

Compost derived from local organic materials as source of plant nutrients

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Abstract. The aim of this study was to produce high quality compost and to interpret data during the composting process. Compost materials used in the composting were carbon-rich materials, nitrogen, and goat dung, added with topsoil from garden, rice husk, cow urine, and EM₄ (microorganism effective 4). The method used was Indore method. The principle of this method is by placing every material in layers in a certain width, starting with carbon-rich material, nitrogen-rich material, goat dung, top soil, rice husk, and cow urine up to the surface of the compost bin. All the materials were watered until saturated condition. Incubation of compost took time 1.5 months. Data collected during the incubation process were temperature, moisture content, population of soil fungi and soilworms, compost texture, colour, pH, and nitrogen (N), phosphorus (P), potassium (K) contents. The results were as followed: temperature 37°C, moisture content 62%, population of fungus ++, population of soilworm +, the color black to brown, texture coarse to fine, no stinky smell, pH 7.0, and high N, P, K levels. The conclusions were that the compost was high in quality, all qualitative and quantitative data were correlated with the standards of a high quality compost.

1. Introduction

Soil organic matter (humus) is lost through crop harvesting, erosion, and leaching. This is a very serious issue in increasing the humus content, quality of humus, and soil quality [1]. We need a strategy to restore the lost soil humus by giving the rest of the plants, manure, and/or compost. This paper only presented the process and interpretation of compost fertilizer resulted from indore method [2, 3].

Compost fertilizer is an organic material containing balanced nutrients, and as a mulch for plants [4]. In terms of soil quality, compost can increase the number of living soil, soil structure, water content, cation exchange capacity, soil aggregate stability, and infiltration of water into the soil [4, 5]. Other research results show that quality compost fertilizer has a C / N ratio of 15-20, organic matter of 8-10%, nitrogen (N) 0.3 - 0.6%, phosphorus (P) 0.1 - 0.4%, and potassium (K) 0.3 - 1.0% [6, 3]. Briefly, compost fertilizer can improve the quality of soil and crop yield [7].

The characteristics of good quality compost fertilizers are as follows: Compost fertilizer is crumb, the ratio of the amount of coarse and fine material is balanced, adequate water and air content, adequate nutrient levels, free of pests and diseases, usually dark, usually brown and/or black, and pH ranges from 7-8 [4].



Fertilizer made in rare factory availability, although the price is very expensive, so farmers can not afford to buy the fertilizer [2]. Many fertilizers are misused by irresponsible people, such as fertilizer speculators who replace fertilizer packaging labels subsidized with non-subsidized fertilizer packaging labels to obtain financial benefits [2].

Compost fertilizers made from crop residues and/or animal waste are incubated for several days up to 3 months [8, 9]. Various ways of making compost, indore, bangalore, block, pit, trench, basketball, and boma. Each way has its advantages and disadvantages. Most preferred and easy to apply is the indore method [10].

The known composting process is heating, cooling down, and maturity. In the first stage, microorganism activity is very high due to the heating process of organic materials by bacteria, worms, and insects. This stage runs very quickly 1-2 weeks, living organisms remodel organic materials (carbohydrates, proteins, fats, and vitamins) into simple compounds and release nutrients in pH values ranging from 7.0 – 8.0. Cooling stage, the temperature gradually decreases from 50 to 30 °C so that the heat generated is also decreased. This stage takes one month. At the stage of maturity, the temperature drops to 15 °C to 25 °C depending on weather conditions or climate. The active living bodies at this stage are termites. This stage runs infinitely so that the mature compost fertilizer is set with crumb and brown characteristics and/ or black [8, 11].

The purpose of this research is to produce good quality compost fertilizer and interpretation of compost fertilizer. Its benefit is to provide good compost fertilizer to build, maintain soil humus so that soil quality and crop productivity can be achieved continuously.

2. Materials and Methods

The research was conducted at Integrated Agriculture Zone, Faculty of Agriculture, University of Bengkulu from April to May 2015. The composting process took place in compost bin near water source and banana trees. Fertilization experiments were in ultisol and inceptisol fields for 115 days using maize as plant modelling.

Nitrogen-rich compost material (N) was used such as kipahit (*Thitonia diversifolia*), skewer (*Widelia trilobata*), arasungsang (*Asystasia gangetica*), and carbon-rich (C) such as dried leaves, rice straw, and rice husk (Figure 1). The mature goat's feces (dry-shaped and crumbly, when pressed with both hands) was also used as compost material. Additional materials were also used to enrich nutrients of N and K such as cow urine, topsoil of mineral soil from the banana garden, and burnt ash of rice husks. Another additional material used to accelerate the composting is the microorganism effective 4 (abbreviated EM₄). The other material was bamboo diameter 8 cm, length 2 m which has been hollowed alternate with a distance of 10 cm from the end to the base of bamboo for air traffic / gas from compost to the atmosphere. The bamboo was plugged into the compost material.

Compost bin prepared with size 5 m (length) x 2 m (width) x 1m (thick). The ground floor of compost bin made oblique 5° to remove water when raining or when watering the compost. Compost and incubation of compost material are presented in Figure 2. *Thitoniadiversifolia*, *wideliarostrata*, *asystasiagangetica*, and rice straw cut into pieces with a sharp knife 1-2 cm to facilitate composting, while the leaves are dry and rice husks were not cut up. Goat dung was taken from the goat cage and separated from the rest of the grass feed. Urine the cow was taken directly from the cow shed, the topsoil was taken from the banana garden, burnt ash from the burned rice husk (white color). EM₄ is purchased from comparison of the amount of compost is 1 part rich material N: 1 part rich material C: 2 parts of goat

dung. The total amount of 1000kg compost fertilizer required 250kg of rich material N, 250kg of rich material C, and 500kg of goat droppings. Urine of 50 liters of cow is dissolved in water and the solution is splashed into compost fertilizer. Topsoil 50 kg is taken from the ground surface with 2.5 cm thick. Burn grain of rice husk used 50 kg. EM₄ 1 liter dissolved in 10 liters plus 1 kg of sugar and 1 kg of urea. The indore method is used for composting [10, 11] in the following order: From floor to composted surfaces, dried leaves are placed at the bottom of the compost bin floor, followed by rice straw, rice husks, *Thitoniadiversifolia*, *Wideliatrilobata*, *Asystasiaganetica*, goat droppings, topsoil, burnt ash, and covered with banana leaves. Each thick layer of compost material rich in N, rich in C, and goat droppings is 10 cm. Then the topsoil and gray husk ash are approximately 1 cm thick. All the compost material is inserted into the compost tub with a leveled surface, each time the compost is inserted into the compostable tub used fork or hoe. This procedure can be repeated for the remaining compost material. After completion of all compost ingredients into the compost tub, then watered with a solution of cow urine on the surface of the compost and continued sprinkling with well water until the compost saturated water. Compost is declared saturated when water comes out from the bottom of the compost tank floor to drainage channels. Bamboo is placed in the center of the compost tub as an air/ gaschannel from compost to the atmosphere. Compost material is covered with banana leaves as tightly as possible and allowed incubation for up to 1.5 months. After the organic material was incubated for 2 weeks, EM₄ solution was given 2 x at 3 and 4 weeks respectively. EM₄ solution was splashed onto the surface of the compost material. Then proceed with watering well water to help the EM₄ solution can be spread evenly into the compost material. EM₄ helps to accelerate the decomposition of organic materials, especially rice straw, rice husk, and dried leaves. Reversal of compost fertilizer is done every 2 weeks to give the maturation of compost fertilizer is flat. Mature compost fertilizer is placed on the outside, whereas immature compost fertilizer is drawn to the center of the compost tub using a hoe or spade. Compost sampling is done every week for observation and measurement of compost manure variable. The trick is to use auger. The auger is inserted into a layer of compost fertilizer 0-20 cm, 20-40 cm, and 40-60 cm. An example of compost fertilizer was taken from drill and observed/ measured variable of compost fertilizer. Sampling of composite fertilizer is taken one example every 40 kg of compost fertilizer, so that if there is 1000 kg of compost fertilizer, hence composite fertilizer sample collected 25 times the composite mixed fertilizer making into one composite compost sample. Composite compost fertilizer is analyzed in Soil Science Laboratory of Faculty of Agriculture University of Bengkulu, Indonesia. Variable observation of composted fertilizer in the field is temperature (Hg thermometer), water content (gravimetric method), presence / no mushroom and earthworm (percentage of compost surface area), color (Munsell soil color chart), coarse-grained (hand smell), smell (smell method), pH (pH paper indicator, 0-14 scale Merck, made in Germany). Fine / texture is measured qualitatively by using the thumb and forefinger Hand. The way the compost fertilizer is pressed with the thumb and forefinger of the hand when it feels rough means coarse compost, and vice versa. The odor is measured by smelling the odor coming out of the compost, usually the gas coming out of the compost. The observation variable of composite compost is as follows: Water content (gravimetry method), total carbon (C) (Walkley-Black method), total nitrogen (N) (Kjeldahl method), total phosphorus (P) (spectrophotometry method), total potassium (K) (Spectrophotometry method), total calcium (Ca) (titrimetry method), total magnesium (Mg) (titrimetry method), and cation exchange capacity (CEC) (Kjeldahl method). The percentage of basic saturation is the amount of base cation (Ca-dd + Mg-dd + K-dd + Na-dd) divided by

CEC multiplied by 100. The percentage of aluminum saturation is the content of Al-dd divided by CEC multiplied by 100. Variable observation of maize as follows: Nitrogen (N), phosphorus (P), and potassium (K) of leave of maize plants 60 days after planting with 6 doses of compost and 4 replicates (24 plant leaf samples) were tested significantly with Fisher and DMRT test α 0.05.

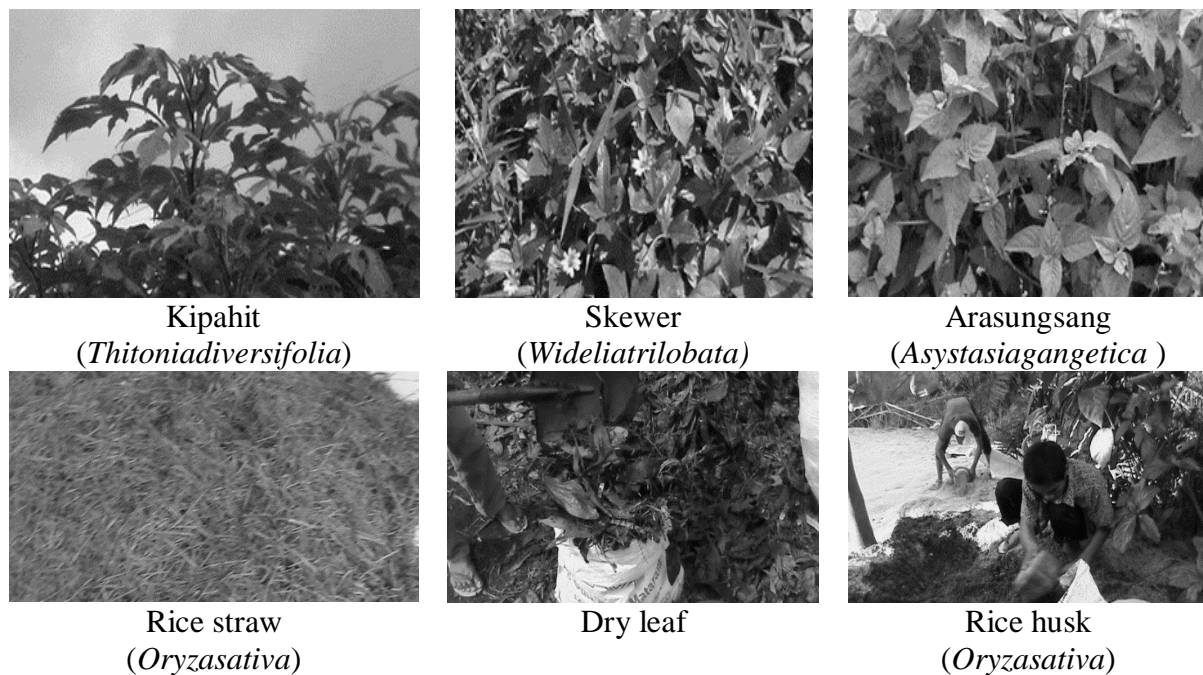


Figure 1. Compost materials (Upper: rich of N, Below: rich of C) (Photos: Riwandi)

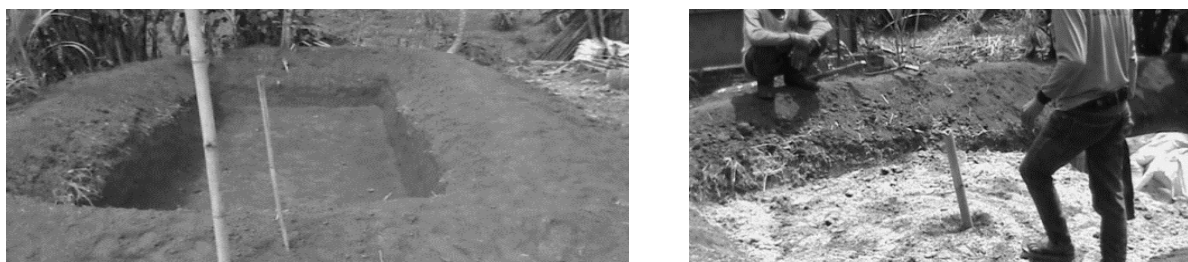


Figure 2. Compost bin using indore method (Photos: Riwandi)



Figure 3. Compost identification(Photo: Riwandi).



Figure 4. Purple maize leafdefisien ofPoninceptisol fertilized with compost 12.5 tonha⁻¹ (Photo: Riwandi)).



Figure 5. Maize plant sufficient in N, P, dan K onultisol, fertilized with compost 5 tonha⁻¹(Photo:Riwandi)

3. Results and Discussion

Table 1 showed that all compost materials have a total C content ranging from 30% - 51.37%, total N ranges from 0.42% - 2.62%, and the C / N ratio ranges from 19.50 to 105.07 . From table 1 it can be concluded that all compost materials have a high total C, some compost materials have high N content (ordered from highest to lowest, i.e. *Thitoniadiversifolia* 2.62% N, *Wideliarostrata* 1.96% N, *Asystasiagangetica* 1.68% N and goat 1.17% N), while other compost materials had relatively low total N levels, ie rice straw 1.07% N, dry leaves 0.49% N, and rice husk 0.42% N. Some compost materials have a low C / N ratio (<30), i.e. *Asystasiagangetica*, goat dung, *Wideliarostrata*, and *Thitoniadiversifolia*, while some other compost material has a high C / N ratio (> 30), i.e. rice husk, dried leaves, and rice straw.

Table 1. Analyzes of total carbon (C), total nitrogen (N), and C/N ratio of compost materials.

Compost Materials	Total C (%)	Total N (%)	C/N ratio
Goat feces	30.00	1.17	25.64
Skewer (<i>Wideliatrilobata</i>)	47.92	1.96	24.45
Kipahit (<i>Thitoniadiversifolia</i>)	51.10	2.62	19.50
Arasungsang (<i>Asystasiagangetica</i>)	43.63	1.68	25.97
Rice husk (<i>Oryza sativa</i>)	44.13	0.42	105.07
Rice straw (<i>Oryza sativa</i>)	39.81	1.07	37.21
Dry leaf	51.37	0.49	104.84

The combination of compost materials having a C / N ratio of < 30 and > 30 is very useful for maintaining the sustainability of the presence of compost in the soil, since the compost having a C / N ratio < 30 easier to provide nutrients for plants (easy to decompose) than compost has a C / N ratio of > 30 (difficult to decompose). Not only maintains the nutrient sustainability available, but also improves soil quality (physical, chemical, and biological properties of the soil). This is supported by previous researchers saying that the ratio of C/N plays an important role in providing nitrogen (N) into the soil. The same researchers say further that the C/N ratio > 30, microorganisms will consume soil N so that N is not available to plants [12]. Other researchers say that compost material is a source of nutrients for plants and soil humus. The soil formula is formed from a combination of lignin and protein called ligno-protein [13]. Both materials are obtained from compost rich in C and N such as compost materials used in this study.

Table 2. The mean of compost analyzes after 1.5 month incubation in compost bin.

Date of observation	T (°C)	WC (%)	Fungus	Earthworm	Odor	Coarse/ fine	Color	pH
21-3-2015	40.6	53.8	-	-	+++	k	10YR2/1	7.8
28-3-2015	36.9	57.0	-	-	+++	k	10YR2/1	7.4
4-4-2015	36.3	56.4	-	-	+++	k	10YR2/1	7.0
11-4-2015	35.0	62.3	++	+	-	h	10YR2/1	6.8
18-4-2015	36.0	58.5	+	+	-	h	10YR2/1	6.8
25-4-2015	35.5	60.5	+	+	-	h	10YR2/1	6.7

Note: WC = Water content; +++ = presence of fungus/earthworm/odor; - = none of fungus/earthworm/odor; k=coarse; h=fine; 10 YR2/1 = black. Samples of compost identified was 15 which were 5 spots x 3 compost layers (0-20 cm; 20-40 cm; 40-60 cm)

Table 2 shows that the average temperature for 6 weeks of the composting process has decreased the temperature from 40.6°C to 35.0°C. Compared with the results of the [14] research, the mature compost temperature approached the groundwater temperature (estimated at 25-35°C), then the compost temperature was in accordance with the standard compost fertilizer criteria. The water

content of the compost is about 53.8% - 62.3% higher than the 50% raw water content of compost, but the water content of the compost is not problematic, as it can be dried up to the raw compost water content. During the composting process there are found mushrooms and earthworms. Compost at the beginning of the first week to the third week, smelly, but after that no more odors arise, because the composting run smoothly. Compost texture was originally rough, but gradually changed into smooth. The compost color appears black and the pH of the compost approaches neutral (7). The smell, texture, color, and compost pH have met the standard compost fertilizer criteria [14].

Table 3. Analyzes of compost after 1.5 month.

Compost	C (%)	N (%)	Rasio C/N	P (%)	K (%)	Ca (%)	Mg (%)	CEC cmol(+)kg ⁻¹
UNB	18.21	2.08	8.75	0.31	1.14	0.29	0.26	32.25

Note: CEC = cation exchange capacity

Table 3 shows that UNB compost fertilizer (short for University of Bengkulu) has a low C / N ratio (8.75). When compared to the ratio of C / N of various compost origin ingredients (see Table 1), the compost has undergone a very good composting process. Plant nutrient levels resulting from carbon-rich compost (C), nitrogen (N), potassium (K), and phosphorus (P), but low calcium (Ca), magnesium (Mg), and cation exchange capacity (CEC).

Table 4. Compost quality standards [14].

Parameter	Score
Temperature (°C)	Soil water tempetature
Water content (%)	50
Color	Black
Particles (mm) (= fine to coarse)	0.55 – 25.00
Odor	Smell of soil
pH	6.00 – 7.49
N (%)	0.40
P ₂ O ₅ (%)	0.10
K ₂ O (%)	0.20

Table 5. Analyzes of the characteristics of ultisoldaninceptisol.

Soil Ordo	WC (%)	pH (H ₂ O) 1:2.5	Total C (%)	Total N (%)	Av P (ppm)	ExchCa (cmol(+)kg ⁻¹)	Exch Mg (cmol(+)kg ⁻¹)	Exch K (cmol(+)kg ⁻¹)	Exch Na (cmol(+)kg ⁻¹)	CEC (cmol(+)kg ⁻¹)	Exch Al (cmol(+)kg ⁻¹)	Exch H (cmol(+)kg ⁻¹)
Ultisol	13.46	4.00	3.97	0.14	3.00	0.86	0.53	0.12	0.15	7.26	4.80	0.48
Inceptisol	16.21	4.70	2.65	0.17	6.40	1.52	0.70	0.18	0.26	12.91	2.34	0.36

Note: WC = water content; av P = available P; exchCa = exchangeableCa; exch Mg = exchangeable Mg; exch K = exchangeable K ; exch Na = exchangeable Na; CEC = Cation Exchange Capacity; exch Al = exchangeable Al; exch H = exchangeable H

Table 5 showed that soil fertility of inceptisol was better than ultisol. Soil reaction (pH) of inceptisol 4.70 higher than the pH ultisols 4.00, but both include acid land. The level P inceptisol also higher than the P ultisol, even 2 x fold higher rates of P inceptisol. The amount of base cations (exchCa + exch Mg + exch K + exch Na) is 2.06 cmol (+) kg⁻¹ on the ultisols, and 3.06 cmol (+) kg⁻¹ on the inceptisol. If the calculated percentage of base saturation of soil each ultisol and inceptisol, the soil base saturation of 28.3% in ultisol and base saturation of 23.7% in inceptisol. Both two soils has a low base saturation of 20-40% [15]. Base saturation of the soil < 35% indicates that the soil belongs to the category soil fertility of the soil is low. The Al saturation of the ultisol of 66.1%, and the

saturation of the inceptisol of 18.1%. The ultisols have a much higher Al saturation of soil than inceptisol. So, the ultisols have lower fertility of the inceptisol. Soil Al saturation > 60% is very dangerous, because it can be toxic for plants growing on the soil.

Table 6. The means of nitrogen (N), phosphorus (P), and potassium (K) of maize leaf 60 days after planting in Ultisol.

Dose of compost (tonha ⁻¹)	N (%)	P (%)	K (%)
0	2.12a	0.30ab	2.14b
2.5	1.70a	0.28b	2.17ab
5.0	4.45a	0.34a	2.32a
7.5	1.97a	0.34a	2.28ab
10.0	2.09a	0.30ab	2.24ab
12.5	2.13a	0.32ab	2.34a

Table 6 showed that the application of fertilizer affects the levels of nitrogen (N), phosphorus (P), and potassium (K) of maize leaves in ultisols. The test using Duncan's Multiple Range Test (DMRT) α 0.05, leaf N content did not show significant difference between fertilized soil with no fertilizer compost, while P and K leaf content was significantly different between doses of compost. The dose of 5 tonha⁻¹ compost fertilizer produces the highest levels of N, P, and K corn leaves. The highest levels of N, P, and K of maize were 4.45% N, 0.34% P, and 2.32% K, respectively. If compared to N, P, and K leaves of maize obtained by previous researchers that 2.93% N, 0.22% P, and 1.22% K, the results obtained in this study, 4.45% N, 0.34% P, and 1.32% K were higher than those obtained by previous researchers (Jones, 1998). In general, the range of leaf N level (ear leaf) 2.70% - 4.00%, P 0.25% - 0.50%, and K 1.70% - 3.00% [16]. Thus, the leaf N content has exceeded the sufficient N range, while the levels of P and K are still within the sufficient range of P and K.

Table 7. The mean of nitrogen (N), phosphorus (P), and potassium (K) of leaf maize 60 days after planting in Inceptisol.

Dose of Compost (tonha ⁻¹)	N (%)	P (%)	K (%)
0	1.67ab	0.20a	1.32c
2.5	1.84a	0.21a	1.54bc
5.0	1.57b	0.19ab	1.37c
7.5	1.62ab	0.17b	1.95a
10.0	1.73ab	0.18ab	1.94a
12.5	1.53b	0.20a	1.83ab

Table 7 showed that the doses of compost fertilizer affect the levels of N, P, and K leaves of maize. Further test with DMRT α 0.05 indicated that the levels of N, P, and K of maize were significantly different between doses of compost. The doses of compost fertilizer giving the highest levels of N, P, and K of corn leaf are 2.5 tonha⁻¹. The highest levels of N, P, and K of corn leaves in inceptisol were 1.84% N, 0.21% P, and 1.54% K. Compared with the levels of N, P, and K of the leaf as mentioned above, the levels of N, P, and K of maize in inceptisol have not reached sufficient N, P, and K levels. Appearance of peptic maize of P on inceptisol is presented in Fig. 4, while the appearance of maize plants with sufficient levels of N, P, and K on composted fertilized ultisols was presented in Fig. 5.

4. Conclusion

Based on the results and discussions that have been mentioned above, it can be concluded that the resulting compost fertilizer has met the standard compost quality standards. The compost criteria that

have the standard quality are as follows: C / N ratio of 8.75 with elemental C (18.21%), N (2.08%), K (1.14%), and P (0.31%), but less Ca (0.29%), Mg (0.26%), and CEC (32.25%). Highest N, P, and K content of maize leaves in ultisol were obtained with a dose of 5 tonha⁻¹ compost, whereas in inceptisol was obtained at a dose of 2.5 tonha⁻¹ compost. The 2.5 tonha⁻¹ compost dose had not been able to meet the N, P, and optimized maize kits in inceptisol. It is suggested to conduct further research in inceptisol to determine optimal dosage of compost.

5. Acknowledgement

The authors would like to extend their gratitude to the Directorate of Research and Community Service, Ministry of Research, Technology and Higher Education, Jakarta, Indonesia, which has provided research grants for Research Competition grant year 2014-2015.

References

- [1] Rivero C, Chirenje T, Mac L Q and Martinez G 2004 *Geoderma* **123** 355–361
- [2] Riwardi M, Handajaningsih and Hasanudin 2012 *Teknologi Tepat Guna: Pupuk Kompos dan Teknologi Pembuatannya* (Unib Press) 61p
- [3] Riwardi, Prasetyo and Hasanudin 2015 *Teknologi Tepat Guna: Pupuk Kompos Input Ganda Metode Indore* (Unib Press) ISBN 978-979-9431-89-9 74p
- [4] Scholl L and Rien N 2007 *Soil Fertility Management* ed 5 (Wageningen: Agromina Foundation) 83p
- [5] Abdel-Rahman G 2009 *American-Eurasian J. Agric. & Environ. Sci.* **6** 220–226
- [6] Fernando 2012 *Compost for Coconut Plantations* (Srilanka: Coconut Research Institute)
- [7] HDRA 1998 *Composting in The Tropics I* (United Kingdom: Ryton Organic Gardens Coventry CV8 3LG) 19p
- [8] Inckel M, de Semet P, Tersmette T and Veldkamp T 2005 *Preparation and Use of Compost* Agrodok 8 (Wageningen: Agromisa Foundation) 65p
- [9] CTA 2007 *Enriched Compost for Higher Yields* (Wageningen: CTA Practical Guide No. 7)
- [10] HDRA 2001 *Composting in The Tropics II* (United Kingdom: Ryton Organic Gardens Coventry CV8 3LG) 23p
- [11] IFOAM 2012 *Composting: Training Manual on Organic Agriculture in the Tropis* (Keerbeen: Betuco)
- [12] Mangan F, Bakers A, Bodine S and Borten P 2017 *Compost Use and Soil Fertilizer* (Switzerland: Sustainable Sanitation and Water Management Toolbox)
- [13] Stevenson F J 1982 *Humus Chemistry, Genesis, Composition, Reactions* (New York: A Wiley-Interscience Publ. John Wiley & Sons) 443p
- [14] Isroi 2008 *Kompos* (Bogor: BPBPI)
- [15] Sulaeman, Suparto, and Eviati 2005 *Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk* ed 1 (Bogor: Balai Penelitian Tanah, Balai Penelitian dan Pengembangan Pertanian, Departemen Pertanian) 136p
- [16] Jones, J B Jr 1998 *Plant Nutrition Manual* (Washington: CRC Press) 149p