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PERFORMANCE ANALYSIS OF BIOPORE INFILTRATION HOLE (BIH) COMPOSTING BASE ON SOIL TEXTURE AND WATER INFILTRATION RATE

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ABSTRACT

One of the household-scale composting methods currently being developed is Biopore Infiltration Hole (BIH) Composting. This composting is built by making cylindrical holes in the soil with a 10 cm diameter and 100 cm depth, then adding organic waste to feed soil organisms to form biopores. The study aims to analyze BIH composting's performance in terms of soil texture and water infiltration rate. Composting consisted of four variations, namely clay texture with a water infiltration rate of 1.8 cm/hour, loamy clay texture with a water infiltration rate of 2.3 cm/hour, sandy clay loam texture with a water infiltration rate of 6.7 cm/hour, and sandy clay soil texture with the water infiltration rate of 13.4 cm/hour. Compost raw materials consist of 50% food waste and 50% chopped yard waste. Composting performance analysis was based on a maturity test and compost's quality and quantity test. The results showed that all compost variations had met the standards of maturity and quality of compost, with composting time ranging from 47 to 58 days and the percentage of the quantity of solid compost produced ranging from 62.1 to 72.1% of the weight of the compost raw material. From the results of the correlation test, there is a strong relationship between water infiltration rate and time of composting. The higher the rate of groundwater infiltration, the faster the compost maturity time. Composting variation with sandy clay soil texture and water infiltration rate of 13.4 cm/hour is the most optimal variation in terms of maturity, quality, and quantity of compost produced. Soil texture containing a sand and a high-speed water infiltration rate can accelerate compost maturity, especially during the rainy season. Rainwater is absorbed into the soil faster so that the moisture in the BIH can be maintained for the activity of microorganisms to decompose organic waste.

Keywords: biopore infiltration hole (BIH), compost, soil texture, water infiltration rate.

INTRODUCTION

Based on data from the Ministry of Environment and Forestry in 2019, waste generation in Indonesia is 64 million tons annually. The waste composition consists of organic waste, namely food waste and plant waste, with a percentage of 50%, 15% plastic waste, 10% paper waste, and the rest consists of metal, rubber, cloth, glass, and others [1]. Organic waste is waste that easily decomposes and causes odors, such as yard waste and food waste. In Indonesia, organic waste comes from markets, households, restaurants, and others. Organic waste can be processed into usable materials [2]. One of the organic waste processing is composting with the Biopore Infiltration Hole (BIH) method.

BIH is a cylindrical hole made vertically into the ground with a 10 cm diameter and a depth of about 100 cm or not exceeding the depth of the groundwater table. The hole is then filled with organic waste that serves to revive soil organisms, such as worms. These organisms or fauna in the soil will form pores or tunnels (biopore), accelerating horizontal infiltration of water into the soil. The rate of water infiltration increases due to the increase in biopore formed so that the process of weathering organic waste occurs in a sufficiently oxygenated environment. The soil absorbs the leachate and becomes the adhesive for soil pore aggregates [3]. BIH functions as a water absorber and an organic waste composter, thus producing compost that is beneficial for plants [4].

BIH composting is influenced by several factors, including the C/N ratio of raw materials, composition of raw materials, humidity, temperature, and microorganisms [5]. Optimization of BIH composting performance has been carried out in several studies. The type of waste affects the length of time for composting. BIH filled with leaf waste takes one month to decompose, leaf waste and kitchen waste or food waste take seven days, while kitchen waste takes 1 to 3 days [4]. The composition of raw materials affects the quality and quantity of compost. The most optimal results of BIH composting were found in the composition of raw materials of 50% yard waste and 50% food waste [6]. Chopping raw materials into sizes of 0.3 to 1.5 cm can speed up the composting time by 10 to 15 days [7]. Adding an activator can speed up the composting time of BIH by 15 to 25 days but reduce the quantity of solid compost produced. The addition of the Stardec activator gave a better result in terms of maturity, quality, and quantity of compost, compared to the EM4 activator [8].

Soil conditions affect BIH in terms of the rate of water infiltration. Loose soil texture has more pores than clay soil texture. Sandy soil absorbs water faster than clay soil [3]. Soil texture related to the water infiltration rate is supposed to affect the quality and quantity of compost produced. It is related to the humidity parameter that must be maintained during the composting process. For this reason, in this study, an analysis of the performance of BIH composting was carried out in terms of soil texture and water infiltration rate. Composting performance

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includes the compost maturity process and the quality and quantity of solid compost produced.

METHODOLOGY

Research preparation began with determining the location of composting and preparing raw materials and composting equipment. The composting location was determined based on the literature on soil texture research in several locations in Padang city. There are four soil texture categories at Padang City: clay, loamy clay, sandy clay loam, and sandy clay soil. Furthermore, laboratory testing is carried out to ensure the soil texture at the selected candidate locations. Testing is done by taking soil samples from the field and then analyzed in the laboratory. Soil texture testing was measured by calculating the percentage of particles contained, namely sand, clay, and dust particles, using the Pipette Method [9]. The next step is to measure the rate of water infiltration at the selected soil texture location by measuring the permeability of the soil. Measurements of soil texture and water infiltration rate were carried out at the Soil Physics Laboratory, Faculty of Agriculture, Universitas Andalas.

From the results of soil texture measurements and water infiltration rate, it was obtained that there were four composting locations, each representing four soil textures and four water infiltration rates. The location of BIH composting for clay texture with slow water infiltration rate (variant 1) was carried out at the Faculty of Agriculture, Universitas Andalas; loamy clay texture with moderate water infiltration rate (variant 2) was carried out in the yard of the Faculty of Engineering, Universitas Andalas; the texture of sandy clay loam with fast category water infiltration rate (variant 3) carried out in the yard of Koto Panjang Village; and sandy clay soil texture with high-speed water infiltration rate category (variant 4) carried out in the yard of Kapalo Koto's house. Composting variations in this study can be seen in Table-1.

Table-1. Variation of soil texture.

Variant	Soil Texture	Water Infiltration Rate (cm/hour)	
		Measurement Results	Category [3].
1	Clay	1.8	Slow (0.5-2.0)
2	Loamy Clay	2.3	Moderate (2.0-6.3)
3	Sandy Clay Loam	6.7	Fast (6.3-12.7)
4	Sandy Clay Soil	13.4	Very Fast (>12.7)

Composting preparation is the preparation of raw materials used for composting. The compost raw materials used in this study were 50% food waste and 50% yard waste which has been chopped to 0.3 to 1.5 cm. The food waste composition consists of vegetable waste 54.40%, fruit 28.55%, rice 11.77%, and side dishes 5.27%. This composition follows the most optimal results in previous studies, such as research by Ruslinda *et al.* [6]. The types of equipment used in this BIH composting research can be seen in Table-2.

Table-2. Research equipment’s.

Equipment	Function
BIH drill	Make the BIH
Pipe and PVC cover	Cover the BIH
Organic waste shredder	Shred raw material
pH meter	Measure the compost pH
Thermometer	Measure the compost temperature
Sieve (diameter 3 cm)	Sieve compost
Scale	Weigh solid compost
Spectrophotometer	MeasureC-Organic and Phosphor
Atomic Absorption Spectrophotometer (AAS)	Measure Kalium level

The next step is carrying out the research, including making BIH, analyzing compost raw materials, entering compost raw materials into the BIH, observing compost maturity, observing weather conditions during composting, and testing the quality and quantity of solid compost produced. The BIH was made using a BIH drill at each composting variation location. As many as eight holes were made because the research was carried out in duplicate. The diameter of the holes is 10 cm, the depths are 100 cm, and the distance between the holes is 50 cm. A PVC pipe is installed at the top of the hole, equipped with a cover with small holes for the water inlet. The image of the BIH section shows in Figure-1.

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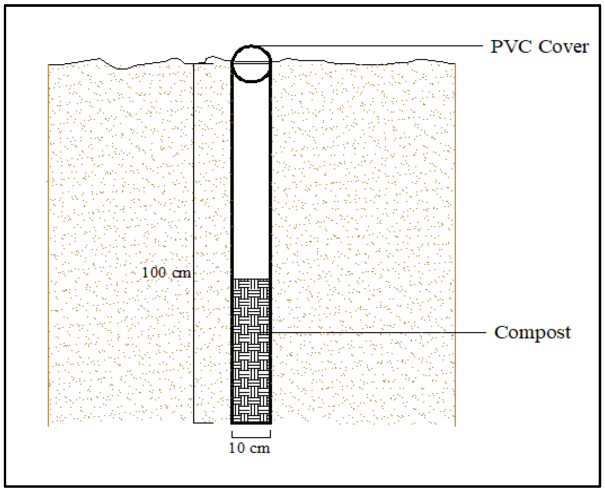

Figure-1. BIH cross-section.

Before composting, an analysis of the raw materials of the compost was carried out. This analysis aims to determine whether the raw materials meet the requirements as raw materials for compost. The parameters analyzed were temperature, pH, water content, and C/N ratio. If the raw materials meet the requirements, then raw materials are mixed and passed into the BIH. The BIH was covered with a PVC cover, and the compost maturity was monitored. The compost maturity test was carried out every day with some parameters, including composting time, temperature with a thermometer, pH with a pH meter, reduction level by measuring the decrease in compost height, and humidity by inserting a wooden stick into the BIH. If the wooden sticks were wet, the compost was still moist; otherwise, the compost was less moist if the wooden sticks were dry. Smell, texture, and color analysis were done virtually.

After the compost was ripened, the compost was removed from the BIH and then dried. The next step was to test the quality and quantity of the compost. Compost quality testing was carried out on physical and macro elements according to SNI 19-7030-2004 regarding compost specifications from domestic organic waste. Parameters of physical elements include water content, temperature, pH, color, and odor, while macro elements include C-organic, total N, C/N ratio, Phosphorus, and Potassium [10]. The compost quantity test is carried out by weighing the weight of the solid compost produced using a scale.

Data processing and analysis include composting performance analysis, namely maturity, quality and quantity of compost, analysis of the effect of soil texture and water infiltration rate on composting time and compost quantity, selection of optimal composting variations, and recommendations. Compost maturity analysis was carried out by comparing the results of maturity daily observations with the standard of compost maturity. Compost is ripe if the temperature is close to 30°C, the pH is close to neutral, the smell and color are like soil [10], the reduction rate is 20-40%, and less humid [11].

Compost quality analysis was conducted by comparing the measurement results of physical and macro elements with domestic organic waste compost standards according to SNI 19-7030-2004. Quantity analysis was carried out by comparing the weight of each compost produced from all compost variations. The effect of soil texture and water infiltration rate on the performance of BIH composting was analyzed using a correlation test using Microsoft Excel.

The selection of the most optimal BIH composting variation is determined by scoring. The scoring category consists of three criteria, namely:

- **Criterion 1:** a value of 1 is given if the parameters of the quality and maturity of the compost meet the quality standard of SNI 19-7030-2004.
- **Criterion 2:** a value of 0 is given if the compost's quality and maturity parameters do not meet the quality standard of SNI 19-7030-2004.
- **Criterion 3:** parameters that do not have quality standards, for example composting time and compost quantity, scoring is based on ranking. The minimum score is given to the lowest rank, while the maximum score is given to the highest.

The scoring results will show which compost variation has the most optimal composting performance when viewed from the maturity, quality, and quantity of compost produced. Optimal composting variation is the variation that has the highest total value for all parameters assessed.

RESULTS AND DISCUSSIONS

Environmental Conditions

Environmental condition analysis was carried out on soil and weather conditions. The soil conditions tested were soil textures and water infiltration rates. In this study, there were four types of soil texture and four water infiltration rates, which were the variations of composting, as shown in Table-1. The weather condition observed in the field was the rain duration at the BIH locations. Observations of weather conditions were carried out every day until the compost in each BIH matured. The duration of the rain was recorded manually.

In contrast, for the rain category (light, medium, and heavy), rain intensity data was used from the Meteorology, Climatology, and Geophysics Agency (BMKG) station of Padang City. During the composting process, there were several days of rain from the very light to very heavy category [12], with rain duration ranging from 1 to 9 hours. The results of observations for rain durations and categories can be seen in Figure-2.

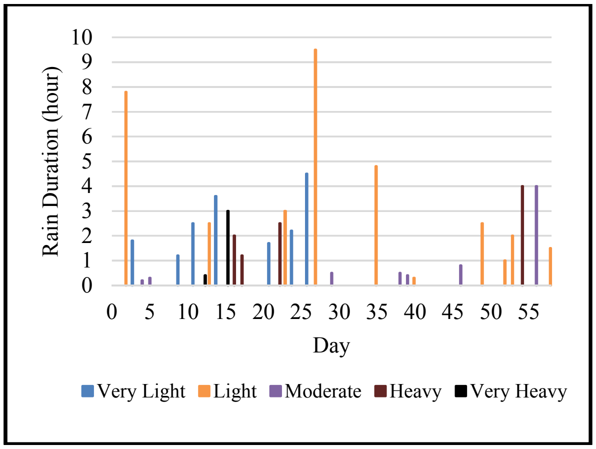

Figure-2. Observation of duration and category of rain during BIH composting.

Raw Material Analysis

Before composting, raw materials are analyzed to determine whether raw materials have met the requirements for composting. The analysis of compost raw materials can be seen in Table-3. The analysis results show that the temperature of the raw material from food waste is lower than that of yard waste. It is influenced by the water content contained in food waste is higher than yard waste. The criteria for compost raw materials are temperatures ranging from 25^{o}C to 28^{o}C, and the initial pH is acidic to neutral, with a pH range of 6 to 7. The water content of compost raw materials is around 50-60%, and the C/N ratio is around 25-50 [13]. From comparing the results of the analysis of the raw materials with the compost criteria, it was found that all parameters had been met so that the two raw materials, namely food waste and yard waste, could be used as compost raw materials.

Table-3. Analysis of compost raw materials.

Parameter	Raw Material		Standards [13]	Remarks
	Yard Waste	Food Waste		
Temperature	28°C	26°C	25-28°C	Accepted
pH	6.6	6.5	6-7	Accepted
Water Content	51%	58%	50-60%	Accepted
C/N Ratio	40	34.8	25-50	Accepted

Compost Maturity Analysis

Monitoring of compost maturity is carried out every day from the raw materials introduced until the compost is ripe. The parameters observed were temperature, pH, level of reduction, humidity, texture, color and odor, and composting time. In the beginning, all variations of composting experienced a decrease in temperature because, on the second day, it rained with a moderate category for almost 8 hours. However, after the fourth day, the temperature began to increase, which indicated that the microorganisms had started their activities in decomposing organic waste.

Peak temperature occurs at the beginning of the composting process because food or substrate is available in large quantities so that microorganisms have an activity to decompose food ingredients. This process produces energy in the form of heat, which makes the composting temperature increase [14]. This study's peak temperature of all composting variations occurred between 29-31^{o}C. This temperature falls into the mesophilic phase range. Thermophilic microorganisms live in a temperature range of 45-60^{o}C. These microorganisms consume carbohydrates and proteins, so the compost material can be degraded quickly. After most of the material decomposes, the temperature will gradually decrease [15]. The temperature of mature compost from all compost variations ranges from 27 to 28^{o}C and has met the criteria for compost maturity, which the temperature is below 30°C or equal to the groundwater temperature [10].

The decrease in pH occurred at the beginning of composting, from day 1 to day 8. At the beginning of composting, acid-forming microorganisms will lower the pH so that the compost is acidic. Acidic properties are caused by the process of restructuring organic compounds into simple organic acids. After the eighth day of composting, the pH increased to alkaline due to the decomposition of protein into ammonium by microorganisms. Some ammonium is released or converted to nitrate, and then the nitrate is denitrified by microorganisms, so the pH becomes neutral. According to Damanhuri and Padmi, the pH will drop at the beginning of composting because microorganisms will convert organic waste into organic acids and rise again and be stable. After all, the organic acids are consumed by other microorganisms until the compost is riped [2]. The pH of mature compost for all research variations ranged from 6.8 to 7, which met the criteria that pH was close to neutral 6.8-7.49 [10].

The level of reduction indicates the process of decomposition of compost raw materials. Over time there is an increase in the level of reduction until the compost is ripe. In this study, the level of reduction achieved ranged from 30% to 40%. This reduction rate follows the literature where the reduction rate of mature compost ranges from 20-40% or has been reduced by a third of its initial volume [11].

From the results of humidity monitoring, BIH which experienced the fastest decrease in humidity or lack of moisture, was in the texture of sandy clay loam with a water infiltration rate of 6.7 cm/hour (variant 3) and sandy clay soil with a water infiltration rate of 13.4 cm/hour (variant 4). Composting variants 3 and 4 have come into the less humid phase on day 20. In soil textures containing sand with high-speed water infiltration rates, rainwater that enters the BIH is absorbed into the soil faster so that the BIH dries faster and the composting process can run better. During the rainy season, the BIH is inundated, especially on soils with low water infiltration rates, and this results in increased compost moisture and interferes with the activity of microorganisms [16].The reduction of runoff that can be achieved for silt soil is 38.98 - 95.73% and for clay soil is 20.67 - 54.28% [17].

During composting, there is a change in texture and color. At the beginning of composting, the texture is still in the form of raw material and is brown, then it crumbles and turns black, then the texture and color of the compost are like soil which indicates the compost is ripe. BIH composting with sandy clay soil texture with a water infiltration rate of 13.4 cm/hour (variant 4) achieves changes in texture and color to resemble soil faster than other variants, which takes 46 days. Meanwhile, composting with clay texture with a water infiltration rate of 1.8 cm/hour (variant 1) accomplishes texture and color changing as the latest, on day 57. The difference in the time of changes in texture and color of each variation is influenced by the activity of decomposer microorganisms. If the activity of microorganisms is disturbed, the longer the compost becomes a soil form.

The same phenomenon also happens for the odor parameter. At the beginning of composting, the smell that arises is a bad smell due to microorganisms' decomposition of organic waste. Furthermore, there is a change in smell to a slight odor and finally to an earthy smell that indicates the compost is ripe. Ripe compost smells like soil because its material contains soil nutrients and a blackish color formed due to the influence of stable organic matter [15]. BIH composting with a sandy clay soil texture and water infiltration rate of 13.4 cm/hour (variant 4) also undergoes a change in odor to an earthy odor faster than other variations. On the 21st day of composting, variant 4 already smells of soil.

Composting time for all variations ranged from 47 days to 58 days. The fastest BIH composting to produce mature compost occurred in composting on a sandy clay soil texture and water infiltration rate of 13.4 cm/hour (variant 4), which took 47 days. Then, in a row, composting with sandy clay loam texture and infiltration rate of 6.7 cm/hour (variant 3) for 50 days, composting on loamy clay texture and water infiltration rate of 2.3 cm/hour (variant 2) for 55 days, and finally, on clay texture and water infiltration rate of 1.8 cm/hour (variant 1) for 58 days. Soil texture containing sand with a high-speed infiltration rate can accelerate the BIH composting process. The activity of microorganisms in the decomposition of organic waste is not disturbed in this composting because rainwater that enters the hole is absorbed into the soil more quickly so that the moisture in the BIH can be maintained. The results of the compost maturity analysis can be seen in Table-4.

Compost Quality Analysis

The compost's quality is analyzed after the compost is ripe and throughout the drying process. The analysis was carried out covering physical elements and macro elements according to SNI 18-7030-2004. The analysis results of the compost's quality can be seen in Tables 5 and 6. The analysis of the compost quality results shows that all composting variations have met the SNI 19-7030-2004. The analysis results of physical elements are the water content of the compost in the range 17.04 to 21.87, temperature 27 to 28ºC, pH 6.8 to 7.0, and smell, texture, and color like soil. The analysis results of macroelements C-Organic are in the range 9.90 to 10.13, N-Total in the range 0.49 to 0.54, C/N ratio 18 to 20, phosphorus 0.20 to 0.40, and potassium 1.81 to 2.57.

Compost Quantity Analysis

Analysis of the quantity of compost can be seen in Table 7. The weights of solid compost produced by all variations are 0.84 kg to 1.01 kg, with the percentage of compost quantity ranging from 62.1 to 72.1%. The highest amount of solid compost was produced in loamy clay texture and a water absorption rate of 2.3 cm/hour (variant 2). It happened because the level of reduction in variant 2 is lower than the other variations. The quantity of compost is related to the degree of reduction. The smaller the reduction rate, the greater the quantity of solid compost produced [8].

Selection of BIH Composting Variation

The selection of the most optimal variety of compost is formulated by giving a score (scoring) on the maturity test results, the quality of physical elements and macro elements, and the quantity of solid compost produced. The most optimal compost variation is the variation with the highest total score. The results of the assessment can be seen in Table-8. Based on the scoring results, the highest total score was obtained in variant 4, namely BIH composting on sandy clay soil texture with a high-speed water infiltration rate of 13.4 cm/hour.

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Table-4. Compost maturity analysis.

Variant	Temperature (°C)	pH	Reduction Level (%)	Humidity	Texture and Colour	Odor	Composting Duration (days)
1	27	6.8	35	Less humid	Soil and black	Soil	58
2	28	6.9	31	Less humid	Soil and black	Soil	55
3	28	7.0	38	Less humid	Soil and black	Soil	50
4	28	6.9	36	Less humid	Soil and black	Soil	47

Table-5. Physical elements analysis.

Variant	Water Content (%)	Temperature (°C)	pH	Colour	Odor	Remarks
1	21.87	27	6.8	Black	Soil	Accepted
2	18.50	28	6.9	Black	Soil	Accepted
3	17.04	28	7.0	Black	Soil	Accepted
4	20.91	28	6.9	Black	Soil	Accepted
Standard	<50%	<30°C	6.8-7.49	Black	Soil	

Table-6. Macro elements analysis.

Variant	C-Organic	N Total	C/N Ratio	Phosphor	Potassium
1	9.90	0.49	20	0.20	1.81
2	9.97	0.54	18	0.26	2.04
3	9.99	0.54	18	0.40	2.57
4	10.13	0.50	20	0.38	2.23
Standard	9.8-32%	>0.4%	10-20	>0.1%	>0.2%

Table-7. Compost quantity analysis.

Variant	Raw Material (kg)	Solid Compost (kg)	Quantity Percentage (%)
1	1.4	0.87	62.1
2	1.4	1.01	72.1
3	1.4	0.86	61.4
4	1.4	0.94	67.1

Table-8. Scoring.

Variant	Compost Maturity	Compost Quality	Compost Quantity	Total Score
1	7	10	2	19
2	8	10	4	22
3	9	10	1	20
4	10	10	3	23

Variant 4 is the variation with the fastest maturity time and fulfills all compost quality criteria. Soil texture containing sand has a faster water infiltration rate, so rainwater that inundates BIH can seep into the ground. It makes the composting process run more optimally because the humidity in the BIH can be maintained. The activity of microorganisms in decomposing organic waste is not hindered.

The effect of water absorption rate on composting time and compost quantity in BIH composting was analyzed using a correlation test. The infiltration rate variable was the independent variable, while the

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composting time and compost quantity were the dependent variables. The correlation between water infiltration rate with composting time and compost quantity can be seen in Figure-3 and Figure-4.

The correlation coefficient between the water infiltration rate and the composting time is -0.943. This value indicates a solid correlation between the water infiltration rate and the composting time. A negative sign of this value means that the relationship between the two is opposite. It means that if the water infiltration rate is high, the composting time is fast. The correlation coefficient between the water infiltration rate and the compost quantity is -0.163. This value indicates a poor relationship between the rate of water infiltration and the quantity of compost. In this study, the quantity of compost for each variation did not show a significant difference. The type and composition of the raw materials used in each composting variation are the same. The highest quantity of compost was produced in variant 2, namely composting on loamy clay texture and water infiltration rate of 2.3 cm/hour.

RECOMMENDATIONS

The results showed that BIH composting was influenced by environmental conditions such as weather conditions. BIH composting in this study took place between 47 to 58 days. Rain during the composting process causes the compost to become wet, nutrients are washed out, and the decomposition process runs slowly.

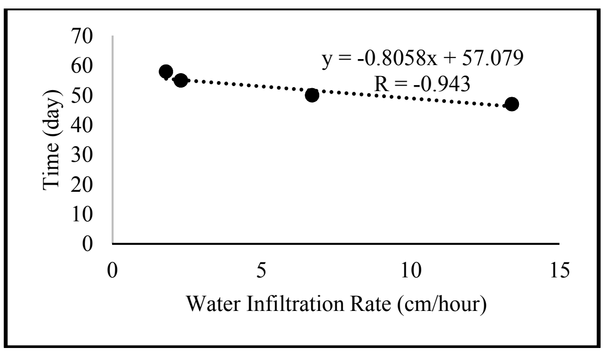

Figure-3. Correlation of water infiltration rate with composting time.

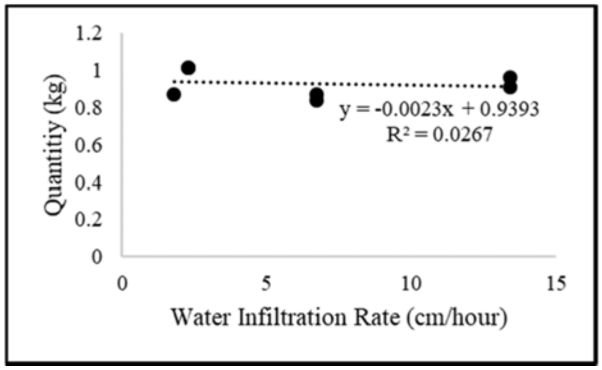

Figure-4. Correlation of water infiltration rate with compost quantity.

BIH has the benefit of reducing puddles and can be used as a composting method. The recommendation from the results of this study is the creating of BIH as rainwater infiltration and composting more optimally carried out on sandy clay soil textures, and the water infiltration rate is very fast, 13.4 cm/hour. In this condition, rainwater entering the BIH is more quickly absorbed into the soil so that the moisture in the BIH can be reduced. The humidity that is maintained during composting helps the activity of microorganisms in breaking down organic waste. Compost matures faster. The composition of organic waste used as raw material for compost is 50% food waste and 50% yard waste that has been chopped up to 0.3 to 1.5 cm.

CONCLUSIONS

The BIH composting carried out on each soil texture and in the slow to high-speed category of water infiltration rate had met the compost's maturity, quality, and quantity tests. BIH composting time ranged from 47 to 58 days, with the percentage of the quantity of solid compost produced ranging from 62.1-72.1% of the weight of the compost raw material. BIH composting is more optimally carried out on sandy clay soil textures with a high-speed water infiltration rate of 13.4 cm/hour. The texture of the soil containing sand and the high-speed rate of water infiltration can speed up the composting time, especially during the rainy season. In this condition, the logged rainwater in BIH is more quickly absorbed into the soil so that the humidity in BIH can be maintained to optimize the activity of microorganisms in decomposing organic waste.

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