International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(4): 2699-2702

Received: 14-05-2018
Accepted: 21-06-2018

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Recycling of leaf litters on cocoa (*Theobroma cacao* L.) plantation

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Abstract
Field experiment was carried out to standardize the protocol for effective decomposing of cocoa wastes, which includes both leaf litters and pod husk. For these, the experiment comprise of five treatments: cowdung slurry, earthworms, TNAU Biomineralizer, *Phanerochaete chrysosporium* and *Pleurotus sajor-caju.* Data on temperature, pH, electrical conductivity (EC), organic carbon, total nitrogen, carbon: nitrogen ratio, total phosphorus and total potassium were analyzed. The experiment was laid out in a Randomized Block Design (RBD) with four replications. The cocoa waste imposed with *chrysosporium* and *Pleurotus sajor-caju* showed the rapid decomposition rate than compared with other treatments used in the experiment. The nutrient content of N, P, K were found to be more in the treatment with TNAU Biomineralizer followed by *Phanerochaete chrysosporium* and *Pleurotus sajor-caju*.

Keywords: Cocoa waste, cocoa pod husk, cocoa leaf, cocoa waste compost

Introduction

Cocoa, the most important tropical crops belongs to the genus *Theobroma* a group of small trees that occurs as wild in the Amazon basin and other tropical areas of South and Central America. Cocoa is the third important beverage crop next to coffee and tea, which ranks third highest traded commodity in the world after coffee and sugar. The fruit of the cocoa is an important commodity because of the economic value of its beans. Commercial cultivation of cocoa started in India during 1970. This crop is widely grown as intercrop crop in coconut and arecanut gardens in India.

Generally, agro-wastes are converted into composts or farmyard manure before being used in crop production to improve soil fertility. Enrichments in composting improve nutritive value; augment disease suppressive activity and beneficial microbial populations in the composts. Addition of organic matter to soil not only provide plant available nutrients on its decomposition but also offer an energy (carbon) source to the soil ecosystem and build soil fertility and structure in the long run.

Litterfall and litter decomposition and subsequent nutrient release represent major biological pathways for element transfer from vegetation to soils, and play an important role in regulating nutrient cycling, and in maintaining soil fertility in forest and agro-ecosystems (Yang *et al.*, 2003) [21]. For the majority of farmers, fertility of soils under cocoa plantations is maintained through the recycling of nutrients through leaf fall and decomposition of leaf litter (ISSER 2004; Appiah *et al.*, 2006) [2]. A number of factors influence the decomposition process. These comprise: (1) microclimate, mainly temperature and humidity, (2) litter quality, (3) soil nutrient content and (4) the qualitative and quantitative compositions of decomposer communities (Anderson and Swift, 1983) [1]. These factors interact to determine decomposition rates.

The present study is aimed for the generation of nutrient- enriched composts using cocoa leaf litter. However, under normal condition it will take longer time for decomposition. The present investigation was done with the objective to hasten the decomposition process and for obtaining enriched compost from cocoa leaf litter.

Materials and Methods

Field experiment ware carried out at VSR farms, Pollachi, Coimbatore district during 2015-2016. Main materials used were cocoa leaf, cocoa pod husk, cowdung slurry, earthworms, TNAU Biomineralizer, *Phanerochaete chrysosporium* and *Pleurotus sajor-caju*.

The cocoa pod husk collected from the processing yard after beans were extracted and dried leaves were collected from the field were used as substrates or raw material for composting process. Composting method used for the experiment was aerobic composting. The treatment datails were, T_1 (Cocoa leaf waste + cow dung slurry), T_2 (Cocoa leaf waste + Earthworm), T_3 (Cocoa leaf waste + TNAU Biomineralizer), T_4 (Cocoa leaf waste + *Phanerochaete chrysosporium*) and T_5 (Cocoa leaf waste + *Pleurotus Sajor- Caju*) and the similar treatments were followed in case of composting of cocoa pod husk. The CPH was chopped into smaller pieces before composting to reduce the particle size. The temperature, pH and EC of each pile was monitored for four weeks interval until the end of the composting with the use of digital thermometer. The mixtures were turned every fortnight and watered. The organic materials were composted for four months after which they were allowed to cure for two weeks, shredded and bagged for use. At maturity of the composts, samples were randomly taken from each compost type, milled, sieved through a 2 mm sieve and subjected to chemical analysis.

The following analyses were carried out at the end of each of the incubation period. pH and EC were determined in water (1:2 soils: water ratio) and measured in digital meter (Jackson, 1973) [15]. Organic carbon was determined by the method of chromic acid wet digestion (Walkely and Black, 1934). Mineralized total Nitrogen was determined by Kjedahl method (Bremner and Mulvaney, 1982) [6], mineralized available P was extracted from the incubation samples using Bray P method (Olsen *et al*., 1954) and mineralized K was extracted with 1N ammonium acetate at neutral pH and the amount of K were determined using flame photometer (Jackson, 1973) [15]. The data obtained from the above experiments were analysed using Randomized block design (RBD) as suggested by Panse and Sukhatme (1961) [17]. The critical difference was worked out at five per cent probability level and the result were interpreted.

Result and Discussion

All the composts appeared to be granular and dark grey in colour at 120 days of composting. Although colour and odour are the simplest criteria to evaluate the maturity and stability of the compost but for confirmation some physical, chemical and biological parameters were also studied.

Temperature

Changes in temperature at various stages of decomposition of different composting mixtures are shown in table 1. Temperature of all the composts reached maximum (55.8 C – 60.5^0 C and 56.9^{0}C – 62.0 ^{0} C) at 30 days of composting in cocoa leaf and pod husk respectively and it reflected the rapid initiation of composting process and it decreased gradually but remained in thermophilic range (>40 ^{0} C) up to 60 days. It further decreased and reached ambient level between 90 and 120 days of composting in all the treatments and Maximum days of highest temperature was noted in cocoa waste (both leaf and pod husk) treated with *Phanerochaete chrysosporium* (T_4) and *Pleurotus sajor-caju* (T_5). In general, temperature decreased after each turning indicating decrease in easily decomposable organic matter. Therefore, turning of pile, maintenance of moisture at optimum level and addition of easily available carbon sources are necessary to enhance microbial activity during composting (Tiquia *et al*., 1997) [19]. The compost indicates a good degree of stability when temperature during composting approaches the ambient level (Satisha and Devaranjan, 2007) [18]. All the composts attained ambient temperature at 120 days indicating compost stability.

pH

The pH is a good indicator to determine the maturity of compost. The initial pH ranged between 7.26 to 7.74 for various treatments in cocoa leaf waste and 7.68 to 7.90 in cocoa pod husk. In cocoa leaf waste, T_1 recorded highest pH 7.74 at 30 days of study and T_3 recorded lowest pH 7.26. In cocoa pod husk, T_3 recorded highest pH 7.68 at 30 days of study and T_5 recorded lowest pH 7.90 (Table 1). The compost pH is a good indicator of compost maturity. During the initial days of composting, it descends slightly to maintain high pH and later decreases as the material gradually decomposes and stabilities, finally staying between 6.00 and 7.00 (Cardenas and Wang 1980). The pH values were significantly ($P<0.05$) decreased with the increase of days in all the treatments.

Organic Carbon

The organic carbon loss increased with composting time in all the composts due to greater availability of easily biodegradable substances to microbes (Benito *et al*., 2003) [3]. Highest losses of organic matter were observed during first 60 days of composting in all the composts which slowed down thereafter. Maximum losses (31.56% and 21.10 %) of organic matter were observed in cocoa waste treated with *Phanerochaete chrysosporium* (T_5) followed by *Pleurotus sajor-caju* (32.26% and 21.80 %) (T_5), earthworms (32.78% and 22.80%) (T_2), TNAU Biominerlizer (32.87 % and 24.60%) (T_3) and cow dung slurry (34. 12 % and 25.50 %) compost (T_1). This fact indicates that the addition of fungal culture enhanced the decomposition rate of organic matter. The organic matter loss >42% may be accepted as an index value for mature compost. The initial nitrogen content varied between 1.27% and 1.57% in cocoa leaf waste and 0.45% to 0.76% in cocoa pod husk respectively. It was significantly increased ($P<0.05$) and attained maximum value on the 120th day. The statement of Gaur (1982) [13] that the macro and micro nutrients were increased during composting due to the loss of organic carbon content as CO_2. The breakdown of complex organic compounds into simpler compounds due to bio-degradation and conversion of carbon into CO_2 and other by products increased the total nitrogen content in the final matured compost in case of all the five treatments (Table 2).

Total Nitrogen

The nutrient nitrogen is required for the growth and development of plants and the compost manure obtained from the treatment T_3 had a total nitrogen content of 2.21% and 1.87% showing that the bacteria played an effective role in the decomposition process while compared to the total nitrogen content of the samples taken from the other four treatments (Table 2).

Carbon/Nitrogen ratio

As the C:N ratio is widely used as an indicator of compost maturity (Bernal *et al*., 1998) [5]. The C:N ratio of all the compost mixtures decreased substantially till 120 days, and stabilized thereafter. As the decomposition progressed due to losses of carbon mainly as carbon dioxide, the carbon content of the compostable material decreased with time and N content per unit material increased which resulted in the decrease of C:N ratio. The cocoa waste composts showed more rapid decrease in C:N ratio than the farm waste compost. Addition of agro-industrial wastes as organic additives might have helped in increasing biological activity. At 120 days of composting, highest C:N ratio (17. 15 and 15.27) was recorded in cowdung slurry (T_1) followed by earthworm (T_2) (16.23 and 13.49), TNAU Biominerlizer (T_3) (14.87 and 13.16), *Pleurotus sajor-caju* (T_5) (15.51 and 12.60) and *Phanerochaete chrysosporium* (T_4) (14.68 and 11.79) respectively in both cocoa leaf and pod husk. Previous researchers reported that a C:N ratio below 20 was assumed to be indicative of maturity compost (Golueke, 1981) [14], and a ratio of 15 or less is preferable (Morel *et al*., 1985; Bernal *et al*., 2009) [16, 4]. By considering this criterion, and *Phanerochaete chrysosporium* (T_4), *Pleurotus sajor-caju* (T_5) and TNAU Biominerlizer (T_3) composts showed their maturity at 120 days (Table 2).

Total Phosphorus

The observations made on total phosphorus during decomposition of cocoa waste showed that there had been gradual increase in total phosphorus from the initiation of study till completion and it was significant at $P<0.05$ level. The initial concentration of phosphorus varied between 0.55% in T_1 and 0.73% T_4 were observed in cocoa leaf waste. Similarly, concentration of phosphorus varied between 0.43% in T_1 and 0.66% T_4 were observed in cocoa pod husk after 30 days of composting. The change in phosphorus content during the course of decomposition process is agreeable with the findings (Elango *et al.*, 2009) [10]. The highest concentration of total phosphorus (0.99% in cocoa leaf waste) and (1.21% in cocoa pod husk) in the compost obtained from the treatment T_3 (TNAU Biominerlizer) had shown that this has highest efficiency in bringing the decomposition of cocoa leaf waste and mineralization of organic phosphorus when compared to other treatments used for composting (Table 3).

Total Potassium

The potassium is a valuable plant nutrient, which is immobilized, in organic matter. During the bio- degradation of organic matter, the potassium is liberated and the end product of the bio-compost contains potassium in the available form composting (Table 3). Potassium is highly soluble in nature and its concentration increases with progressing of decomposition (Gallando and Nogales 1987) [12]. The concentration of total potassium set a slow and steady increase significantly ($P<0.05$) in case of all the five treatments while the decomposition had been progressing and attained stable values on completion of decomposition. The experimental results in this study were found to have similarity with the findings of Gallando and Nogales 1987 [12].

Table 1: Changes in temperature and pH values during composting of cocoa leaf litter

Treatments	Temperatures (^{0}C)				pH			
	Sampling periods (Days)				Sampling periods (Days)			
	30	60	90	120	30	60	90	120
T_1	60.5	41.9	34.5	25.4	7.74	7.14	6.75	6.12
T_2	57.9	49.0	35.2	24.9	7.54	7.09	6.67	6.09
T_3	55.8	50.9	36.4	26.9	7.26	7.15	6.81	6.24
T_4	59.1	51.2	39.2	28.1	7.31	7.1	6.72	6.13
T_5	58.6	53.6	37.5	22.0	7.50	7.06	6.60	6.12

Table 2: Changes in organic carbon content, total nitrogen and C:N ratio during composting of cocoa leaf litter

Treatments	Organic carbon content (%)				Total Nitrogen (%)				C:N ratio			
	Sampling periods (Days)				Sampling periods (Days)				Sampling periods (Days)			
	30	60	90	120	30	60	90	120	30	60	90	120
T_1	38.64	35.94	35.56	34.12	1.36	1.43	1.67	1.99	28.41	25.13	21.29	17.15
T_2	38.12	35.79	35.45	32.78	1.27	1.49	1.78	2.02	30.02	24.02	19.92	16.23
T_3	38.47	36.98	33.45	32.87	1.57	1.7	2.05	2.21	24.50	21.75	16.32	14.87
T_4	36.76	34.94	33.29	31.56	1.45	1.68	1.98	2.15	25.35	20.80	16.81	14.68
T_5	37.21	35.98	33.68	32.26	1.39	1.56	1.84	2.08	26.81	23.06	18.30	15.51

Table 3: Changes in total phosphorus and total potassium contents during composting of cocoa leaf litter

Treatments	Total phosphorus (%)				Total potassium (%)			
	Sampling periods (Days)				Sampling periods (Days)			
	30	60	90	120	30	60	90	120
T_1	0.55	0.58	0.62	0.64	0.31	0.45	0.70	0.95
T_2	0.59	0.60	0.66	0.69	0.20	0.47	0.81	1.19
T_3	0.63	0.68	0.93	0.99	0.37	0.59	0.96	1.10
T_4	0.73	0.86	0.92	0.96	0.23	0.51	0.89	1.20
T_5	0.60	0.63	0.71	0.75	0.27	0.53	0.85	1.07

Conclusion

The decomposition of cocoa wastes (both leaf and pod husk) helps to produce large quantity of good quality compost, which can be effectively used in field as a fertilizer, thereby the pressure on chemical fertilizers for various farming activities can be reduced and good quality of products free from chemical residues can be produced. Out of various organisms used for decomposing cocoa wastes and application of those composts in crop production had shown that promising results could be obtained from the application of compost produced by *Phanerochaete chrysosporium* and *Pleurotus sajor-caju*.

Acknowledgement

We acknowledge the technical and financial support of the Tamil Nadu Agricultural University, Coimbatore, Mondelez International Foods Private Limited and Microbial Type Culture collection (MTCC) IMPECH, Chandigarh.

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