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EFFECTS OF *in-situ* BIOCONVERSION OF FARM RESIDUES ON GROWTH AND QUALITY OF BANANA *cv. Nendran* IN LATERITE SOILS OF KERALA

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Fruit quality

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ABSTRACT

Field experiment was conducted to test the response of organic and inorganic nutrition on growth, yield and quality of banana *cv. nendran*. The treatments used were absolute control, package of practices (300:115:450g N:P₂O₅:K₂O/plant + Farm Yard Manure @ 20 kg/plant), *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg/plant), *ex-situ* vermicompost in silpaulin vermibeds with *Eisenia foetida* (20 kg/plant), *in-situ* vermicompost in crop pits with *Perionyx excavatus* (20 kg/plant), *in-situ* vermicompost in crop pits with *Eisenia foetida* (20 kg/plant) and *in-situ* compost (20 kg/plant). The package of practices and recommendations (POP) involving combined application of mineral fertilizers and farm yard manure (FYM) recorded the highest bunch yield (10.81kg/plant), while all the organic treatments produced lower but comparable yields. However, higher contents of total sugars (22.42%), reducing sugars (3.71%), non-reducing sugars (18.80%), lower titratable acidity (0.29%) and reduced number of days to bunching (206 days) and harvest (297 days) were observed for banana grown under the *in-situ* mode of organic nutrition. Banana plants treated with compost were found to produce significantly higher and comparable values for quality parameters like vitamin C and shelf life than that of mineral fertilizer + FYM. Cost: benefit ratio was also higher for the organic treatments than inorganic nutrient management. Increased absorption and translocation of nutrients (N, P, K and Mg) in fruits were observed in banana plants treated with vermicomposts prepared using native worms, *P. excavatus*. *In-situ* mode of organic nutrition was found to remarkably improve chemical and biochemical properties (pH, organic carbon, N, Mg, urease and dehydrogenase activity) of the rhizosphere soils.

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1 Introduction

Banana and plantains occupy the fourth important position among universal food commodities. It was grown in about 120 countries in the world with a production of 86 metric ton (National Horticultural Board, 2015). In India, it is cultivated in 4.6 lakh ha area (13 % of total fruit area) with a production of 14.2 metric ton (33.4 % to the total fruit production) and a productivity of 30.5 mt / ha. In Kerala, banana is a major fruit crop raised on plantation scale and spans an area of 61936 ha. Current production of banana is 545431t and productivity is 14.1 mt / ha in Kerala (Government of Kerala, 2016). *Nendran* is the most popular cultivar of banana in the state of Kerala due to its market and commercial inclinations and occupies 50 percent share of total banana export from the state (National Horticulture Mission, 2005).

However the production of horticultural crops like banana faces many threats such as low productivity, inferior quality, high capital cost of cultivation, high incidence of pests and diseases (Balamohan & Kaviha, 2005). Moreover banana generates about 220t of crop residues / ha in the form of fibrous pseudostem, leaves, peduncle and rhizomes after harvest of the bunch (Ingale et al., 2014). These biomass was absolutely treated as waste in most of the states of India and farmers incur about ₹ 8000 to ₹ 10000 / ha for disposing pseudostem alone (Indian Agricultural Research Institute, 2012). Disposal of pseudostem in regular ways like field bunds and natural drains, harbours insect pests and pathogens and acts as breeding sites for stray dogs, rodents etc. The pathogens were transmuted and much dreadful diseases like dengue fever, malaria and plague are spreading day by day. This situation is going to be worsened in the ensuing years, with accelerated urbanization and scarcity of land areas. Moreover the increased usage of pesticides, high analysis fertilizers and plant protection chemicals add to the irreversible degradation of the air, water and soil. Indiscriminate stubble burning expels more CO₂ to the atmosphere as evidenced by the recent Delhi smog pollution (www.indianexpress.com). Proper management of banana residue poses a challenge to the farmers and at the same time offers great scope for recycling and use in subsequent crop. The escalating costs of chemical fertilizers and its undesirable effects on soil properties have led to inclusion of organic manures in cultivation of crops. Incorporation of crop residues into soil or converting them into composts is an easy way of waste disposal and managing the organic matter requirement of soils (Indian Agricultural Research Institute, 2012).

Composting is essentially a microbial alteration of mixed organic substrates, under controlled conditions into hygienic, humus rich, relatively stable product which can be used to improve soil physical conditions and nourish crop plants. According to Aremu et al. (2012) the improved growth of plants due to composting may be attributed to the humic acids present in the composts which influence lateral root proliferation, stimulate nutrient uptake and thereby plant development (Trevisan et al., 2010).

Vermicomposting on the other hand, is a mesophilic oxidative conversion of organic matter to mucus coated granular worm casts through the combined action of microorganisms and earthworms. Vermicomposting, besides being a good nutrient source also has an additional advantage of biogenic calcium carbonate enrichment which neutralizes soil acidity (Juarez et al., 2011), hence got the advantage as a soil conditioner in the acid soils of Kerala. Most of the work on earthworms in India is confined to vermicomposting using exotic earthworm species and very little information is available on the indigenous fauna of worms with respect to their utility in vermicomposting or in improving soil health.

Ex-situ composting methods employ the preparation of composts outside the field in suitable containers and in states like Kerala, where wages and labour charges are high, this adds to cost of cultivation. *In-situ* composting emphasises the production of composts from the residues generated from the field which effectively utilize farm wastes in the field itself and thereby cut down the waste management costs drastically and improve soil health at the planting sites (Masciandaro et al., 2000; Athani & Hulamani, 2000; Sarma et al., 2012). Masciandaro et al. (2000) exhorted the addition of fresh sludge directly to soil for *in-situ* composting using *Eisenia foetida*. Exotic earthworm species like *Eisenia foetida*, *Eudrillus eugeniae* and native species like *Perionyx excavatus* were commercially exploited for organic waste reprocessing under controlled environment (Pattnaik & Reddy, 2010). But their potential in *in-situ* waste management in the soil environment wherein the climate and ecology are highly variable is not much investigated. Hence exploring the effect of these *in-situ* developed vermicomposts (using both exotic and native earthworms) *vis-a-vis* crop and soil health will help to further the cause of such methodologies in organic banana cultivation.

2 Materials and Methods

2.1. Experiment details

Field experiment was conducted to assess the growth, yield and crop quality of banana *var. nendran* by using composts prepared using *ex-situ* and *in-situ* modes against recommended doses of fertilizers at Banana Research Station, Kannara, Kerala. The treatment combinations included absolute control (soil) and recommended package of practises (POP) i.e. 300: 115: 450 g N: P₂O₅: K₂O/ plant + FYM at the rate of 20kg / plant (Kerala Agricultural University, 2011). The organic treatments included basal application of *ex-situ* and *in-situ* vermicomposts prepared using native and exotic earthworm species at the rate of 20kg / plant. For vermicomposting native *Perionyx excavatus* and exotic *Eisenia foetida* were used. The *ex-situ* vermicomposts were prepared in silpaulin vermibeds using *E. foetida* (Ex-E) and *P. excavatus* (Ex-P) and were applied at the rate of 20kg per pit. *Ex-situ* vermicomposts were applied to the pits one week before planting. All the pits were covered with soil and left as such for one week.

In-situ vermicomposts using *P. excavatus* (In-P) and *E. foetida* (In-E) were prepared in banana planting pits itself (size 50 cm x 50 cm x 50 cm) three months prior to planting along with control without earthworms (In-C).

Three months old tissue culture banana *cv. nendran* plants were used as test crop. For each replication, four plants were selected (total of 12 plants per treatment). Banana plants grown under POP, were given fertilizers N: P₂O₅: K₂O at the rate of 300: 115: 450 g / plant in six split doses through urea, rajphos and muriate of potash respectively. Experimental soils were collected and analysed for organic carbon using Wet digestion (Walkley & Black, 1934) available N (Subbiah & Asija, 1956) and available Ca and Mg by neutral normal ammonium acetate extraction (Jackson, 1958). Experimental soils were low in organic carbon (0.59%), available N (264.03 kg / ha) and available Mg (83.39 mg /kg). All the biometric observations were taken at the time of bunching. The yield attributes were recorded at harvesting of bunches. The fruit samples were taken from the D finger and were kept for ripening.

2.2. Physico-chemical characterization of compost, soil and plant

The composts prepared were subject to chemical analysis: pH, N, P, K and Ca was estimated by using the standard procedures as outlined in Fertilizer Control Order, (Government of India, 1985). The auxin like activity of humic substances in composts was hypothesised by many authors (Trevisan et al., 2010; Smith, 2012; Canellas & Olivares, 2014). Indole Acetic Acid is a premier bioregulator regulates the growth of meristematic tissues. The concentrations of auxins in plants are regulated by the activity of the IAA oxidase enzyme. In soils, auxin production is purely biogenic and mainly by the action of microbes on L-tryptophan added through root exudates (Dakora & Phillips, 2002) which works as physiological precursor for the biosynthesis of auxin in plants and microorganisms. Hence the indole acetic acid content in composts was determined and expressed as amount of un-oxidized auxin or activity of indole acetic acid oxidase enzyme using Salkowski reagent (2 ml 0.5 M FeCl₃ and 98 ml 35% HClO₄) and pink colour intensity was measured using spectrophotometer at 535nm (Wohler, 1997). Dehydrogenase activity was assessed according to Pepper et al. (2004). The intensity of red colour due to formation of 1, 3, 5 triphenylformazan (TPF) was determined spectrophotometrically at 485 nm and results were expressed as mg TPF kg⁻¹ day⁻¹ compost. The total viable microbial cells were determined by serial dilution plate technique (Wollum, 1982). The humic acids were estimated using sequential fractionation procedure of Schintzer (1982).

Representative soil samples were collected from rhizosphere (0-30 cm depth) and analysed as per standard procedures as outlined by Jackson (1958).

Analyses of plant samples for C, N, and S were carried out using CHNS analyser (Model: Elementar Vario EL Cube). Powdered substrates were sieved (2 mm sieve) and sub samples (0.5g) were

digested with concentrated HNO₃ in a microwave digestion system (Model: MARSX 250/40). Nutrient estimation was done in the acid extract using inductively coupled argon plasma optical emission spectrometer (ICP- OES Model: Optima 8x00). The fruit quality parameters were assessed using the protocols as prescribed by Association of Official Analytical Chemists (2000).

2.3. Statistical analysis

Analysis of variance (ANOVA) was done using SPSS (Version 20) to test the level of significance between treatments means (Das & Giri, 1986).

3 Results and Discussions

3.1. Chemical and biochemical characters of compost

The pH of resultant composts ranged from neutral to moderately alkaline (7.1 to 8.3). *Ex-situ* composts have significantly higher pH than those prepared under *in-situ* mode of composting. The pH of the experimental soil was under strongly acidic range (4.7). However, *in-situ* mode of composting was found to have a significant ameliorating effect on the soil pH of the crop pits (Table 1).

The sum total of N, P₂O₅ and K₂O produced by compost and vermicomposts, irrespective of the treatments were above 2.5 percent, hence can be considered of good quality as prescribed by the fertilizer (Control) Order (Government of India, 1985). The enhanced levels of primary nutrients in the compost and vermicompost as compared to initial substrates indicated efficient decomposition of residues by the combined action of earthworms and microbes. Studies have revealed that organic residue decomposition by earthworms and microbes accelerates nitrogen mineralization process and thereby the substrate nitrogen profile (Suthar, 2009; Parthasarathi, 2010; Parthasarathi et al., 2016). In earthworms, 60 – 70 % (dry mass) of the body tissue is made up of proteins and a major portion of this is mineralized from the dead tissues of worms and returned to the soil during composting. The content of P in the resultant composts was also higher than the initial substrate concentration. This enrichment of P occurs due to the phosphatase enzyme mediated conversion of P to available forms in the earthworm gut (Lee, 1992; Vinotha et al., 2000). Recently Parthasarathi (2010) have been also reported 6–8 folds increase in available phosphorus content in vermicasts produced by *E. eugeniae*, *E. foetida*, *L. mauritii* and *P. excavatus*. Potassium contents in the composts and vermicomposts was also higher than the initial material and this was in agreement with previous reports that the composting process accelerates microbial populations in the residues and subsequently enriches them with more available plant nutrients (Suthar, 2009; Parthasarathi et al., 2007; Parthasarathi, 2010).

In crop pits (*in-situ*) *E. foetida* was found best for enriching Ca contents in composts. Padmavathiamma et al. (2008) suggested that this Ca enrichment occurs in vermicasts when soil and

Table 1 Chemical and biochemical characteristics of composts used for the experiment

Treatments	Chemical characteristics			Biochemical characteristics				
	pH	N+P ₂ O ₅ +K ₂ O (%)	Ca as CaO (%)	Compost yield (%)	Auxin equivalents (µg g ⁻¹ of compost)	Dehydrogenase activity ((mg TPF day ⁻¹ kg ⁻¹ of compost)	Viable microbial count (10 ⁴ cfu g ⁻¹)	Humic Acid content (%)
S	4.64 (0.12)	0.73 (0.02)	0.10 (0.00)	-	2.13 (0.80)	7.89 (1.03)	363.42 (2.26)	7.46 (0.33)
Ex-C	7.95 (0.12)	4.47 (0.44)	0.56 (0.05)	70.83 (6.64)	9.86 (0.35)	64.43 (3.45)	723.34 (17.39)	28.61 (7.28)
Ex-P	8.27 (0.11)	4.67 (0.16)	0.53 (0.02)	60.41 (5.98)	18.69 (2.43)	1798.63 (120.69)	480.38 (17.22)	24.99 (1.16)
Ex-E	8.22 (0.13)	4.82 (0.33)	0.55 (0.08)	62.50 (4.98)	26.02 (0.87)	1394.86 (31.80)	445.34 (5.99)	32.79 (5.36)
In-P	7.05 (0.05)	1.93 (0.19)	0.36 (0.16)	69.00 (3.77)	6.05 (0.77)	249.89 (10.28)	455.14 (8.40)	17.71 (0.64)
In-E	7.19 (0.24)	2.64 (0.21)	0.69 (0.04)	62.00 (4.14)	7.75 (0.65)	423.56 (76.22)	652.05 (11.46)	25.99 (3.68)
In-C	7.29 (0.06)	2.24 (0.21)	0.46	70.67 (2.18)	4.91 (0.20)	218.53 (86.55)	463.08 (57.39)	42.15 (7.70)
CD at 5%	0.43	0.77	0.25	-	3.28	93.83	72.08	7.46

*Values in parentheses indicate standard error of means; S: Absolute control; Ex-C: *ex-situ* compost in silpaulin vermibeds (20 kg / plant) ; Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg / plant); Ex-E: *ex-situ* vermicompost in silpaulin vermibeds with *E. foetida* (20 kg / plant); In-P: *in-situ* vermicompost in crop pits with *P. excavatus* (20 kg / plant); In-E: *in-situ* vermicompost in crop pits with *E. foetida* (20 kg / plant) and In-C: *in-situ* compost in crop pits (20 kg / plant)

substrates pass through the digestive tract of earthworms. The results of the present study also confirmed this and all the vermicomposting treatments had significantly higher Ca contents than control. Vermicompost produced in the silpaulin vermibeds showed significantly higher compost yield, total primary nutrient content and auxin content than those produced in banana planting pits.

The relatively low amount of nutrients in composts prepared *in-situ* can be attributed to high leaching, fixation or absorption by nearby small plants. The higher microbial population under *ex-situ* composting process would have led to an increase in compost yield (% w/w basis). On the other hand, the high compost yield under In-P can be attributed to the higher net individual and total biomass gain by indigenous *P. excavatus*. However, under *ex-situ* mode of composting in silpaulin vermibeds, the conditions were more or less uniform and loss of water was limited and hence with high moisture stagnation, *P. excavatus* failed to produce the desirable growth and multiplication.

Though the dehydrogenase activity is the index of microbial activity and was higher in Ex-P, it was found to have no correlation with the total microbial count of the treatment. The mismatch between enzyme activity and total microbial count was also reported by Luo et al. (2001) as the carbon expenditure for enzyme induced microbial respiration could not contribute to the growth and proliferation of microbes. Each type of respiratory carbon expenditure may differ in its response to soil organic matter

quality and availability and this differentiation can impact the dynamics of the microbial growth independent of enzyme concentration (Allison et al., 2010).

3.2. Growth and yield attributes of banana *cv. Nendran*

The study revealed that the modes of nutrition had significant influence on the yield of banana and was observed in the bunch and growth characteristics like number of hands per bunch, number of fingers per hand, weight of fingers and number of functional leaves. There was significant positive correlation of yield with weight of finger ($r=0.88^{**}$), pseudostem girth ($r=0.82^{**}$), number of fingers per hand ($r=0.75^{**}$), number of functional leaves ($r=0.74^{**}$), number of hands per bunch ($r=0.70^{**}$) and pseudostem height ($r=0.64^{**}$) (Table 2). In the mineral fertilizer + FYM (POP) treatment, the effect of pseudostem height and girth (351.75cm and 51.83cm respectively) was significantly pronounced than the other treatments. This might be due to the combined application of N and K through high analysis fertilizers in the available form which is also proved from the positive correlation between pseudostem height and girth with foliar N ($r=0.47^{*}$ and 0.56^{**}) and K ($r=0.53^{*}$ and 0.52^{*}). Ganeshmurthy et al. (2011) have also reported that nitrogen and potassium are the major contributors in dry matter production, yield and quality of banana. The application of lime to correct the pH of rhizosphere in the POP treatment contributes to nutrient solubilization leading to enhanced plant uptake.

The contribution of compost was also found as effective as POP towards increasing the weight of fingers of banana plants (Table 3).

Table 2 Correlation between yield, growth and bunch characteristics of banana

	Functional Leaf (No.)	Pseudostem height	Pseudostem girth	Bunch yield	No. of hands /Bunch	Wt. of fingers	No. of fingers/hand
Functional Leaf (No.)	1						
Pseudostem height	0.407	1					
Pseudostem girth	.619**	.696**	1				
Bunch yield	.704**	.638**	.820**	1			
No. of hands /Bunch	.638**	.711**	.668**	.694**	1		
Wt. of fingers	.816**	.543*	.761**	.877**	.669**	1	
No. of fingers/hand	.746**	.622**	.613**	.751**	.603**	.728**	1

*(p<0.05); **p<0.01

This may be due to the enhanced microbial activity leading to increased nutrient transformations in the soils receiving compost treatments. Zandonadi et al. (2013) have established that compost treated soils have a capacity to alter the root morphology by gene modification thereby improving its nutrient uptake efficiency. The plants grown under organic nutrition through composting under *in-situ* mode took significantly shorter duration of 206 days for flowering than those grown under recommended dose of fertilizers (264 days). The early maturity was also significantly higher under organic nutrition of plants. The highest benefit: cost ratio of 1.26 was manifested under *in-situ* composting.

Soils fertilized with mineral fertilizer + FYM (POP), receives a high concentration of nitrogen during the active growth stages which extends the vegetative phase, hence a delayed flowering and harvest. Kranthi (2015) emphasized that the excess nitrogen fuels lead to fast growth of foliage with wider surface so that energy for flower growth is redirected to foliage proliferation leading to

delayed development of necessary reproductive organs. Organic manures on the other hand, prevent an excessive nitrogen influx at any point of time thereby promoting the growth and reproductive phases to take its natural cycles. *In-situ* vermicomposting could also be more promising due to enrichment of humic substances more acclimatized to that particular environment than those prepared outside the field (Masciandaro et al., 2000)

3.3. Biochemical quality and sensory parameters of banana cv. Nendran

According to Kramer (1965) quality of foods may be called as the combination of certain characteristics that segregate individual units of a product, and have significance in determining the degree of adequacy of that unit to the consumer. According to Barrett et al. (2010), the characteristics of fruit quality may be defined by four different traits: 1) appearance and colour, 2) taste and aroma i.e. flavour, 3) texture and 4) dietary value. In the present study, the sensory parameters in terms of overall acceptability were more

Figure 1 Effect of organic and inorganic nutrition on sensory characteristics of banana fruits

Table 3 Effect of organic and inorganic nutrition on yield, yield attributes and growth parameters of banana cv. nendran

Treatments	Bunch yield (kg / plant)	Number of hands per bunch	Number of fingers per hand	Weight of one finger (g)	Pseudostem		Time taken (days) for		Benefit : Cost Ratio
					Height (cm)	Girth (cm)	Bunching	Harvest	
S	4.25 (1.12)	4.67 (0.33)	6.67 (0.88)	101.67 (19.13)	247.17 (40.65)	39.66 (2.59)	340 (14.45)	431 (36.39)	-
POP	10.81 (0.49)	6.33 (0.14)	10.33 (0.43)	178.67 (9.91)	351.75 (9.27)	51.83 (1.24)	264 (9.17)	345 (10.04)	1.11
Ex-P	7.02 (0.57)	6.00 (0.08)	8.67 (0.30)	147.33 (7.65)	295.89 (7.23)	45.89 (1.56)	248 (2.18)	333 (5.79)	1.01
Ex-E	6.73 (0.27)	5.33 (0.20)	8.33 (0.17)	150.67 (8.98)	288.39 (5.69)	42.42 (0.84)	234 (3.83)	321 (4.02)	1.21
In-P	6.77 (0.68)	5.67 (0.33)	9.00 (0.44)	155.00 (7.60)	298.67 (7.16)	44.25 (0.87)	221 (6.15)	293 (10.12)	1.13
In-E	6.79 (0.27)	5.33 (0.25)	9.33 (0.33)	140.67 (4.68)	295.25 (2.24)	44.33 (2.09)	232 (18.75)	310 (13.81)	1.17
In-C	7.24 (0.24)	6.00 (0.00)	9.00 (1.00)	146.33 (2.95)	296.08 (3.10)	43.83 (1.01)	206 (11.41)	297 (9.73)	1.26
CD(p=0.05)	1.62	0.64	1.92	29.15	48.49	4.55	33.52	49.79	-

*Values in parentheses indicate standard error of means; S:Absolute control; POP:300:115:450g N:P₂O₅:K₂O/plant + FYM (20 kg/plant); Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg / plant); Ex-E: *ex-situ* vermicompost in silpaulin vermibeds with *Eisenia foetida* (20 kg / plant); In-P: *in-situ* vermicompost in crop pits with *Perionyx excavatus* (20 kg / plant); In-E: *in-situ* vermicompost in crop pits with *Eisenia foetida* (20 kg / plant) and In-C: *in-situ* compost in crop pits (20 kg / plant)

Table 4 Effect of organic and inorganic nutrition on chemical and biochemical quality parameters of banana cv. nendran

Treatments	C	N	P	K	Ca	Mg	Vitamin C (mg 100g ⁻¹ of fruit)	Titrateable Acidity (g of citric acid 100g ⁻¹ of fruit)	Shelf life* (days)	Total sugars	Reducing sugars (%)	Non-reducing sugars
				(%)								
S	33.75 (0.11)	2.51 (0.02)	0.13 (0.00)	0.27 (0.00)	0.09 (0.00)	0.05 (0.00)	9.78 (0.13)	0.97 (0.24)	10 (1.00)	8.30 (0.37)	1.65 (0.04)	6.66 (0.34)
POP	39.97 (0.32)	2.83 (0.08)	0.15 (0.00)	0.52 (0.00)	0.09 (0.00)	0.10 (0.00)	20.58 (4.51)	0.63 (0.09)	20 (2.00)	13.35 (0.91)	2.72 (0.27)	10.63 (0.65)
Ex-P	35.91 (0.07)	3.46 (0.08)	0.26 (0.00)	0.60 (0.00)	0.16 (0.00)	0.15 (0.00)	17.74 (1.10)	0.49 (0.04)	18 (2.00)	17.82 (0.85)	2.55 (0.01)	15.27 (0.86)
Ex-E	38.43 (0.61)	2.67 (0.03)	0.22 (0.00)	0.49 (0.00)	0.15 (0.00)	0.13 (0.00)	17.86 (4.02)	0.54 (0.01)	14 (2.00)	16.42 (0.56)	2.55 (0.14)	13.87 (0.56)
In-P	39.59 (0.24)	2.59 (0.03)	0.22 (0.00)	0.51 (0.00)	0.08 (0.01)	0.12 (0.00)	17.93 (0.65)	0.50 (0.01)	18 (2.00)	20.96 (1.01)	3.71 (0.24)	17.25 (0.87)
In-E	36.65 (0.28)	2.38 (0.03)	0.20 (0.00)	0.43 (0.00)	0.07 (0.00)	0.11 (0.00)	17.12 (0.98)	0.29 (0.06)	13 (1.00)	22.41 (1.58)	3.61 (0.50)	18.80 (1.10)
In-C	36.35 (0.30)	2.56 (0.09)	0.25 (0.00)	0.59 (0.00)	0.12 (0.00)	0.14 (0.00)	19.03 (1.87)	0.43 (0.01)	15 (1.00)	22.27 (1.77)	3.54 (0.10)	18.74 (1.69)
CD (at 5%)	1.02	0.18	0.01	0.01	0.02	0.01	2.92	0.29	4.98	3.55	0.79	3.06

*Values in parentheses indicate standard error of means

S:Absolute control; POP:300:115:450g N:P₂O₅:K₂O/plant + FYM (20 kg/plant); Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg / plant); Ex-E: *ex-situ* vermicompost in silpaulin vermibeds with *Eisenia foetida* (20 kg / plant); In-P: *in-situ* vermicompost in crop pits with *Perionyx excavatus* (20 kg / plant); In-E: *in-situ* vermicompost in crop pits with *Eisenia foetida* (20 kg / plant) and In-C: *in-situ* compost in crop pits (20 kg / plant)

significant in mineral fertilizer + FYM treated plants (score of 8.5) (Figure 1). However, both mineral and organic modes of nutrition had a more or less similar influence on the vitamin C content as evidenced in Table 4, the vitamin C content of 20.58 mg/100g of

fruit in POP and 19.03mg/100g of fruit in IN-C and shelf life of 20days for POP as against 19.03 days in EX-P. The titrateable acidity was more pronounced under inorganic mode of nutrition whereas the sugar content of the fruits was superior under *in-situ*

composting mode. The return of residues to soil as compost enriches the site with more biological activity, increased growth and plant performances and ultimately enhances yield and quality of crops (Pathma & Sakthivel, 2012).

The highest content of total sugars was recorded in plants grown under vermicompost prepared in banana planting pits using *E. foetida* which was at par with the *in-situ* compost. *In-situ* composting process always favoured formation of humic acids rich in polysaccharides, which might have resulted in the translocation of assimilates. Among the treatments, the fruits from mineral fertilizer + FYM treated plants were significantly superior in all the parameters.

The highest content of C was from fruits of plants which received mineral fertilizer + FYM and that received *in-situ* vermicompost prepared by native earthworms. The increased translocation of photosynthates to the sink under conjunctive application of inorganic fertilizers + FYM and vermicompost was proved from this study. This is further confirmed by the higher number of functional leaves and weight of finger obtained from those plants receiving recommended dose of fertilizers and FYM and vermicompost.

The content of P, K, Ca and Mg was significantly higher in fruits of plants that received native earthworm worked *ex-situ* vermicompost prepared in silpaulin vermibeds. However the P, K, Ca and Mg content of fruits were significantly higher in the *in-situ* compost treated plots. The presence of earthworm derived humic substances in the rhizosphere soils might have stimulated the proliferation of lateral roots and thereby increased the uptake and translocation of nutrients to fruits (Trevisan et al., 2010). The slow release coupled with constant uptake of nutrients would have a stimulatory effect on the content of nutrients in the fruits receiving organic nutrition through vermicomposting. Zandonadi et al. (2013) reported that humic substances have direct influence on the root morphology and nutrient uptake. Undeniably, composts and vermicomposts from agricultural wastes have proved to be influential sources of natural organic fertilizers (Busato et al., 2012) with biological properties directly affecting the physiological functioning of plants and thereby structural modification unlike that of mineral fertilizers (Zandonadi & Busato, 2012). Significantly higher Ca content in fruits was recorded from plants treated with exotic earthworm (*E. foetida*) worked vermicompost.

Table 5 Effect of organic and inorganic nutrition on chemical properties of rhizosphere soils (0-30cm depth) after the harvest of banana

Treatments	pH	EC dSm ⁻¹	Walkley Black Carbon (%)	Av. N	Av. P	Av. K	Av. Ca	Av. Mg
				(kg / ha)			mg kg ⁻¹ of soil	
S	4.50	0.01	0.59	232.88	35.47	229.84	307.41	90.07
	(0.15)	(0.00)	(0.07)	(3.19)	(1.17)	(26.88)	(4.60)	(0.70)
POP	5.30	0.04	0.76	295.64	72.95	638.38	656.47	90.94
	(0.13)	(0.00)	(0.14)	(5.45)	(1.23)	(92.27)	(4.88)	(1.85)
Ex-P	5.3	0.03	1.18	267.99	62.85	510.44	417.31	93.93
	(0.04)	(0.00)	(0.11)	(5.01)	(1.08)	(65.83)	(19.49)	(1.58)
Ex-E	5.9	0.05	0.98	291.22	63.93	370.98	371.25	90.31
	(0.09)	(0.00)	(0.15)	(12.33)	(1.05)	(17.66)	(10.98)	(1.54)
In-P	5.6	0.02	1.04	280.86	47.08	579.63	540.07	91.59
	(0.04)	(0.00)	(0.04)	(1.91)	(1.91)	(5.17)	(16.96)	(0.65)
In-E	4.8	0.02	0.78	312.58	50.89	410.68	449.64	92.65
	(0.10)	(0.00)	(0.09)	(3.63)	(2.31)	(75.06)	(21.91)	(0.61)
In-C	5.8	0.02	1.26	310.00	33.60	447.21	587.12	103.27
	(0.06)	(0.00)	(0.11)	(15.12)	(0.76)	(20.66)	(7.82)	(0.51)
CD(p=0.05)	0.4	0.001	0.11	26.64	4.56	166.27	46.02	3.74

S: Absolute control; POP: 300:115:450g N:P2O5:K2O/plant + FYM (20 kg/plant); Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with S: Absolute control; POP: 300:115:450g N:P2O5:K2O/plant + FYM (20 kg/plant); Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg / plant); Ex-E: *ex-situ* vermicompost in silpaulin vermibeds with *Eisenia foetida* *Values in parentheses indicate standard error of means; (20 kg / plant); In-P: *in-situ* vermicompost in crop pits with *Perionyx excavatus* (20 kg / plant); In-E: *in-situ* vermicompost in crop pits with *Eisenia foetida* (20 kg / plant) and In-C: *in-situ* compost in crop pits (20 kg / plant)

Table 6 Effect of organic and inorganic nutrition on biochemical properties of rhizosphere soils (0-30cm depth) after the harvest of banana

Treatments	Microbial biomass carbon	Auxin equivalents	Total microbial count	Urease activity	Asparaginase activity	Dehydrogenase activity	Alkaline phosphatase	Acid phosphatase
	$\mu\text{g g}^{-1}$ of soil		10^5 CFU g^{-1} of soil		mg kg^{-1} of soil	$(\mu\text{g TPF day}^{-1} \text{ kg}^{-1})$	$(\mu\text{g PNP g}^{-1} \text{ hr}^{-1})$	
S	80.94 (0.82)	50.80 (1.31)	30.03 (2.14)	62.66 (3.94)	101.61 (1.14)	72.87 (2.57)	25.01 (0.37)	21.86 (0.19)
POP	117.51 (1.41)	128.72 (2.16)	62.04 (11.05)	87.91 (3.23)	163.31 (7.52)	178.81 (4.02)	356.18 (1.35)	622.35 (2.69)
Ex-P	144.68 (5.36)	117.86 (13.20)	109.01 (9.79)	70.90 (1.41)	154.02 (4.05)	143.56 (3.10)	82.48 (7.98)	120.66 (5.68)
Ex-E	268.16 (1.11)	61.21 (0.62)	21.32 (1.39)	87.79 (4.03)	149.65 (6.09)	74.36 (10.74)	183.33 (4.29)	27.40 (0.74)
In-P	280.72 (2.64)	61.43 (0.66)	44.01 (7.39)	101.29 (4.61)	163.68 (5.59)	88.07 (1.46)	35.96 (0.79)	337.30 (4.96)
In-E	504.61 (14.44)	65.82 (3.74)	69.16 (5.48)	100.06 (1.71)	203.42 (5.71)	113.43 (2.78)	28.10 (2.21)	64.09 (3.79)
In-C	427.92 (3.28)	144.14 (2.36)	89.31 (4.24)	141.81 (2.44)	168.29 (11.65)	223.78 (7.03)	60.46 (3.32)	267.20 (7.57)
CD at 5%	17.94	16.73	9.29	8.75	16.13	14.52	11.75	12.35

*Values in parentheses indicate standard error of means; S: Absolute control; POP: 300:115:450g N:P₂O₅:K₂O/plant + FYM (20 kg/plant); Ex-P: *ex-situ* vermicompost in silpaulin vermibeds with *Perionyx excavatus* (20 kg / plant); Ex-E: *ex-situ* vermicompost in silpaulin vermibeds with *Eisenia foetida* (20 kg / plant); In-P: *in-situ* vermicompost in crop pits with *Perionyx excavatus* (20 kg / plant); In-E: *in-situ* vermicompost in crop pits with *Eisenia foetida* (20 kg / plant) and In-C: *in-situ* compost in crop pits (20 kg / plant)

The study shows that combined use of fertilizers and FYM had significant influence on the available nutrient status of the rhizosphere soil particularly the level of N, P, K and Ca (Table 5). Since the availability of P is in plenty, the activity of phosphatase enzyme was significantly higher under mineral fertilizer + FYM treatment. The high concentration of auxins from rhizosphere of banana grown under mineral fertilizer + FYM may be due to the root exudation and microbial production. Different modes of organic nutrition also have significant influence on soil fertility. For example, the *ex-situ* mode of composting using native earthworm *P. excavatus* improved the soil with more content of Walkley Black Carbon, available K and microbial count, whereas soil factors such as pH and available N content of soil were higher under *ex-situ* vermicomposting using exotic worms *E. foetida*.

Under *in-situ* vermicomposting, native earthworms had significant influence on available K content of the soil, whereas available N, microbial biomass, carbon and asparaginase activity was significantly pronounced under *E. foetida* produced wormcasts. Further, *in-situ* composting also had significant influence on rhizosphere pH, Walkley Black Carbon, available nutrients like N and Mg, auxin content, urease and dehydrogenases activities of soil (Table 6). In general, the integrated management practices (mineral fertilizers + FYM) resulted in better yields of banana, but the benefit: cost ratio was more for the crops grown under organic nutrition. The higher benefit: cost ratio under organic banana nutrition can be attributed primarily to the less cost involved in the farming practices compared to mineral fertilizer + FYM treatment and also to premium price for the organic fruits in the market.

Conclusion

The soil ameliorant properties of compost was proved by their pH and calcium content. Besides soil reaction, composts could also effectively manage the chemical and biochemical properties of soil. The quality parameters of banana fruits as well as the soil health were remarkably improved under *in-situ* composting besides assuring the economic viability. Though the integrated management practices (mineral fertilizers + FYM) resulted in better yields of banana, but maximum benefit: cost ratio was reported from the crops grown under organic nutrition. Thus organic nutrition using *in-situ* composting could be considered a promising technology for *in-situ* waste management and organic nutrient recycling.

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