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NUTRIENT UPTAKE, NITROGEN USE EFFICIENCY AND YIELD OF RICE AS INFLUENCED BY ORGANICS AND FERTILIZER NITROGEN IN LOWLAND RICE SOILS

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Abstract

Field experiments were conducted in farmers field at kuttalam in sandy clay loam (Typic Ustifluvents) and clay loam (Typic Haplusterts) to study the effect of organics and fertilizer nitrogen on yield, nutrient uptake and nitrogen use efficiencies in rice on N equivalence basis. The treatments consisted of addition of different organics *viz.*, composted coir pith (CCP), green manures (GM), sugarcane trash compost (STC), vermicompost (VC), poultry manure (PM) and FYM applied at 100% N and combination of above organics @50% N and urea@50% N besides 100% N as urea and control. The results revealed that crop raised with different organic manures alone or fertilizer nitrogen alone or in combination significantly increased the grain and straw yield, nutrients uptake and nitrogen use efficiency over control in both soils. The highest grain (4615, 5078 kg ha^{-1}) and straw yield (5847, 6746 kg ha^{-1}) were recorded in 50% N through fertilizer nitrogen (urea) + 50% N through vermicompost in both soils. Among the organics alone the highest grain (4615, 5078 kg ha^{-1}) and straw yield (5847, 6746 kg ha^{-1}) were recorded in vermicompost alone (100 % N) which was followed by poultry manure (100% N). The same treatment also noticed significant influence on the nutrient uptake in both the soils. Plots received with 50 % N through urea + 50% N through vermicompost registered highest values of nitrogen use efficiencies *viz.*, agronomic efficiency, apparent nitrogen recovery (ANR), physiological efficiency and internal efficiency. From the above experimental results, it could be concluded that with application 50% N through urea along with 50 % N through vermicompost resulted in higher rice grain yield and also superior in respect of nutrient uptake and conserve the nitrogen under rice cultivation.

Key words: organics, fertilizer nitrogen, grain, straw yield, nutrient uptake, nitrogen use efficiency, rice

Introduction

Rice (*Oryza sativa* L.) is one of the of the most important cereal crop and the staple food feeding over half of the world's population. With the expanding growth of world's population and gradually deteoriating environment, food security has become a major challenge around the world. Increasing rice yield has become the most important goal of rice production with limited land and resources. Almost 90% of the total rice production is concentrated in Asia. India is the second largest producer of rice after china with total production of 104 million tonnes in the year 2015-16 out of 45 M ha areas. Nitrogen (N) is one of the most significant minerals required by plants for their growth and development. "N " plays an extensive role during vegetative growth of the plant it also aids in branching of root carbon allocation and increases grain yield (Ali *et al.* 2018; Anandhan *et al.* 2018). Earlier investigations disclosed that the proper use of fertilizers may considerably enhance the yield and quality of rice (Mahender *et al.* 2016) but the excessive application of fertilizers decreases the N use efficiency (NUE).

Organic manures addition is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Organic manures to the soil is necessary for maintaining soil organic matter which is important for favourable soil structure soil water retention and soil microbial flora and fauna activities. Use of organic manures in conjunction or as an alternative to chemical fertilizers is receiving attention. The excessive application of chemical fertilizers made it imperative that a part of inorganic fertilizer may be substituted with organic manures. Organic manures has been recorded to enhance the efficiency and reduce the requirement of chemical fertilizers (Khan *et al.* 2002). Hence to maintain the sustainable productivity of rice, experiments were carried out to study the effect of organics and inorganics on the productivity of rice.

Materials and Methods

Field experiments were conducted in farmers field at kuttalam in two different textured soils (sandy clay loam and clay loam) to study the grain yield, nutrient uptake and nitrogen use efficiency as influenced by different sources of organics and fertilizer nitrogen in rice cultivation. The experimental soil was sandy clay loam (Typic Ustifluvents) and clay loam (Typic Haplusterts), pH (6.79, 8.19), EC (0.31, 0.36), available nitrogen (226.2, 227.9 kgha^{-1}), available phosphorus (14.1, 14.9 kg ha^{-1}), available potassium (345.7, 316.7 kg ha^{-1}) and organic carbon (6.10, 6.20 g kg^{-1}). The experiment was laid out in randomized block design and replicated thrice. A short duration rice variety cv. ADT 43 was chosen for both the soils. The treatment consisted of T_1- Absolute control, T_2-Composted coir pith (CCP-100% N), T_3-Green manure (GM-100% N), T_4-Sugarcane trash compost (STC-100%N), T_5-Vermicompost (VC-100% N), T_6-Poultry Manure (PM-100%N), T_7- Farmyard Manure (FYM-100%N), T_8- CCP(50% N) + Urea (50% N), T_9- GM(50% N) + Urea (50% N) , T_{10}- STC(50% N) + Urea (50% N), T_{11}-VC (50% N) + Urea (50% N), T_{12}- PM (50% N) + Urea (50%N), T_{13}- FYM(50% N) + Urea (50% N), T_{14}- RDF(120:60:60 N, P_2O5, K_2O Kg ha^{-1}). The N content in different organics include CCP (1.06%), GM (1.90%), STC(0.45%), VC (1.80%), PM (2.15%) and FYM (0.60%). The treatments T_2 to T_7 received 120 kg N ha^{-1} through various organics only and T_8 to T_{13} received 60 kg N ha^{-1} through various organics (50% N) and 60 kg N ha^{-1} through urea (50%N). Accordingly quantity of organics added varied depending on N content.

The recommended dose of 120: 38:38 kg ha^{-1} of N, P_2O_5 and K_2O was applied. N and K_2O were applied as per the treatment schedule in four equal splits *viz.*, basal, tillering, panicle initiation and heading stages of rice. The entire dose of P_2O_5 was applied basally before transplanting. Efforts were taken to maintain a water level of 2.5 and 5 cm in the early and later stages of crop growth period respectively. Irrigation was withheld 10 days before harvesting.

All necessary management practices were carried out as per standard recommendation for rice crop. Observations on grain and straw yield were recorded. Plants were also analyzed for N, P and K uptake after harvest. The plant samples after estimation of dry matter were chopped and powdered by using a Willey mill and were analysed for N, P and K contents. The plant samples were analysed for nitrogen content by Microkjeldahl method as suggested by Yoshida *et al.* (1981) and expressed in kg ha^{-1}. Phosphorus and potassium content in plant samples was determined calorimetrically and by flame photometer using triple acid digestion method suggested by Jackson (1973) and their uptake was calculated by multiplied with dry matter production and expressed in kg ha^{-1}. Efforts was also made for assessment of N use efficiency by following method.

Indices for assessment of N use efficiency

Agronomic use efficiency (AEN): Most commonly used index by agronomic researchers. It is expressed as units increase in economic yield per unit N fertilizer applied. The calculation on AEN essentially requires establishment of research plot without N input (termed as controlled plot). It can be calculated by: AEN (kg kg-1) = Gf – Gu/Na, where Gf is the grain output from N fertilized plot (kg), Gu is the grain output from the controlled plot and Na is the quantity of nitrogen applied (kg).

Apparent recovery efficiency (REN): Apparent N recovery can be described by difference in N uptake (above-ground biomass of crops) between the N fertilized and that of controlled plot relative to the quantity of N applied. It can be calculated by: REN (%) = (Nf – Nu/ Na) × 100, where, Nf is the nitrogen uptake by crop (above ground biomass) from fertilized plot (kg), Nu is the nutrient uptake by crop (above ground biomass) from unfertilized plot (kg), and Na is the doses of N fertilizer applied (kg).

Internal utilization efficiency (IEN): It is a simple measure of NUE based on crop yield and nitrogen uptake. The value of this index is depending upon agro-climatic conditions, crop cultivar, and level of soil-plant management. Nutrient utilization efficiency is the cross product of physiological efficiency and apparent recovery efficiency of N. It can be calculated by: IEN (kg kg-1) = PEN × REN.

Physiological efficiency (PEN): It is defined as the yield increase in relation to the increase in crop uptake of the N in above - ground biomass of the crop. It can be calculated by: PE (kg kg-1) = BYf – BYu / Nf–Nu, where, BYf is the biological yield from N fertilized plot (kg), BYu is the biological yield from unfertilized plot (kg), Nf is the nitrogen uptake (above ground biomass) in N fertilized plot, and Nu is the nitrogen uptake (above ground biomass) in unfertilized plot (kg).

Statistical analysis: The data on observations and characters studied were statistically analysed by adopting the standard procedures.

Results and Discussion

Rice yield

In both the soils, all the treatments attained significant influence on the grain and straw yield over control. Plots received with 50% N through urea + 50 % N through vermicompost (T_{11}) significantly registered the highest grain (5050, 5332 kg ha^{-1}) and straw yield (6398, 7725 kg ha^{-1}) respectively. Among the organics alone, the highest grain(4615, 5078 kg ha^{-1}) and straw yield (5847, 6746 kg ha^{-1}) were recorded in vermicompost alone (T_5) which was closely followed by poultry manure alone in both the soils. Besides, aforesaid increased yields due to vermicompost might be due to the constant release of N from organic manure, particularly from vermicompost supplemented with NPK fertilizers might have satisfied the demand of the rice crop at every phenophase of rice crop as opined by Das *et al.* (2003). Application of recommended fertilizer produced higher grain yields than plots receiving organic manure alone. It may be because of the fact that organic manures are not able to release the nutrients synchronizing with the peak crop requirement because of their slow mineralization rate. The increase in grain yield with the combined application of both organic and inorganic sources may be due to the beneficial effect of both organic and inorganic fertilizers on crop yield. The organic manures besides providing essential nutrients to crop also improve the soil properties and inorganic fertilizers supply nutrients to synchronize with the crop nutrient demand (Zahoor, 2013). The increase in the grain yield might have happened due to high production of photosynthates with integrated application and their effective translocation from source to sink which led to the proper formation of grains during grain filling period (Sunita Devi *et al.* 2019).

Crop nutrient uptake

Influence of organics alone or fertilizer nitrogen alone or both significantly increased nutrients uptake (N, P, K) over control in sandy clay loam and clay loam soils respectively (Table 2). Combined application of organics and fertilizer nitrogen recorded highest nutrients uptake compared to organics alone or fertilizer nitrogen alone. The highest nutrient uptake (N, P, K) were registered in 50% N through urea + 50 % N through vermicompost (T_{11}) *viz.*, nitrogen uptake (59.6, 27.9 kg ha^{-1}), (51.4, 49.4 kg ha^{-1}), phosphorus uptake (11.86, 8.23 kg ha^{-1}), (17.06, 12.36 kg ha^{-1}), potassium uptake (48,4, 68.4 kg ha^{-1}), (28.3, 51.7 kg ha^{-1}) in grain and straw in sandy clay loam and clay loam soils respectively. The maximum uptake of NPK by grain and straw was recorded with integrated treatments could be ascribed to the increase in available N, P and K contents in soil resulting from the increased availability of nutrients which ultimately increased nutrient content in the plant tissues and also greater biomass production. Since the uptake of nutrient is a function of dry matter and nutrients content the increased grain and straw yields together with higher NPK content resulted in greater uptake of these elements (Srivastava *et al.* 2014). An increased uptake of nitrogen, phosphorus and potassium by rice might be due to constant release of nutrients that satisfied the demand of the rice (Sudhakar and Kuppuswamy, 2007). The higher nutrients uptake of N, P, K due to vermicompost could be attributed to the comparatively lower C:N ratio which resulted in faster decomposition and release of nutrients as compared to FYM (Pareek and Yadav, 2011).

Nitrogen use efficiency

Application of organics alone or inorganics alone or in combination significantly increased the nitrogen use efficiency *viz.*, response ratio, apparent nitrogen recovery (%), physiological efficiency and internal efficiency over

Table 1: Effect of organics and mineral nitrogen on grain and straw yield (kg/ha) in rice in sandy clay loam and clay loam soils

Treatments	Grain Yield (kg/ha)				Straw Yield (kg/ha)			
	Sandy clay loam	% increase over control	Clay loam	% increase loam control	Sandy clay over	% increase loam control	Clay	% increase over control
T_1	3815	–	4300	–	4825	–	6235	–
T_2	4215	10.5	4752	10.5	5353	10.9	6728	7.9
T_3	4225	18.6	4962	15.4	5738	18.9	7108	14.0
T_4	4330	13.5	4777	11.1	5502	14.0	6746	8.2
T_5	4615	20.9	5078	18.1	5847	21.1	6746	8.2
T_6	4560	19.5	4881	13.5	5782	19.8	7239	16.1
T_7	4420	15.9	4825	12.2	5595	15.9	7040	12.9
T_8	4635	21.5	5070	17.9	6130	27.0	6765	8.5
T_9	5010	31.3	5088	18.3	6334	31.2	7108	14.0
T_{10}	4765	24.9	5113	18.9	6032	25.0	7201	15.5
T_{11}	5050	32.4	5332	22.9	6398	32.6	7725	23.8
T_{12}	5015	31.4	5285	24.0	6359	31.7	7607	22.0
T_{13}	4845	27.0	5135	22.9	6143	27.3	7600	212.8
T_{14}	4982	30.6	5210	21.2	6317	30.9	7575	21.5
C.D@5%	21.4	—	91.5	-	23.3	—	104.5	—

control (Table 3). Among the integrated treatments, 50% N through urea + 50 % N through vermicompost (T_{11}) registered the highest response ratio (10.3, 8.60 kg kg^{-1}), apparent nitrogen recovery (49.3, 44.3%) in both the soils. The highest physiological efficiency (46.5 and 55.0 kg kg^{-1}), internal efficiency (75.0, 69.8) were recorded in composted coir pith (50%N) + urea(50%N) in sandy clay loam and clay loam soils respectively. Among the organics alone, the highest response ratio (6.6, 6.48 kg kg^{-1}), apparent nitrogen recovery (25.1, 17.8%) were recorded in vermicompost (100% alone) in both the soils. The highest physiological efficiency (95.3 and 95.7 kg kg^{-1}), internal efficiency (62.1, 73.4) were registered in composted coir pith (T_2) (100%N) in sandy clay loam and clay loam soils respectively. This might be due to increased availability of N in organic manures especially in vermicompost in the form of mucous nitrogenous excretory substances which were not present in other organic sources (Vivel et al. 1987). Nitrogen fixing bacteria were also found to be more in vermicompost which might have reduced the loss of nitrogen from the soil and increased the use efficiency of inorganic fertilizers

Table 2: Effect of organics and fertilizer nitrogen on nutrients (N, P, K) uptake (kg ha^{-1}) in rice in sandy clay loam and clay loam soils

Treatments	Sandy clay loam						Clay loam					
	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	15.6	10.7	4.57	2.74	9.12	19.31	28.4	19.3	5.16	3.11	11.2	20.5
T_2	19.4	13.6	6.047	3.28	13.26	23.2	32.2	22.9	6.65	4.70	14.3	25.5
T_3	30.0	17.8	8.93	4.42	22.27	33.1	36.1	28.9	7.93	5.48	19.4	31.2
T_4	29.4	16.7	6.61	3.37	16.02	27.6	33.6	24.5	7.16	4.72	15.3	27.6
T_5	37.7	18.7	9.95	5.72	24.42	36.1	40.5	28.6	9.14	6.74	21.3	34.4
T_6	32.1	18.2	9.87	5.08	23.23	34.3	36.4	28.7	8.29	6.51	19.2	34.0
T_7	28.6	17.4	8.62	3.76	19.42	31.4	35.2	26.3	7.72	4.92	19.3	29.6
T_8	33.2	22.4	7.92	6.79	27.31	37.6	42.4	30.2	9.63	8.11	22.3	35.9
T_9	42.7	25.6	12.12	8.12	44.14	58.1	46.5	45.9	17.29	9.24	22.4	38.3
T_{10}	38.9	24.6	8.29	7.26	30.92	39.2	43.3	36.0	9.71	7.92	22.5	41.1
T_{11}	59.6	27.9	13.17	8.32	49.61	70.1	51.4	49.4	17.06	12.36	28.3	51.7
T_{12}	41.6	26.8	11.86	8.23	48.42	68.4	48.7	47.4	15.32	10.64	25.9	47.9
T_{13}	39.7	25.2	9.23	7.96	40.21	61.6	44.2	42.6	11.81	9.12	23.6	45.6
T_{14}	55.8	26.9	10.94	8.12	44.82	63.3	46.5	43.9	14.51	9.84	24.5	46.2
C.D@ 5%	0.20	0.18	0.03	0.03	0.02	0.21	2.15	0.70	0.33	0.15	1.62	0.25

Table 3: Effect of organics and mineral nitrogen on nitrogen use efficiency (NUE) in rice in sandy clay loam and clay loam soils

Treatments	Response ratio (kg kg^{-1})		Apparent N recovery (%)		Physiological efficiency (kg kg^{-1})		Internal efficiency	
	Sandy clay loam	Clay loam	Sandy clay loam	Clay loam	Sandy clay loam	Clay loam	Sandy clay loam	Clay loam
T_1	–	–	–	–	-	–	—	—
T_2	3.33	3.77	5.6	6.2	95.3	95.7	127.7	86.2
T_3	5.91	5.52	17.9	14.4	28.5	85.9	94.6	76.3
T_4	4.30	3.98	16.5	8.7	37.3	91.7	92.7	82.2
T_5	6.66	6.48	25.1	17.8	36.1	64.2	81.8	73.4
T_6	6.20	4.84	20.0	14.5	45.1	72.6	90.6	74.9
T_7	5.04	4.38	16.4	11.5	46.5	77.2	96.0	78.4
T_8	6.83	6.42	24.4	20.8	46.5	55.0	83.3	69.8
T_9	9.90	6.57	35.0	37.3	44.0	43.5	73.3	55.3
T_{10}	7.91	6.78	31.0	26.3	40.9	54.5	75.0	67.2
T_{11}	10.3	8.60	49.3	44.3	28.0	44.8	59.0	52.8
T_{12}	10.0	8.21	35.0	40.8	46.1	48.5	73.3	54.9
T_{13}	8.6	6.96	32.2	32.6	42.7	52.8	74.6	59.1
T_{14}	9.7	7.58	47.0	35.6	29.0	50.2	60.2	57.6
C.D@ 5%	0.05	0.02	0.37	0.21	0.63	0.70	0.28	0.17

applied (Ihseen, 2003). This treatment also recorded significantly higher values of internal efficiency. This is because of prolonged supply of organic bound N as a result of mineralization which reflected on higher internal efficiency under integrated treatment (Veerendra Kumar and Ahlawat, 2004). The lesser values were observed in recommended dose of nitrogen (100% RDN) . This might be due to characteristics of mineral inorganic N fertilizer its susceptibility different types of losses and hence less NUE as compared to INM treatments (Tayofe et al 2011).

Conclusion

Thus from the present study, it can be concluded that application 50% N through urea + 50 % N through vermicompost produces higher grain yield, increases nutrients uptake and nitrogen use efficiency in rice cultivation.

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