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Effect of Organic Amendments on Productivity of Rice (*Oryza sativa*) Based Cropping Systems under Upland Rainfed Ecology in Tripura

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Abstract

Field experiments were conducted in soils of upland rainfed ecology in Tripura to study the efficacy of various organic amendments on rice based cropping systems. The superiority of oilcakes in augmenting the productivity of upland rice was noted with 71 to 81% and 89 to 138% increase in grain and dry matter yield over control, respectively. Vermicompost at 60 kg N/ha showed a substantially high efficacy in enhancing the productivity of rice-feld pea crop rotation but cattle manure (30 kg N/ha) in combination with 50 and 25% NPK could raise the maximum productivity in rice and field pea, respectively. Through this combined dose of cattle manure and NPK, N-use efficiency was raised to 32 kg rice grain and 8 kg field pea pod/kg N applied. There was a tangible rise in nutrient availability and its uptake by crops in organic amendment treated soils. Nutrient budget in rice-field pea crop rotation showed nutrient surplus in gliricidia and cattle manure treated soils and nutrient shortage in soils treated with vermicompost alone. So the supplementation of inorganic fertilizers may be adopted to replenish nutrient shortage.

Key words : Rice, Field pea, Vermicompost, Gliricidia leaf, Oilcake, N-use efficiency.

Organic matter, since it serves as a primary source and temporary sink for plant nutrients, is the most important determinant of soil quality (1). Soils under upland ecology covering nearly 60% of the total geographical area in Tripura as classified by Bhattacharys et al. (2) either under Alfisols or Ultisols, are generally of low fertility as revealed earlier (3, 4). So the necessity of organic matter replenishment is felt for sustainable crop production particularly in the context of depleting stage of SOM in soils. Besides livestock wastes which are not available in bulk to supply organic nutrition for high and increased crop yield, an alternative feasible option (5) is to use crop residues. The quantity of residue from the principal grain producing crops in India is about 340 million tonnes / annum (6). Bujarbaruah (7) reported that the annual production of crop residues in NE region was around 8.9 million tonnes and the quantum of nutrient supply from these materials, if used properly, can be appreciably high. The incorporation of green tree leaf is suitable for soil fertility maintenance in organic agriculture and this eliminates the time taken by green manuring crops for growth in the field. Dinesh et al. (8) reported the use of leaf of *Sesbania rostrata* and *Gliricidia maculata* as organic nutrition in rice based cropping systems. Vermicompost prepared from the farm wastes is being used largely as a source of manure. Epigeic earthworms which are successfully utilized for vermicomposting are *Perionyx excavatus*, *Eudrillus eugeniae* and *Eisenia fetida/andrei* (9). Some selective endogeic species viz., *Lampito mauritii*, *Polyptheretima elongata, Drawida nepalensis*, and andegic species like *Metaphire houlleti, Drawida willsi* can also be cultured. Vermicompost has been shown to promote the growth of cereals, vegetable and ornamentals (10—12). In this aspect, Yadav (13) reported that all locally available organic sources should be supplemented with minimum chemical fertilizers to maximize farm produce and raise the SOC content for better soil quality. The present study was carried out to investigate the effect of various organic amendments on crop productivity, soil nutrient status and its crop uptake in upland soils (Typic Paleochrults) of Tripura.

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Table 1. Effect of various organic amendment on crop productivity (t/ha).

Treatment	Experiment I (upland rice) Grain	Dry matter	Harvest index (%)	Experiment II (upland rice Grain	Dry matter	Harvest index (%)	Experiment III (field pea) Pod	Haulm	Harvest index (%)
T_0	0.93	3.33	28	0.90	1.75	52	1.08	1.12	96
T_1	1.28	4.29	29	1.27	2.15	59	1.14	1.52	75
T_2	1.47	5.88	25	1.05	3.33	32	1.31	1.39	95
T_3	1.28	4.43	29	1.54	4.23	37	1.27	1.47	87
T_4	1.36	5.08	27	1.97	4.30	46	1.32	1.37	97
T_5	1.33	5.60	24	2.18	4.56	48	1.09	1.38	79
T_6	1.53	6.35	24	2.79	6.07	46	0.97	1.10	88
T_7	1.29	5.23	25	2.27	4.68	49	1.24	1.38	90
T_8	1.37	4.20	33	2.01	3.74	54	1.37	1.55	88
T_9	1.68	6.28	27	1.77	3.47	51	1.56	1.77	87
T_{10}	1.59	7.93	20	1.84	3.62	51	1.34	1.38	96
T_{11}	–	–	–	1.39	2.79	50	1.33	1.42	93
SE (±)	0.14	0.65	–	0.31	0.79	–	0.066	0.13	–
CD (5%)	0.29	1.36	–	0.64	1.62	–	0.13	0.25	–

Methods

Field experiment was conducted on Upland rice (var TRC-87-251) with various organic amendment (Expt. I) viz., T_0 (Control), T_1 (Cattle manure-5 t/ha), T_2 (Cattle manure-20 t/ha), T_3 (Groundnut haulm-10 t/ha), T_4 (Groundnut haulm-20 t/ha), T_5 (Poultry manure-5 t/ha), T_6 (Poultry manure-20 t/ha), T_7 (Gobar gas slurry-5 t/ha), T_8 (Gobar gas slurry-20 t/ha), T_9 (Sesamum oil cake-20 t/ha) and T_{10} (Groundnut oil cake-20 t/ha). Cattle and poultry manure on over dry basis contained 0.38% N, 0.91% P and 0.87% K, 0.42% N, 0.16% P and 0.26% K, respectively. Groundnut haulm was observed to contain 1.67% N, 0.35% P and 1.18% K. Gobar gas slurry contained 0.45% N, 0.87% P and 0.68% K. Groundnut and sesamum oilcake contained 5.58% N, 1.12% P and 1.28% K, 3.81% N, 0.82% P and 1.02% thus indicating high manurial value.

Field experiment was also conducted on upland rice with vermicompost and other amendments (Expt. II) viz., T_0 (Control), T_1 (NPK-60 : 30 : 30), T_2 (gliricidia leaf-60 kg N/ha), T_3 (cattle manure-60 kg N/ha), T_4 (vermicompost-40 kg N/ha), T_5 (1/2 NPK + 1/2 T_2), T_6 (1/2 NPK + 1/2 T_3), T_7 (1/2 NPK + 1/2 T_4), T_8 (1/4 NPK + 45 kg N as gliricidia leaf), T_9 (1/4 NPK + 45 kg cattle manure), T_{10} (1/4 NPK + 45 kg N as vermicompost), T_{11} (20 kg N each as gliricidia leaf, cattle manure and vermicompost). Residual experiment (Expt. III) was conducted in field pea (var Pant P-8) after harvest of upland rice. Gliricidia leaf on oven dry basis contained 3.46% N, 0.24% P and 2.8% K. Vermicompost using the earthworm, *Perionyx excavatus* contained 1.88% N, 0.20% P, 0.38% K and C/N ratio was 3.84. Soil samples and plant materials were collected at harvest and composite sample was used for chemical analysis. Grain and straw samples were digested and analyzed for their K and P content using standard procedure and total N by Kjeldahl method (14).

Results and Discussion

Crop Yield

The crop productivity in experiment I after the application of various amendments is presented in Table 1. The application of 20 t sesamum or groundnut oilcake/ha could produce 71.0 to 81.4% increase in yield of rice over control in experiment I. Similarly, an increase of 88.5 to 138.1% over control in dry matter was recorded in oilcake treated soil. The trend in increase of productivity in upland rice after manuring with various sources is as follows. Sesamum oilcake >Groundnut oilcake > Poultry manure > Cattle manure > Gobar gas slurry > Groundnut haulm.

In experiment II, the application of vermicompost at 60 kg N/ha in T_4 could produce 118.5% and 146% increase in grain and dry matter yield of upland rice over control, respectively. Similarly, significant in-

Table 2. Effect of various organics (experiments I, II and III) on soil chemical properties.

Treatment	pH			O. carbon (g/kg)			Exchangeable cations {c mole (p+) / kg}		
	I	II	III	I	II	III	I	II	III
T_0	4.9	5.0	4.5	4.4	7.65	8.24	0.89	1.45	1.52
T_1	5.0	5.0	4.5	4.5	8.70	9.12	1.05	1.61	1.51
T_2	5.1	5.0	5.0	5.1	6.63	9.12	1.42	2.24	1.64
T_3	5.1	4.5	5.0	5.5	10.17	8.09	1.43	1.49	1.44
T_4	5.4	5.0	4.5	6.0	9.0	8.83	1.58	1.45	1.29
T_5	5.2	4.5	5.0	4.6	9.30	8.40	1.03	1.08	1.12
T_6	5.3	5.0	4.5	5.2	9.15	9.57	1.40	1.21	1.34
T_7	5.1	5.0	5.0	4.7	8.55	7.26	1.21	1.26	1.38
T_8	5.1	4.5	5.0	5.7	8.70	7.91	1.23	1.32	1.39
T_9	5.1	5.0	5.0	6.1	8.55	8.43	1.02	1.63	1.52
T_{10}	4.9	5.0	5.0	5.1	7.95	8.73	1.27	2.26	1.30
T_{11}	–	5.0	5.0	–	9.0	7.68	–	2.29	1.39
Mean	5.1	4.9	4.8	5.2	8.6	8.3	1.23	1.60	1.40
CV (%)	2.8	4.5	4.9	10.9	9.9	12.1	16.65	25.5	9.3

crease in both grain and straw yield of upland rice in soils of Tripura after application of vermicompost upto 20 t/ha (15). In experiment II, vermicompost supplemented by NPK (25 or 50%) in T_{10} and T_7 could raise the rice grain yield by 0.94 to 1.37 t over control. Similarly, the effects of 10—15 tonnes of vermicompost/ha and supplementation of NPK with 5 t of vermicompost/ha were not significantly different (15). It is noted that 60 kg N/ha is supplied by 5.32 tonnes of fresh vermicompost (40% moisture). In residial trial (experiment III), an increase of 22.2 and 21.9% in pod and haulm of field pea over control was observed in vermicompost treated plot in T_4. So the increase in crop yield after manuring without NPK supplementation is of the following trend : Vermicompost > Cattle manure > Gliricidia leaf for upland rice. Vermicompost > Gliricidia leaf > Cattle manure for field pea.

But maximum grain yield in rice from 0.90 to 2.79 t/ha was obtained after application of cattle manure (65% moisture) as 30 kg N/ha (22.6 t fresh manure/ha) supplemented by 50% NPK in T_6. On the other hand, application of cattle manure as 45 kg N/ha (33.8 t fresh manure/ha) supplemented by 25% NPK in T_9 could produce the maximum increase in pod yield of field pea from 1.08 to 1.56 t/ha. Due to high amount of moisture and low content (0.38%) pf N, requirement of cattle manure was higher than vermicompost (1.88% N) to have the desired productivity.

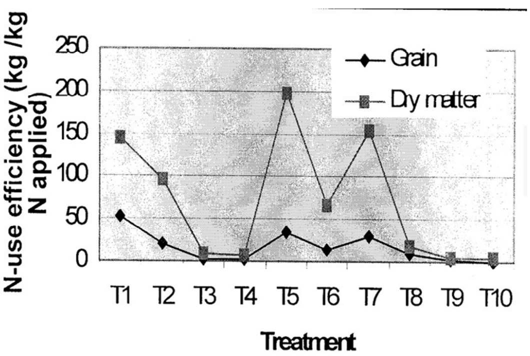

Figure 1. N-use efficiency in rice (kg/kg N applied) in experiment.

Nitrogen use efficiency of amendment treated soil was estimated and presented in Figures 1 and 2. In experiment I, the application of 5 t cattle manure/ha supplying 6.65 kg N/ha in T_1 could produce 52.2 and 144.4 kg grain and dry matter of rice per kg N applied followed by a decline to 0.78 kg grain and 4.8 kg dry matter after the application of oilcakes. Comparatively high N-use efficiency of 34.9 kg grain and 196.5 kg dry matter were obtained by the application of poultry manure (5 t/ha) in T_5 supplying 11.55 kg N. In experiment II, there was a concomitant rise in N-use efficiency in rice grain (31.6 kg/kg N) after the application of 50% cattle manure (30 kg N/ha) supplemented by 50% NPK. But 8 kg field pea pod/kg N applied was obtained after the application of cattle manure (45 kg N/ha) supplemented by 25 % NPK in T_9.

Data on changes of soil chemical properties in experiment I are presented in Table 2. Soil pH was observed to vary from 4.9 to 5.4 with a mean value of 5.1 and there was maximum rise in organic carbon from 4.4 to 6.1 g/kg in sesamum oilcake treated soil (T_9). The application of organics could produce the rise in organic carbon from 0.1 to 1.7 g/kg. Exchangeable cation in soil was found to vary from 0.89 to 1.58 c mole (p+)/kg and the maximum value of cations was noted in soils treated with groundnut haulm (T_4).

The changes in soil chemical properties after the application of vermicompost and other organics alone or in combination with inorganics at the rate of 60 kg N/ha are also presented in Table 2. Not much variation in soil pH was noted. There was rise in organic carbon from 0.9 to 2.52 g/kg and 0.16 to 1.33 g/kg in

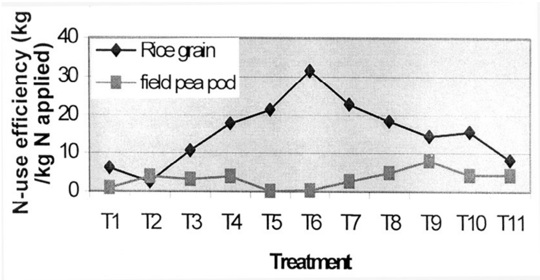

Figure 2. N-use efficiency in experiments II and III.

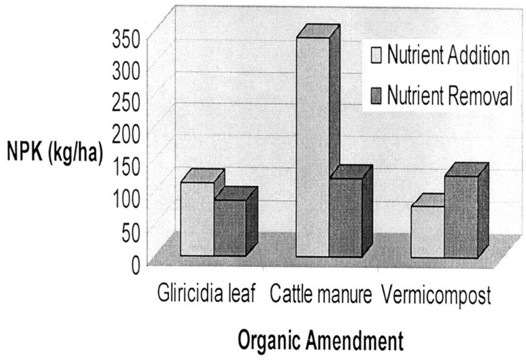

Figure 3. Nutrient budget in rice-field pea cropping system.

direct and residual experiments, respectively. Vermicompost at 60 kg N/ha (T_4) raised the organic carbon from 7.65 to 9.0 and 8.24 to 8.83 g/kg in experiments under upland rice field pea, respectively. Similarly, organic matter turnover is the key to management in low input agriculture as reported by Phiri et al. (16) and Tiessen et al. (17). The application of gliricidia leaf at 60 kg N/ha in T_2 failed to raise organic carbon in direct experiment probably due to slow rate of decomposition but an increase from 8.24 to 9.12 g/kg was noted in residual experiment under field pea. This was substantiated by the maximum rise in exchangeable cation from 1.52 to 1.64 c mole (p+)/kg due to high mineralization of gliricidia leaf in residual trial.

Soil available nutrients after the application of vermicompost and other amendments were estimated and the data are presented in Table 3. In experiment I, available NPK showed a rise from 477 to 604 kg/ha, 15.2 to 27.3 kg/ha and 100 to 261 kg/ha, respectively in groundnut oilcake treated soil (T_{10}) probably due to high nutrient contents. Vermicompost or cattle manure at 45 kg N/ha supplemented by 25% NPK in T_9 or T_{10} raised the nitrogen availability from medium to high status. Available phosphorus was also raised from medium to high status in both the experiments. But there was marginal rise in available K from 69 to 89 kg/ha in experiment II under upland rice and K-availability was increased from 109 to 138 kg/ha in experiment III under field pea. Increase in nutrient availability, soil aggregation and water use was reported by Bhattacharjee et al. (3) after vermicompost application in soils of Tripura.

Table 3. Effect of organics (experiments I, II and III) on soil available nutrients.

Treat-ment	Available nutrient (kg/ha)								
	N			P			K		
	I	II	III	I	II	III	I	II	III
T_0	477	343	347	15.2	15	16	100	69	113
T_1	455	482	357	18.3	16	18	122	71	109
T_2	518	345	405	18.7	50	44	183	71	127
T_3	559	468	516	16.5	47	48	183	131	139
T_4	604	508	482	17.9	70	38	200	69	222
T_5	499	520	427	18.2	26	26	128	62	109
T_6	582	406	571	20.5	29	76	211	71	135
T_7	492	394	562	22.3	30	36	155	69	190
T_8	548	427	596	25.2	50	35	155	69	115
T_9	600	469	626	26.3	87	76	200	89	138
T_{10}	604	615	461	27.3	44	44	261	78	104
T_{11}	–	550	567	–	41	47	–	78	155
Mean	540	460	501	20.6	42	49	173	77	122
CV (%)	9.6	170	173	19.6	48	51	25.6	23	13

Nutrient Uptake

Data on nutrient uptake in crops after the application of various organics (experiment I) are presented in Table 4. N, P, K uptake in experiment I in rice grain were raised 2.36, 1.78, 1.20 times over control after the application of oilcake. But in rice straw, N and P-uptake was raised from 11.9 to 47.0 kg/ha in T_2 (cattle manure-20 t/ha) and from 6.9 to 13.2 kg/ha in T_6 (poultry manure-20 t/ha). Similar to rice grain, there was a maximum rise in K from 17.9 to 72.9 in rice straw, respectively.

In rice-field pea cropping system (Table 4), uptake of nitrogen was raised from 10.9 to 27.5 and 14.5 to 80.1 kg/ha in rice grain and straw after the application of organics (20 kg N/ha) in T_{11} and 50% cattle

Table 4. Effect of various organics on nutrient uptake (kg/ha).

Treat-ment	Nitrogen Experi-ment I Grain	Straw	Experi-ment II Grain	Straw	Experi-ment III Pod	Haulm	Phosphorus Experi-ment I Grain	Straw	Experi-ment II Grain	Straw	Experi-ment III Pod	Haulm	Potassium Experi-ment I Grain	Straw	Experi-ment II Grain	Straw	Experi-ment III Pod	Haulm
T_0	11.5	11.9	10.9	14.5	4.9	2.4	1.9	6.9	0.54	1.38	1.2	0.39	2.9	17.9	2.7	11.4	5.3	3.3
T_1	11.2	25.3	14.9	22.4	6.4	2.0	2.6	7.1	0.46	1.59	0.75	0.29	3.7	36.9	3.1	13.2	7.5	2.5
T_2	24.3	47.0	12.1	28.6	5.9	1.7	2.9	8.1	0.59	0.48	0.69	0.62	3.2	51.7	2.8	21.6	6.5	3.7
T_3	11.6	38.1	19.0	40.6	5.7	2.1	2.6	9.2	0.54	2.04	0.84	0.78	3.4	32.3	3.8	33.1	6.5	4.3
T_4	16.1	44.7	24.0	45.2	4.5	2.8	2.7	10.1	0.70	3.60	0.75	0.39	2.9	32.0	4.6	28.9	6.1	4.1
T_5	13.6	37.5	26.4	43.3	6.4	1.9	2.6	12.3	0.76	1.10	3.31	0.53	2.8	45.4	4.6	35.5	6.7	4.3
T_6	22.0	42.5	31.0	80.1	4.6	1.9	3.1	12.2	1.07	0.89	0.56	0.54	3.2	46.4	5.8	49.6	6.5	3.9
T_7	16.3	43.9	27.2	55.3	7.4	1.4	2.6	10.3	0.54	1.2	0.81	0.34	2.7	46.5	4.9	41.0	5.2	3.2
T_8	16.0	33.2	21.9	44.5	6.9	2.1	2.7	9.5	0.91	1.8	0.99	0.35	3.3	28.9	4.6	24.9	6.5	7.5

manure supplemented by 50% NPK in T_6, respectively in experiment II. But vermicompost in T_7 and T_4 could raise the N-uptake from 4.9 to 7.4 kg/ha and 2.4 to 2.8 kg/ha in residual trial (experiment III) under field pea, respectively. This may be due to increased nitrogen supply from the decomposition of vermicompost (1.88% N). P-uptake in rice grain and straw was raised from 0.54 to 1.07 kg/ha and 1.38 to 3.60 kg/ha, respectively after the application of cattle manure in T_6 and vermicompost in T_4, respectively. But in residual trial (experiment III), gliricidia leaf in T_5 increased P-uptake from 1.2 to 3.31 kg/ha in field pea. Vermicompost supplemented by chemical fertilizers was found to promote nutrient uptake in cereals as documented by Kale et al. (18), Subler et al. (19) and Zhao Shiwei and Huong Fuzhen (20). In experiment II, cattle manure in T_6 produced the maximum rise in K-uptake (2.7 to 5.8 kg/ha) in rice grain and in straw from 11.4 to 49.6 kg/ha. But in experiment III, vermicompost supplemented by 25% NPK in T_{10} raised K-uptake in field pea pod from 5.3 to 8.5 kg/ha and an increase from 3.3 to 7.5 kg/ha in field pea haulm was noted after the application of gliricidia leaf supplemented by 25% NPK in T_8.

Nutrient Budget

Nutrient budget of rice-field pea cropping system in experiments II and III was estimated and the data are depicted in Figure 3. In addition to 60 kg N/ha, gliricidia leaf (1.73 t/ha on oven dry basis), cattle manure (15.79 t/ha) and vermicompost (3.19 t/ha) could supply 4.2, 143.7 and 6.4 kg P and 48.6, 137.4 and 12.1 kg K, respectively. The removal of NPK by rice and field pea varied from 85.28 to 125.64 kg/ha thus indicating surplus in nutrients in soils treated with gliricidia and cattle manure and a shortage in 47.14 kg nutrients in vermicompost treated soils. So it can be said that the locally available gliricidia leaf can be a source of nutrient supply in augmenting the crop productivity in infertile uplands of Tripura.

Under upland ecology, the application of organics to maintain the soil fertility and sustainable crop production is the need of the hour. Out of various types of available organic amendments, the application of green leaf from *Gliricidia maculata* may be encouraged considering its abundant availability in subtropical humid climate. Other organic sources particularly cattle munure or vermicompost have also enhanced effectiveness but they are presently of scarce commodity. Moreover, the rise in organic matter followed by nutrient release in residual trials treated with gliricidia leaf, are advantageous in the aspect of sustainable productivity.

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