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Research Paper

Composting rice straw using earthworm (*Eudrilus eugeniae*) or fungal inoculant (*Trichoderma viridae*) and its utilization in rice (*Oryza sativa*)–groundnut (*Arachis hypogaea*) cropping system

S.K. SARANGI[1] AND T.D. LAMA[2]

ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya 793 103

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ABSTRACT

An experiment was conducted at ICAR Research Complex for North Eastern Hill (NEH) Region, Meghalaya during 2007-09 on composting of paddy straw and its effect on rice (*Oryza sativa* L.)-groundnut (*Arachis hypogaea* L.) cropping system. The composting experiment started during first week of February consisted of eight treatments (i) Earthworm (*Eudrilus eugeniae*), (ii) Earthworm + 2.5% lime, (iii) Earthworm + 5.0% lime, (iv) Earthworm + 7.5% lime, (v) *Trichoderma viridae*, (vi) *T. viridae* + 2.5% lime, (vii) *T. viridae* + 5.0% lime, (viii) *T. viridae* + 7.5% lime. The composting was faster by 67 days and multiplication of earthworm was 22 times higher in the treatment with earthworm + 5.0% lime. Lime application @ 5% of dry weight of composting substrate increased pH of the compost from 6.24 to 7.09 and nitrogen content from 1.69 to 1.91%. The field experiment consisted of 11 treatments *viz*., eight composts produced from composting experiment @ 6 t/ha, farmyard manure (FYM) @ 6 t/ha, recommended dose of fertilizer (80-26.2-33.3 kg N-P-K/ha) and control. There was an increase in soil moisture in 0-15 cm layer by 3.06%, pH from 4.9 to 6.0 and soil organic carbon by 0.39% due to application vermicompost. Application of vermicompost prepared with 5.0% of lime increased the soil microbial biomass by 147% over control and the same was increased by 51% due to application of *T. viridae* compost prepared with 2.5% lime. The grain and pod yields of upland rice and groundnut increased by 120% and 107% respectively over control due to application of vermicompost prepared with 5.0% lime @ 6.0 t/ha in rice crop.

Key words: Compost, Earthworm, Fungal inoculant, Groundnut, Lime, Paddy straw, Rice

Rice is the staple food crop of the North Eastern Region of India (NER) accounting for 7.68% of total rice area and 6.02% of rice production of India (Diwakar, 2009). One of the major reasons for low rice yield is soil acidity. About 54% of the acid soils (pH <5.5) of the country are concentrated in the NER (Patiram, 2007). Since rice is grown widely in this region, a huge quantity (~ 8 million tonnes) of straw is produced. Storing half of the straw produced for domestic uses and as cattle fodder, 4 million tonnes of paddy straw would be available for recycling in the cropping system (Hazarika *et al*., 2006). Composting is an effective way of utilizing of paddy straw in crop production. Composts not only reduce the dependence on chemical fertilizers by supplying essential macronutrients, but also improve the soil structure, encourage the growth and activity of beneficial soil microorganisms, supply some of the essential secondary and micronutrients, growth promoting substances, as well as, sustain higher productivity. Inclusion of erosion restricting, nitrogen-fixing crops like groundnut in the cropping systems that are followed in hilly region also adds to the sustainability. Koraikanthimath and Manjunath (2009) found rice-groundnut as most promising cropping system in terms of potential yield and sustainability yield index (0.78). Therefore, in the present investigation, means for effective utilization of paddy straw through composting using earthworm and fungal inoculant and its application in rice-groundnut cropping system was studied.

[1]**Corresponding author Email**: sksarangicanning@gmail.com
[1]Senior Scientist (Agronomy), Central Soil Salinity Research Institute, Regional Research Station, Canning Town; [2]Senior Scientist (Soil Physics), Indian Institute of Vegetable Research, Varanasi

MATERIALS AND METHODS

Field experiment was conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya under rainfed condition during 2007-09. The institute farm is located at 25^0 302 N latitude and 91^0 512 E longitude with an elevation of 980 m above mean sea level. The soil was silty clay loam in texture, medium in alkaline permanganate oxidizable available N (290 kg/ ha) and high in

Olsen's available P (45 kg/ha) and 1M ammonium acetate exchangeable K (320 kg/ha). The *p*H and organic carbon content of the soil was 4.9 and 1.2%, respectively. The experiment had two parts: (1) preparation of compost and (2) field experiment with application of compost in rice-groundnut cropping system. The composting process consisted of eight different treatments *viz*., (i) Earthworm (*Eudrilus eugeniae*) (ii) Earthworm + 2.5% lime (iii) Earthworm + 5.0% lime (iv) Earthworm + 7.5% lime (v) Fungal inoculant (*Trichoderma viridae*) (vi) *T. viridae* + 2.5% lime (vii) *T. viridae* + 5.0% lime (viii) *T. viridae* + 7.5% lime. Earthworm sp. *E. eugeniae*, brown and red to dark violet worms originally from Africa and popularly called the 'African night crawler' having excellent growth and high conversion ratio and an effective cellulolytic fungal culture of *T. viridae* (Gaur and Singh, 1995) were used in the experiment. The composting experiment was started during first week of February with measured amount of paddy straw of around 3 months old as initial substrate taken in eight different pits (pit size 1m × 1m × 0.75 m) under shed and spread layer after layer, each having a thickness of 15 cm and mixed with lime as per treatment (2.5, 5.0 and 7.5%). Lime was applied at the time of filling the pits on the dry weight basis of paddy straw. The calculated amount of lime for each treatment was divided into five parts and was spread along with the half decomposed paddy straw and cow dung slurry in five layers. Fresh cow dung slurry was sprinkled at a straw: slurry ratio of 8:1 in each layer to bring to a moisture content at which few drops of water comes out when squeezed. After a week earthworm @ 400 nos. were added to four pits, while phosphate-solubilizing fungi (*T. viridae*) @ 300 g/ tonne of raw material was added to the remaining four pits and covered with wet gunny bags. Regular monitoring of compost was done for moisture and when required water was added till the material released few drops of water when squeezed (60-70% moisture). Aeration was given by turning the material fortnightly. The compos was observed for maturity when it turned black to brown in colour with tea leaf dust like appearance and feed material was converted to loose granular mounds due to feeding and defecation by the worms. Sprinkling of water was stopped to lower the moisture content and days to maturity, bulk density, pH and nitrogen content for different treatments were recorded. The prepared compost was passed through 3 mm sieve for counting the number of earthworms present after composting and loosening the compost mass for final use.

The field experiment in RBD with three replications was started on 16th June with sowing of rainfed upland rice variety 'RCPL 1-29' (Highly blast resistant variety for uplands in mid altitude areas, maturity duration of 126 days, released as 'Bhalum 2' in the year 2002) and consisted of eleven treatments: T1: Vermicompost, T2: Vermicompost prepared with 2.5% lime, T3: Vermicompost prepared with 5.0% lime, T4: Vermicompost prepared with 7.5% lime, T5: *Trichoderma* compost prepared with 7.5% lime, T6: *Trichoderma* compost prepared with 5.0% lime, T7: *Trichoderma* compost prepared with 2.5% lime, T8: *Trichoderma* compost, T9: FYM, T10: RDF (80-26.2-33.3 kg N-P-K/ha), T11: Control (no external source of nutrient application). Compost and FYM were applied @ 6.0 t/ha to the experimental plots of net size 5.0 m x 4.0 m at the final land preparation. Seeds @ 60 kg/ha were sown manually in lines 15 cm apart and thinned to 15 cm at 30 days after sowing during weeding. Observations on soil moisture during booting stage (critical period for upland rice), soil bulk density (core sampler method), soil pH (1:2.5 soil: water extract), panicles/m^2, grain and straw yield were recorded following standard procedures. After harvest of rice, groundnut 'JL 220' was grown under rainfed conditions on the same layout with common recommended package of practices to find out the residual effect of the treatments on the subsequent crop. The soil properties like pH, soil organic carbon (SOC), bulk density and microbial biomass were studied after harvest of the groundnut crop. Microbial biomass of soil after the harvest of groundnut crop was determined by fumigation extraction technique (Vance *et al*., 1987). Field moist soil samples (25 g) were fumigated with ethanol-free chloroform at 25^{0}C for 24 hours, after removal of chloroform vapour by repeated evacuation, the soils were then extracted with 100 mL 0.5M K_2SO_4 (4:1). Controls were prepared by extracting soils without fumigation. Total organic carbon was measured by dichromate oxidation method and subsequent titration with ferrous ammonium sulphate. All the results presented are mean values of three replicates and pooled data of two years. Data were subjected to an analysis of variance (ANOVA) with F-test and for comparing the difference between specific treatments, critical difference (CD) was used. Economics of the system were calculated based on the prevailing market price of the input and produce.

RESULTS AND DISCUSSION

Compost quality and multiplication of earthworms

The duration of composting varied significantly with different treatments from 67 days with earthworm + 5.0% lime to 112 days with inoculation of *T. viridae* without addition of lime (Table 1). In the compost involving earthworm, multiplication of *E. eugeniae* was maximum (22 times) when 5.0% lime was mixed with the substrate, and this might have resulted in a faster decomposition. The bulk density of the prepared compost varied from 0.625 to

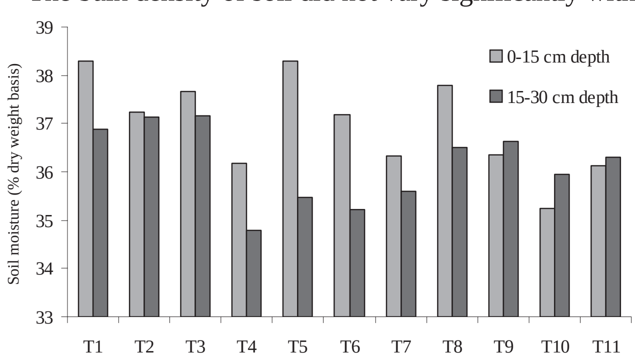
0.995 g/cm^3 in earthworm + 2.5% lime and *T. viridae* + 7.5% lime, respectively. There was a positive effect of lime application on the compost pH with the reaction tending to become neutral with 5.0 and 7.5% application of lime. Averaged over earthworm and fungal inoculation, the pH of various prepared composts were 6.24, 6.41, 7.09 and 6.77 for without lime, 2.5%, 5.0% and 7.5% lime, respectively. Kumari *et al*. (2008) at Hisar, Haryana observed that addition of tricalcium phosphate and Udaipur rock phosphate @ 10% of rice straw on dry weight basis increased the initial pH to 8.6 and 8.8 respectively, at 15 days then it declined and again increased at 30 and 60 days of composting. The nitrogen content of vermicompost prepared with addition of 5.0% lime was highest (2.15%) and at par with that prepared from 7.5% lime, but superior to all other treatments studied. The nitrogen content increased from 1.69 to 1.91% due to addition of 5% lime to the composting substrate averaged over earthworm and fungal inoculation treatments.

Soil moisture

Optimum soil moisture at the booting stage of upland rice is critical for better grain filling and grain yield. It was observed that due to application of compost there was an increase in the soil moisture in the root zone in comparison to application of chemical fertilizer and control (Fig. 1). Soil moisture on oven dry weight basis varied from 35.24% in fertilizer applied plots to 38.30% in vermicompost applied plots in the upper 0-15 cm soil layer. Rawls *et al*., (2003) reported higher water retention in soils at high organic carbon values under light as well as fine textured soils.

Changes in soil properties

The bulk density of soil did not vary significantly with application of various composts, however, this property of the soil needs to be studied in a long term basis to reflect its actual effect (Table 2). The soil pH was increased from 4.9 to 6.0 due to application of various composts as well as FYM. The average increment in pH was to the tune of 0.9 units in compost applied plots over control. This could be ascribed to the fact that the decomposition of organic wastes released Ca and Mg ions, which could have increased soil pH (Tran and Ramaswami, 1997). There was a significant increase (33%) in SOC due to application of compost as well as FYM over control and chemical fertilizer application. It varied from 1.16 in RDF applied plots to 1.55% in vermicompost applied plot. Pramanik *et al* (2009) reported an increase of 78 to 91% of SOC as a result of vermicompost application. The increase in SOC in organic nutrient applied plots after legume crop may be due to effective root nodules produced by legumes, which will have contributed atmospheric nitrogen to the soil (Jeyabal and Kuppuswamy, 2001). Tran *et al.*, (2008) at Vietnam reported 6% higher average values of SOC with application of composted paddy straw by *Trichoderma sp*. fungus over farmers' practice of application of chemical fertilizers. The SOC was not affected due to mixing of lime in the composting material. Significantly higher microbial biomass was observed in vermicompost applied plots (6 t/ha) than that of *Trichoderma* compost, FYM and recommended dose of chemical fertilizer. It may be due to the fact the vermicompost itself is a rich source of diverse microbial population. Their application to soil can add diversity and activity of indigenous soil microbial population. However, Gaind and Nain (2007) observed non-significant variation in microbial biomass due to application of vermicompost @ 3 t/ha and recommended dose of inorganic fertilizer. Application of lime to the composting material had a significant effect on the soil microbial biomass, the highest being in the 5.0% lime applied treatment with vermicomposting (314.21 μg/g) followed by 2.5% lime applied treatment with *Trichoderma* composting (192.57 μg/g). This might be due to creation a favorable pH regime for microbial growth in the soil due to application of lime. Under favorable pH regime, crop residues and their decomposition products provide energy and nutrients to the soil microbial population (Rao and Siddaramappa, 2008). Caravaca and Roldan (2003) reported addition of composted residue significantly increased microbial biomass carbon across soils having different textures.



T1: Vermicompost, T2: Vermicompost prepared with 2.5% lime, T3: Vermicompost prepared with 5.0% lime, T4: Vermicompost prepared with 7.5% lime, T5: *Trichoderma* compost prepared with 7.5% lime, T6: *Trichoderma* compost prepared with 5.0% lime, T7: *Trichoderma* compost prepared with 2.5% lime, T8: *Trichoderma* compost, T9: FYM, T10: RDF (80-26.2-33.3 kg N-P-K/ha), T11: Control

Fig. 1. Effect of application of various composts on soil moisture in upland rice (var. 'RCPL 1-29')

Effect on panicle number, grain and straw yield of upland rice and pod yield of groundnut

The number of panicles/m^2 in upland rice increased significantly from 104 in control to 238 due to the application of vermicompost prepared from paddy straw having lime added @ 5.0% (Table 2). The results are also at par with that of *T. viridae* compost prepared with 5.0% lime and FYM application. The grain and straw yield of upland rice increased significantly due to application of various types of compost over control, however it was at par with application of recommended dose of fertilizer. Highest grain (2.71 t/ha) and straw (3.85 t/ha) yield was recorded in case of application of vermicompost @ 6 t/ha prepared with 5.0% lime. The same was lowest (1.23 and 1.50 t/ha grain and straw respectively) in case of control. Luu *et al*. (2006) reported 13.5% and 5.5% increase in rice yields due to application of the rice straw manure @ 6 t/ha. Application of lime to the composting material did not affect yield under earthworm and fungal inoculation. There was a significant effect of application of compost to the upland rice on the pod yield of succeeding groundnut crop. The trend of increase in pod yield was similar as observed in case of upland rice and highest pod yield of 5.08 t/ha was recorded in case of application of vermicompost @ 6t/ha prepared with 5.0% lime to the preceding upland rice crop. Due to residual effect, nodulation and microbial activity in the root zone was enhanced, thereby creating a congenial rhizosphere for pegging, pod formation and pod development, which is turn resulted in a significant increase of groundnut yield. Nath *et al*. (2012) observed an increase in yield of rice-toria sequence due to application of rice straw enriched compost (primed with *Azospirillum*/*Azotobacter* and phosphate solubilizing bacteria @ 1 t/ha + 50% NP + 100% K) over recommended dose of fertilizer application.

System Rice Equivalent Yield (REY) and Economics

Highest system REY (11.74 t/ha) was obtained with application of vermicompost prepared with 5% lime, which was significantly superior over *Trichoderma* com-

Table 1. Effect of various composting treatments on compost quality and earthworm multiplication (Pooled data of two years)

Treatment	Composting duration (days)	Number of earthworms released	Number of earthworms at end of composting	Bulk density (g/cm^3) of final compost	pH of final compost	N content of final compost (%)
Earthworm	87	400	6,641	0.653	6.24	1.91
Earthworm + 2.5% lime	79	400	7,255	0.625	6.45	1.98
Earthworm + 5.0 % lime	67	400	8,760	0.714	6.78	2.15
Earthworm + 7.5% lime	72	400	7,930	0.633	6.42	2.13
*Trichoderm*a + 7.5% lime	99	-	-	0.995	7.13	1.67
Trichoderma + 5.0% lime	87	-	-	0.928	7.40	1.67
Trichoderma + 2.5% lime	105	-	-	0.931	6.37	1.54
Trichoderma	112	-	-	0.984	6.25	1.47
SEm±	4.5	-	-	0.07	0.13	0.03
CD (P=0.05)	13.3	-	-	0.20	0.37	0.09

Table 2. Soil properties after harvest of groundnut crop, panicles/m^2, grain and straw yield of rice and pod yield of subsequent groundnut crop as affected by application of different compost, FYM and fertilizer to rainfed upland rice (Pooled data of two years)

Treatment*	Bulk density (g/cm^3)	pH	Organic carbon (%)	Microbial biomass (μg/g)	Panicles/ m^2	Rice grain yield (t/ha)	Rice straw yield (t/ha)	Groundnut pod yield (t/ha)
Vermicompost	1.8	5.7	1.55	273.81	141	2.25	3.42	4.25
Vermicompost prepared with 2.5% lime	1.9	5.7	1.51	287.45	200	2.35	3.50	4.67
Vermicompost prepared with 5.0% lime	1.9	5.8	1.49	314.21	238	2.71	3.85	5.08
Vermicompost prepared with 7.5% lime	1.8	6.0	1.50	291.83	151	2.52	3.00	4.90
Trichoderma compost prepared with 7.5% lime	1.7	5.9	1.56	146.74	161	2.10	3.17	4.42
Trichoderma compost prepared with 5.0% lime	1.7	5.8	1.43	172.15	188	2.15	3.25	4.50
Trichoderma compost prepared with 2.5% lime	1.8	5.6	1.41	192.57	147	2.00	2.77	3.80
Trichoderma compost	1.8	5.5	1.45	147.19	157	1.75	2.75	3.58
FYM	2.0	5.4	1.40	164.58	195	1.83	2.92	4.12
RDF (80-26.2-33.3 kg N-P-K/ha)	1.8	5.0	1.16	189.47	149	2.02	3.08	3.97
Control	1.8	4.9	1.17	127.31	104	1.23	1.50	2.45
SEm±	0.07	0.12	0.08	4.39	23.5	0.24	0.39	0.47
CD (P=0.05)	NS	0.36	0.25	12.98	69.5	0.71	1.15	1.40

Table 3. Effect of application of compost, FYM and fertilizers to rice on system rice equivalent yield (REY) and economics of Rice-Groundnut cropping system (pooled data of two years)

Treatment*	System REY (t/ha)	Cost of cultivation (× 10^3₹/ha)	Gross returns (× 10^3 ₹/ha)	Net returns (× 10^3₹/ha)	B : C ratio
Vermicompost	9.81	30.34	88.25	57.91	1.91
Vermicompost prepared with 2.5% lime	10.65	30.89	95.82	64.93	2.10
Vermicompost prepared with 5.0% lime	11.74	31.51	105.69	74.18	2.35
Vermicompost prepared with 7.5% lime	11.23	32.20	101.05	68.85	2.14
Trichoderma compost prepared with 7.5% lime	9.95	31.23	89.57	58.34	1.87
Trichoderma compost prepared with 5.0% lime	10.15	30.47	91.35	60.88	2.00
Trichoderma compost prepared with 2.5% lime	8.76	29.77	78.80	49.04	1.65
Trichoderma compost	8.12	29.34	73.08	43.75	1.49
FYM	9.16	29.27	82.47	53.20	1.82
RDF (80-26.2-33.3 kg N-P-K/ha)	9.08	28.85	81.68	52.83	1.83
Control	5.59	18.52	50.30	31.78	1.72
SEm±	0.78	0.03	7.05	7.05	0.23
CD (P=0.05)	2.32	0.10	20.85	20.85	NS

*Different compost and FYM applied @ 6 t/ha

post prepared with 2.5% lime (8.76 t/ha), *Trichoderma* compost (8.12 t/ha), FYM (9.16 t/ha), RDF (9.08 t/ha) and control (5.59 t/ha), but at par with all other treatments (Table 3). Cost of cultivation was highest in vermicompost prepared with 7.5% lime (₹ 32200/ha), followed by vermicompost prepared with 5% lime (₹31510/ha) due to the labour and input charges. The cost of cultivation was much lower in the control plot (₹18520/ha) followed by application of RDF (₹28850/ha) and FYM (₹29270/ha). Highest net return was obtained from the treatment with application of vermicompost prepared with 5% lime (₹74180/ha), however it was at par with application of other composts except *Trichoderma* compost (₹43750/ha) and *Trichoderma* compost prepared with 2.5% lime (₹49040/ha) and significantly superior over application of FYM (₹53200/ha), RDF (₹52830/ha) and control (₹ 31780/ha). Though B:C ratio was higher in vermicompost applied treatments, the differences were statistically insignificant, this which be due to lower cost of cultivation in FYM and inorganic fertilizer applied treatments.

Composting of rice straw mixed with 5% lime was completed in 67 days by earthworm and was faster than fungal inoculant by 20 days. Application of vermicompost @ 6 t/ha to rice crop improved the soil physico-chemical and biological properties of the soil after groundnut harvest. The system yield and net return of upland rice-groundnut cropping system increased significantly due to application of vermicompost @ 6.0 t/ha over control, recommended dose of fertilizer and FYM applied to rice.

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