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Comparison of Sago Pith Waste Vermicompost Characteristics to Vermicomposts of Different Feedstock in Malaysia

Elton T.[1], A.B. Rosenani [1*], C.I. Fauziah[1] and J. Kadir[2]

[1]Department of Land Management, [2]Department of Plant Protection
Faculty of Agriculture, Universiti Putra Malaysia
43400 Serdang, Selangor, Malaysia

ABSTRACT

The vermicompost industry in Malaysia has grown rapidly in recent years. However, there is a lack of documentation on the quality of commercially available vermicomposts; moreover, there are no guidelines for the production of quality vermicomposts. Therefore, a trial was conducted in Universiti Putra Malaysia to convert sago pith waste into a value-added organic fertilizer through vermicomposting using cow, goat and horse dung manure as co-composting materials. Two types of sago pith waste vermicomposts were produced in Universiti Putra Malaysia and compared with fifteen different vermicomposts available in the market. The chemical characteristics of these vermicomposts were determined. Results showed that pH of the vermicomposts ranged from 4.5-6.5 indicating significant difference between the different feedstock. The macronutrients of the different vermicomposts varied greatly, that is, total N, total P and total K were 1.5-2.16, 0.54-1.89 and 0.39-1.73%, respectively. Humic acid concentration in the vermicomposts ranged from 16.7- 24%. Study results indicate that the chemical properties of the vermicomposts varied according to the type of initial feedstock and earthworms used and the vermicomposting procedure adopted.

Keywords: Agricultural waste, earthworms, vermicompost.

INTRODUCTION

There has been a rapid increase in agricultural activities in Malaysia. The growth in agriculture has led to increased production of waste materials which can lead detrimental environmental impacts. There is a dire need to put in place a sustainable agrowaste management system. An agrowaste that is of increasing concern is sago pith waste. Lai *et al.* (2013) estimated that 52, 000 tonnes of sago pith waste were produced in 2011.

Vermicomposting is a globally popular option for converting these wastes into a value added product and consequently reducing environmental problems. Vermicomposting is a process where earthworms consume organic residue to produce vermicompost that is also known as vermicast. As vermicompost is a type of soil conditioner that has high nutrient bioavailability for plant growth and can improve soil health for sustainable agriculture. According to Pramanik

*Corresponding author : E-mail: rosenani@upm.edu.my

et al. (2007), vermicomposting offers rapid recovery of valuable resources from biodegradable wastes (plant residue) within a short decomposition period and generate humus-like vermicompost.

Currently, the vermicompost industry in Malaysia is growing due to the increasing demand for organic fertilizers from organic farms and also home gardening. The different types of feedstock currently used in Malaysia for vermicomposting are easily available agricultural wastes such as rice straw, sawdust, oil palm empty fruit bunch and spent mushroom substrate while the co-composting material used are cow, goat and horse dung manure. Examples of feedstock used for commercially available vermicomposts are spent mushroom media (Moore and Chiu 2001), toxic cassava peels (Mba 1996), and rice residue (Shak *et. al.* 2013)

Although the vermicomposting industry has been in existence for several years in Malaysia, there is still lack of documented information and data on the nutrient characteristics and quality of vermicomposts as well as guidelines for quality production of vermicomposts and quality control for the benefit of both the producers and consumers. The lack of guidelines could lead to the production of low quality vermicomposts and marketing of immature vermicomposts. Currently, there is no quality assurance for vermicomposts sold in the market although these composts enjoy a higher price compared to the common organic fertilizers.

The sago starch industry in Sarawak produces much agricultural wastes particularly sago pith waste. According to Awang-Adeni *et al.* (2010), sago starch processing residues are washed off into nearby streams along with the wastewater which could lead to serious environmental problems. Therefore, a trial was conducted in Universiti Putra Malaysia to convert sago pith waste into a value-added organic fertilizer through vermicomposting using goat and cow dung manure as co-composting materials.

This paper presents the chemical characteristics and crop growth performance of the sago pith waste vermicompost produced in UPM with comparisons to selected locally available commercial vermicomposts produced from different feedstock.

MATERIALS AND METHODS

Collection and Analyses of Vermicomposts

Two sago pith waste vermicomposts were produced by UPM using cow manure and goat manure, separately. To compare for chemical characteristics, vermicomposts of other feedstocks were also collected for this study. A total of 12 vermicomposts were purchased directly from producers in Selangor and another three vermicomposts produced in Terengganu, Kelantan and Sarawak were purchased from the local markets. The locally produced vermicomposts used four types of feedstock which were sawdust (SD), spent mushroom substrate (SMS), paddy straw (PS), oil palm empty fruit bunch (EFB) and fresh market waste

(FMW) while the co-composting materials were cow dung manure (CM), goat dung manure (GM) and horse dung manure (HM). As production procedures were similar for some of the vermicomposts, ten vermicomposts were finally selected and analyzed. They were (i) spent mushroom substrate with cow dung manure and goat dung manure (SMS+CM+GM); (ii) spent mushroom substrate with cow dung manure (SMS+CM); (iii) oil palm empty fruit bunch with cow dung manure (EFB+CM); (iv) sawdust with cow dung manure and goat dung manure (SD+CM+GM); (v) sawdust with cow dung, goat dung and horse dung manure (SD+CM+GM+HM); (vi) goat dung manure only (GM); (vii) paddy straw with cow dung manure (PS+CM); (viii) fresh market waste with cow dung manure (FMW+CM); (ix) sago pith waste with cow dung manure (SPW+CM), and (x) sago pith waste with goat dung manure (SPW+GM).

In this study, Australian Standard AS 4454 (Standard Australia, 2012) and Official Organic Fertilizer Standard of Korea (2001) were used to benchmark the chemical quality characteristics of the collected vermicomposts. The vermicompost were oven-dried at 70°C for 48 hours and ground for chemical analysis. Each vermicompost was analyzed in triplicate. The pH of the vermicompost was determined in the ratio of 1:5 (vermicompost: water) using a pH meter (Mettler MP 225). The samples were also analyzed for organic carbon according to the combustion method (McKeague 1976) with a CR-412 carbon autoanalyser (LECO Corporation, St Joseph, USA) and total N using the Kjedahl method (Bremmer and Mulvaney 1982). The macronutrient contents (P, K, Ca and Mg) were determined using dry-ashing method (Mitra 2003) while micronutrient (Fe, Cu, Mn and Zn) were determined using the (Thermo Scientific S-Series) atomic absorption spectrophotometry. Humic acid (HA) was isolated using the method of Ahmed *et al.* (2005).

Crop Growth Performance of Vermicomposts

A pot experiment was carried out in a glasshouse with maize (Zea mays) as the test crop to investigate growth performance using sago pith waste vermicompost in comparison to a commercial spent mushroom vermicompost. The study consisted of four treatments: (i) chemical fertilizer, (ii) SMS+GM+CM, (iii) SPW+CM, (iv) SPW+GM. Twenty experimental units were laid out in randomized complete block design (RCBD) with 4 treatments and 5 replications. Each pot was filled with ten kg of sieved air-dried soil from Munchong series. The plants were harvested on the 50th day after sowing by cutting the plant 5 cm above the ground. Tissue samples were taken, oven dried at 70°C and ground for analysis of nutrient concentrations and uptake.

Statistical Analysis

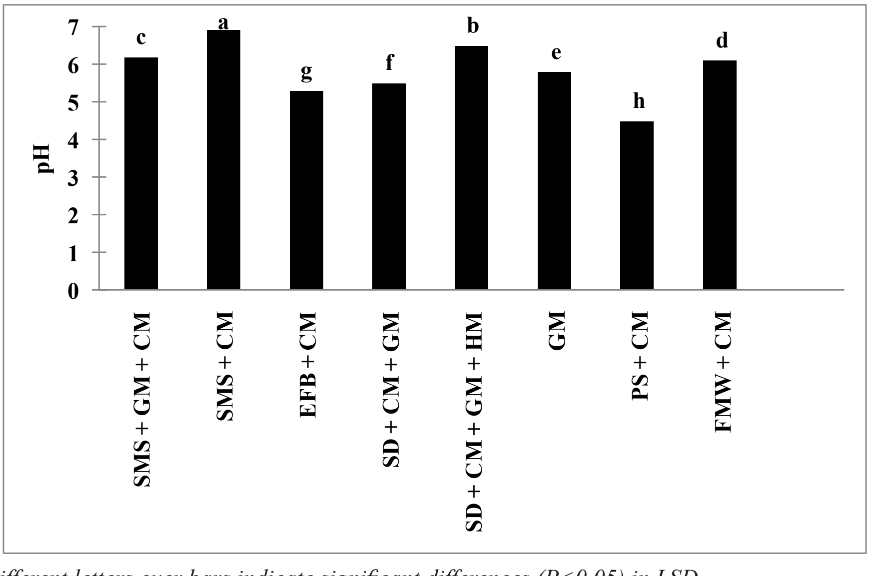
Variables were statistically analyzed using ANOVA and LSD (Least significant difference) to test for significant differences between treatment means. All statistical analyses were performed using Statistical Analysis System (SAS 1999).

RESULTS AND DISCUSSION

Chemical Characteristics of Vermicompost

pH

The pH for SPW vermicompost was in the range of 5.8 - 6.0 (Table 3), which is acceptable according to the Australian Standard AS 4454 (pH 5.0 - 7.5). The pH range for other commercial vermicomposts was between pH 4.5 - 6.5, with PS vermicompost having the lowest pH and SMS+CM vermicompost the highest *(Figure 1)*. According to Ndegwa and Thomson (2000), the pH decreases during vermicomposting because of the bioconversion of organic materials into various intermediate types of organic acids. Further, the low pH in EFB + CM could be due to the production of CO_2 and organic acids from the microbial decomposition of the substrate. Another explanation for the low pH in PS + CM could be the adoption of certain practices during the vermicomposting process such as the soaking of the paddy straw for at least 6 weeks to soften the fibrous straw before vermicomposting. Different types of earthworms will produce different types of vermicompost. The earthworm used for the paddy straw vermicompost was a local species, possibly the night crawler species. Meanwhile, other producers used *Eisenia fetida* and this could offer an explanation for the lower pH obtained for the paddy straw vermicompost.



Different letters over bars indicate significant differences (P<0.05) in LSD.

Note: SMS: Spent mushroom substrate; EFB: empty fruit bunch; SD: Sawdust; PS: Paddy straw; FMW: Fresh market waste; CM: cow dung manure; GM: goat dung manure; HM: Horse dung manure.

Figure 1: pH of eight types of local vermicompost.

Total N

Total N in SPW vermicompost was found to be in the range of 2.57-3.14% (Table 1). This range is well above the Australian Standard AS 4454 (Standard Australia, 2012) which requires a minimum total N value of 0.8%. Total N in other commercial vermicomposts ranged from 1.50-2.16%. However, the total N content for SPW vermicompost and other commercial vermicomposts was below the requirement of the Official Organic Fertilizer Standard of Korea (2001) which requires organic fertilizers to contain a minimum total N value of 4.0 %.

TABLE 1
Plant macronutrients concentrations of vermicomposts according to different types of feedstock

Treatments	N	P	K	Ca	Mg
			(%)		
SPW+CM	3.14a	1.31c	0.85cd	1.10de	0.32c
SPW+GM	2.57b	1.25c	0.78de	1.04e	0.38c
EFB+CM	1.60e	1.89a	0.60ef	1.04e	0.63abc
SD+CM+GM	1.50e	0.62ef	0.39g	2.10bcd	0.95a
SD+CM+GM+HM	1.50e	0.73de	0.74de	3.57a	0.63abc
GM	2.14c	0.81d	0.99c	1.96bcde	0.56c
PS+CM	2.16c	0.54f	1.73a	2.94ab	0.46c
FMW+CM	1.70de	0.67def	0.65ef	2.69abc	0.91ab
SMS+CM+GM	2.14c	1.72b	1.40b	2.05bcde	0.45c
SMS+CM	1.94cd	1.59b	0.50fg	1.82cde	0.58bc

Note: Different letters indicates statistically significant different values among treatment in LSD ($p<0.05$. SPW: Sago pith waste; EFB: Empty fruit bunch; SD: Saw dust; PS: Paddy straw; FMW: Fresh market waste; SMS: Spent mushroom substrate; CM: Cow dung manure; GM: Goat dung manure.

A comparison of the different vermicomposts shows SPW+CM to contain a significantly high total N value at 3.14% followed by SPW+GM at 2.5%. This was followed by SMS+CM+GM, SMS+CM, GM and PS+CMat 1.94-2.15%. EFB+CM, SD+CM+GM, SD+CM+GM+HM and MFW+CM had significantly low values in the range of 1.5-1.7 % total N. The lower total N values of EFB+CM, SD+CM+GM, SD+CM+GM+HM and FMW+CM vermicomposts were due to the lower animal dung manure composition compared to SMS+CM+GM, SMS+CM, GM and PS+CM. In SMS+CM+GM, SMS+CM, GM and PS+CM vermicomposts where the animal dung manure or animal dung manure mixture (cow and goat dung manure) constituted more than 50 % of the total bedding ratio. The highest total N content was in GM which used 100% goat dung manure. In the case of EFB+CM, SD+CM+GM, SD+CM+GM+HM and FMW+CM vermicomposts, the animal dung manure mixture was less than 50% of the mixture. Thus it can be deduced that animal dung manure contributed significantly to the total N content of the final products.

Total P

The total P measured in SPW vermicompost ranged between 1.25 to 1.31% while total P in other commercial vermicomposts was between 0.54-1.89% (Table 1). Empty fruit bunch vermicompost had the highest total P content at 1.89%, followed by SMS vermicompost (SMS+CM+GM and SMS+CM) and SPW vermicomposts (SPW+CM and SPW+GM). Vermicomposts produced from this feedstock fulfilled the requirement set by the Official Organic Fertilizer Standard of Korea (2001) which stipulates a minimum content of 1.00 % total P. The lowest total P content of FMW and PS vermicomposts was 0.67% and 0.54% respectively. Vermicomposts are rich in soluble inorganic phosphate and exchangeable phosphorus (Manshell *et al*. 1981). The high P content of vermicomposts is due to the mineralization of phosphorus as a result of bacterial and fecal phosphate activity of earthworm (Edward and Lofty 1972). The very high P content in EFB could be due to the practice of composting the fibres for a month to soften them prior to the vermicomposting process; this practice also facilitates the vermicomposting process. Spent mushroom substrate originates from sawdust. It is easier for ingestion by earthworms compared to sawdust due to the breaking down of the media from mushroom culturing activity. This promotes greater earthworms fecal activities compared to other feedstock.

Total K

SPW vermicompost was found to contain 0.78-0.85% total K while total K for the other commercial vermicomposts contained between 0.39-1.73% (Table 1). Among the commercial vermicomposts, the highest K content was from PS + CM (1.73%). This could be due to the high potassium uptake by paddy straw during the maturity period. Different types of feedstock used can affect the K content of the vermicompost. According to Delgado et al. (1995), sewage sludge vermicompost has higher K content compared to the initial substrate.

Micronutrients (Fe, Zn, Cu and Mn)

The micronutrient concentration of the vermicomposts tested is shown in Table 2. Zn concentration ranged from 22.5–56.5 mg kg^{-1} while Cu concentration was between 11.1-21.3 mg kg^{-1}. The concentrations were within the permitted level according to the Official Organic Fertilizer Standard of Korea (2001) which stipulates maximum permitted levels of below 900 mg kg^{-1} for Zn and below 500 mg kg^{-1} for Cu. The concentration obtained for Mn was within 78.2 - 140.8 mg kg^{-1} while for Fe, it was within 1251-6611 mg kg^{-1}. These results were within the range obtained for commercial organic fertilizers in Malaysia (Kala *et al.* 2011), that is, the concentration was between 45 mg kg^{-1} to 353 mg kg^{-1} for Zn, 17-88mg kg^{-1} for Cu, 912-24740 mg kg^{-1} for Fe and 89-827 mg kg^{-1} for Mn.

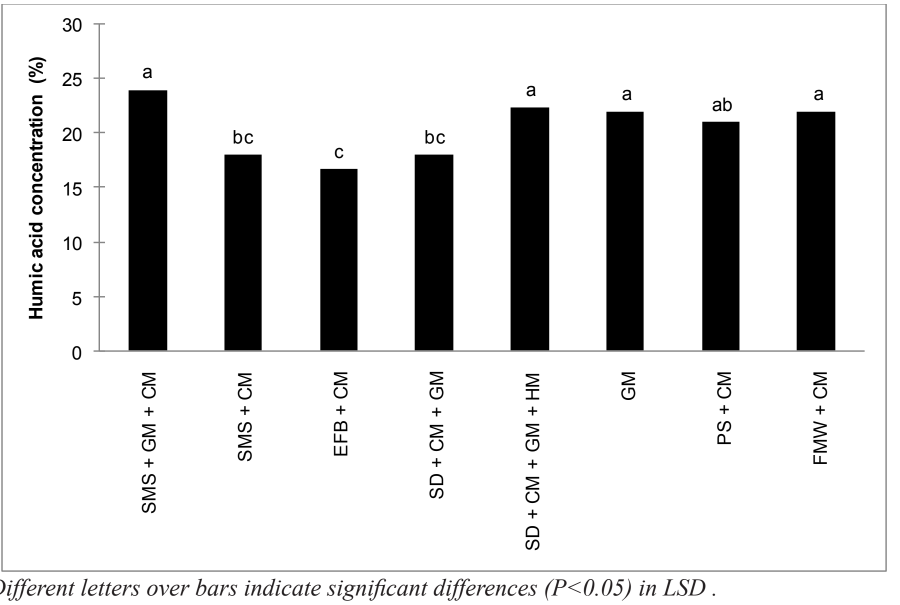
Humic Acid

The humic acid content of the vermicompost was between 16-24% *(Figure 2).* SMS+CM+GM, SD+CM+GM+HM, GM and PS+CM had the highest humic acid

TABLE 2
Plant micronutrients concentrations of vermicomposts according to different types of feedstocks

Treatments	Zn	Cu	Fe	Mn
	Concentration (mg kg^{-1})			
SPW+CM	36.2c	16.0c	2236.0de	106.5bc
SPW+GM	28.9cd	12.5de	1620.7ef	100.9c
EFB+CM	36.9c	21.3a	6611.3a	106.7bc
SD+CM+GM	26.8d	11.9ef	2354.7cde	78.2d
SD+CM+GM+HM	36.8c	15.4cd	2932.3bcd	110.5bc
GM	22.5d	8.9f	1251.7f	65.4d
PS+CM	58.5a	11.1ef	1703.7ef	71.5d
FMW+CM	36.2c	10.7ef	2016.0e	74.5d
SMS+CM+GM	56.5a	20.3ab	3338.0b	126.4ab
SMS+CM	47.7b	17.5bc	3101.0bc	140.8a

Note: Different letters indicates statistically significant different values among treatment in LSD $p<0.05$. SPW: Sago pith waste; EFB: Empty fruit bunch; SD: Saw dust; PS: Paddy straw; FMW: Fresh market waste; SMS: Spent mushroom substrate; CM: Cow dung manure; GM: Goat dung manure.



Different letters over bars indicate significant differences (P<0.05) in LSD .

Note: SMS: Spent mushroom substrate; EFB: empty fruit bunch; SD: Sawdust; PS: Paddy straw; FMW: Fresh market waste; CM: cow dung manure; GM: goat dung manure; HM: Horse dung manure.

Figure 2: Humic acid contents of eight types of local vermicompost.

content among the vermicomposts analyzed while EFB had the lowest. Although SMS+CM+GM had a mixture of spent mushroom substrate with cow and goat dung manure, the humic acid content of spent mushroom substrate at 40% was in fact lower compared to other feedstock at 60 to 70 %. It can be deduced that the humic acid content was contributed by the animal dung manure. This is strongly

TABLE 3
The chemical properties of the sago pith waste vermicompost, locally produced vermicompost and organic fertilizer

Characteristics	SPW vermicompost	Commercial vermicomposts	Organic fertilizer (Kala *et. al.* 2011)	Official Organic Fertilizer Standard of Korea (Myung and Youn 2001)
pH	5.9	4.5 - 6.5	4.5-9.8	na
C/N ratio	15.53	6.2 - 18.3	3.8-42.7	na
Total N (%)	2.86	1.50 - 2.16	0.70 -4.40	>4.00
Total P (%)	1.28	0.54 - 1.89	0.04-8.85	>1.00
Total K (%)	0.82	0.39 - 1.73	1.29-6.94	>1.00
Total Ca (%)	1.07	0.52 - 1.78	0.12-12.00	na
Total Mg (%)	0.35	0.27 - 0.50	0.3-3.3	na
Zn	32.6	22.5-56.5	45-353	<900
Cu	14.3	11.1-21.3	17-88	<500
Fe	1928	1251 - 6611	912-24740	na
Mn	103.7	78.2-140.8	89-827	na
Humic acid (%)	21.17	16.67 - 24.00	na	na

supported by GM which is 100 % goat dung manure and PS+CM which comprised 50 % paddy straw and 50 % cow dung manure. Orlov and Biryukova (1996) reported that vermicomposts in general contain 17–36% of humic acid. From the results of the vermicomposts tested, the humic acid contents are within the range reported by Orlov and Biryukova (1996). The presence of a high humic acid content is due to the humification process which occurs naturally in mature animal dung manure. Compared to traditional composting, the vermicomposting process increases the rate of humic acid production drastically from 40% to 60%. The fragmentation and size reduction of organic matter inside the earthworm intestine during the vermicomposting process enhances the humification process and also increases the microbial activity within the earthworm intestine (Dominguez and Edwards 2004).

Crop Growth Performance of Vermicomposts

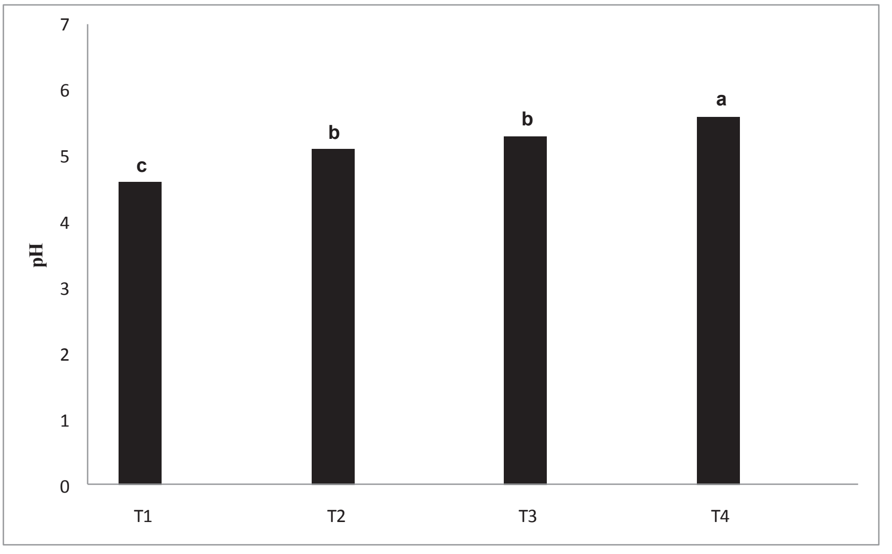
The effect of different type of fertilizers on crop growth performance (dry weight and uptake of N, P, K, Ca uptake and Mg) are shown in Table 4 and soil pH in *Figure. 3*. Maize planted using SPW vermicompost showed significantly higher dry weight compared to the other treatments. There were no significant differences in term of N uptake among maize planted with vermicompost while maize planted with chemical fertilizers showed significantly lower N uptake in comparison to the other three treatments. Phosphorus uptake among the plants showed no significant differences. SPW+GM showed the best performance in term of K, Ca and Mg while K, Ca and Mg uptake from plant grown with SPW+CM was at par with SMS+GM+CM. However, chemical fertilizers had the lowest K, Ca and Mg uptake among all treatments. Treatments with SPW+GM showed the highest soil pH value while chemical fertilizer treatment had the lowest soil pH (*Figure 3*). As the ideal soil pH for maize growth is between 6.0-7.0; problems emerge when the soil pH is lower than 5.5 (Mississippi State University 2008). According to Mallarino (2011), low soil pH affects plant growth directly and indirectly by affecting plant nutrients uptake and by increasing phytotoxic element concentration in soil and influencing microbial activity.

TABLE 4

Nutrients uptake (g) for maize according to different types of fertilizers

Treatment	Dry weight ($g\ pot^{-1}$)	N	P	K	Ca	Mg
				$g\ pot^{-1}$		
CF	10.2b	0.26b	2.51a	4.62b	3.35b	0.74c
SMS+GM+CM	15.2ab	0.44a	2.07a	6.17ab	5.23ab	2.60b
SPW+CM	18.1a	0.48a	2.79a	6.82ab	6.58a	3.33ab
SPW+GM	20.2a	0.50a	2.80a	8.82a	7.00a	3.83a

Note: CF: Chemical fertilizer; SMS: Spent mushroom substrate; SPW: Sago pith waste; GM: Goat dung manure; CM: Cow dung manure



Note: T1: chemical fertilizer; T2: local vermicompost (SMS+GM+CM); T3: SPW+CM vermicompost; T4: SPW+GM.
Different letters over bars indicate significant differences ($P<0.05$) in LSD.

Figure 3: pH of soil at harvest according to the treatment.

CONCLUSION

Sago pith waste is of better quality in term of N and humic acid content compared to other vermicomposts. This could be due to sago pith waste vermicompost having a longer vermicomposting period (30 days) compared to the commercial vermicomposts (14 days). Different types of feedstock showed varying results in term of chemical content. Different ratios of co-composting material such as cow, goat and horse dung manure have an effect on the chemical content compared to the main feedstock. Beside feedstock, type of earthworms used may affect the quality of the vermicomposts produced; however, it is to be noted that these earthworms depend on the composition of the main feedstock. In this study, local earthworms were used for the paddy straw vermicompost; this vermicompost had the lowest pH at 4.5. Vermicompost produced from spent mushroom substrate co-composted with a mixture of cow and goat dung manure showed the best quality among the local vermicomposts. SPW+GM showed better plant growth compared to SMS+GM+CM while SPW+CM was at par with SMS+GM+CM. SPW exhibited good prospects for vermicomposting. However, further studies need to be conducted and results have to be compared with other organic fertilizers such as composts of different feedstock.

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