the seasons produced significantly taller plants than control treatment. Nitrogen fertilization on an average has increased the rice plant height by 26.7 (dry season) to 30.7 cm (wet season) over no N applied control treatment. Application of recommended dose of N (RDN) has significantly enhanced the panicle number over control in both the seasons and in dry season only over 75% RDN. The increase in panicle number with application of RDN over control was to the tune 100 and 33% in dry and wet seasons. Further, bioactivator

Table 1. Growth, yield attributes, grain and straw yields (t ha^{-1}) of rice as influenced by N fertilization with and without bioactivator

Treatment	Plant height (cm) at harvest		No. of panicles/m^2		Grains / panicle		Test weight (g)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Control	61.3	76.5	100	200	60.0	130.8	23.8	23.5	1.65	3.57	3.01	5.15
RDN	89.2	110.2	200	266	92.0	151.3	24.5	24.0	3.70	6.01	5.56	6.91
RDN + Bioactivator	90.0	108.7	243	300	92.8	155.0	24.5	24.1	4.06	6.34	6.02	7.25
75% RDN	86.9	105.3	167	250	90.0	147.6	24.4	23.9	3.08	5.53	4.21	6.04
75% RDN + Bioactivator	87.3	106.0	233	283	89.8	149.0	24.4	24.0	3.73	6.23	5.96	6.85
50% RDN + 25% RDN through VC + Bioactivator	86.7	105.8	196	256	90.9	150.2	24.5	24.0	3.65	6.01	5.46	6.44
Mean	83.6	102.1	189.8	259.2	85.9	147.3	24.4	23.9	3.31	5.62	5.04	6.44
CD (P<0.05)	3.42	5.03	26.1	23.2	11.52	15.21	0.50	0.43	0.262	0.323	0.434	0.332

VC: Vermicompost ; RDN: recommended dose of nitrogen i.e.180 (dry season) and 120 (wet season) kg ha^{-1}

treatment of N at both RDN and 75% RDN levels has increased the panicle number/m^2 on an average (over seasons) by 48.5 and 51.5 over their respective untreated N application. Application of 50% RDN + 25% RDN through vermicompost + bioactivator has registered similar panicle productions as that of RDN. Bioactivator treated RDN has recorded highest panicle production in both the seasons; however, it has at par values as that of bioactivator + 75% RDN.

Grains/panicle and test weight of rice did not differ among different levels of N fertilization with and without bioactivator in both the seasons except that N fertilized crop has recorded significantly higher panicle production than no N fertilized control treatment. On average grains /panicle and test weight of N fertilized crop was higher by 31.2 & 19.8 and 0.66 g & 0.5 g in dry and wet seasons, respectively. The data revealed that application of RDN has improved grain yields by 224 and 168.4% in dry and wet seasons, respectively over unfertilized control (1.67 and 3.57 t ha^{-1}). Bioactivator treated N fertilization has significantly enhanced the rice grain and straw yields over N alone at 75% RDN and 100% RDN level. Though the bioactivator treated N enhanced the rice grain and straw yields even at 100% RDN, the relative increase was higher at 75% RDN (31.4% and 27.5% for grain and straw yields) as compared to 100% RDN (7.1% and 6.59%). Application of 50% RDN + 25% RDN through vermicompost + bioactivator has produced rice grain yields at par with that of 100% RDN indicating a 25% saving in N could be made by integration of vermicompost (equivalent to 25%RDN) and bioactivator treatment of N (50%). In general, dry season has 2.31 t low grain yields as compared to wet season crop (5.62 t ha^{-1}). This was most probably due to delayed dry season crop transplanting (February) and use of aged seedlings (45 day old). The dry season crop reproductive stage coinciding with high summer temperatures has resulted in poor panicle production and grain filling and thus the yield. The increase in plant height in response to N fertilization was probably due to enhanced availability of N in soil for crop plants uptake which promoted rapid the cell division and thus increase in height. The n being part of chlorophyll, its application has resulted in more green leaf area production that made higher photo assimilates production. Higher photosynthates produced has promoted more productive tiller (panicle) production having higher number of grains/panicle and test weight than no N applied crop. Bioactivator by prolonging the applied N availability period by curtailing N mineralization induced losses has improved growth, yield attributes formation and thus yield over untreated N fertilization. The positive impacts of N fertilization on growth, yield attributes and yield of rice in the current study are in close agreement with the findings of Indira

(2005). The impacts of bioactivator treatments of nitrogen on rice crop in the present study are in close agreement with the findings of Martineau *et al*. (1993) who conducted similar experiments using this bioactivator in corn at three places *viz*., Iowa, Nebraska, and Missouri in United States.

Nitrogen fertilization with and without bioactivator has significant influence on N concentration of plant at all stages during wet season and at 15 DAT only during dry season (Table 2). Nitrogen concentration of unfertilized (control) rice crop was significantly lower than all other N fertilized treatments at all the growth stages in wet season and at 15 DAT in dry season. Though bioactivator treated RDN treatments have recorded significantly higher values of N concentration over 75% RDN at early stages (15 DAT in dry season and 30 DAT in wet season), these differences disappeared at later stages of observation making all N fertilizer applied treatments to have statistically at par N concentration values.

Total (grain + straw) N uptake of rice crop and N use indices were significantly influenced by N fertilization with and without bioactivator during both the seasons (Table 3). Nitrogen uptake of rice crop that was lowest in control treatment was increased markedly with each increase in N dose up to RDN with and without bioactivator treatment. RDN application has increased the total N uptake of rice crop by 141.4 and 91.8% over control treatment. Further, bioactivator treatment of N has markedly improved the total N uptake of rice crop over their respective no bioactivator treated N doses (75 RDN and RDN level). Bioactivator treated RDN treatment has recorded the highest N uptake in both the seasons. Nitrogen uptake in the treatment of 50% RDN + 25% RDN as vermicompost + Bioactivator was at par with 75% RDN + Bioactivator. Agronomic N use efficiency was highest in 75% RDN + Bioactivator treatment and was closely followed by 50% RDN + 25% RDN as vermicompost + Bioactivator treatment. Apparent N recovery improved substantially with the integration of bioactivator with N as compared

Table 2. Nitrogen content (%) of rice as influenced by N fertilization with and without bioactivator

Treatment	Dry season				Wet season			
	15 DAT	40 DAT	Grain	Straw	30 DAT	60 DAT	Grain	Straw
Control	3.42	2.73	1.36	0.60	3.08	2.67	1.03	0.46
RDN	3.93	3.01	1.52	0.76	3.59	3.02	1.26	0.58
RDN + Bioactivator	3.97	3.07	1.58	0.82	3.79	3.03	1.31	0.68
75% RDN	3.61	2.88	1.39	0.63	3.42	2.96	1.21	0.50
75% RDN + Bioactivator	3.88	2.98	1.50	0.74	3.69	3.00	1.23	0.59
50% RDN + 25% RDN through VC + Bioactivator	3.84	2.90	1.46	0.70	3.57	2.99	1.24	0.50
CD (P<0.05)	0.185	NS	NS	NS	0.323	0.212	0.112	0.119

VC: Vermicompost ; RDN: recommended dose of nitrogen 180 (dry season) and 120 (wet season) kg ha $^{-1}$

Table 3. Total nitrogen uptake (grain + straw) and its use efficiency in rice as influenced by N fertilization with and without bioactivator

Treatment	N uptake (kg ha^{-1})		Agronomic N use efficiency		Apparent N Recovery	
	Dry	Wet	Dry	Wet	Dry	Wet
Control	40.8	60.1	-	-		
RDN	98.5	115.3	11.4	20.3	0.32	0.34
RDN + Bioactivator	113.6	132.5	13.4	23.1	0.40	0.48
75% RDN	69.5	96.9	10.6	21.8	0.21	0.31
75% RDN + Bioactivator	99.1	117.3	15.4	29.6	0.43	0.47
50% RDN + 25% RDN through VC + Bioactivator	91.6	106.1	14.8	27.1	0.38	0.37
CD (P<0.05)	14.15	11.74	-	-		

VC: Vermicompost ; RDN: recommended dose of nitrogen i.e.180 (dry season) and 120 (wet seasn) kg ha $^{-1}$

to fertilizer alone irrespective of N dose. Nitrogen uptake (grain and straw) is the product of its concentration and biomass. The increased supply of N to crop with N fertilization has increased the concentration and yields and thus the uptake has increased with N fertilization. Agronomic use efficiency a product of change in yield and uptake with N fertilization has also increased with combined effect of N fertilization and its bioactivator treatment as compared to N fertilization alone.

The available N content (kg ha^{-1}) in soil was significantly influenced by N fertilization with and without bioactivator (Table 4). Unfertilized plots have recorded significantly lower available N content of soil than all N fertilized treatments during all the observation periods in both the seasons. Nitrogen fertilized treatments among themselves have statistically similar available N content at all the stages of observation during both the years. The soil N content decreased with progress of crop growth from seedling to harvest stage and is ascribed to the increased uptake. The increased available N content of soil in all N fertilized treatments (at 15 and 40 DAT sampling) over initial content (258 kg at start of dry season experiment) was ascribed to the N addition exceeding its uptake by the crop initially due to low biomass accumulation. The cultivation of rice over two seasons without N fertilization has resulted in a loss of 29 kg ha^{-1} of available N. In N fertilized treatments, the loss ranged from the lowest of 5 kg (RDN) to the highest of 9 kg ha^{-1} (75%RDN).

Economics (₹ha^{-1}) of rice cultivation as influenced by N fertilization with and without bioactivator indicated significant differences among treatments (Table 5). Application of RDN along with bioactivator has registered the highest net returns and net B:C ratio during both the seasons; however, the increases were of higher order during wet season as compared to dry season. This high net returns in wet season was ascribed to 2.31 t ha^{-1} of higher grain yields as compared to dry season (3.31 t ha^{-1}). The low yields and high cost of cultivation has resulted in net loss in unfertilized control, 75% RDN and 50% RDN + bioactivator + 25% RDN as VC treatments, respectively during dry season and thus have negative BC ratios. Substitution of 25% RDN with VC owing to its high cost has reduced the net returns and BC ratio as compared to 75% RDN + bioactivator.

Microbial counts (bacteria, actinomycetes at all the stages of observation and fungi at 70 DAT only) of soil were significantly influenced by N fertilization with and without bioactivator (Table 6). Irrespective of the observation time, treatment receiving vermicompost (50% RDN + 25% RDN as VC + bioactivator) recorded the highest microbial count of all the three microbes over rest of the treatments. Vermicompost integrated N fertilization has registered significantly more bacterial and actinomycetes at all the three stages and fungal population than no N receiving treatment. Significant improvement in bacterial and actinomycetes population of soil were noticed from 10 DAT with VC application, however, other N fertilized treatment effects were seen from 40 DAT (bacteria) and at 70 DAT (actinomycetes and fungi). The fungal populations of soil in bioactivator integrated N treatments were significantly higher than no N application. All N fertilized plots have registered statistically similar microbial counts at all the stages of observation. The bacterial populations (40 and 70 DAT)

Table 4. Soil available N content (kg ha^{-1}) as influenced by N fertilization with and without bioactivator

Treatment	Dry season			Wet season		
	15 DAT	40 DAT	At harvest	30 DAT	60 DAT	At harvest
Control	252	244	241	241	238	229
RDN	263	261	257	260	257	253
RDN + Bioactivator	264	261	255	259	256	250
75% RDN	262	260	257	258	255	249
75% RDN + Bioactivator	262	259	256	257	253	251
50% RDN + 25% RDN through VC + Bioactivator	262	260	256	258	256	252
CD (P<0.05)	NS	14.4	15.6	15.3	16.2	18.1

VC: Vermicompost; RDN: recommended dose of nitrogen i.e. 180 (dry season) and 120 (wet seasn) kg ha^{-1}; Initial N content of soil: 258 kg ha^{-1}

Table 5. Economics (x10^3 Rs. Ha^{-1}) of rice cultivation as influenced by N fertilization with and without bioactivator

Treatment	Cost of cultivation		Net returns		Net B:C Ratio	
	Dry	Wet	Dry	Wet	Dry	Wet
Control	43.44	43.44	-19.81	6.33	-0.46	0.15
RDN	45.79	45.01	6.02	37.03	0.13	0.82
RDN + Bioactivator	46.53	45.51	10.24	41.00	0.22	0.90
75% RDN	45.20	44.62	-2.49	30.55	-0.06	0.68
75% RDN + Bioactivator	45.76	44.99	6.83	39.74	0.15	0.88
50% RDN + 25% RDN through VC + Bioactivator	55.58	51.53	-4.49	30.04	-0.08	0.58

VC: Vermicompost ; RDN: recommended dose of nitrogen i.e. 180 (dry season) and 120 (wet seasn) kg ha^{-1}

Table 6. Microbial population (log CFU/g soil) as influenced by N fertilization with and without bioactivator during wet season 2012.

Treatment	Bacteria			Actinomycetes			Fungi		
	10 DAT	40 DAT	70 DAT	10 DAT	40 DAT	70 DAT	10 DAT	40 DAT	70 DAT
Control	6.21	6.30	6.27	5.63	5.63	5.58	3.40	3.47	3.46
RDN	6.38	6.51	6.47	5.72	5.78	5.78	3.56	3.59	3.62
RDN + Bioactivator	6.42	6.52	6.57	5.77	5.83	5.80	3.53	3.62	3.66
75% RDN	6.37	6.42	6.41	5.69	5.70	5.80	3.61	3.63	3.64
75% RDN + Bioactivator	6.38	6.46	6.48	5.75	5.79	5.83	3.64	3.66	3.70
50% RDN + 25% VC-N + Bioactivator	6.76	6.61	6.65	5.91	5.88	5.83	3.68	3.69	3.75
Mean	6.42	6.47	6.48	5.74	5.76	5.75	3.57	3.61	3.64
CD (P<0.05)	0.483	0.165	0.203	0.264	0.242	0.103	NS	NS	0.192

VC: Vermicompost ; RDN: recommended dose of nitrogen i.e.180 (dry season) and 120 (wet season) kg ha^{-1}

of 75% RDN were at par with control showing that bioactivator was effective in increasing microbial activity. Thus the microbial count was significantly altered by VC and to some extent by bioactivator also.

From the study it is proved that bioactivator has potential to economise up to 25% of recommended dose of N by improving its use efficiency without compromising rice productivity. However, this needs to be reassessed at different locations across the country so as to establish its utility and take this to farmer's fields.

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