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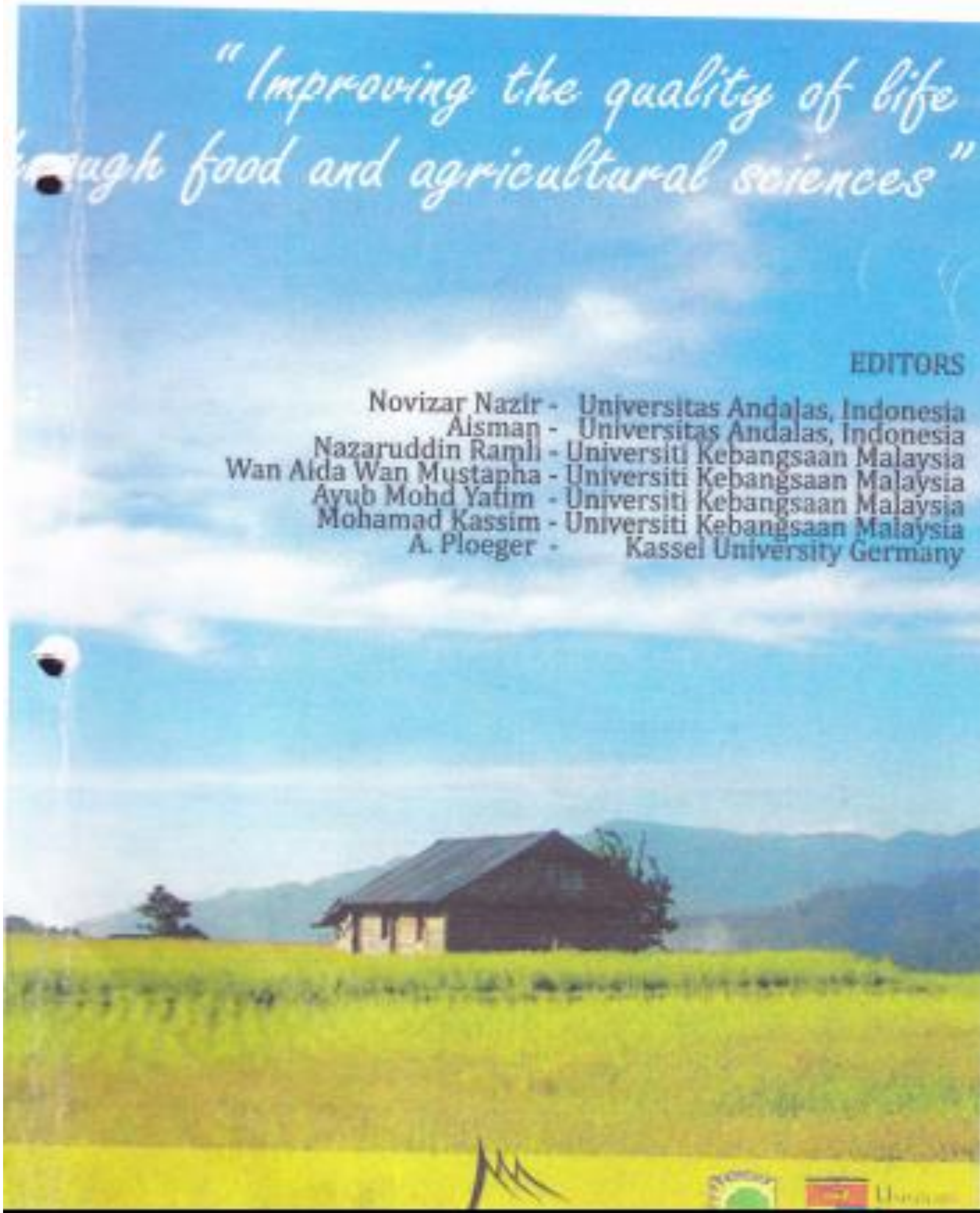

"Improving the quality of life through food and agricultural sciences"

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ROLE OF ORGANIC MATTER *IN SITU* FOR AGGREGATE STABILITY IMPROVEMENT OF ULTISOL IN WEST SUMATRA AND CHILLI (*CAPSICUM ANNUM*) PRODUTION

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Abstract

A field research about improving soil aggregate stability of marginal soils was conducted through increasing soil organic carbon content by using organic matter (OM) in situ. Organic matter is not only a qualified soil binding agent, but also relatively cheap and easy to find around farmland. This research was located in Limau Manis, lower footslope of Mount Gadut, West Sumatra, Indonesia (100° 27' 46.5" E, 00° 54'28.2" S, ± 276 m asl.). This area receives high annual rainfall (> 5000 mm) and is dominated by Ultisols, marginal soil which is intensively cultivated by farmers for seasonal crops. Farming activities in that sloping area can enhance erosion process in the environment. Therefore, efforts to anticipate the erosion must be found. The objectives of this research were to identify soil physical properties of Ultisols after OM application, then to determine the best OM to improve the aggregate stability and crop yield. Three sources of OM used in this research were Thitonia diversifolia, Gliiricidia sepium, and Chromolaena odorata. All were found in research location. The OMs were applied freshly to three different classes of slope (3%, 12%, and 25%). Then, chili seedlings were transplanted a month after the OM application. The results after harvesting (5 months OM application) showed that SOM content increased by 1.7 - 2.3%, 1.1-2.6%, and 3.0-4.3% at slope 3, 12, and 25%, respectively. Then, the aggregate stability index increased as well by 10.5-17.3, 20.5-28.9, and 23.4-37.0 point. Soil physical properties (BD, TRP, and permeability) were also affected. The highest production (biomass and fresh fruit yield) was found under Gliricidia sepium application.

Keywords

Ultisols, soil aggregate stability, soil organic matter

INTRODUCTION

Ultisols is one of marginal soil dominated dry land in Indonesia. The area covered approximately 45.8 million ha or 24.3% of Indonesian terrestrial (Subagyo *et al.*, 2000). It has low productivity due to its poor chemical and physical properties. In West Sumatra, especially in Limau Manis the soil is classified into sub ordo Udult and sub group Orthoxic Tropoudults (Imbang *et al.*, 1994 and Fitrisia, 2003). The soil is not suitable for annual crops due to its topography and physical properties, but it is still used by farmers for seasonal crop farming with intensive cultivation. This kind of activities accelerated SOM oxidation and agregrate degradation (Yulnafatmawita, 2006).

Stabilizing soil aggregates as well as keeping the pore size well distributed was very important to increase infiltration rate into soil in order to anticipate runoff on soil surface. Besides that, balanced quantity between water and air within soils will optimize microorganism activities and maximize nutrient availability as well as its absorption by crops. Stabile soil aggregates can be due to OM addition to soils, since OM plays a significant role in creating and stabilizing soil aggregates. As reported by Annabi *et al.* (2007) that compost could increase soil aggregate stability by increasing cohesion among soil particles due to organic substance diffusion into soil aggregates.

Aggregates created by OM binding agent are quite stabile against energy input impact and promptly wetting the soils. This is due to the properties of OM which cannot be dissolved in water as other binding agent, like clay, and many others. That is really important for farming land in wet tropical and sloping areas, such in West Sumatra, to anticipate soil structure degradation which finally ends with natural disaster, such as erosion, land slide, flood during rainy and lack of water during dry season.

However, SOM content in tropical soils is used to be low due to high temperature and soil moisture enhancing SOM decomposition. Additionally, management given to a piece of land will also affect SOM degradation. Soil OM decomposition rate will be accelerated if the OM is exposed to the atmosphere, such as due to tillage practice, and easy to reach by decomposers. As reported by Yulnafatmawita *et al.* (2003) that SOM would be oxidized faster under more than less tillage intensity. Furthermore, she explained that land use change from rainforest into grassland for approximately 100 years in sub-tropical region decreased org-C Ferrosol from 6.9 to 5.6% (Yulnafatmawita, 2004).

Intensive soil cultivation is used to practice for preparing seasonal farming system, especially for grain (cerealia) and vegetable crops. Farmers, in West Sumatra, still consider that the best way to prepare land for farming is by cultivating soils as intensive as possible until the aggre-

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Soil OM oxidation rate in West Sumatra, such as in Padang is quite fast. Yulnafatmawita (2006) found that SOM content of Ultisol Limau Manis decreased by 55% (from 9.86% to 4.42%) at 0-10 cm and 18% (from 3.79% to 3.10%) at 10-20 cm depth as land use change from forest ecosystem into seasonal farming system after approximately 10 years.

Theoretically, based on its climate and topography, the land was not suitable anymore for annual crops, but it is still cultivated by people to grow food crops for their life. This kind of farming practice has caused erosion if it is rain. This can be proved by differences of river current as well as the water color between under rain and no rain.

In order to anticipate the greater disasters as well as to keep sustainable land productivity, improvement of soil physical properties, for example stabilizing soil aggregates, is a must. This can be achieved by increasing SOM content. Sources of OM could be from manure, compost, green manure, organic waste, and many others. Organic matter derived from vegetations grown in the farming land will give several advantageous. The most important thing is that it does not need transportation as other sources and can be used as needed. It also functions as a fence for farming land. Three types OM source found *in situ* (Limau Manis) were Chromolaena, Gliricidia, and Tithonia. These plants are known as green manure, because they contribute some nutrients for plant growth. Hakim *et al.* (2005) and Gusnidar *et al.* (2007) has used tithonia, Jamilah (2006) has used chromolaena and gliricidia for corn, soybean, rice and other seasonal crops. Based on the above facts, this research was conducted to identify soil physical properties of Ultisols after OM application, then to determine the best OM source to improve the aggregate stability and crop yield. The result are hoped to provide data in founding conservation technology for hilly and marginal land cultivated for seasonal crops under super wet tropical areas.

MATERIALS AND METHODS

This research was conducted as field experiment in Ultisol Limau Manis and soil laboratory. The experiment was started by sampling soil in the field. Then, soil was cultivated, incubated with fresh OM and lime for 1 month, planted with chili seedling, and harvested before final soil sample was taken.

Soil samples, disturbed and undisturbed, were uptake for analysis bulk density, total porosity, permeability, texture, organic-C, percent aggregation, and aggregate stability index. Gravimetric method was employed for soil BD and total porosity, pipette and sieve method for soil texture, constant head method based on Darcy's law for permeability, Walkley and Black method for OC content, dry and wet sieving for percent aggregation and soil aggregate stability.

Field experiment was conducted by applying fresh OM (*Chromolaena odorata, Gliricidia sepium, and Tithonia diversifolia*) at 20 t /ha on dry matter base to Ultisol Limau Manis at three different slopes (3%, 12%, and 25%). After 1-month OM and lime incubation, the land was cultivated again before chili seedlings were planted. Besides liming, crops were also fertilized with synthetic fertilizers to fulfill their nutrients need. The crops were maintained for 4 months, and then harvested before the second soil samples were taken. Crops were only harvested once.

RESULT AND DISCUSSION

Research location, was located in Limau Manis, Pauh region, Padang (100° 27' 46.5" E, 00° 54'28.2" S, ± 276 m *asl)* the lower footslope of Mount Gadut (Figure 1). The physiographic of the land was alluvial van from strato volcanic having hilly topography. It has wet tropical rainforest climate (type A based on Schmidt and Ferguson) with quite high annual rainfall (>5000 mm). Rasyidin (1994) reported that the annual rainfall reached 6500 mm in the upper area. Therefore, high annual rainfall combined with hilly topography, this location is really susceptible to erosion and land degradation.

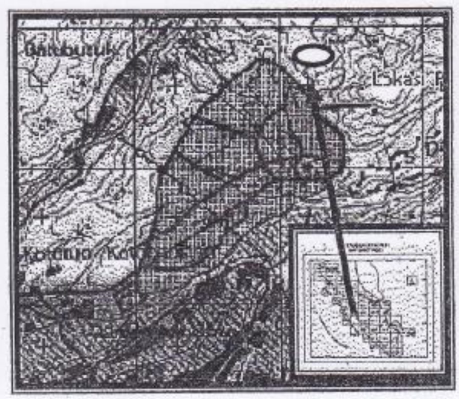

Figure 1. Research location in Limau Manis, Pauh Region, Padang, West Sumatra Indonesia

Soil physical properties

Initial soil properties

Laboratory analysis of soil physical properties was presented on Table 1. In general, the physical properties of the soil in each slope degree were quite the same. The soil texture was fine (>75% clay), explaining that the soil has been weathered for a long time. Fine soil texture causes lower soil bulk density than sandy soils, but slightly inhibited aeration. Soil bulk density as well as total soil porosity was classified into medium class. This could be understood that fine textured soils will have high percentage of spaces among the aggregates and the soil particles; therefore it has high porosity and low weight per unit volume. Soil OM content was in medium class (4.5 %) in the upper 0-20 cm.

Tabel 1. Soil Physical Properties Ultisol Limau Manis Before (original Soil) and After OM Application, as well as Crop Production

Slope	OM Application	OM Sources	BV g cm^{-3}	TRP %	Permeability cm jam^{-1}	SOM %	Aggr. (%)	Aggr. Stab Index	Yield t ha^{-1}	Biomass t ha^{-1}	Soil Texture %Sand, Silt, Clay - Class
3%	Before	-	1.00	62.37	0.78	4.5 (± *1.40*)	41.75(± *4.14*)	39.93 (± *8.60*)	-	-	11,11,78-Clay
	After	No-OM	0.76	71.27	91.68	4.5 (± *0.90*)	56.9 (± *7.14*)	60.4 (± *19.20*)	0.4 (± *0.01*)	1.1 (± *0.09*)	
		Tithonia	0.83	68.49	201.28	6.4 (± *1.40*)	48.3 (± *6.75*)	87.7 (± *14.60*)	1.3 (± *0.10*)	1.9 (± *0.04*)	
		Chromolaena	0.74	71.93	163.96	6.2 (± *1.10*)	51.2 (± *4.98*)	70.9 (± *8.60*)	2.0 (± *0.00*)	3.1 (± *0.05*)	
		Gliricidia	0.77	82.18	545.13	6.8 (± *1.20*)	55.2 (± *5.68*)	83.6 (± *12.90*)	1.6 (± *0.73*)	4.2 (± *0.09*)	
12%	Before	-	1.04	61.01	0.38	3.6 (± *1.40*)	40.55(± *5.10*)	42.37 (± *9.20*)	-	-	10,13,77-Clay
	After	No-OM	0.71	73.04	138.51	4.9 (± *1.30*)	58.7 (± *4.97*)	51.3 (± *14.60*)	0.5 (± *0.26*)	0.8 (± *0.03*)	
		Tithonia	0.87	67.02	119.67	7.4 (± *2.20*)	58.0 (± *3.54*)	80.2 (± *7.60*)	1.7 (± *0.00*)	1.8 (± *0.21*)	
		Chromolaena	0.65	75.38	333.45	5.9 (± *2.10*)	56.1 (± *6.98*)	79.7 (± *8.00*)	1.1 (± *0.02*)	1.7 (± *0.15*)	
		Gliricidia	0.75	71.68	117.20	6.8 (± *0.90*)	60.6 (± *3.21*)	71.8 (± *8.90*)	2.4 (± *0.00*)	2.7 (± *0.09*)	
25%	Before	-	1.04	60.88	2.62	3.1 (± *1.40*)	41.20(± *4.26*)	41.70 (± *7.00*)	-	-	10,14,76-Clay
	After	No-OM	0.83	68.82	52.11	2.5 (± *0.50*)	56.6 (± *2.46*)	42.2 (± *11.20*)	0.3 (± *0.35*)	0.4 (± *0.10*)	
		Tithonia	0.86	67.45	33.39	6.8 (± *1.44*)	52.3 (± *4.87*)	79.2 (± *6.00*)	0.8 (± *0.09*)	1.5 (± *0.30*)	
		Chromolaena	0.90	65.87	34.95	6.3 (± *1.32*)	44.7 (± *2.65*)	65.6 (± *7.10*)	0.9 (± *0.00*)	1.4 (± *0.90*)	
		Gliricidia	1.00	62.21	25.13	5.6 (± *1.10*)	59.3 (± *2.32*)	74.8 (± *5.00*)	2.0 (± *0.62*)	2.5 (± *0.08*)	

Note: Number in brackets is Standard Deviation (SD)

However, it was not enough to make soil porous under clay content > 75%. Then, the soil aggregate stability indexes for the three slopes were less than 50 (categorized as unstable) as well as the percentage of soil aggregation. This means that the soil is susceptible to degradation causing natural disaster as well as environmental pollution.

Soil properties after organic matter application

In general, soil physical properties of Ultisol Limau Manis showed improvement after 5 months OM application as presented in Table 1. This was determined through increasing SOM content, percent soil aggregation, and stability index of soil aggregates. However, decreasing values of soil bulk density (BD), increasing total porosity (TP) as well as permeability was only compared to initial soil samples, but not to control treatment. If it was compared to the plots cultivated and planted with crops, application of OM to the soil did not significantly affect the three soil physical properties. This approved that improving soil properties toward BD, TP, and permeability was really due to tillage rather than OM addition. Tillage had caused soil become porous or high macropore percentage, low BD, and high TP. Therefore, the permeability of the soil became much higher than the original condition. This could be concluded that cultivation can keep porous soil until 5 month after being tilled.

The results of laboratory analyses for SOM content after harvesting crops (5 months after OM application) showed that SOM content increased by 1.7 - 2.3% or, 1.1-2.6%, and 3.0-4.3% at 3, 12, and 25% slope, respectively, compared to the control plot. It means that 5 months after application in form of fresh one into soil, the OM had degraded and contributed into soil as SOM. This also reported by Yulnafatmawita *et al.* (2008) that SOM content at field increased after cultivation as well as OM application until the following 3 months without planting crops.

Among fresh OM applied, tithonia contributed more SOM into Ultisols Limau Manis after 5 months application. This could be explained by the performance or physical as well as chemical characteristics of the tithonia. Tithonia is a kind of weed having soft branch and contains more water, therefore, it is easy to decompose. In addition, tithonia belonging to family Asteraceae contains high N (3.5-4%) in the leaves (Jama *et al.*, 2000). Since N is needed by microorganism to build their bodies, they decompose tithonia faster than other materials having lower N content. Therefore, tithonia could build more SOM than two other OM sources used for the first cropping season.

Aggregation percentage also increased after one cropping season for plots both with and without OM application compared to the original soil samples. If it was compared to the control, OM application did not give significant increment to soil aggregation percentage. Even, some of the soil aggregation tended to be lower than the control. Among the OM sources, gliricidia gave higher percentage of soil aggregation than other sources. However, it did not linearly affect stability index of the soil aggregates. This means that stability index of the soil aggregates did not depend on how much the aggregates were created in this soil.

Besides aggregation percentage, increasing SOM content resulted in improving the stability index of the aggregates of Ultisol Limau Manis. The stability index increased by 10.5-17.3, 20.5-28.9, and 23.4-37.0 point compared to the control for slope 3, 12, and 25%, respectively. This could be explained that OM is a kind of binding agent that could not only bind the soil particles into aggregates, but also be able to stabilize the aggregates against external energy disturbing them. This is due to the characteristics of the OM that cannot be dissolved in water. Yulnafatmawita (2006) reported that there was positive correlation between SOM content and aggregate stability of Ultisol Limau Manis.

Crop Production

Crop yield was significantly higher between plots with and without OM application. Since the SOM content as well as the aggregate stability index was not significantly different between plots with and without OM application, higher crop production (fresh fruit yield and the biomass) under plots with OM application was not due to soil physical properties. This could be explained by other function of OM which can contribute some nutrients for plant growth. As the OM was applied in fresh form, it degraded fast and released some elements such as N, P, K and other essential nutrients in the soils. Hakim and Agustian (2005), had used tithonia to substitute some of commercial fertilizers for seasonal crops, such as corn (*Zea mays*), soybean (*Glycine max* Merr) since 2003. They concluded that tithonia can be considered as a kind of green manure. Then, Hakim *et al.* (2007) reported again that tithonia could be composted and saved before given to soils.

Tabel 1 showed that crop yield increased by 325 to 500% at slope 3%, 220-480% at slope 12%, and 270-670% at slope 25% by OM application. This means that fresh OM played a significant role on improving Ultisol fertility. Among the OM sources used, gliricidia significantly increased chili production, especially on sloping lands (slope 12 and 25%) for the first cropping season.

CONCLUSION

After 5 month (one cropping season) application of fresh OM to fine textured Ultisol planted with chili (*Capsicum annum*) under wet tropical rain forest, it can be concluded that:

- OM significantly increased soil physical properties, except soil bulk density, soil porosity which was due to cultivation effect
- Fresh OM application increased SOM content of Ultisol from 1 to 4.3%, aggregation percentage from 3-20%, and aggregate stability from 5 to 45 point
- Tithonia tended to increase SOM and soil aggregate stability higher than the other OM sources used
- Fresh OM application increased crop yield from 220 to 670%

- Gliricidia contributed highest chili production among the fresh OM applied

Based on conclusion above, it can be suggested that fresh OM is really valuable to improve physical properties especially SOM content and aggregate stability of Ultisol Limau Manis used for seasonal crops.

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