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Mineralization of Thippi (Cassava Starch Factory Solid Residue) Compost Under Incubation

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Abstract

Cassava (*Manihot esculenta* Crantz) is an important tropical tuber crop, the tubers of which are used both for edible purpose and for industrial uses. In Tamil Nadu, more than 500 cassava based small to large scale starch and sago producing factories are generating more than 250 tonnes of solid residue called 'thippi' per annum. This is an environmental pollutant affecting soil and human health and was found very difficult to dispose too. At ICAR-CTCRI, the same was converted to a nutritious organic manure through different composting methods where comosting resulted in the highest nutrient increase and the C: N ratio narrowed to 8:1 from 82:1. Experiments conducted in cassava showed its suitability as a good organic manure alternative to the commonly used organic manures like farm yard manure, green manuring *in situ* with cowpea, vermicompost, coir pith compost and crop residue as well as can substitute for 50% of the NPK requirement as per package of practices (PoP) and secondary nutrient Mg and micronutrient Zn to a great extent. While using any organic manure, the decomposition of the same to release the nutrients (mineralization) especially during the critical growth stage of the crop or as per the nutrient requirement of the crop needs to be understood. Hence, to understand the nutrient release pattern of thippi compost, a pot study was conducted by incubating the soil mixed with thippi compost and analysed the soil samples at monthly intervals for pH, organic carbon, electrical conductivity (EC), available N, P and K, exchangeable Ca, Mg, Fe, Cu, Mn and Zn for one year. The mean data of the soil chemical properties for one year indicated the pH, EC, available N, P and K, exchangeable Ca, Mg, available S, Fe, Cu, Mn, Zn and B increased to the tune of 0.64, 0.055 dS m^{-1}, 99.8, 46.1, 87.2 kg ha^{-1}, 0.73, 0.99 meq $100g^{-1}$, 15.8, 9.4, 0.18, 1.07, 3.07 and 0.19 mg kg^{-1} which in turn was 13.8 , 35.4, 46, 88.3, 107.5, 68.2, 176.7, 158, 23.5, 16.4, 72.8, 56.7 and 17.9% over the initial status. Among the nine composting options, vermicomposted thippi compost had the highest nutrient release and the maximum nutrient release was found during 5 to 8th month of incubation.

Key words: Thippi, sago, starch, vermicomposting, environmental pollutant, nutrient release, C: N ratio

Introduction

While cassava is a crop of food security in Kerala, by virtue of its diversified uses, it has become an important commercial crop in the agricultural economy of the states like Tamil Nadu and Andhra Pradesh. Among the different value added products from cassava, starch and sago are the commercially important products manufactured in Tamil Nadu. Establishment of cassava based sago and starch industry in Tamil Nadu is the result of the decline in sago and starch import from Singapore, Malaysia, Holland, Japan and U.S.A during the second world war period. In Tamil Nadu, starch and sago production units were first started in 1943. By 1945, production of sago and starch increased appreciably resulting in the fast expansion of the industry. During 2008-09, there were about 800 sago industries in Tamil Nadu with 700 industrial units constituting 89.5 percent of the total national production in Salem District alone (Ramachandran, 2014). Production of starch and sago from cassava tubers involves lot of processing resulting in the discharge of huge quantity of both solid and liquid residue which in turn are pollutants having disastrous effect on natural resources especially in areas where the industry is highly concentrated. As regards to the liquid residue called ‘effluents’, large factories have well built sewage tanks and treatment facilities for its safe disposal. But in the case of small scale production units, the residual water usually flow towards the nearby water bodies or canals, resulting in serious environmental pollution.

The solid fibrous residue discarded along with the liquid effluent during crushing of fresh tubers for starch extraction during cassava processing is called ‘thippi’. According to the recent estimates of starch suppliers and manufacturing traders, there are more than 800 starch producing and about 550 sago producing units in Salem and Namakkal districts and all these are generating about 250 tonnes of solid residue per annum (Ramachandran, 2014). If this residue is not properly managed, it will cause serious environmental pollution especially during the rainy season with a foul smell and the leachate from the heap contaminate the ground water. According to Sriroth et al., (2000), dealing this residue is difficult, as it is not easily dried due to its high moisture and starch contents. Under a research project undertaken at ICAR-CTCRI, we have attempted different composting procedures and converted it into a nutritious organic manure. Vermicomposting resulted in the best compost with a C:N ratio 8:1and the mean N, P, K, Ca, Mg, Fe, Mn, Cu and Zn content in thippi compost was 1.32, 3.82, 0.40, 2.18, 0.96, 1.11, 0.08%, 11.23 and 89.93 mg kg^{-1} respectively which was 3.5, 49, 7, 32.5, 8, 185, 100, 2.5 and 12 times more than thippi (Chithra et al., 2017). Application of this compost in cassava for two seasons indicated it as a good substitute to the commonly used organic manures like farm yard manure (FYM), green manuring *in situ* with cowpea, vermicompost, crop residue and coir pith compost. Moreover, this compost can substitute 50 percent of the recommended NPK as per package of practices (PoP) as well as secondary nutrient (Mg) and micronutrient (Zn) as $MgSO_4$ and $ZnSO_4$ @ 2.5 kg ha^{-1} each (Susan John et al., 2019).

According to Chae and Tabatabai (1986), while applying any manure or compost to fulfil the nutrient requirement of a crop, knowledge on the amount of nutrients mineralized following application is needed. Though the nutrient mineralization from applied manure depends on many abiotic and biotic factors, since these factors cannot be accurately predicted, it can only be approximated (Eghball, 2000). Helgason et al., (2007) stated that, when a manure is used as source nutrients, knowledge on the mineralization rate under field conditions is needed. Mamo et al., (1999) was of the opinion that, for effectively utilizing the nutrients in a manure, the mineralization potential should be considered while determining the application rates. Since nutrient release from decomposition of organic manures are very important to understand its utility on field application especially with respect to the availability of the released nutrients in soil solution for plant uptake, we have studied the mineralization pattern of thippi compost by incubating it with soil for one year and determined the release of all nutrients at monthly intervals. The objective was to evaluate the best compost out of the nine with respect to the amount of nutrients released over the initial status and the month of incubation at which there is maximum availability of all nutrients.

Materials and Methods

The treatments details are given in Table 1.

Microbial consortium used contained *Trichoderma* sp., P and K solubilizers, the residue management culture was a ready made mixed inoculum containing nutrient use efficient microbes viz., N fixer (*Bacillus cereus*), P solubilizer (*Bacillus megaterium*) and K solubilizer (*Bacillus subtilis*). The earth worm species used was *Eudrilus euginea*. Composting was done for period of two months.

The nine composts made as per the details given in Table 1 were used for the study. The thippi composts from the nine different treatments (350 g) were mixed with soil (laterite soil of good physico-chemical properties) (6 kg) per pot and incubated in fibre pots of 25 x 30 x 30 cm dimension. The quantity of thippi compost was arrived based on N equivalent of the compost to give an N recommendation of 100 kg ha^{-1} along with FYM @ 12.5 t ha^{-1} for cassava. During composting, proper moistening as per the estimated water holding capacity of the thippi compost and was kept under normal atmospheric temperature only. Soil samples were drawn from each pot before mixing it with compost to evaluate the initial nutrient status. The experiment was replicated twice and soil samples were drawn monthly from each pot for 12 months and were analysed for chemical characters viz., pH, EC, OC, available N, P, K, Ca, Mg, S, Fe, Cu, Zn, Mn and B (Page et al., 1982).

Table 1. Treatment details of composting thippi with other organic/inorganic materials

Treatment	Components	Culture/Organisms used	Ratio
T1	Thippi, cowdung, Mussooriphos, rock powder	Microbial consortium	5:1:0.1:0.1
T2	Thippi, cowdung, Mussooriphos, rock powder	Earthworm (100 g)	5:1:0.1:0.1
T3	Thippi, cowdung, Mussooriphos, rock powder	Residue management culture	5:1:0.1:0.1
T4	Thippi, cowdung, G*lyricidia* leaves, cassava leaves, Mussooriphos, rock powder	Microbial consortium	5:1:0.5:0.5 0.1:0.1
T5	Thippi, cowdung, G*lyricidia* leaves, cassava leaves, Mussooriphos, rock powder	Earthworm (100 g)	5:1:0.5:0.5 0.1:0.1
T6	Thippi, cowdung, G*lyricidia* leaves, cassava leaves, Mussooriphos, rock powder	Residue management culture	5:1:0.5:0.5 0.1:0.1
T7	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder	Microbial consortium	5:1:1:0.1:0.1
T8	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder	Earthworm (100 g)	5:1:1:0.1:0.1
T9	Thippi, cowdung, *Azolla*, Mussooriphos, rock powder	Residue management culture	5:1:1:0.1:0.1

Results and Discussion

The important details studied included the initial nutrient status of the soil filled in the pots, the effect of different treatments, period of incubation and their interaction on the increase/decrease in the soil chemical parameters over the initial status.

Initial chemical properties of the soil

Chemical analysis of the initial soil samples indicated the pH, EC, OC as 4.62, 0.153dSm^{-1} and 1.77% respectively. The primary nutrients N, P, K were to the tune of 216.87 kg ha^{-1}, 52.18 kg ha^{-1}, 81.14 kg ha^{-1} and secondary nutrients viz., available Ca, Mg and S were observed to the tune of 1.07 meq100 g^{-1}, 0.56 meq100 g^{-1}, 10.03 ppm and the micronutrients Fe, Cu, Zn, Mn and B were 40, 1.1, 1.47, 5.41 and1.06 ppm respectively. In general, the soil is acidic, with high organic carbon, available P, S, Fe, Cu, Mn, Zn and B with low available N, K, exchangeable Ca and Mg.

Effect of treatments on release of major and secondary nutrients

As regards to the influence of the compost made through different methods on the nutrient release, it is seen that, there was significant effect on all chemical parameters.

Though the pH seems to be similar under different treatments, there was significant difference among treatments with T3 (5.32) having the highest pH on par with T2, T4, T5, T6, T7 and T9. The pH was minimum under T8 (5.15). The increase in soil pH from 4.62 to above 5 is a good indication of correcting soil acidity towards neutral facilitating better nutrient release and availability as per the reports of Fan and Li (2010) that, soil with a minimum pH value of 5-6.25 is ideal for plant nutrient uptake. The substantially good increase in soil pH noted with thippi compost under different treatments can be justified as per Ahmed et al., (2007) that, the raw materials used in preparing compost have a direct role in decreasing or increasing the pH level of the soil. Rise in soil pH under vermicomposting can be justified as per Edwards and Bohlen (1996) and Lukkari et al., (2006) that, in earthworm mediated composting, the organic matter gets digested resulting in an increase in both pH and microbial activity. Electrical conductivity (EC) was significantly higher under T9 (0.216 dS m^{-1}) and was on par with T5 and T8. This in turn corroborates to the reports of Broschat and Moore (2007) that, compost prepared with rich green and organic matter can increase the cation exchange capacity of soils, enabling the soils to hold more plant nutrients for longer periods. Though the CEC of the incubated soil is not analysed, the increase in EC in terms of the soluble salts made available in soil solution resulted in concomitant increase in CEC.

As regards to all nutrients and organic carbon, T5 involving earthworm mediated composting had significantly the higher nutrient content over others (Table 2a, 2b). The data given in Table 2a is mean over one year treatment wise. In the case of organic carbon, the month wise data for each treatments revealed increase in soil organic carbon content till 5th month and thereafter decrease (Chithra, 2019). This can be attributed to the reports of Manivannan et al., (2009) that, the addition of organic residues increase the soil organic carbon level initially and with the course of time,

Table 2a. Nutrient release from thippi composts under different treatments over a period of one year (Mean of 12 months)

Treatment	pH	EC	OC	N	P	K	Ca	Mg	S
		dS m^{-1}	%		kg ha^{-1}		meq 100g^{-1}		mg kg^{-1}
T1	5.17^{bc}	0.202^{c}	1.59^{bc}	298.0^{d}	99.8^{ab}	175.8^{ab}	1.79^{b}	1.51^{c}	25.6^{b}
T2	5.31^{a}	0.207^{bc}	1.58^{bc}	290.4^{d}	98.8^{bc}	166.1^{bcd}	1.83^{b}	1.52^{c}	25.0^{b}
T3	5.32^{a}	0.206^{bc}	1.52^{cd}	303.6^{d}	97.3^{cd}	164.0^{cd}	1.81^{b}	1.57^{b}	24.9^{b}
T4	5.28^{a}	0.209^{b}	1.65^{b}	359.5^{ab}	99.9^{ab}	171.5^{abc}	1.81^{b}	1.58^{b}	25.6^{b}
T5	5.30^{a}	0.209^{ab}	1.73^{a}	364.2^{a}	101.8^{a}	178.6^{a}	1.91^{a}	1.64^{a}	28.4^{a}
T6	5.29^{a}	0.204^{bc}	1.65^{b}	334.5^{bc}	96.4^{cd}	165.9^{bcd}	1.81^{b}	1.6^{b}	26.2^{b}
T7	5.30^{a}	0.208^{b}	1.50^{d}	312.7^{cd}	98.3^{bc}	167.1^{bcd}	1.82^{b}	1.5^{c}	25.5^{b}
T8	5.15^{c}	0.211^{ab}	1.51^{d}	295.2^{d}	95.1^{d}	160.9^{d}	1.76^{b}	1.46^{c}	25.5^{b}
T9	5.23^{ab}	0.216^{a}	1.55^{cd}	292.6^{d}	97.1^{cd}	164.4^{cd}	1.79^{b}	1.53^{c}	25.7^{b}

Table 2b. Nutrient release from thippi composts under different treatments over a period of one year (Mean of 12 months)

Treatment	Fe	Cu	Zn	Mn	B
			mg kg^{-1}		
T1	49.32^{ab}	1.24^{b}	2.27^{c}	8.31^{bc}	1.25^{bc}
T2	49.27^{ab}	1.26^{b}	2.28^{c}	8.34^{bc}	1.21^{cd}
T3	49.78^{ab}	1.28^{ab}	2.67^{b}	8.49^{bc}	1.26^{bc}
T4	48.54^{b}	1.34^{a}	2.69^{b}	8.36^{bc}	1.27^{bc}
T5	50.88^{a}	1.33^{a}	2.93^{a}	9.03^{a}	1.33^{a}
T6	49.97^{ab}	1.29^{ab}	2.55^{b}	8.43^{bc}	1.19^{cd}
T7	50.26^{ab}	1.27^{ab}	2.46^{bc}	8.62^{ab}	1.27^{bc}
T8	48.59^{b}	1.29^{ab}	2.49^{bc}	8.65^{ab}	1.2^{cd}
T9	48.36^{b}	1.28^{ab}	2.55^{b}	8.04^{c}	1.16^{d}

its content decreases in soil. If the decomposing organisms like earthworms are used, it will facilitate faster mineralization of N, P, K and other essential nutrients. The results obtained under this study support the findings of Huett and Gogel (2000) that, compost mineralization rates will vary depending upon the compost, soil characteristics, environmental conditions, nutrient percentage of raw materials used and decomposing organisms. It is seen that, the mean N, P, K, S, Fe and Mn status of the soil after application of different types of thippi compost was to the tune of 316.7, 98.3, 168.3 kg ha^{-1}, 25.8, 49.4 and 8.48 ppm and the per cent increase over the initial status was 46, 88.3, 107.5, 158, 23.5 and 56.7 % respectively (Fig.1).

In the case of pH, EC, organic carbon, available Ca, Mg, Cu, Zn and B, the mean soil status after application of thippi compost over a period of one year was 5.26, 0.208 dS m^{-1}, 1.59%, 1.82, 1.55 meq 100g^{-1}, 1.28, 2.54 and 1.25

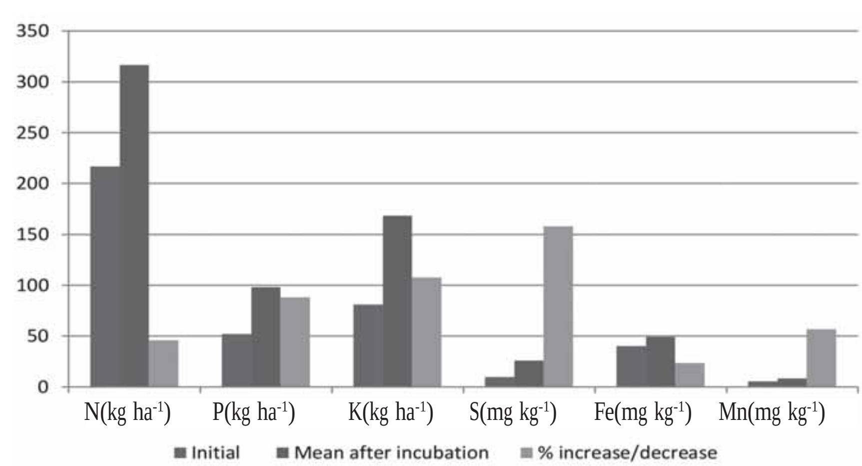

Fig. 1. Effect of thippi compost on the release of available N, P, K, S, Fe, Mn

mg kg^{-1} which in turn was 13.8, 35.94, -11.3, 68.2, 176.7, 16.4, 72.8 and 17.9 percent over the initial soil status (Fig.2) (Chithra et al., 2016) . The increase in primary, secondary and micronutrient status of soil over initial value was due to the mineralization of nutrients from compost to soil. Hadas (1997), described mineralization of composted manure as first order reaction kinetics because nitrogen mineralization generally occurs in two phases, a rapid exponential immobilization or mineralization phase, followed by a slow linear mineralization phase. The C: N ratio of the composted manure determines whether immobilization or mineralization will dominate in the early stages of decomposition. As the C: N ratio of the prepared thippi compost was 8:1, it has resulted in proper mineralization process. Among the different soil properties, the decrease was noted only in soil organic carbon content after incubation and is attributed to the reports of Aggelides and Londra (2000) that, in late incubation periods, a noticeable decrease in percentage of organic carbon was seen, probably due to more substrate demands of microorganisms in soil.

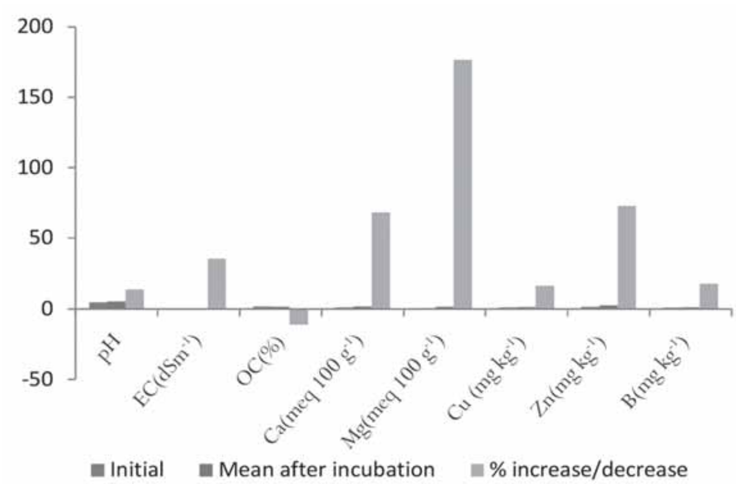

Fig. 2. Effect of thippi compost on pH, EC,OC and release of available Ca, Mg, Cu, Zn, B

Effect of incubation period on release of nutrients

The period at which the maximum release of nutrients takes place is very important with respect to its application under field condition. Table 3a depicts the month at which there was maximum release of nutrients from thippi compost. In the case of pH, the peak was observed during 8th month (5.7) and afterwards it declined. According to Kochba et al., (1990), composts usually act as a buffer without causing much change in pH, but in acidic soils, pH is slightly increased due to absorption of enough ions bringing the pH closer to neutral and further increase with time. It is seen that, EC and organic carbon status attained significantly the highest value by 5th month and thereafter reduced gradually

Table 3a. Nutrient (Major and secondary nutrients) release over 12 months under pot incubation with thippi compost (Mean of treatments)

Period	pH	EC	OC	N	P	K	Ca	Mg	S
(Months)		dS m^{-1}	%		kg ha^{-1}		meq100g^{-1}		mg kg^{-1}
0	4.64^{h}	0.153^{f}	1.77^{bc}	216.9^{h}	52.18^{j}	81.42^{j}	1.06^{i}	0.566^{j}	10.03^{i}
1	4.55^{i}	0.157^{f}	1.43^{f}	127.2^{j}	70.57^{i}	92.58^{i}	1.09h^{i}	0.619^{j}	11.16h^{i}
2	4.84^{g}	0.152^{f}	1.63^{d}	143.3^{j}	75.49^{h}	103.54^{h}	1.12h^{i}	0.679^{i}	12.07^{h}
3	5.01^{f}	0.153^{f}	1.52^{e}	241.5^{gh}	81.99^{g}	135.52^{g}	1.16^{h}	0.931^{h}	17.24^{g}
4	5.51^{c}	0.222^{e}	1.83^{b}	182.2^{i}	93.71^{f}	143.86^{fg}	1.24^{g}	1.63^{g}	21.32^{f}
5	5.62^{ab}	0.254^{a}	2.05^{a}	407.7^{d}	103.52^{d}	172.11^{e}	1.37^{f}	1.84^{e}	25.09^{e}
6	5.31^{de}	0.227^{cde}	1.32^{g}	362.7^{e}	111.82^{c}	200.17^{d}	1.82^{e}	1.95^{d}	32.57^{c}
7	5.63^{a}	0.234^{bc}	1.81^{b}	518.3^{b}	118.89^{b}	222.88^{c}	2.41^{b}	2.09^{c}	37.07^{b}
8	5.7^{a}	0.231^{bcd}	1.63^{d}	305.8^{f}	126.39^{a}	282.16^{a}	2.83^{a}	2.28^{b}	42.53^{a}
9	5.55^{bc}	0.225^{de}	1.71^{cd}	561.3^{a}	128.84^{a}	267.05^{b}	2.89^{a}	2.47^{a}	42.95^{a}
10	5.41^{d}	0.237^{b}	1.72^{c}	484.3^{c}	109.75^{c}	195.38^{d}	2.44^{b}	1.73^{f}	32.65^{c}
11	5.29^{e}	0.229^{cd}	1.34^{g}	302.3^{f}	104.68^{d}	167.78^{e}	2.26^{c}	1.66^{g}	28.82^{d}
12	5.34^{de}	0.228^{cd}	0.911^{h}	264.3^{g}	99.73^{e}	153.44^{f}	2.91^{d}	1.65^{g}	22.07^{f}
Mean	5.26	0.208	1.59	316.7	98.3	168.3	1.82	1.55	25.8

till 12th month. De Neves et al., (2000) was of the view that, compost can absorb enough ions to enhance EC and is useful in monitoring the mineralization of organic matter in soil as they are correlating factors and have parallel effects on soil.

In the case of major nutrients viz., N, P and K, maximum availability was found during 5 to 8th month. According to Bernal and Kirchmann (1992) and Hammac et al., (2007), the mineralization or immobilization of organic N in soil is a function of the decomposability of C compounds in the amendment. In our study, a temporary net immobilization of mineral N, P and K during the first four months of incubation was noticed and it may be because of the high carbon rich organic compound added along with thippi during compost preparation. The N immobilization seen under the present study with thippi, (being an organic C rich substrate) adheres to the studies of Medina et al., (2008) that, incorporation of organic amendments rich in organic carbon as main components in the preparation of compost will directly affect the mineralization pattern of nutrients during its application in soil. In this study with Mussooriphos (inorganic P) as the source of P added while composting, maximum availability of P was noticed during 6 to 7th month of incubation and this in turn corroborates the findings of Eghball (2002) that, P availability from all animal manures is high ($> 70\%$), as most of the manure P is inorganic form and becomes available to plant after 4 to 5 months of application. Decrease in P availability seen after 8 to 9th month may be due to the soil microbial activity resulting in immobilization of available soil P as reported by Meadows and Fuller (1983). The dissolution of Mussooriphos (rock phosphate) under the acidic condition created by the decomposition of organic manure favoured the release of sufficient P in soil solution in the available form. Rock powder containing K in the fixed form was used as a substratum for the K solubilizers to act and release the available K in soil solution which in turn increase the mineralized K during incubation. Moreover, certain beneficiary soil microorganisms such as N fixers, P solubilizers and K mobilizers play key roles in the case of N, P and K nutrient release and make them available to plants, whereas this is lacking with secondary and micronutrients (Shaviv, 2005).

Data on the release of secondary and micronutrients from various thippi composts revealed that, (Table 3b) the maximum availability of these (mean of nine composts) nutrients in the soil is during 8-11th month and not rapid as in the case of primary nutrients (Chithra et al., 2013).

Table 4 gives in nut shell regarding the initial soil status with respect to the nutrients, the nutrients present in the thippi compost, maximum chemical parameter or nutrient present after incubation, which treatment gave the highest nutrient content and the time at which there was maximum availability after application. The Table clearly depicts that, vermicomposting (T5) as the best in terms of maximum release with respect to all nutrients.

Table 3b. Nutrient (micronutrients) release over 12 months under soil incubation with thippi compost

Period (Months)	Fe	Cu	Zn	Mn	B
	mg kg^{-1}				
0	39.98^{g}	1.11^{e}	1.47^{g}	5.41^{j}	1.06^{e}
1	42.09^{fg}	1.16^{d}	1.52^{fg}	5.95^{i}	1.05^{e}
2	43.56^{ef}	1.19^{cd}	1.58^{efg}	6.21^{hi}	1.23^{d}
3	45.63^{cde}	1.21^{cd}	1.64^{efg}	6.57^{h}	1.22^{d}
4	46.03^{cd}	1.32^{b}	1.72^{defg}	7.89^{fg}	1.41^{c}
5	47.41^{c}	1.34^{b}	1.84^{de}	8.75^{e}	1.49^{b}
6	54.05^{b}	1.36^{b}	1.98^{d}	9.74^{d}	1.57^{a}
7	63.12^{a}	1.43^{a}	4.35^{a}	10.51^{c}	1.63^{a}
8	63.68^{a}	1.44^{a}	4.58^{a}	11.35^{b}	1.61^{a}
9	64.16^{a}	1.43^{a}	4.52^{a}	12.19^{a}	1.609^{a}
10	46.65^{cd}	1.25^{c}	3.66^{b}	9.72^{d}	0.995^{e}
11	44.97^{de}	1.21^{cd}	2.39^{c}	8.24^{f}	0.721^{f}
12	41.41^{fg}	1.17^{d}	1.79^{def}	7.61^{g}	0.589^{g}
Mean	49.4	1.28	2.54	8.48	1.25

Table 4. An over view of the release pattern of nutrients under incubation with thippi compost

Para-meters	Initial nutrient status of the soil filled in pot	Status/ content in thippi compost	Treatments showing highest soil nutrient availability	Month of maximum nutrient availability (Months after application)	Content of maximum nutrient availability in soil	% increase in soil nutrient availability over initial
pH	4.62	7.82	T7,T3	8	5.71	24
EC	0.153dS m^{-1}	4.1d Sm^{-1}	T9	5	0.25 dS m^{-1}	31
OC	1.77%	10.3%	T5	5	2.05%	16
N	216.87 kg ha^{-1}	2.09	T5	9	561.26 kg ha^{-1}	159
P	52.18 kg ha^{-1}	1.63%	T5	8	126.40 kg ha^{-1}	142
K	81.14 kg ha^{-1}	0.49%	T5	9	267.06 kg ha^{-1}	229
Ca	1.07meq100 g^{-1}	2.67%	T5	8, 9	2.90 meq100g^{-1}	171
Mg	0.56meq100 g^{-1}	1.4%	T5	9	2.47 meq100g^{-1}	339
S	10.03 µg g^{-1}	-	T5	8, 9	42.95 µg g^{-1}	328
Fe	40 µg g^{-1}	1.23%	T5	7,8 ,9	64.16 µg g^{-1}	60
Cu	1.1 µg g^{-1}	1.23%	T4, T5	7,8, 9	1.44 µg g^{-1}	31
Zn	1.47 µg g^{-1}	49.6 µg g^{-1}	T5	7,8,9	4.58 µg g^{-1}	212
Mn	5.41 µg g^{-1}	121.3 µg g^{-1}	T5	9	12.19 µg g^{-1}	125
B	1.06 µg g^{-1}	850.8 µg g^{-1}	T5	6,7,8, 9	1.63 µg g^{-1}	54

The highest availability was seen during 5-9th month in the case of most of the nutrients. Taking into account the maximum availability of each chemical parameter, it was seen that, there is substantial increase in soil nutrient status due to thippi compost application thus affirming the suitability of vermicomposted thippi as one of the best organic manure sources for crops (Chithra et al., 2019).

Conclusion

Environmental pollutants from industries are nowadays a challenge for the existing biodiversity either plant, animal or microbes. This paper narrated the way this was handled for cassava starch factory solid residue (thippi). Nine different types of composts were prepared by altering the components intended for making compost as well as the agents for composting. These composts were found as much nutritious with respect to the nutrients contained in it. For field use of any organic manures, decomposition and release of nutrients is of paramount importance especially with respect to the maximum availability for plant uptake and the month after application during which there is highest release. The incubation study we have conducted for a period of one year using the nine different thippi composts clearly revealed earthworm (vermi) composting as the best and the extent of release of all nutrients was found better during 5-9 months. In this regard, the critical growth stage of the crop with respect to vegetative and yielding periods are important. Thippi composted through vermicomposting was found as the best with respect to highest nutrient release for plant uptake, which can be recommended for field application. Similarly, as the decomposition was found better since five months, it can be very well recommended for annual crops especially tuber crops having 8-10 months duration where the maximum nutrient requirement is usually at 4-5 month growth stage coinciding with the highest nutrient release as evidenced from the two seasons experiment in cassava. In the case of perennials, vegetables and short duration crops below six months duration, the residual nutrients retained in the soil on decomposition can definitely help which in turn require full proof studies before recommendation. Popularising the thippi composting technology to farmers is relevant and important in the context of 'wealth from waste'.

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