

Research Article

Improvement of soil moisture storage in clove plantation land using biopore technology and organic material litters

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Abstract: The biopore infiltration hole with organic material litter can increase the soil capacity to accommodate and store soil moisture. This study was aimed to determine the effect of biopores and organic material litter on soil moisture storage and the relationship of climatic conditions on soil moisture storage. The experiment was carried out on clove plantations on Ternate Island, North Maluku from December 2018 to February 2019. This study used a factorial randomized block design. The first factor was the biopores with a depth of 50 cm and 90 cm, and the second factor was 4 types of organic material litters in the form of nutmeg leaves, clove leaves, Guinea grass leaves and a mixture of clove leaves and Guinea grass. The factors observed were total soil water storage and at depths of 0-20, 20-40, 40-60 and 60-80 cm; organic matter content; C/N ratio and soil total N. Data analysis used the GenStat program with analysis of variance test (ANOVA) and Duncan's Multiple Distance Test. Results of the study showed that evaporation and percolation are climatic factors that affect water loss. Increase in soil water storage at 20-40 cm soil depth of 107.56 mm was yielded by the treatment of 50 cm biopore and Guinea grass leaf litter but it was not significantly different from the 50 cm biopore and clove leaf litter + chicken manure treatment. The treatment of biopore and organic material litter also increased the organic matter and soil total N and decreased the soil C/N ratio, but it did not have a significant effect.

Keywords: *biopore, clove plant, organic material litter, soil moisture storage*

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Introduction

Clove plantations on Ternate Island are formed from pyroclastic materials and parent materials from weathered basalt andesite rocks deposited after the eruption of Gamalama volcano so that the soil units formed are generally the Andisol Order (Hadun et al., 2016). The process of soil formation originating from volcanic ash materials makes the dominant soil are in silt and sand fractions, loam, silty loam and sandy loam textures and granular structures (Anda et al., 2015). Andisol is a soil with a low bulk density, less than 0.90 g/cm³ (Soil Survey Staff, 2014), high total porosity, high organic matter and high water holding capacity

(Sukarman and Dariah, 2014). So, the soil contains water but is not easily available to meet the needs of plants. As a result, many clove plantations experienced drought during the dry season in 2015 (Amiruddin and Umasugi, 2018).

Groundwater is available during the rainy season and becomes unavailable in the soil during the dry season. If within a certain period of time there is no addition of water to the soil, either by rain or irrigation, the soil will soon dry out and will affect negatively on the growth of cultivated plants (Ayu et al., 2013). Although the annual rainfall is high in tropical areas, the air temperature is also high, so that the water is easy to lose and has low availability at one time. It makes rainfall as the

main source of water for plant growth and also as the most determining limiting factor in dryland agriculture.

The biopore infiltration hole technology is a hole on the soil surface to a certain depth in the soil to drain and store water and air, as a place for the decomposition of plant litter into organic material which then provides nutrients from the decomposed organic matter (Permatasari, 2015). The biopore holes that contain organic matter are expected to increase the absorption and reserves of water in the soil in the dry season, thus supporting plant growth (Landl et al., 2019). This is because biopores or infiltration holes will increase water reserves in the soil and prevent surface water flow (Prameswari et al., 2014).

Drying and distilling clove leaves can produce clove leaf oil which has economic value (Andries et al., 2014). Clove oil (eugenol) has functions as anti-microbial, anti-oxidant, and anti-fungal (Manganyi et al., 2015). Leaves, branches and roots of plants that have died are plant litter which will be decomposed and become organic material in the soil in the clove plantation land, then the organic material becomes very important for soil fertility, especially for increasing nutrients and physical ability of the soil to support plant growth and production of clove. Several indicators of soil physical properties related to soil organic matter are aggregate formation and stability (Zhou et al., 2013), soil unit density and soil porosity (Robin et al., 2018), soil moisture characteristics (Minasny & McBratney, 2018).

On the island of Ternate, generally litter from clove and nutmeg plants in the form of leaves is widely available and mostly not treated as waste so that during the harvest season it is collected and burned. It also happens with the Guinea grass plants that grow wild around the clove plantations. The plant leaf litter is more beneficial when optimized as organic matter. The results of the research showed that the application of organic matter could improve soil physical properties, such as increasing soil aggregate stability, porosity, soil moisture content and reducing soil bulk density (Chaudhari et al., 2013). This causes a wider distribution and penetration of roots, resulting in greater nutrient and water uptake and an impact on increased plant growth and production. The addition of organic matter into the sandy soil will increase the number of medium-sized pores and reduce macro pores. The pore space in the soil determines the water and air content in the soil and determines the ratio of good air and water systems (Dexter et al., 2008). Thus, it will increase the ability to hold water (Ankenbauer and Loheide, 2017). However, if there is a decrease in soil organic matter, it will cause an increase in soil bulk

density, decrease in soil porosity, aggregate stability and water content of field capacity (Olness and Archer, 2005).

The aim of this study was to elucidate the increase in the effectiveness of soil water storage in clove plantations.

Materials and Methods

Research location

The research was carried out on the drought clove plantation land and Typic Hapludant soil type, which is located in the northern part of Ternate Island, North Maluku, 00°50'27.3" N and 127°20'27.0" E, altitude OD 264 m above sea level, and slope of 15-20%.

Soil characteristics

Soil characteristics, namely soil texture, soil organic matter, soil bulk density, soil density, saturated hydraulic conductivity and soil moisture content (pF 2.5 and pF 4.2) at a depth of 0-20, 20-40, 40- 60 and 60-80 cm were obtained from observation of soil profiles in the field and analysis of soil samples in the laboratory.

Climatic characteristics

Daily rainfall was measured using an artificial rain gauge (umbrometer), using a 100 ml measuring cup and a 9 cm diameter glass funnel, which is installed on open land as high as 1.2 meters from the ground. Rainfall observations were carried out 24 hours/day during the study. Measurement of air temperature used *digital thermometer HTC-1 (humidity temperature clock)*. The tool was placed 1.5 m above the ground. Observations of air temperature were at 07.00, 13.00 and 15.00.

Soil moisture storage

Soil moisture storage was calculated using the following equation,

Moisture storage equation; $S_{total} = (\phi_x \times D_x) + (\phi_x \times D_x) + \dots + (\phi_x \times D_x)$

Notes: S_{total} = total moisture storage for each observation location (mm); ϕ_x = actual volume of water content x depth (cm³) D_x = soil layer depth x (cm) (Priyono, 2010). Volume of water content = gravimetric water content x bulk density (Sojka et al., 2008; Priyono and Laksmana, 2016)

Experimental design and data analysis

The experiment used plant litter, which is considered waste, to become compost, namely leaf litter from cloves, nutmeg and Guinea grass as organic material in the biopore technology. The field experiment consisted of two factors: (1) depth

of biopores (B1. 50 cm biopores, B2. 90 cm biopores), artificial biopore holes using 10 cm PVC pipe and (2) organic material (S1. Nutmeg leaf litter + chicken manure, S2. Clove leaf litter + chicken manure, S3. Guinea grass leaf litter + chicken manure, S4. Clove leaf litter + Guinea grass leaf + chicken manure with an amount of 1:1 kg). There were 32 experimental units of biopore and organic matter treatments with a factorial randomized block design to determine the response

to the variables of total soil water storage and each soil layer, soil organic matter content, soil C/N ratio and soil total N. Descriptive data analysis and analysis of variance were continued with the DMRT (Duncan Multiple Range Test) at a significant level of $\alpha = 0.05$. The data were analyzed using the GenStat program. Observations of climatic conditions and field experiment took place from December 2018 to January and February 2019).

Table 1. The parameters and methods of soil analysis.

No.	Parameter	Methods for Analysis/Tools
1	Texture	Pipette (Kurnia et al., 2006; Prijono, 2008)
2	Bulk density	Cylinders (Kurnia et al., 2006; Prijono, 2008)
3	Particle density	Pycnometer (Kurnia et al., 2006; Prijono, 2008)
4	Total pore space	1-BI/BJ x 100% (Kurnia et al., 2006; Moradi et al., 2015)
5	Moisture content	Gravimetry (Kurnia et al., 2006; Prijono, 2008)
6	Saturated hydra. Conductivity	Constant head (Kurnia et al., 2006; Prijono, 2008)
7	Soil moisture (pF 0, 1, 2, 2.5, 4.2)	Sand box and Kaolin box, Pressure Plate Chamber (Kurnia et al., 2006; Prijono, 2008)
8	Organic matter	Walkley and Black (Balitan, 2005)
9	Rainfall	Umbrometer (Tjiptanto, 2011)
10	Evaporation	Micro-lysimeter (Flumignan et al., 2012)
11	Percolation	Darcy's law and the SPAW model (Saxton and Willey, 2005)

Results and Discussions

Characteristics of soil physical properties and soil moisture availability

The soil in the research location is dominated by silt (26-74%) and sand (25-67%) fractions in each of its layers, with a loam to silty loam texture in the topsoil and sandy loam in the subsoil. The loam texture in the top layer causes the low ability of the soil to absorb water, which was 0.9 mm available moisture and field capacity (pF 2) of 0.23 cm³/cm³ (Table 2). The low available water in the soil was caused by the reduced supply of rainwater because the water source in dryland agriculture is rainwater, and water in macro pores is easily lost due to the evaporation process. In addition, the strong soil resistance to water by the dominant meso pore in the silt fraction in the topsoil causes water to become unavailable for absorption by plant roots. Soil texture and porosity affect water storage, water retention and evaporation rates (Li et al., 2013). As according to Sojka et al. (2008), texture affects groundwater holding capacity and water loss due to evaporation. Furthermore, in the subsoil, which has a sand fraction, the ability to retain water is low because it circulates in and out more quickly due to the domination of large pores. Soil porosity ranged from 67.26-75.91% in the top

layer and 75.67-79.28% in the lower layers. Such soil porosity is very good for water entry and exit, but the ability to hold water is low. As a result, the soil is easy to lose water and plants lack water during the dry season.

The dominance of silt and sand particles increases soil porosity of clove plantations, which is 67.26% to 79.28%. As a result, the ability of the soil to hold and store water is low, in turn, accelerates movement and loss of water in the soil. The size and distribution of pores in the solid phase of the soil will affect the moisture content and, conversely, the water content can also affect the physical volume of the soil and the configuration of pore sizes (Sojka et al., 2008). So, total porosity and pore size distribution are important factors that influence the movement of water in the soil. Macro pores play a role in the infiltration process and movement of water in the soil (Prijono and Laksmana, 2016).

Based on the results of the analysis of soil physical properties presented in Table 2, texture, bulk density, particle density and porosity of the soil in clove plantation land had different potentials in each layer. It can be stated that the deeper the soil, the coarser the texture, where the soil texture in 0-20 cm layer is loam (36% sand, 43% silt and 21% clay), while at a soil depth of 40-60 cm, the

texture is sandy loam with a sand fraction of 67%. So, the deeper the soil (0 cm to 60 cm depth), the more dominated the sand fraction. This means that the soil's ability to maintain available soil moisture is lower in deeper soils. Sojka et al. (2008) stated that sandy soil has a very low water holding

capacity compared to loam and silt per volume. Soil bulk density ranged from 0.44 to 0.67 g/cm³, indicating light and developed soil from the volcanic material of Gamalama Volcano. Low bulk density is characteristic of volcanic soils (Soil Survey Staff, 2014).

Table 2. Soil characteristics.

Soil properties	The depth of soil layer (cm)			
	0-20	20-40	40-60	60-80
Bulk density (g/cm ³)	0.48	0.67	0.52	0.44
Particle density (g/cm ³)	2.00	2.06	2.12	2.13
Porosity (%)	75.91	67.26	75.67	79.28
Sand (%)	36	31	67	25
Silt (%)	43	61	26	74
Clay (%)	21	8	7	1
Textural class	loam	Silty loam	Sandy loam	Silty loam
Saturated hydraulic conductivity (cm/hour)	154.8	115.0	370.9	115.6
Penetration resistance (MPa)	2.55	2.55	1.18	1.18
Organic matter (%)	6.78	5.38	2.94	1.02
Moisture content at;				
pF 0 (cm ³ /cm ³)	0.76	0.67	0.76	0.79
pF 1 (cm ³ /cm ³)	0.41	0.53	0.32	0.37
pF 2 (cm ³ /cm ³)	0.37	0.46	0.31	0.32
pF 2.5 (cm ³ /cm ³)	0.23	0.4	0.26	0.19
pF 4.2 (cm ³ /cm ³)	0.14	0.21	0.14	0.10
Moisture available (cm ³ /cm ³)	0.09	0.19	0,1.2	0.09

Furthermore, most of the soil layer is dominated by the silt fraction and has a silty loam texture. Most of these soil characteristics characterize the soil in the clove plantations in the research location. This is due to the soil formation material originating from pyroclastic materials and volcanic ash from the Gamalama Volcano which is dominated by the size of the silt and sand particles at all depths. The results of research by Prasetya et al. (2012) on Andisols showed that the dominant texture classes are loam, silty clay loam, clayey loam, silty clay. The textures of loam, silty loam and sandy loam in the research location show that the soil is dominated by silt and sand fractions. Loam and silty loam textures make the soil to be able to store more water in each layer of soil. As according to Sojka et al. (2008), soil texture is determined by the proportion of primary particles sized clay, silt and sand.

Penetration resistance has a negative correlation ($p \leq 0,01$), and soil organic matter has a positive correlation ($p \leq 0,05$) with soil moisture content in the conditions of field capacity (FC), permanent wilting point (PWP) and available moisture. Meanwhile, saturated hydraulic conductivity (SHC) and soil porosity also have a positive but insignificant effect on the increase or

decrease in soil moisture content. The higher the soil organic matter, the higher the available water, and the coarser the soil texture and the greater the number and size of the macro pores, the lower the available water because water is easily released from the soil (Baskoro and Tarigan, 2007).

Climatic characteristics and soil moisture content

The moisture content in the 20-40 cm layer was higher and it lasted longer in the soil than the 0-20 cm layer after rain occurred (Table 3). This is due to the density of clove and ground cover vegetation and the accumulation of leaf litter on the soil surface of clove plantation. In addition, there is water loss due to evaporation, percolation and surface runoff during rain. Water in the soil can be reduced due to evaporation, percolation, and water absorption by plant roots (Ayu et al., 2013).

Based on Table 4, there was a significant correlation between hydrological factors and groundwater content. Rainfall increased groundwater content, whereas evaporation decreased groundwater content. In addition to water content, there was also an increase in surface runoff and percolation due to increased rainfall. Soil with vegetation and litter covers on its surface

will be able to intercept and retain water longer after rain occurs than in forests with open land without or with little litter on its surface. Rain events with different intensities affect soil storage capacity and water availability at each soil layer. High rainfall increases water content in the surface layer and the lower soil layers, while low rainfall

causes little water potential and water content is stored at the soil surface and then lost due to evaporation. According to Xu et al. (2011), the greater the rainfall, the greater the increase in groundwater content in all soil layers. The effect of rainfall on soil moisture depends on the intensity of rainfall and evapotranspiration.

Table 3. The hydrological parameters and soil moisture content.

Date	Evaporation (mm)	Percolation (mm)	Rainfall (mm)	Moisture content in 0-20 cm (mm)	Moisture content in 20-40 cm (mm)
28-Jan	0.0	1.8	4.0	3.4	4.2
29-Jan	0.0	1.0	2.7	3.2	4.0
30-Jan	0.3	0.6	0.0	2.8	3.7
31-Jan	0.5	0.0	0.0	2.3	3.4
01-Feb	0.2	0.0	1.4	2.4	3.5
02-Feb	0.0	0.7	2.7	3.0	3.8
03-Feb	0.9	0.3	0.0	2.8	3.6
04-Feb	0.5	0.0	0.0	2.2	3.3

Table 4. The relationship between climatic factors and soil moisture content.

	Rainfall	Evaporation	Percolation	Moisture content in 0-20 cm
Evaporation (mm)	-0.823* (0.012)			
Percolation (mm)	0.831* (0.011)	-0.617 (0.103)		
Moisture content in 0-20 cm (mm)	0.865** (0.006)	-0.821* (0.012)	0.913** (0.002)	
Moisture content in 20-40 cm (mm)	0.763* (0.027)	-0.764* (0.072)	0.807* (0.015)	0.953** (<0.01)

Pearson correlation coefficient with (p value); *) significant at the 0.05 level; and; **) 0.01 level.

Soil moisture content

Soil moisture content increased in each layer of soil in clove plantations due to the provision of organic material from cloves, nutmeg and Guinea grass and a mixture of clove leaves and Guinea grass at all biopore depths. Table 5 shows that soil moisture content in the soil layer of 20-40 cm is very significant due to the provision of organic material litter, especially a mixture of organic material litter from clove leaves and Guinea grass compared to other organic material litters. This is due to the accumulation of soil organic matter which has undergone decomposition resulting in an increase in soil organic matter. Increase in organic matter causes an increase in the ability of the soil to store more soil moisture. This is in accordance with Hardjowigeno (2003), which stated that the more organic matter content in the soil, the higher the moisture content in the soil because the organic matter will increase its water-binding ability. Soil porosity also increases with the increase in organic

matter. The results of observation showed that the addition of organic material litter into the soil of clove plantations with a loamy and sandy texture increased the available moisture content, which may be due to the higher organic matter and soil porosity resulting in a lot of water being stored into the soil. The total porosity of sandy soils increases by adding clay soil and organic matter (Heliyanto and Hidayah, 2011). It is in line with the findings of Bescansa et al. (2006) indicated that plant residues which are decomposed into organic matter increase the proportion of soil mesopores.

Soil moisture storage

Total soil moisture storage

Soil moisture storage in clove plantation land has increased due to an increase in organic matter obtained from the application of organic material litter that had undergone decomposition so that it mixed to form soil at a layer of 0-90 cm in the soil. In this study, the provision of nutmeg leaf, clove

leaf and Guinea grass leaf litters were able to bind and store soil moisture of 2465.69 mm/ha with the average soil moisture storage per organic material litter was 308.20 mm. The results of the research

on the treatment of biopores and organic material litter on total soil moisture storage showed that the organic material litter factor responded to the increase in total soil moisture storage.

Table 5. The effectiveness of biopores and organic matter on soil moisture content.

Treatment	Moisture content in each soil layer			
	0-20 cm	20-40 cm	40-60 cm	60-80 cm
	(% volume)			
B50+nutmeg leaf litter+chicken manure	23.61	43.79 ab	37.54	30.25
B50+clove leaf litter+chicken manure	23.43	45.27 abc	41.58	32.30
B50+Guinea grass leaf litter+chicken manure	25.12	53.78 c	42.99	31.29
B50+clove leaf litter+ Guinea grass+chicken manure	23.97	44.45 ab	39.58	33.00
B90+nutmeg leaf litter+chicken manure	23.19	39.90 a	37.77	31.05
B90+clove leaf litter+chicken manure	23.99	41.14 ab	39.81	33.69
B90+Guinea grass leaf litter+chicken manure	23.53	41.96 ab	41.44	34.42
B90+clove leaf litter+Guinea grass+chicken manure	24.88	50.26 bc	43.75	35.68

Notes; B50 is a biopore with a depth of 50 cm; B90 is a biopore with a depth of 90 cm; Figures followed by the same letter in the same column are not significantly different at the 5% DMRT level.

The results of statistical tests at the 5% level are significant, where $p < \alpha (0.05)$. This shows that the provision of organic material litter in the form of nutmeg leaf litter (S1); clove leaf litter (S2); Guinea grass leaf litter (S3) and a mixture of clove leaf litter + Guinea grass leaf litter (S4) gave respond to soil moisture deposits. Data presented in Table 6 show that the soil moisture storages for 4 levels of organic material litter were 290.5 mm (S1), 304.9 mm (S2), 316.1 mm (S3), and 320.0 mm (S4). Clove leaf + Guinea grass leaf litter (S4) was the level that gave the best response and had a significant effect in increasing the total moisture storage of the soil, but it was not significantly different from nutmeg leaf and Guinea grass leaf litters. Because the availability of clove litter is generally high around clove plantations, the use of clove leaf litter is the main choice for increasing soil water storage. The plant leaf litter that has undergone decomposition affects the available water in the soil (Intara et al., 2011). Furthermore, according to Wang et al. (2017), soil moisture content at a depth of 0-50 cm and under 150 cm soil depth will be maintained stably at 25% and 18% with the use of organic fertilizers. Organic material litter from Guinea grass leaves and a mixture of clove leaf + Guinea grass leaf litters gave the best contribution to increasing soil moisture storage in clove crop fields. This is because the leaf litter of Guinea grass is fast and easy to decompose than the litter of clove and nutmeg leaves so that it is smoother and mixes with the soil to absorb and store more water. This is due to the increase in organic matter in the soil and a smoother soil texture, which increases the soil holding power and reduces the rate of evaporation and percolation that

occurs in the soil. Furthermore, according to Intara et al. (2011), the application of organic matter to the soil reduces the amount of evaporation, thereby it increases the available water content.

Table 6. Effectiveness of organic matter on the total soil moisture storage.

Treatment	Soil moisture storage (mm)
Nutmeg leaf litter+chicken manure	290.51 a
Clove leaf litter+chicken manure	304.93 ab
Guinea grass leaf litter+chicken manure	316.08 b
Clove leaf litter+Guinea grass+chicken manure	319.97 b

Notes: numbers followed by the same letter in the same column are not significantly different at the 5% DMRT level.

Soil moisture storage of each layer

The highest soil moisture storage for each layer was in the 20-40 cm layer, which was 90.14 mm, then at a soil layer depth of 40 - 60 cm as much as 81.12 mm, at the layer depth of 0-20 cm was 71.89 mm and the lowest soil moisture storage was at a layer depth of 60-80 cm, which was 65.05 mm (Figure 1). A large amount of soil moisture storage in the 20 - 40 cm layer was caused by the high organic matter content in the layer. This is due to the fact that organic matter can increase the holding power of the soil to water so that an increase in soil organic matter at a layer of 20-40 cm will also increase the amount of water stored in the soil.

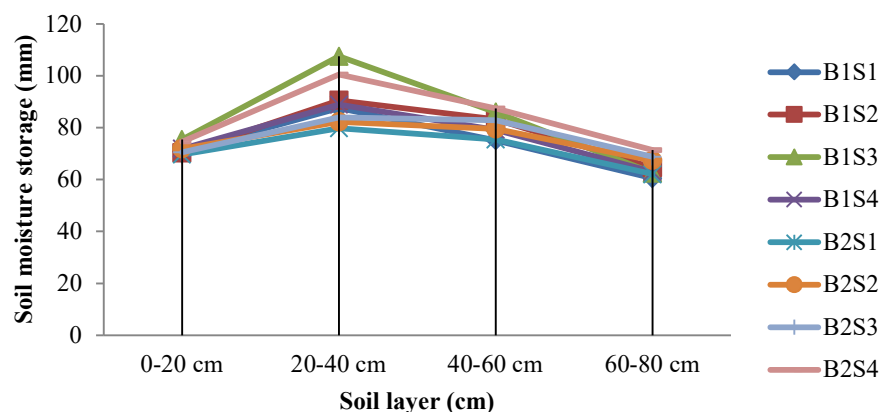


Figure 1. Soil moisture storage of each soil layer.

Notes; B1S1 (Biopore 50+nutmeg leaf litter+chicken manure); B1S2 (Biopore 50+clove leaf litter+chicken manure); B1S3 (Biopore 50+Guinea grass leaf litter+chicken manure); B1S4 (Biopore 50+clove leaf litter+Guinea grass leaf litter+chicken manure); B2S1 (Biopore 90+ nutmeg leaf litter+chicken manure); B2S2 (Biopore 90+clove leaf litter+chicken manure); B2S3 (Biopore 90+Guinea grass leaf litter+chicken manure); and B2S4(B90+clove leaf litter+ Guinea grass leaf+chicken manure).

Table 7. Biopores and organic matters on soil moisture storage in 20-40 cm layer.

Treatments	Soil water moisture storage (mm)
B50+nutmeg leaf litter+chicken manure	87.58 ab
B50+clove leaf litter+chicken manure	90.55 abc
B50+Guinea grass leaf litter+chicken manure	107.56 c
B50+clove leaf litter+Guinea grass leaf+chicken manure	88.89 ab
B90+ nutmeg leaf litter+chicken manure	79.80 a
B90+clove leaf litter+chicken manure	82.27 ab
B90+Guinea grass leaf litter+chicken manure	83.94 ab
B90+clove leaf litter+ Guinea grass leaf+chicken manure	100.52 bc

Notes; B50 is a biopore with a depth of 50 cm; B90 is a biopore with a depth of 90 cm; Figures followed by the same letter in the same column are not significantly different at the 5% DMRT level.

Table 7, the results of the analysis of variance showed that the interaction between biopore and organic material litter treatments gave a positive response and had a significant effect on increasing soil moisture storage at a soil depth of 20 - 40 cm. DMRT test ($\alpha = 0.05$), 50 cm biopore and Guinea grass leaf litter + chicken manure gave the best response to an increase in soil moisture storage of 107.56 mm but the effect was not significantly different from the 50 cm biopore treatment and clove leaf litter + chicken manure. This is due to the decomposition of Guinea grass leaf litter and clove leaves, which increases the soil organic matter content of 7.02% (Figure 2) so that it was able to absorb and store more soil moisture.

Soil organic matter, C/N ratio and total N

Soil organic matter and soil total N in clove plantation land increased while the soil C/N ratio decreased during the application of organic

material litter and at all biopore depth levels, but had a significant effect (Figure 2).

Soil organic matter content

Soil organic matter increased in clove plantation lands due to the provision of organic material litter from nutmeg leaves, clove leaves and Guinea grass leaves. Plant litter undergoes decomposition by microorganisms and the environment so that it becomes nutrients and organic matter for the soil. The role of litter decomposition is that the soil fauna will distribute organic matter into the soil profile (Frouz, 2018). The response of biopores and organic material litter in all experimental treatments increased the average soil organic matter content of each layer, especially 20-40 cm and 60-80 cm layers (Figure 2). The average of 60-80 cm-layer soil organic matter increased by 4.19% at the end of the study from the initial organic matter content of 2.68%.

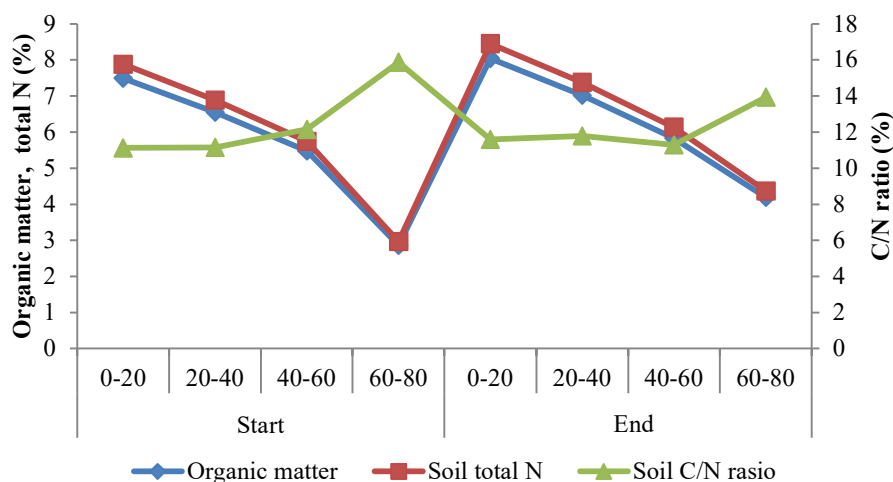


Figure 2. Average organic matter content, C/N ratio and total N for each soil layer during the beginning and the end of organic material litter application and biopore treatment.

The increasing level of soil organic matter due to the treatment of biopores and organic material litter will increase the ability of water storage in the soil in clove plantation lands.

Soil C/N ratio

The addition of organic material litter from nutmeg, clove leaves and Guinea grass leaves into all biopore depths decreased the C/N ratio in the soil in clove plantations. This is due to carbon reduction and nitrogen increase during the decomposition process and after the decomposition of plant leaf litter into organic matter. The value of the C/N ratio of soil in the 40-60 cm and 60-80 cm layers had decreased, while the 0-20 cm and 20-40 cm soil layers were balanced after giving organic material litter (Figure 2). The average C/N value of 6-80 cm layer decreased by 1.94% from the average of initial soil C/N ratio, 15.88% to 13.94 at the end of the study. The treatment of biopores and organic material litter did not significantly affect the decrease in soil C/N ratio. The decrease in the amount of soil C/N ratio was caused by the need of soil microorganisms for metabolism needed for the decomposition of litter into organic matter. According to Widarti et al. (2015), the metabolism of living microorganisms utilizes about 30 parts of carbon for each part of nitrogen, of which about 20 parts of carbon are oxidized into CO₂, and 10 parts are used to synthesize protoplasm.

Soil total nitrogen content

Soil total N content in clove plantation land increased after 90 days of giving nutmeg leaf litter, clove leaf litter and Guinea grass leaf litter into the soil. The results showed that the biopores with a

depth of 50 cm and the Guinea grass leaf litter + chicken manure increased soil organic matter by 1.405% compared to other treatments. This is the result of the decomposition process of organic material litter resulting in the decomposition and release of nitrogen compounds contained in the litter of organic matter into the soil (Xiong et al., 2014). Decomposed litter of clove, nutmeg and Guinea grass leaves increases the amount of carbon and soil nitrogen at a depth of 0-90 cm. The increase in total N-soil on clove cropland comes from the mineralization of the organic material litter which is given in the soil. The availability of nitrogen in the soil is influenced by the needs of plants and soil organisms. According to Hardjowigeno (2003), available nitrogen in the soil is bound by illite in clay mineral in the form of NH₄⁺ so that it cannot be used by plants, but nitrogen in the soil can be lost due to uptake by plant roots and used by soil microorganisms.

Conclusion

The soils of the clove plantation land in the study area have silty loam and sandy loam textures. Evaporation and percolation as well as porosity and soil organic matter are factors affecting the level of water availability in the soil in clove plantations. Biopores with a diameter of 50 cm and clove leaf litter + chicken manure was the best and economical litter to increase the total soil water storage and soil water storage at a depth of 20-40 cm. The treatment of biopores and organic material litter increased the organic matter and soil total nitrogen and decreased the soil C/N ratio but did not have a significant effect.

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