Indian Journal of Agricultural Sciences **83** (4): 420–5, April 2013/Article

Straw composting using earthworm (*Eudrilus eugeniae*) and fungal inoculant (*Trichoderma viridae*) and its utilization in rice (*Oryza sativa*)-groundnut (*Arachis hypogaea*) cropping system

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Received: 3 September 2012; Revised accepted: 5 February 2013

ABSTRACT

An experiment was conducted at ICAR Research Complex for North Eastern Hill (NEH) Region, India 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 consisted of eight treatments (i) *Eudrilus eugeniae,* (ii) *E. eugeniae* + 2.5% lime, (iii) *E. eugeniae* + 5.0% lime, (iv) *E. eugeniae* + 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 (67 days) and multiplication of earthworm was highest (22 times) with earthworm + 5.0% lime. There was a positive effect of lime application on the pH of the compost and it increased from 6.24 to 7.09 due to application of 5.0% lime to the composting substrate. The field experiment consisted of 11 treatments, viz. eight composts produced from composting experiment @ 6 tonnes/ha, farmyard manure (FYM) @ 6 tonnes/ha, recommended dose of fertilizer (80-26.2-33.3 kg N-P-K/ha) and control. Soil moisture in 0-15 cm layer increased by 3.06%, pH changed from acidic to neutral and soil organic carbon increased by 0.39% due to application vermicompost. Addition of vermicompost prepared with 5% lime increased the soil microbial biomass carbon by 147% over control, while 51% increase was recorded with application of *T. viridae* compost 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.

Key words: Earthworm, Fungal inoculant, Groundnut, Lime, Rice, Straw compost

During the tenth plan period, North Eastern Region of India (NER) accounted for 7.68% of total rice area and 6.02% of the total rice production in the country with average productivity of rice of 1.57 tonnes/ha which is much below the national average of 2.01 tonnes/ha (Diwakar 2009). However, rice is the main staple food crop of the region and cropping systems are predominantly rice based under low-input low-risk and low yield conditions. One of the major reasons for low yield is soil acidity with about 54% of the acid soils (pH <5.5) of the country being concentrated in the NER (Patiram 2007).

Since rice is grown widely in this region, a huge quantity (~ 8 million tonnes) of straw is produced. Keeping aside half of the straw produced for domestic uses and as cattle fodder, 4 MT of paddy straw would be available for recycling in the cropping system (Hazarika *et al*. 2006). Composting is one of the ways for effective utilization of paddy straw in crop production to enrich the soil. 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) at Goa reported that among the rice based cropping systems studied, rice-groundnut system was more stable in terms of its yield potential as reflected by higher sustainability yield index (0.78), due to leguminous nature of groundnut crop with substantial leaf shedding, biological nitrogen fixation through root nodules and turning of its biomass. Therefore, in the present investigation, means for effective utilization of paddy straw through composting using earthworm and fungal inoculant along with liming was studied in rice-groundnut cropping system through application

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of various compost preparations *vis-à-vis* chemical fertilizers and farmyard manure.

MATERIALS AND METHODS

Field experiment was conducted at Farming System Research Project, ICAR Research Complex for NEH Region, Umiam, Meghalaya under rainfed condition during 2007-09. The institute farm is located at 25^0 30' N latitude and 91^0 51' E longitude with an elevation of 980 m above mean sea level. The soil was silty clay loam in texture, medium in available N (290 kg/ ha) and high in available P (45 kg/ha) and K (320 kg/ha). The pH and organic carbon content of the soil were 4.9 and 1.2%, respectively. The experiment has two parts: (1) preparation of compost, (2) field experiment with application of compost on rice-groundnut cropping system. The composting process consisted of eight different treatments, viz. (i) earthworm (*Eudrilus eugeniae*), (ii) *E. eugeniae* + 2.5% lime, (iii) *E. eugeniae* + 5.0% lime, (iv) *E. eugeniae* + 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. The choice of earthworms for vermicomposting in India is limited to a few, since these worms have to not only effect quick conversion, but also reproduce faster. *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 the most effective cellulolytic fungal culture of *T. viridae* was used in the experiment. 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. The detailed stepwise method of preparation is given in Fig 1. The field experiment in RBD with three replications was started in June with sowing of upland rice variety RCPL 1-29 (126 days) and consisted of eleven treatments: eight different composts, FYM, recommended dose of fertilizer (80-26.2-33.3 kg N-P-K/ha) and one control (no external source of nutrient application). Compost and FYM were applied @ 6.0 tonnes/ha to the experimental plots of net size 5.0 m × 4.0 m at the final land preparation. Seeds were sown manually in lines 15 cm apart and thinned to 15 cm after 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 on the same layout with common recommended package of practices to find out the residual effect of the treatments on the subsequent crop. Soil microbial biomass carbon content (SMBC) 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

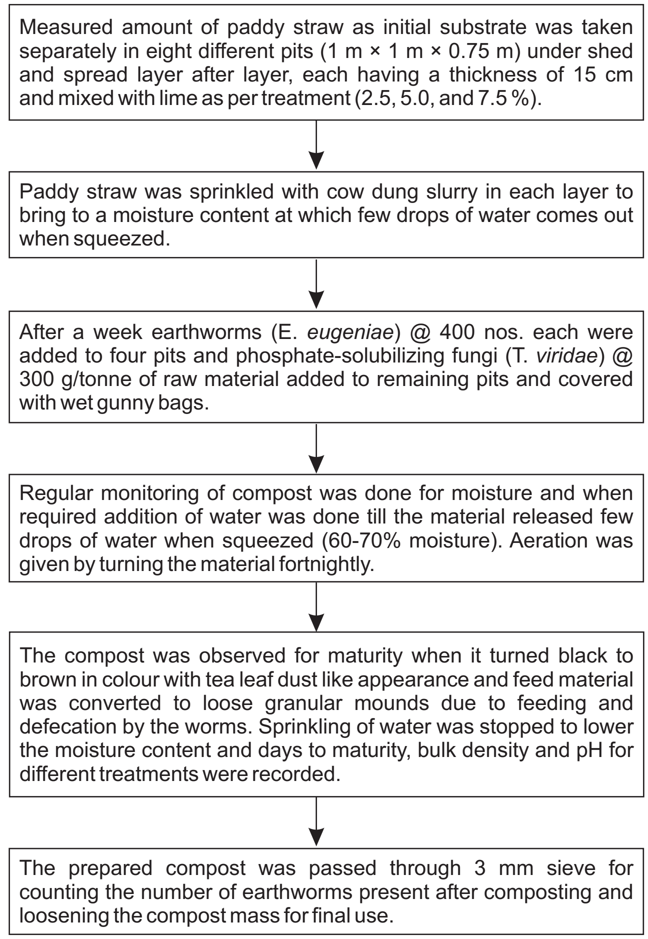


Fig 1 Schematic diagram showing steps used for preparation of compost

at 25°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 (Walkley and Black 1934).

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 (Panse and Sukhatme 1978).

RESULTS AND DISCUSSION

Compost quality and multiplication of earthworms

The days required for preparation of compost varied significantly with different treatments from 67 days with earthworm + 5.0% lime to 112 days with fungal inoculation of *T. viridae* without addition of lime (Table 1). Wiedow *et al.* (2007) demonstrated the potential contribution of *T. saturnisporum* to accelerate wheat straw decomposition on

Table 1 Effect of various composting treatments on compost quality and earthworm multiplication (pooled data)

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
Earthworm	87	400	6 641	0.653	6.24
Earthworm + 2.5% lime	79	400	7 255	0.625	6.45
Earthworm + 5.0 % lime	67	400	8 760	0.714	6.78
Earthworm + 7.5% lime	72	400	7 930	0.633	6.42
*Trichoderm*a + 7.5% lime	99			0.995	7.13
Trichoderma + 5.0% lime	87			0.928	7.40
Trichoderma + 2.5% lime	105			0.931	6.37
Trichoderma	112			0.984	6.25
SEm±	4.5			0.07	0.13
CD (P=0.05)	13.3			0.20	0.37

soil. The C/N ratio of the inoculated straw decreased strongly from an initial value of 76 to 43 after 4 weeks and to 30 after 13 weeks. 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.

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 2). 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 that water retention in soils is affected by soil organic carbon and texture. At high organic carbon values, light as well as fine textured soils showed an increase in water retention.

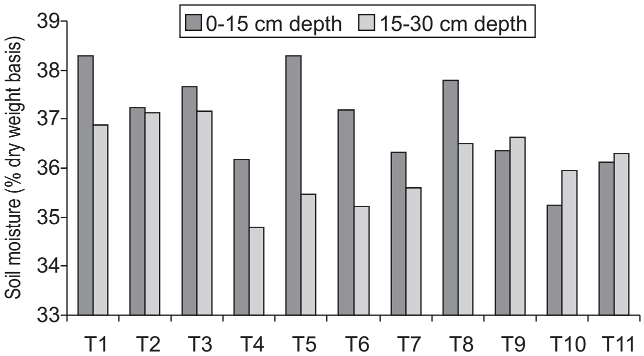
Changes in soil properties

The soil properties like pH, soil organic carbon (SOC), bulk density and soil microbial biomass cabon (SMBC) were studied after harvest of the groundnut crop (Table 2). The bulk density of soil did not vary significantly with application

Table 2 Soil properties after harvest of crop as affected by different compost, FYM and fertilizer (pooled data)

Treatments*	Bulk density (g/cm^3)	pH	Organic carbon (%)	Soil microbial biomass carbon (µg/g)
T1: Vermicompost	1.8	5.7	1.55	273.81
T2: Vermicompost prepared with 2.5% lime	1.9	5.7	1.51	287.45
T3: Vermicompost prepared with 5.0% lime	1.9	5.8	1.49	314.21
T4: Vermicompost prepared with 7.5% lime	1.8	6.0	1.50	291.83
T5: *Trichoderma* compost prepared with 7.5% lime	1.7	5.9	1.56	146.74
T6: *Trichoderma* compost prepared with 5.0% lime	1.7	5.8	1.43	172.15
T7: *Trichoderma* compost prepared with 2.5% lime	1.8	5.6	1.41	192.57
T8: *Trichoderma* compost	1.8	5.5	1.45	147.19
T9: FYM	2.0	5.4	1.40	164.58
T10: RDF (80-26.2-33.3 kg N-P-K/ha)	1.8	5.0	1.16	189.47
T11: Control	1.8	4.9	1.17	127.31
SEm±	0.07	0.12	0.08	4.39
CD (P=0.05)	NS	0.36	0.25	12.98

*T1 to T9 dose of application: 6tonnes/ha



[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 2 Effect of application of various composts on soil moisture in upland rice (var RCPL 1-29)

of various composts, however, this property of the soil needs to be studied in a long-term basis to reflect its actual effect. However, Azarmi *et al.* (2008) reported that increase in the rates of vermicompost application from 0 to 15 tonnes/ha reduced the bulk density of a loamy textured soil at Iran from 1.69 to 1.56 g/cm^3, respectively. The soil pH was increased from acid range to neutrality 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 Thi Ngoc Son and Ramaswami 1997). There was a significant increase 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. Tran Thi Ngoc Son *et al.* (2008) at Vietnam reported higher average values of SOC with application of composted paddy straw by *Trichoderma* sp fungus. The SOC was not affected due to mixing of lime in the composting material. Significantly higher soil microbial biomass cabon (SMBC) was observed in vermicompost applied plots (6 tonnes/ha) than that of *Trichoderma* compost, FYM and recommended dose of chemical fertilizer. This is in contrary to that reported by Gaind and Nain (2007), who observed that application of vermicompost @ 3 tonnes/ha resulted in microbial biomass though higher than the recommended dose of inorganic fertilizer but statistically at par with each other. Application of lime to the composting material had a significant effect on the SMBC, the highest being in the 5.0% lime applied treatment with vermicomposting (314.21 µg/g) and 2.5% lime applied treatment with *Trichoderma* composting (192.57 µg/g). This might be due to application of lime, which created a favourable pH regime for microbial growth in the soil. Further crop residues and their decomposition products provide energy and nutrients to the soil microbial population (Rajashekhara Rao and Siddaramappa 2008). Caravaca and Roldan (2003) reported that changes in microbial biomass carbon depend on the texture of the soil, *E. foetida* promote a less stable and more dynamic microflora in the sandy soil. In clay loam and clay soils, the addition of *E. foetida* only decreased the amount of CO_2-C evolved from the clay loam

Table 3 Effect of application of various composts, FYM, chemical fertilizer on panicles/m^2, grain and straw yield of rice and pod yield of subsequent groundnut crop (pooled data)

Treatments*	Upland rice			Groundnut
	Panicles/m^2	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Pod yield (tonnes/ha)
T1: Vermicompost	141	2.25	3.42	4.25
T2: Vermicompost prepared with 2.5% lime	200	2.35	3.50	4.67
T3: Vermicompost prepared with 5.0% lime	238	2.71	3.85	5.08
T4: Vermicompost prepared with 7.5% lime	151	2.52	3.00	4.90
T5: *Trichoderma* compost prepared with 7.5% lime	161	2.10	3.17	4.42
T6: *Trichoderma* compost prepared with 5.0% lime	188	2.15	3.25	4.50
T7: *Trichoderma* compost prepared with 2.5% lime	147	2.00	2.77	3.80
T8: *Trichoderma* compost	157	1.75	2.75	3.58
T9: FYM	195	1.83	2.92	4.12
T10: RDF (80-26.2-33.3 kg N-P-K/ha)	149	2.02	3.08	3.97
T11: Control	104	1.23	1.50	2.45
SEm±	23.5	0.24	0.39	0.47
CD (P=0.05)	69.5	0.71	1.15	1.40

*T1 to T9 dose of application: 6tonnes/ha soil, but did not affect the microbial biomass content or the qCO_2 of either soil types.

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 3). The results are also at par with that of *T. viridae* compost prepared with 5.0% lime and FYM application. Singh *et al.* (2006) at Varanasi, India reported that incorporation of rice-straw compost inoculated with *Azotobacter* + *Bacillus polymyxa* in combination with NPK proved significantly superior to other treatments except NPK + *T. viridae* compost + *Azotobacter chroococcum* + *Bacillus polymyxa* for number of panicles/m^2. 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 tonnes/ha) and straw (3.85 tonnes/ha) yield was recorded in case of application of vermicompost @ 6 tonnes/ha prepared with 5.0% lime. The same was lowest (1.23 and 1.50 tonnes/ha grain and straw respectively) in case of control. Luu Hong Man *et al.* (2006) reported that when compared with control treatment (no chemical fertilizer, no rice straw manure), solo application of the rice straw manure @ 6 tonnes/ha increased average rice yields by 13.5% and 5.5% in the wet and dry seasons, respectively. The grain and straw yields were at par for application of lime to the composting material both for earthworm (*E. eugeniae*) and fungal inoculant (*T. viridae*). 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 tonnes/ha was recorded in case of application of vermicompost @ 6 tonnes/ha prepared with 5.0% lime to the preceding upland rice crop. Nath *et al*. (2012) at Asom observed an increase in yield of rice-toria sequence due to application of enriched compost from rice straw (primed with *Azospirillum*/*Azotobacter* and phosphate solubilizing bacteria @ 1 tonne/ha + 50% NP + 100% K) over recommended dose of fertilizer application.

Recycling of paddy straw by composting with earthworm (*Eudrilus eugeniae*) or fungal inoculant (*Trichoderma viridae*) and 5.0% lime improved the soil physico-chemical and biological properties. The yield of upland rice-groundnut cropping system increased significantly due to application of vermicompost @ 6.0 tonnes/ha over control and was at par with recommended dose of fertilizer applied to rice.

ACKNOWLEDGEMENT

The authors are very much thankful to Dr K K Satapathy, former Head, Division of Agricultural Engineering, ICAR Research Complex for NEH Region for his encouragement and providing all the facility in carrying out the experiment.

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