

## Productivity, nutrient harvest index, nutrient balance sheet and economics of lowland rice (*Oryza sativa*) as influenced by composts made from locally available plant biomass

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### ABSTRACT

A field study was conducted during 2004–06 on the performance of 8 different type of composts prepared from rice (*Oryza sativa* L.) straw, *Eupatorium adenophorum* Spreng, *Lantana camara* L. and weed mixtures were evaluated (10 tonnes/ha) and compared with the recommended NPK (80:60:40 kg/ha) and farmyard manure (10 tonnes/ha) on productivity, nutrient harvest index and nutrient balance sheet of lowland rice. Two composting procedures were tried, one was microbial enriched compost consisting of biomass + cowdung (1:1 on weight basis) + compost culture with cowdung slurry and another was microbial and nutrient fortified compost consisting of microbial enriched compost + rock phosphate @ 2.5% (w/w) + neem cake 1%. Bioinoculums such as cellulose decomposers (*Aspergillus terreus*, *Trichoderma harzianum*, *T. viride*, *T. virens*), P-solubilizing microbes (*Bacillus polymyxa* and *Pseudomonas striata*) and free-living N-fixers (*Azotobacter* spp) were used as compost culture to hasten the composting process and improve the quality of the composts. The results indicated that significantly ( $P < 0.05$ ) higher grain yield was recorded with rice straw microbial and nutrient fortified compost followed by the *Eupatorium* microbial and nutrient fortified compost, which were 5.5 & 46 % and 2 & 38 % higher than recommended NPK and control, respectively. The nutrient uptake and soil fertility status was found to be significantly improved due to application of various composts. Rice straw microbial and nutrient fortified compost recorded the highest net returns (Rs 29 420/ha), followed by *Eupatorium* microbial and nutrient fortified compost (Rs 28 530/ha).

**Keywords:** Composting, Economics, Energetic, North Eastern Region, Nutrient harvest index, Organic production

The growing concern for scarcity of organic manure for crop production, especially under organic farming in the north-eastern region of India could be mitigated through addition of composts prepared from abundantly growing weeds and shrub species, viz *Eupatorium adenophorum* Spreng, *Ambrosia artemisiifolia*, *Lantana camara* L., *Mikania micrantha* Kirnth ex. HBK, *Galinsoga parviflora* (Cav.), other grassy and broad leave weeds. It is very difficult to eradicate these weeds from crop field, forest and wasteland. Therefore, composting will be considered as a means to encourage the useful utilization of these biomass in crop production to enrich the soil. The nutrient supply through composts and other organic manures not only reduce the dependence on chemical fertilizers but also improve the soil structure, encourage the growth and activity of mycorrhizae and other beneficial organisms in the soil,

alleviate the deficiency of secondary and micronutrients, sustain higher productivity due to improved soil health (Singh *et al.* 2006). Hence, it is important to develop a suitable technique for preparation of enriched compost in the shortest possible time and evaluate its quality.

The favourable climatic conditions of the north-eastern region of India encourages vegetation to produce good growth of biomass. Many of those are often a menace for agricultural activities. These plants are very rich in essential nutrients (Das *et al.* 2006) and can be effectively recycled in crop production through composting (Saha *et al.* 2007, Gopinath *et al.* 2008). Recycling of residues and plant biomass in the soil is one of the best alternative practices for replenishing the depleted soil fertility, improving the physico-chemical properties of the soil and ultimately crop yield (Kolawole *et al.* 2004).

The information on effect of organic composts on rice is meager under mid altitude conditions of north-eastern India. Therefore, a field experiment was conducted to study the comparative efficacy of various composts vis-à-vis fertilizer and farmyard manure on productivity, economics and nutrient balance sheet of lowland rice.

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## MATERIALS AND METHODS

Field experiments were conducted at lowland, Division of Agronomy, ICAR Research Complex for NEH Region, Umiam, Meghalaya (950 m above mean sea level) under irrigated condition during rainy (*kharif*) seasons of 2004–06. The experimental soil was sandy clay loam in texture, low in available N (199.3 kg/ha) and P (5.3 kg/ha) and medium in available K (183 kg/ha). The organic C content and the pH of the soil was 2.01 % and 4.8, respectively. The mean minimum and maximum temperature ranged from 12.5 to 21.1 and from 23.6 to 29.4°C, respectively, with a total rainfall of 1 454 mm during the cropping season.

*E. adhenophorum*, *L. camara*, weed mixture (grass and broad-leaved weeds) and rice straw were raw materials for compost. Two composting procedures were tried (Fig 1). One was microbial enriched compost (MEC) consisting of biomass/substrate + cow dung (1:1) and compost culture with cowdung slurry (prepared by mixing fresh cow dung : virgin

soil : well rotten compost in a ratio of 1:1:0.5) and another was microbial and nutrient fortified compost (MNFC) consisting of MEC + rock phosphate @ 2.5% + neem cake 1%. Compost culture consisted of combination of microbes, ie P-solubilizer (*Bacillus polymyxa*, *Pseudomonas striata*), cellulose decomposer (*Trichoderma harzianum*, *T. virens*, *T. viride*, *Aspergillus terrus*) and free living N- fixer (*Azotobacter chroococcum*). The fungal culture was inoculated @ 300 g/tonne, while bacterial culture @ 500 g/tonne of raw materials. Rockphosphate (2.5% w/w) was used for P-enrichment and neem cake (1% w/w) was used for N-enrichment of the compost. Compost culture was added in the pit (1m × 1m × 0.75 m) after about a week of filling the pit with substrate and cowdung to protect the microbes from direct exposure to excess heat generated from the materials. Addition of compost culture to the composting substrate was repeated after one month along with first turning the materials. In total 3 turnings were made and the materials were allowed to decompose for about 100 days. A moisture level of 60-70 % was maintained by sprinkling water.

Performance of different composts was compared with farmyard manure, recommended NPK (80:60:40 kg/ha) and control. The composts and farmyard manure were applied @ 10 tonne/ha 15 days ahead of transplanting and incorporated during last ploughing. The nursery of high-yielding rice 'Sahsarang 1' was sown in 7 June and transplanted in 2 July in both the year with a spacing of 20 cm × 15 cm and 3 seedlings/hill. All other recommended cultural practices were followed. No inorganic inputs were used in compost treatments. Need-based pest and disease management was adopted using organic pesticides like neem oil (3 ml/litre), *Beauvaria bassiana* (2 ml/litre), derisome (karanjin product) etc.

Grain and straw samples of rice were collected at harvest and analyzed for total N using a micro-Kjeldahl method, while total P and K were determined using sulphuric-nitric-perchloric acid digest as per Prasad (1998). Nutrient removal was estimated by multiplying the NP and K concentration (%) of grain and straw with their respective yield (kg/ha) and finally the nutrient uptake by grain and straw was sum up to obtain total nutrient uptake. Nutrient harvest index was computed using the formula given below:

$$\text{Nutrient harvest index} = \frac{\text{Uptake of a particular nutrient by the grain}}{\text{Total uptake of that nutrient in biomass}} \times 100$$

The post harvest soil samples were collected from 0-20 cm depth for analyzing available nutrient status. The soil samples were analyzed for alkaline permanganate oxidizable N, 0.5 M NaHCO<sub>3</sub> extractable P and 1 N NH<sub>4</sub>OAC exchangeable K as per the procedure described by Prasad (1998). Organic carbon was analyzed by dichromate oxidation and titration with ferrous ammonium sulphate

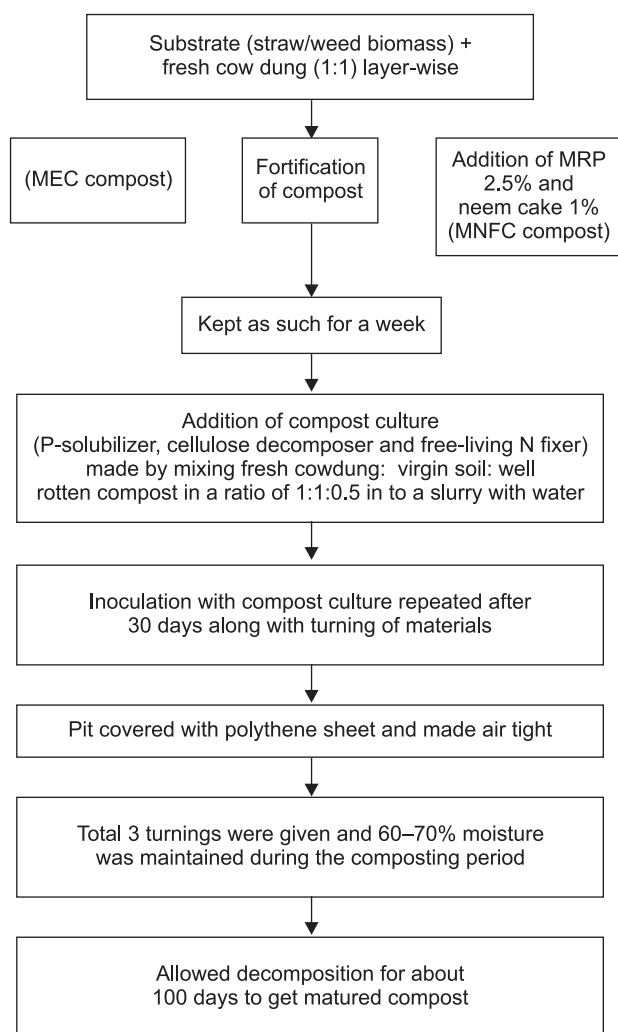


Fig 1 Schematic diagram showing steps used in compost preparation

(Walkley and Black 1934). Soil microbial biomass carbon was determined by using chloroform fumigation extraction method (Anderson 1982). Economics were calculated based on the prevailing market price of the input and produce. Energy balance was computed based on the equivalent values of input and output in energy terms (MJ/ha) as per Mittal *et al.* (1985).

## RESULTS AND DISCUSSION

### *Nutrient content of composts*

The nutritional composition of prepared composts was analyzed and are presented in Table 1. Various composting methods markedly improved the NPK status of all the substrates. The data revealed that the N content of different composts ranged from 2.31 to 3.48%, highest being with the *Eupatorium* microbial and nutrient fortified compost. Similarly, the P and K status ranged from 0.31 to 2.98 and 0.85 to 1.89%, respectively. The highest P (2.98%) and K (1.89%) status was recorded with the rice straw microbial and nutrient fortified compost. It is apparent from the data that the microbial enrichment and fortification of the compost with rock phosphate and neem cake improved the nutrient status of the compost substantially, especially N and P. Based on the nutrient status, the composts could be ranked in the order of rice straw > *Eupatorium* > weed mixture > *Lantana* compost.

### *Yield attributes and yield*

There was significant improvement in yield attributes of rice due to application of different composts, recommended fertilizer and farmyard manure (Table 2). In general composts prepared with microbial and nutrient fortified compost (enriched with microbial culture, rock phosphate and neem cake) gave higher values of yield attributes compared to that with microbial enriched compost (microbial culture only). All the microbial and nutrient fortified composts recorded higher number of panicles/m<sup>2</sup> and grains/panicle compared to microbial enriched composts, showing the beneficial effect of fortification of composts with rock phosphate and neem cake. The effect of recommended NPK on yield attributes was similar to various composts.

Various organic amendments and recommended NPK improved the grain and straw yield of rice significantly over control (Table 3). Highest grain yield was recorded with rice straw microbial and nutrient fortified compost (4.60 tonnes/ha), followed by *Eupatorium* microbial and nutrient fortified compost (4.45 tonnes/ha) which were at par with grass and *Lantana* microbial and nutrient fortified composts as well as recommended NPK (4.36 tonnes/ha) and farmyard manure but significantly superior to all the microbial enriched composts and control. Significant increase in rice yield due to addition of organic amendments, like *L. camara* compost was also reported by other researchers (Saha *et al.* 2007, Sharma *et al.* 2003). Various composts improved the harvest

index significantly over application of NPK, farmyard manure and control.

The favourable effect of compost treated with microbial inoculants on yield parameters is attributed to improvement in compost quality. *Azotobacter* and phosphorus-solubilizing bacteria (PSB) not only provided N and P but also produced amino acids, vitamins and growth-promoting substances like indole acetic acid and gibberellic acid. These are thought to promoted growth, yield attributes and improved yield (Singh *et al.* 2006).

The increase in grain yield and harvest index due to various composts might be due to efficient supply of nutrients that delayed the senescence and increased the life-cycle of the rice plant which resulted in higher economic yield (Singh *et al.* 2005). The noticeable performance of rice straw compost as compared to others in terms of yield improvement was attributed to improved nutritional status, narrow C/N ratio, improved phosphate solubilization and availability of micronutrients as well as improved soil condition (Gaur 1999). Further, supplementation of rock phosphate and neem cake in microbial and nutrient fortified composts improves overall P solubilization, particularly citrate soluble form of P, which activate extra cellular enzymes, like acid phosphates as well as promote release of organic acids during decomposition process (Singh *et al.* 2004).

### *Nutrient harvest index*

In general nutrient harvest index values were higher for phosphorus harvest index, followed by nitrogen harvest index. Lower values were observed for potassium harvest index (KHI). The Phosphorus harvest index values of rice ranged from 0.67 with rice straw microbial and nutrient fortified compost to 0.74 with control and nitrogen harvest index ranged from 0.63 with recommended NPK to 0.67 with control. On the other hand, potassium harvest index values varied from 0.31 with weed mixture microbial enriched compost to 0.34 with control (Table 3). The higher nutrient harvest index with control might be due to the reason that under nutrient starved condition, plant tries to extract more from the soil and converts maximum towards seeds for completion of life-cycle.

### *Nutrient balance sheet*

The data on nutrient addition, harvest and balance sheet are presented in Table 4. Perusal of the data revealed that various composts, recommended NPK and farmyard manure had favourable and significant effect on total NPK uptake of rice. Maximum amount of nitrogen addition to soil was recorded with *Eupatorium* microbial and nutrient fortified compost, followed by rice straw microbial and nutrient fortified compost, which were 96% and 93% higher than recommended NPK and 175% and 170% higher than control, respectively. Whereas, higher P and K addition was recorded with rice straw microbial and nutrient fortified compost. The

higher nutrient supply with composts was due to their higher nutrient content and enrichment with rock phosphate and neem cake.

In general, all the microbial and nutrient fortified composts recorded significantly higher N uptake of rice compared to microbial enriched composts, farmyard manure and control. Significantly higher N uptake was observed with application of rice straw microbial and nutrient fortified compost over other composts but remained similar to *Eupatorium* microbial and nutrient fortified compost and recommended NPK. Similar trends were also observed in respect to P and K uptake. The nutrient uptake with farmyard manure was found significantly inferior to microbial and nutrient fortified composts and recommended NPK but at par with microbial enriched composts. Different composts made favourable soil condition for rice with respect to physico-chemical properties of the soil that could have increased nutrient uptake. Insoluble P of rock phosphate could be transformed to plant available form during composting process and increase P-uptake of crop (Singh *et al.* 2004). The increase in nutrient uptake may be ascribed to increase in the available N, P and K contents in the soil, resulting from increased availability of nutrients and improved soil structure, texture, and tilth, creating better environment for higher uptake of nutrients (Manna *et al.* 2001).

The organic amendments had substantial residual effect which is why improvement in fertility was observed. This might be due to the cumulative residual effect of the compost. The highest available N (235 kg/ha) was recorded with rice straw microbial and nutrient fortified compost, whereas available P (9.7 kg/ha) and K (223 kg/ha) was more with *Eupatorium* microbial enriched compost, which were 11, 17 & 10% and 16, 80 & 20% higher than those recorded with recommended NPK and control, respectively. The organic C content was also highest with *Eupatorium* microbial and nutrient fortified compost, followed by rice straw microbial enriched compost. Improvement in chemical status of soil due to addition of fortified rice straw compost inoculated with *Azotobacter* + PSB was reported by Singh *et al.* (2006). The buildup in fertility status may be attributed to recycling of nutrients, solubilization of P and mineralization of K due to increase in organic matter and activities of microorganisms (Mishra *et al.* 2001).

The application of composts marginally improved the soil organic carbon, whereas the improvement in soil microbial biomass carbon was significantly improved ( $P < 0.05$ ) due to application of various composts and farmyard manure (Table 5). The increase in soil microbial biomass carbon was attributed to presence of easily water soluble carbon which acts as a source of energy for soil microorganisms (Manna *et al.* 2001).

Perusal of the data revealed that most of the expected values of soil N and P are much higher than the actual values except with farmyard manure, recommended NPK and

control. The value was even found negative with control for soil P. Contrary to N and P, the expected values for K status was much lower than the actual observed values. This suggests that the soil has its own resilience and it is very difficult to influence the actual soil nutrient status by agricultural practices like addition of fertilizer and manures. However, addition of fertilizer and manures could improve the fertility status to some extent and the values remained markedly higher than control or no fertilizer addition. That explains the need for nutrient supply in crop production for sustainability and maintenance of soil health.

#### *Energy calculation*

The energy input, output and productivity data is presented in Table 5. In general rice cultivated with microbial and nutrient fortified composts required more energy inputs (9 164 MJ/ha), followed by recommended NPK. The higher energy inputs in microbial and nutrient fortified compost and recommended NPK was due to involvement of rock phosphate, neem cake and fertilizer, respectively. Energy output was also higher in rice straw (143 620 MJ/ha) and *Eupatorium* microbial and nutrient fortified compost (141 790 MJ/ha) composts treatments followed by recommended NPK (151 342 MJ/ha). In contrary, microbial enriched compost treatments recorded higher output : input ratio and higher energy productivity. However, highest energy productivity (1.22 kg grain/MJ) was recorded with control, mainly because of relatively low energy requirement (2 564 MJ/ha) coupled with a reasonably good yield of rice.

#### *Economics*

Cost of cultivation was maximum in *Lantana* microbial and nutrient fortified compost (Rs 18 650/ha), followed by *Eupatorium* microbial and nutrient fortified compost (Rs 18 150/ha) mainly due to higher labour charges for collection of biomass (Table 5). Application of farmyard manure (Rs 14 350/ha) and recommended NPK (Rs 13 000/ha) recorded much lower cost of cultivation. Among different treatments, rice straw microbial and nutrient fortified compost recorded the highest net returns (Rs 29 420/ha), followed by *Eupatorium* microbial and nutrient fortified compost (Rs 28 530/ha). Contrary to net returns, the highest benefit : cost ratio was recorded with recommended NPK due lower cost of cultivation. Higher benefit : cost ratio with application of inorganic fertilizer compared to organic amendments was also reported by Das *et al.* (2004). However, most of the farmers in the north-eastern regions are small and marginal. They utilizes their own farm produced farmyard manure and engaged mainly family labours for various agricultural operations. The family labours are otherwise not used for any other opportunity enterprises. Therefore, if the cost involved for labour is deducted from the economic evaluation, application of organic amendments like composts would be much more beneficial. Moreover,

the organic amendments have direct effect on improving the soil physico-chemical properties and thereby maintains soil health. The small and marginal farmers cannot effort to purchase costly chemical inputs. On the other hand, the hill farmers have apathy to use chemical fertilizer in crop production. Therefore, use of organic amendments like composts seems to be alternative options for nutrient supply in crop production.

Use of organic amendments like enriched compost prepared from locally available on-and off-farm plant biomass like paddy straw and weed biomass (*Eupatorium adenophorum*) along with non-chemical pest and disease management will serve the purpose of organic food production in the region, as the region is identified as a potential zone for organic food production. The use of rock phosphate in composting process would take care of phosphorus nutrition in highly P-deficient acid soils of north-eastern India. Such organic amendments could serve the purpose of alternative sources of nutrient supply in crop production, especially under organic farming.

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