Available online at http://www.journalijdr.com

IJDR

International Journal of
DEVELOPMENT RESEARCH

ISSN: 2230-9926

International Journal of Development Research
Vol. 06, Issue, 09, pp.9333-9338, September, 2016

Full Length Research Article

DYNAMICS OF INORGANIC FRACTIONS OF NITROGEN IN AN USTIFLUVENTS SOIL ON INCORPORATION OF ORGANIC MANURES AND MINERAL NITROGEN IN RICE

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ARTICLE INFO

Article History:

Received 19th June, 2016
Received in revised form
27th July, 2016
Accepted 14th August, 2016
Published online 30th September, 2016

Key Words:

N forms, Yield,
Organics, Urea,
Rice.

ABSTRACT

Field experiments were conducted during Kharif 2007 and 2008 in sandy clay loam soil to study the effect of organic sources and urea on N transformation and yield of rice. 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% RDN and combination of above organics @50% N and urea@50%N besides 100% RDN as urea and control. The results revealed that addition of organics or mineral N or both significantly improved rice yields over control in both years. The highest grain yield (5067, 5050 kg ha^{-1}) and straw yield (6490, 6398 kg ha^{-1}) was noticed with vermicompost (50% N) + urea (50% N) which was on par with poultry manure (50%N) + urea (50%N) but superior to rest of the treatments. Rice yield was more with 100% Urea N compared to 100% RDN as organics alone. The best treatment caused 34.2% increase in grain yield over control, 1.36% over 100% urea N. Integrated use of organics and urea recorded higher concentration of ammonium and nitrate nitrogen compared to their individual addition. The N forms were more under vermicompost amended soil followed by green manure and poultry manure. The mineral N was higher at initial stages and decreased with crop growth.

INTRODUCTION

Rice is a staple food of 2.7 billion people almost half the world's population and is grown by more than a half of the world's farmers. The production of rice at all India level is 89.13 million tonnes in 41.85 million hectares with productivity of 2130kg ha^{-1}. In Tamil Nadu the area under rice cultivation (2009-10) is 19.35lakh hectares producing of 3113kgha^{-1} (Anonymous, 2010). Nitrogen is the key to any fertilizer management programme and it is the mean by which yield potential of modern rice genotypes can be achieved. Though synthetic fertilizers have contributed more for enhancing agricultural production, their extensive use for longer period have contributed equally or more negatively in erosion of soil fertility and decline in productivity level, environmental pollution with adverse effects on human health, biotic and ecosystem (Myint *et al*., 2010).

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The imbalance usage of fertilizers is one of the main factors responsible for the low productivity and also the continuous use of inorganic fertilizers resulted in declining productivity.(Kandeshwari *et al.,*2016). Utilization of indigenous organic sources, viz. farmyard manure (FYM), and green manures may serve as alternatives or supplements to chemical fertilizers, and help in increasing the productivity of the rice-based cropping system in all zones of the country. Organic matter plays a prominent role in increasing the level of soil fertility and sustaining the productivity of soils. Simultaneously rising costs of chemical fertilizers has further focused attention on recycling of plant nutrients through organic materials. Thus, the potential of organic manure use either alone or in combination with chemical fertilizers in crop production has received world wide attention. (Vel murugan *et al.,* 2013). Organic manures play a vital role in sustaining higher productivity in intensive agriculture and irrigated rice in particular. Complementary use of organic and biological source of plant nutrient along with chemical fertilizer is of great importance for the maintenance of soil health and productivity. However, the availability of organic manures like

Vermicompost, FYM, green manure and crop residue is a major limiting factor for their use. It is widely recognized that neither the use of organic manures alone nor the 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 may 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 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 (Sarangi, *et al.,* 2013). Results have also shown that integrated nutrients management increases the yield and nutrient uptake (Mohanty, *et al.*, 2013).

Application of organic material along with inorganic fertilizers in soil leads to increase in system productivity and also sustained soil health for longer period and system productivity becomes more sustainable in nature. It is well known that organic sources cannot meet the integrated use of nutrients seem to be more appropriate. Incorporation of organic sources and later on its decomposition determines the availability of the nutrients. (Dekhane, *et al.,* 2014). The conjunctive application of organics with inorganic sources of nutrient reduces the dependence on chemical inputs and it not only acts as a source of nutrient but also provides micronutrient as well as modifies the soil physical behaviour and increases the efficiency of applied nutrients (Pandey, *et al.,* 2007). Since different organics mineralize at different rates depending up on their nature of organic constituents and prevailing climatic conditions, combined application of organic manures with urea may not lead to availability of significant amount of N forms at some critical stages. To understand the behaviour of integrated use of organics and mineral N in this regard, it is essential to monitor the availability of NH_4-N and NO_3-N in the soil solution and exchange complex. This study is aimed at determining the sustainability of the application of different organic fertilizers and mineral nitrogen in paddy soils in terms of nitrogen transformations and grain yield in two years.

MATERIALS AND METHODS

Field experiments were conducted in Padugai series (Typic Ustifluvents) during Kharif 2007, 2008) to study the effect of organic sources and urea on N transformation and yield of rice tested at N equivalence. The experimental soil was sandy clay loam in texture with pH-6.8, 6.79, EC-0.32, 0.31 dSm^{-1}, OC-6.09,6.10 g kg^{-1}, CEC-24.2, 24.0 C mol (p^+) kg $^{-1}$, available N(224.1, 226.2 kg ha^{-1}), P(14.3, 14.1 kg ha^{-1}) and K(314.6, 314.9 kg ha^{-1}) at kharif 2007 and 2008 respectively. 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_2O_5 , 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. Grain and straw yields were recorded at harvest.Wet soil samples were collected at tillering stage, panicle initiation and harvest stages and analyzed for ammonium and nitrate nitrogen following the standard procedure. The data was subjected to statistical scrutiny to arrive at meaningful explanation for the effect of treatments on rice crop.

RESULTS AND DISCUSSION

N transformation

Ammonium–N and nitrate-N concentration in soil at various stages of crop growth due to treatments is shown in Table 1a, 1b. The trend of NH_4-N content of soil showed that under flooded condition, it remained in sufficiently higher in all the treatments over control. The concentration of NH_4-N was higher at tillering stage and progressively declined with advancement of crop growth. The ammonium-N concentration was higher under integrated use of organics and urea compared to individual addition and it was consistently highest with vermicompost (60 kg N ha^{-1})and urea(60 kg N ha^{-1}) followed by green manure (60 kg N ha^{-1})and urea(60 kg N ha^{-1}) and poultry manure (60 kg N ha^{-1}) and urea (60 kgNha^{-1}). Ammonium-N concentration was relatively higher with urea compared to organics. On an average, integrated use of organics and urea caused 89.5 to 144.7% increase in NH_4-N over control. The continuous addition of organic manures along with chemical fertilizers may stimulate the mineralization and immobilization of plant nutrients, thereby affecting their amounts in different organic and inorganic forms in soil (Sihang *et al.*, 2005). The repeated application of mineral or organic fertilizer enhanced the mineralization of recalcitrant organic N, whereas the application of organic fertilizers stimulated the mineralization of labile organic N. (Zhang *et al.*, 2012). The application of mineral nitrogen and vermicompost significantly increased the NH_4-N and NO_3-N contents in the soil over control. (Duhan *et al.* 2001).

The increase in the organically amended soil is understandable as the cultivation enhances the decomposition of vermicompost material and mineralization of organic N might have contributed NH_4-N in the soil. (Swapna *et al.*, 2012). These results are in close conformity to the findings of (Santhy *et al.*, 1998) and (Samy *et al.*, 2003). The vermicompost and mineral nitrogen application was highly beneficial for wetland rice cultivation therefore rice growth and yield may be improved with partial substitution of mineral nitrogen as urea. (Antil and Singh, 2007). Addition of vermicompost and mineral nitrogen increased the NH_4-N and this may be due to greater return of organic N to the soil by roots, root exudates and stubbles. The fertilizer combinations containing nitrogen (N, NP and NPK) also markedly increased the NH_4^+-N form of nitrogen in the soil. (Kusro *et al.,* 2014). As the submergence prolonged, the rice crop picked up growth and started to absorb more of NH_4-N which explains the reduction in NH_4-N in soil at later stages (Chakraborty, *et al.*, 1988).

Table 1a. Effect of organics and mineral nitrogen on NH_4-N (mg kg^{-1}) concentration in sandy clay loam soil

Treatments	Kharif 2007			Kharif 2008		
	Tillering stage	Panicle initiation	Harvest stage	Tillering stage	Panicle initiation	Harvest stage
T_1 - Absolute control	20.1	15.2	10.2	17.9	13.5	10.6
T_2 - (CCP-100% N)	27.3	21.7	17.2	27.2	21.9	17.8
T_3 - (GM-100% N)	35.5	25.2	19.1	35.1	25.8	19.4
T_4 - (CST-100% N)	31.2	23.4	17.8	30.7	24.1	18.2
T_5 - (VC-100% N)	37.63	26.2	19.8	36.3	26.9	20.1
T_6 - (PM-100% N)	36.2	24.1	19.5	35.4	24.8	19.8
T_7 - (FYM-100% N)	35.2	24.3	18.2	34.7	25.1	18.6
T_8 - CCP (50% N) + Urea (50% N)	38.1	31.3	20.1	37.6	31.9	20.3
T_9 - GM (50% N) + Urea (50% N)	47.3	36.1	22.1	46.4	36.7	22.7
T_{10} - CST (50% N) + Urea (50% N)	39.8	31.4	20.4	38.7	33.1	20.7
T_{11} - VC (50% N) + Urea (50% N)	49.2	38.7	24.4	48.6	39.2	24.8
T_{12} - PM (50% N) + Urea (50% N)	47.4	37.2	23.3	46.4	38.3	23.9
T_{13} - FYM (50% N) + Urea (50% N)	42.3	33.6	21.4	41.6	34.2	21.7
T_{14} - RDF (120:60:60 N, P_2O_5 K_2O kg ha^{-1})	46.1	36.3	22.8	43.0	38.4	23.4
SE_D	0.13	0.33	.11	0.35	0.24	0.15
LSD (p=05)	0.26	0.68	0.23	0.72	0.49	0.30

Table 1b. Effect of organics and mineral nitrogen on NO_3-N (mg kg^{-1}) concentration in sandy clay loam soil

Treatments	Kharif 2007			Kharif 2008		
	Tillering stage	Panicle initiation	Harvest stage	Tillering stage	Panicle initiation	Harvest stage
T_1 - Absolute control	4.36	3.69	2.49	4.52	3.92	2.73
T_2 - (CCP-100% N)	10.54	8.24	6.86	10.91	8.84	6.84
T_3 - (GM-100% N)	11.43	9.30	7.84	11.92	9.42	7.81
T_4 - (CST-100% N)	10.76	8.64	7.2	11.24	9.03	7.09
T_5 - (VC-100% N)	12.19	10.12	4.49	12.81	9.79	8.08
T_6 - (PM-100% N)	11.68	9.62	8.12	12.43	9.58	8.03
T_7 - (FYM-100% N)	11.18	9.20	7.33	11.60	9.21	7.62
T_8 - CCP (50% N) + Urea (50% N)	12.78	10.74	9.13	13.24	10.23	9.39
T_9 - GM (50% N) + Urea (50% N)	14.69	11.80	10.60	15.19	11.93	10.93
T_{10} - CST (50% N) + Urea (50% N)	13.23	10.91	9.59	13.83	10.94	9.71
T_{11} - VC (50% N) + Urea (50% N)	15.79	12.45	11.40	15.87	12.83	11.62
T_{12} - PM (50% N) + Urea (50% N)	15.11	12.10	11.13	15.41	12.44	11.23
T_{13} - FYM (50% N) + Urea (50% N)	13.81	11.17	10.19	14.56	11.19	10.41
T_{14} - RDF (120:60:60 N, P_2O_5 K_2O kg ha^{-1})	14.22	11.48	10.31	14.88	11.67	10.64
SE_D	0.13	0.12	0.08	0.22	0.03	0.02
LSD (p=05)	0.26	0.25	0.16	0.46	0.07	0.05

Table 2. Effect of organics and mineral nitrogen on rice yield (kg ha^{-1}) in Sandy clay loam soil

Treatments	Kharif 2007				Kharif 2008			
	Grain yield	Percent increase over control	Straw yield	Percent increase over control	Grain yield	Percent increase over control	Straw yield	Percent increase over control
T_1 - Absolute control	3776	–	4872	–	3815	–	4825	–
T_2 - (CCP-100% N)	4253	12.6	5412	11.0	4215	10.5	5353	10.9
T_3 - (GM-100% N)	4606	21.9	5885	20.7	4225	18.6	5738	18.9
T_4 - (CST-100% N)	4349	15.2	5567	14.2	4330	13.5	5502	14.0
T_5 - (VC-100% N)	4672	23.7	5956	22.2	4615	20.9	5847	21.1
T_6 - (PM-100% N)	4629	22.6	5874	20.5	4560	19.5	5782	19.8
T_7 - (FYM-100% N)	4443	17.6	5665	16.3	4420	15.9	5595	15.9
T_8 - CCP (50% N) + Urea (50% N)	4717	24.9	6015	23.4	4635	21.5	6130	27.0
T_9 - GM (50% N) + Urea (50% N)	5022	32.9	6413	31.6	5010	31.3	6334	31.2
T_{10} - CST (50% N) + Urea (50% N)	4814	27.5	6133	25.8	4765	24.9	6032	25.0
T_{11} - VC (50% N) + Urea (50% N)	5067	34.2	6490	33.2	5050	32.4	6398	32.6
T_{12} - PM (50% N) + Urea (50% N)	5031	33.2	6345	30.2	5015	31.4	6359	31.7
T_{13} - FYM (50% N) + Urea (50% N)	4913	30.1	6264	28.5	4845	27.0	6143	27.3
T_{14} - RDF (120:60:60 N, P_2O_5 K_2O kg ha^{-1})	5054	33.8	6418	31.7	4982	30.6	6317	30.9
SE_D	27.1		28.4		10.3		11.3	
LSD (p=05)	55.9	–	58.5	–	21.4	–	23.3	–

In addition of vermicompost which releases the humic acids caused good retention of cations including NH_4^+ ion, ammonia volatilization from urea, and nutrients leaching could be significantly reduced. Ammonia volatilization from urea as an example can be reduced with application of vermicompost which are high in CEC. (Latifah, *et al*., 2011). The NO_3-N concentration in the soil decreased with stages of rice crop.

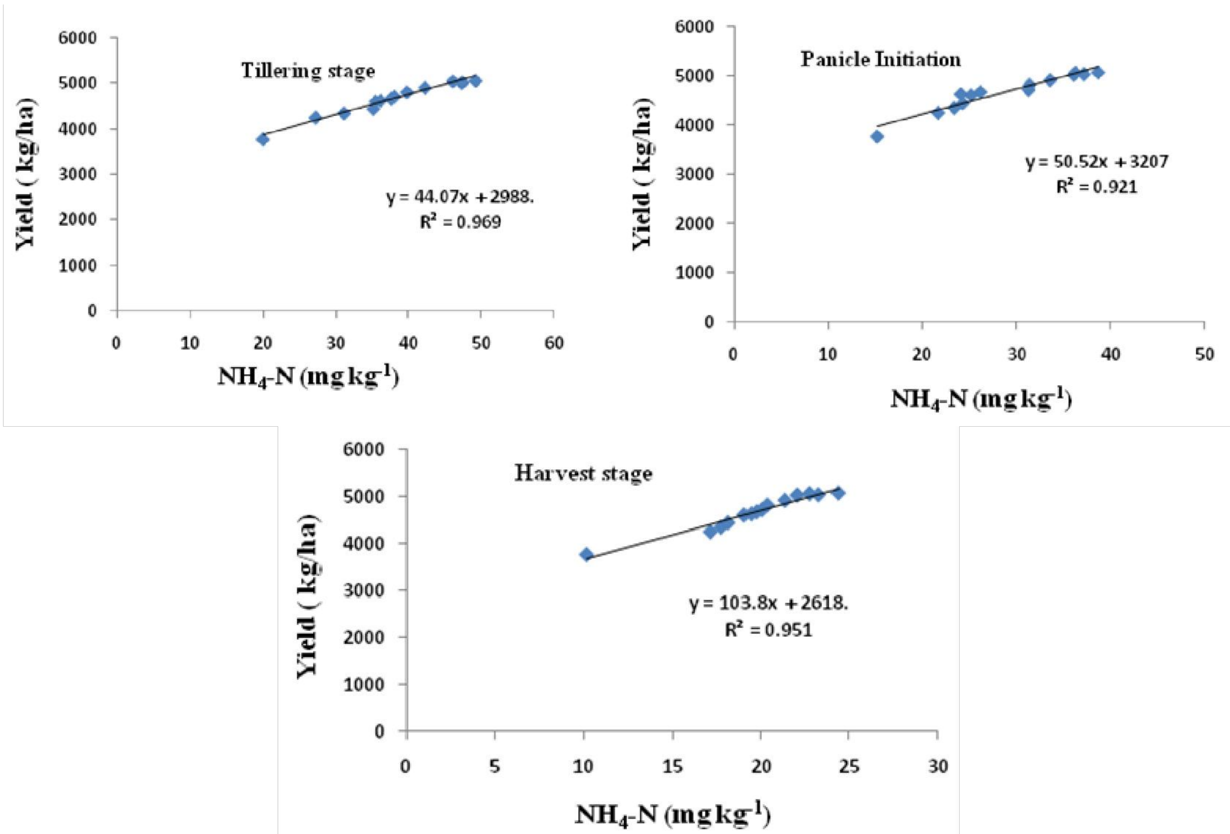

Fig.1. Linear relationship between grain yields with ammonium- nitrogen

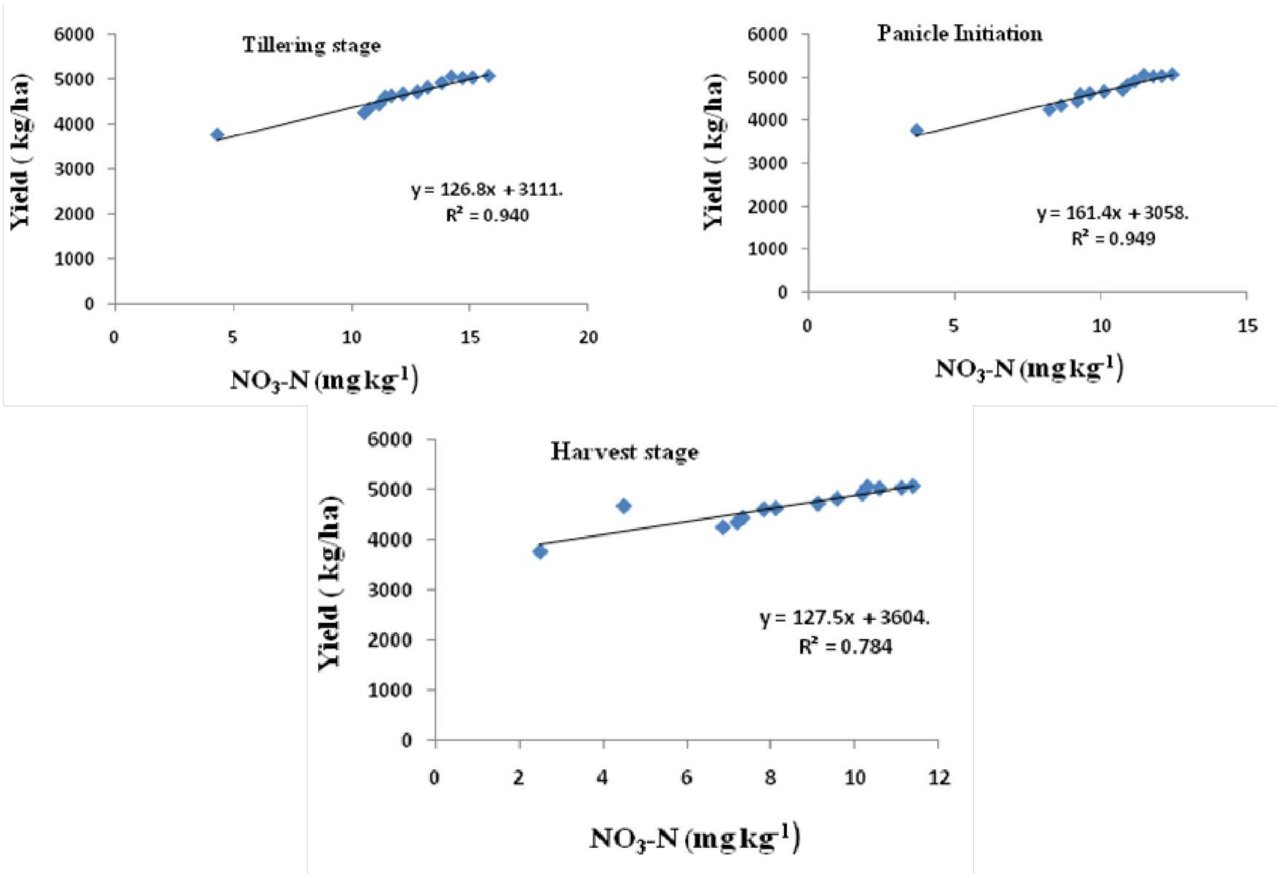

Fig.2. Linear relationship between grain yields with Nitrate- nitrogen

Higher values of NO_3-N in soil were observed in plots which received both organics and urea compared to their individual application. The highest increase in nitrate nitrogen in the treatments where vermicompost and mineral nitrogen were applied (Mukherjee, 1998). However nitrate N in the surface soil at different stages showed lower values in spite of the fact that ammonium N content in soil was relatively high. This might be due to quick loss of nitrate N through denitrification (Ranjan, *et al*., 2006). The lower nitrate nitrogen than ammoniacal nitrogen in the rice soil may be due to more anaerobic condition prevailed than the aerobic condition. In the anaerobic environment of lowland rice soils, the only stable mineral form of nitrogen is NH_4 , nitrate - NO_3 forms of nitrogen, if applied, will enter the anaerobic zone and be subjected to heavy denitrification losses (Duan *et al*., 2006). Fully established rice can rapidly take up applied - NO_3 before it is leached down to the anaerobic soil layer and can become denitrified. (Kronzucker *et al.,* 2000). (Scott, *et al.,* 1998) who also reported that earthworm increases the nitrogen content due to nitrogen mineralization from organic matter in the vermicompost because nitrification is enhanced in worm casts, the ratio of nitrate nitrogen to ammonium nitrogen tends to increase when earthworms are present in the vermicompost. The use of vermicompost helps in maintaining soil fertility since the mineral elements contained in it were changed to forms more that could be readily taken up by plants such as nitrates, (Pashanasi *et al.,* 1996).

Nitrate nitrogen was significantly reduced with progression in crop growth At all stages in both years, nitrate nitrogen was significantly higher when soil was supplied with combined application of organics and fertilizer nitrogen compared to fertilizer nitrogen and organics alone. The maximum nitrate nitrogen was noticed with the combined application of vermicompost (50%N) + urea (50%N) (15.79, 12.45, 11.40 mg kg^{-1}) in kharif 2007 and (15.87, 12.83, 11.62 mg kg^{-1}) in kharif 2008 at tillering stage, panicle initiation and harvest stages respectively. The best treatment caused 262.1, 237.3, 357.8 percent (kharif 2007) and 251.1, 227.2, 325.6 percent (kharif 2008) increase in NO_3- N over control at tillering stage, panicle initiation and harvest stages respectively. (Khankhane and Yadav, 2000) reported that vermicompost application increased the NO_3 - N content in soil may be because of presence of more NH_4^+-N content in soil due to mineralization of vermicompost and its oxidation leads to a higher concentration of NO_3 -N content in soil. (Hardeep singh, *et al*., 2016) reported that accumulation of NO_3 -N content in soil was more with application of vermicompost. This could be because of the much slower release of N from vermicompost resulting in smaller losses of N and building of a higher concentration of NO_3 -N content in soil.

Grain and Straw yield

Grain and straw yield of rice in both years was significantly increased due to addition of various organics alone or urea at 100% RDN or combined addition at equal rate of N equivalence over control (Table 2). Increased grain yield of rice over control (4672**,** 5847 kg ha^{-1}) due to 100 % N organics alone ranged from 12.6 to 23.7% and 10.5 to 20.9% in kharif 2007 and 2008 respectively. Corresponding increase in the straw yield was 11.0 to 22.0 and 10.9 to 21.1%. Grain yield response was higher when recommended dose of N was applied through urea compared to the same rate applied through organics. Crop yields depend mainly on the availability of NH_4-N in submerged conditions. Application of organic and inorganic fertilizers increased the grain and straw yield due to availability of plant nutrients from both sources together proved advantageous as the rice plants could meet their requirements rapidly from inorganic fertilizer and more steadily from the organic source (Ghosh and Sharma,1999). Supply of N in balanced quantity enabled the rice plants to assimilate sufficient photosynthetic products and thus increased the dry matter production with increased dry matter and photosynthetic products coupled with efficient translocation, plant produced more panicles with more number of fertile grains with increased test weight and ultimately higher grain yield (Debiprasad, *et al.*, 2011). Grain yields obtained in this experiment are explained by significant variation in wet soil ammonium N at different stages of crop growth. Application of urea N produced higher yield than organics alone which might be due to optimum release of NH_4-N from urea. (Husan, *et al.,* 2014). The highest grain yield (5067**,** 5050 kg ha^{-1}) and straw yield (6490**,** 6398 kg ha^{-1}) was noticed with addition of vermicompost (50% N) and urea (50% N)-T_{11} which was on par with poultry manure (50% N) and urea (50% N)- T_{12}.

On an average increase in grain yield of rice by best treatment was over 34.2% (control), 23.7% (VC -100% N alone) and 33.8% (100% N- urea). This might be due to lower C: N ratio of vermicompost helpful in release of nutrient in adequate amount quickly after application and reduces the N loss by the formation of organic mineral complexes as compared to FYM ultimately increased the grain yield of rice. Application of vermicompost with chemical fertilizers was found to produce higher NH_4-N in the soil thereby improved the grain yield in rice than from chemical fertilizers alone**.** (Rajput, *et al*., 1992). This was confirmed in the present study by having significant linear relationship between grain yields with NH_4-N at all stages (at tillering stage: Y=44.07 x + 2988 R^2 = 0.969**., Panicle initiation: Y= 50.52 x + 3207 R^2 =0.921** ; harvest stage: Y = 103.8 x + 2618 R^2 = 0.950**) and NO_3- N at all stages (tillering stage; Y= 126.8 x + 3111 R^2 = 0.940*8; panicle initiation: Y = 161.4 x + 3058 R^2= 0.949**; harvest stage: Y = 127.5 x + 3064 R^2 = 0.784**) (Fig. 1 and 2). Integrated application of organic through vermicompost and fertilizer N improved the yield of rice than chemical fertilizers alone may be due to the more favorable environment to rice growth because of the higher moisture content and availability of nitrogen in the form of NH_4-N in the soil. (Jayabal and Kuppuswamy, 1996).

Conclusion

Thus study showed that organics and fertilizer N are not only complimentary but also synergistic since organic inputs have beneficial effects beyond their nutritional components and enhance the effect of applied mineral fertilizers.

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