Available at : https://ejournal.unib.ac.id/index.php/terrajournal ISSN 2621-0207
DOI : https://doi.org/10.31186/terra.7.2.66-71

TERRA
Journal of Land Restoration

Improvement of Selected Soil Physical Properties and Mustard Yield After the Application of Tithonia Compost in Ultisols

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ABSTRACT

Ultisols are widespread in the Indonesian archipelago and have potential for developing the agricultural sector. However, Ultisols have several problems, such as low organic matter content, poor soil structure, unstable soil aggregates, high soil bulk density, and low total soil pore space. These problems result in slow soil infiltration and permeability, which can interfere with plant growth. This study aimed to determine the best dose of tithonia compost to improve certain soil physical properties and increase the yield of green mustard in Ultisols. The study was conducted from March to May 2024 at the Greenhouse of the Department of Crop Production, Faculty of Agriculture, University of Bengkulu. This study used a Completely Randomized Design (CRD) with 6 treatments of tithonia compost doses with 3 replications. The treatments were 0 (control), 5, 10, 15, 20, and 25 ton ha^{-1}. After mustard harvesting, undisturbed soil sample was collected from each polybag and analyzed for soil moisture, bulk density, and soil permeability. Fresh and dry weight of mustard were also measured after harvesting. The results showed that the highest improvement of selected soil physical properties was soil fertilized with tithonia compost at the rate of 15 ton ha^{-1}, as shown in the decrease of bulk density and increase in soil moisture content, total pore space, and soil permeability. The application of tithonia compost at 5 ton ha^{-1} was adequate for the improvement of selected soil physical properties and nutrient release to the soil for green mustard cultivation. The findings of the study will benefit to crop management, especially mustard yield using tithonia compost in Ultisols.

Keywords: *acid soil, organic fertilizer, weed compost*

INTRODUCTION

Soil order in Bengkulu Province is dominated by Ultisols, covering 706.000 hectares or 35.7% of the total area which is 1,978,870 hectares. This soil is acidic, rich in aluminum (Al), iron (Fe), and manganese (Mn), which are often toxic to plants. Ultisols are known to have limitations in absorbing most of the nutrients needed by plants, due to the inefficient root system and the physical and chemical properties of the soil (Candra *et al*., 2020).

Ultisols have obstacles in their physical, chemical, and biological properties due to long time pedological development. The obstacles in physical properties include low aggregate stability, slow permeability rates, and low water holding capacity. This condition causes the water in the soil to be unavailable for plant growth. Proper management, such as adding organic matter and improving soil structure is necessary to overcome these obstacles and maximize the potential of Ultisols for crop production (Nurmalasari, 2023).

In recent decades, crop cultivation still uses synthetic fertilizers for a long period, which can result in a decrease in soil fertility. In fact, this excessive use can lead to the loss of soil organism populations, damage ecosystems, and cause environmental pollution (Widyaningrum, 2019). The use of natural materials, such as green manure, as a base in organic fertilizers not only helps reduce dependence on synthetic fertilizers but also contributes to more environmentally friendly soil management. By integrating organic fertilizers into agricultural practices, we can improve soil health, support crop productivity, and protect ecosystems from further damage (Marpaung *et al*.,, 2014).

The addition of organic matter is an effective method to improve the physical properties of the soil. Organic matter plays an important role in improving soil structure by improving soil particle aggregation, which in turn improves the soil's ability to hold water and aerate. This process also accelerates the rate of water infiltration into the soil, reducing the risk of waterlogging and erosion. Also, by increasing organic matter content, the total pore space in the soil increases, which contributes to improving the overall soil quality. As a result, the soil becomes more fertile and supports more optimal plant growth (Holilullah *et al*., 2015). The improvement using organic fertilizer will benefit for long term soil health, leading to the increase in plant productivity. Tithonia compost is a soil amendment commonly used to improve soil properties.

Tithonia is a type of broadleaf weed which has great potential as a source of organic fertilizer. Parts of the tithonia, such as stems and leaves, can be processed into organic fertilizers, including green fertilizer, liquid organic fertilizer, or compost. Compost prepared from tithonia leaves is effective in improving soil quality indicated by improved organic matter content and increased essential nutrients to support plant growth. The use of tithonia as an organic fertilizer offers a sustainable alternative to reduce dependence on synthetic fertilizers, while using locally available natural resources. The integration of the use of tithonia into the land management system can provide significant ecological and economic benefits, while increasing efficiency and sustainability in agricultural production. (Trisna *et al*., 2022) . According to research by Jasminarni *et al*. 2021) tithonia (*Tithonia diversifolia*) has a nitrogen (N) content of 3.1 – 5.5% , phosphorus (P) 0.2 – 0.55% , and potassium (K) 2.5 – 5.5%. Organic fertilizer such as tithonia compost is commonly used for horticultural crop production such as green mustard. On the other hand, another weed compost such as water hyacinth compost contains lower N (1.78%) (Yunindanova *et al*., 2020), which will have lower effect on plant growth. The application of tithonia compost to Ultisols will improve soil properties, including physical properties.

Green mustard (*Brassica juncea* L.) is a type of horticultural commodity that is in demand because of its enjoyment, ease of obtaining, and relatively simple cultivation techniques. Mustard crop production can be increased by applying proper cultivation techniques, including proper maintenance and fertilization. This includes the use of organic and synthetic fertilizers as needed, as well as effective pest and disease control. In addition, the selection of superior varieties can also contribute to increasing mustard green production yields (Yuliana *et al*., 2021).

The demand for green mustard continues to increase with population growth and increasing awareness of healthy food. However, efforts to increase green mustard production often face challenges related to the lack of nutrients needed for maximum growth. Adding nutrients through proper fertilization is a strategy to overcome such problems. The application of organic fertilizer can improve soil quality and increase the crop productivity. With effective fertilization, green mustard production can be increased sustainably, meet market demand, and support food security (Fadilah *et al*., 2019) . The study was intended to determine the best dose of tithonia compost for improving certain soil physical properties and green mustard yields in Ultisols.

MATERIALS AND METHODS

This research was conducted from March to May 2024 located in the Greenhouse of the Department of Crop Production, Faculty of Agriculture, University of Bengkulu. Soil sample was collected from Beringin Raya Village, Muara Bangka Hulu District, Bengkulu. Soil sample was compositely collected at the dept of 0-20 cm. The initial soil had 14.9% moisture content, 1.52 cmol kg^{-1} exchangeable Al, 2.11% organic-C, 2.65 g cm^{-3} of particle density, 1.00 g cm^{-3} of bulk density, and pH of 4.93.

Experimental design and treatment

This study used a Completely Randomized Design (CRD) with 6 treatments of tithonia compost doses and 3 replications. The treatments included: P_0 : 0 ton ha^{-1} (control), P_1 :5 ton ha^{-1}, P_2 : 10 ton ha^{-1}, P_3 : 15 ton ha^{-1}, P_4 : 20 ton ha^{-1}, and P_5 : 25 ton ha^{-1}

Experimental procedure Tithonia compost preparation

Tithonia compost was prepared by collecting the tithonia leaves and stems from Kepahiang, Central Bengkulu. Sample was washed, weighed for 10 kg and air-dried for 2 days. After air-drying, the sample was chopped into approximately 1 cm in size.

Sample, then was put into a 50 L plastic bin and 100 mL of EM4, 100 g of sugar, and 1200 ml of water were homogenously mixed. The bin was enclosed using a plastic cover. The mixture was incubated for 30 days. The mixture was incorporated every day (Trisna *et al.*, 2022). The compost contains 2.8% total N, 0.43% total P, and 0.79% total K.

Seedling and media preparation

The media for seedlings used 2 mm sieved soil. Seeds were soaked in water for 6 hours before sown in seedling media in planting hole tray. Seedling was transplanted after 2 weeks old or plant had 2 -3 leaves.

Planting media was prepared by weighing 5 kg of 2 mm air-dried soil 2 weeks before planting. The soil was limed using dolomite at a rate of 3.8 g/ polybag. The soil sample was put into the 30 cm x 30 cm polybag and randomly placed in the Greenhouse.

Application of compost and synthetic fertilizer

Tithonia compost was applied a week before planting according to each treatment. Synthetic fertilizer at a rate of a half of recommended dose was applied at planting, consisting of urea fertilizer as much as 0.187 g/polybag, SP36 as much as 0.125 g/ polybag, and KCl as much as 0.094 g/polybag (Usmadi, 2023)

Tansplanting

Transplanting of mustard yield seedlings was carried out after 2 weeks old seedling. A seedling was planted in a prepared hold in the polybag with a depth of around 5 cm. Replanting was conducted 2 weeks after planting, by replacing rotten, damaged, or dead plants. Weeds were manually controlled while pest was sprayed using organic pesticides.

Harvesting

Green mustard was harvested 30 days after transplanting indicated by its height of approximately 30 cm. The plant was cut in the bottom part of the shoot, leaving the plant root. The shoot of green mustard was weighed. Dry shoot was also weighed after the shoot was dried in oven at 60-70 ^{o}C or after the shoot weight was constant.

After harvesting, the undisturbed soil sample was collected for certain physical soil properties. The soil sample was analyzed for soil moisture content using gravimetric method, bulk density using ring sample method, soil permeability with constant head test (CHT) method and total pore space was calculated using particle and bulk densities.

Data analysis

Data were analyzed using *Analysis of Variance* (ANOVA) at 5% confidence level. Treatment means were compared using the Least Significant Difference (LSD) at the 5% level.

RESULTS AND DISCUSSION

Analysis of Variance

The observed data were analyzed using *Analysis of Variance* (ANOVA) at the 5% level. The results showed that tithonia compost had a significant effect on several physical properties of the soil, including soil moisture content, bulk density, total pore space, and soil permeability, as well as shoot fresh weight. However, it did not affect shoot dry weight. (Table 1).

Table 1. Analysis of Variance *(ANOVA)* of selected soil physical properties and mustard yield

Variables	F-value	F-table 5%	CV (%)
Moisture content	16.13*	3.11	3.93
Bulk density	4.94*	3.11	9.69
Total pore space	4.50*	3.11	7.03
Permeability	4.22*	3.11	26.39
Shoot Fresh Weight	4.42*	3.11	12.27
Shoot Dry Weight	1.65	3.11	25.25

Note: * = significant (p =0.05), CV = Coefficient of variation

Effect of Tithonia compost on selected soil physical properties

The application of tithonia compost significantly affected selected soil physical properties such as moisture content, bulk density, total pore space, and soil permeability. Adding tithonia compost rate of 15 ton ha^{-1} increased moisture content, total pore space, and soil permeability, and at the same time reduced soil bulk density (Table 2).

The application of tithonia compost at a dose of 25 ton ha^{-1} provided the highest soil moisture content (38.14%) which was 31.4% higher than control, but was not significantly different from the dose of 20 ton ha^{-1}.

Table 2. Selected soil physical properties as affected by tithonia compost

Tithonia compost dosage (ton ha^{-1})	Moisture content (%)	Bulk density (g cm^{-3})	Total Pore Space (%)	Permeability (cm h^{-1})
0	29.03 c	1.28 c	50.21 c	1.86 b
5	33.41 b	1.19 bc	53.96 bc	2.51 b
10	34.27 b	1.11 b	56.93 abc	2.43 b
15	34.42 b	1.01 ab	60.94 ab	3.07 ab
20	36.85 a	0.99 ab	61.46 ab	4.14 a
25	38.14 a	0.92 a	64.17 a	4.16 a

Note: Numbers followed by the same letter in the same column mean not significantly different in the LSD at 5% level

The addition of tithonia compost at doses of 10 and 15 ton ha^{-1} did not exhibit a significant difference in soil moisture content. So did doses of 20 and 25 ton ha^{-1} (Table 2). This result indicates that tithonia compost has been completely decomposed, leading to the increase in soil moisture content.

The study also resulted that the application of tithonia compost at a dose of 25 ton ha^{-1} had the lowest bulk density (0.92 g cm^{-3}), decreasing 26.7% compared to the control, but was not significantly different from the dose of 20 ton ha^{-1}. The addition of tithonia compost at a dose of 10 and 15 ton ha^{-1} did not provide a significant difference in soil bulk density. So did doses of 20 and 25 ton ha^{-1} (Table 2). This result might be associated with the improvement of soil structure due to the better soil aggregation. The improvement of soil structure will increase the soil volume, thereby reducing soil bulk density.

The application of tithonia compost at a dose of 25 ton ha^{-1} provided the highest increase in total soil pore space of up to 64.17% or an increase of 21.4% compared to the control, but it was not significantly different from the dose of 20 ton ha^{-1}. The addition of tithonia compost at a dose of 15 ton ha^{-1} did not provide a difference in total soil pore space with doses of 20 and 25 ton ha^{-1} (Table 2). The decrease in bulk density will increase total pore space, thereby increasing water infiltration in the soil.

The highest soil permeability was observed in the application of 25 ton ha^{-1} tithonia compost (4.16 cm h^{-1}), increasing 65% compared to control. However, this result was not different from that of 20 ton ha^{-1}. Additionally, the soil permeability in the application of 15 ton ha^{-1} did not differ from those of 20 and 25 ton ha^{-1} (Table 2). Increase in soil permeability is attributed to the increase in total pore space, providing water to easily pass through the soil matrix.

In general, the selected soil physical properties in 15 ton ha^{-1} tithonia compost were not significantly different from 20 and 25 ton ha^{-1}. Therefore, the dose of 15 tons ha^{-1} has demonstrated the most significant effect on soil moisture content, bulk density, total space pore, and permeability. A study by Murniyanto (2007) resulted that the addition of organic materials prepared from *Acasia auriculiformis leaves, Gigantohloa apus* , and *Sacharum officinarum* at a dose of 15 ton ha^{-1} could increase soil moisture content up to 43.2% and was significantly different from soil without the addition of organic materials which only contains 34.7% water. Yulina *et al*. (2021), confirmed that there was a correlation between moisture content and bulk soil density with plant harvest weight. However, plant harvest weight is not directly influenced by soil moisture and bulk density since the plant is cultivated in polybags, which limits the growing space for plant roots. This limited growing space can affect plant growth and yield, regardless of the conditions of moisture content and bulk density.

Another study indicates that the addition of organic materials, such as tithonia compost, leads to crumbly soil. Crumble soil increases its porosity so that plant roots will grow and develop effectively (Widodo & Kusuma, 2018). In this study, the use of tithonia compost decreased bulk density and increased total pore space, which contributed to improving soil quality and supporting plants growth.

The results of the study by Muyassir *et al*. (2012) indicated that the input of organic fertilizer, namely a mixture of manure with rice straw and soybean plant residues at a dose of 15 ton ha^{-1} obtained the lowest Inceptisols bulk density of 1.23 g cm^{-3}. However, it was not significantly different from soil bulk density under other types of organic fertilizers, either applied as one or two mixed. On the other hand, dense soil is characterized with high bulk density, hardened soil and low soil porosity (Junedi *et al.,* 2013). According to Nur *et al.* (2016) low soil bulk density results in increasing soil porosity.

The results of a study by Dewi & Prijono (2018) showed that the application of rice husk biochar at a dose of 20 tons ha^{-1} could increase the total pore space of Ultisols up to 64.58% . According to Zulkarnain *et al*. (2013) the effect of organic fertilizer on increasing soil porosity is closely related to soil aeration and the availability of soil water content. The addition of compost in the soil medium can increase the rate of soil permeability by increasing the total pore space of the soil. Higher total pore space will increase soil aeration, which supports plant root growth, and increases the availability of water needed for plant growth.

The rate of soil permeability, measured in cm/hour, is highly dependent on soil porosity. Higher soil porosity will increase the rate of permeability, allowing water and other substances to move through the soil more rapidly. This fact is important because it increases the soil's ability to facilitate water and nutrients to plant roots. In addition, the rate of soil permeability is closely related to the physical properties of the soil such as texture, structure, consistency, and drainage, all of which affect how water and nutrients are available to plants. Understanding the rate of permeability assists in designing better soil management strategies to increase agricultural productivity and maintain the health of the soil ecosystem (Tewu *et al*., 2016). Andi *et al.* (2023) suggested that the addition of banana peel waste at a dose of 20 ton ha^{-1} can exhibit the highest Inceptisols permeability 5.96 cm h^{-1}.

The Effect of Tithonia compost on green mustard yield

The study indicates that the application of tithonia compost influences shoot fresh weight. The application of 5 ton ha^{-1} significantly increased shoot fresh weight. However, the treatments at doses of 5 to 25 ton ha^{-1}, tithonia compost showed no significant difference in shoot fresh weight. Meanwhile, the application of tithonia compost showed no significant effect on shoot dry weight (Table 3).

Table 3. The effect of tithonia compost on shoot fresh and dry weight

Tithonia compost dosage (ton ha^{-1})	Shoot fresh weight (g)	Shoot dry weight (g)
0	39.67 b	1.40
5	52.67 a	1.73
10	57.67 a	2.13
15	58.33 a	2.23
20	60.00 a	2.30
25	62.33 a	2.37

Note: Numbers followed by the same letter in the same column mean that they are not significantly different in the 5% LSD test

The insignificant effect of tithonia compost at the rate of more than 5 ton ha^{-1} indicates that this dose has provided sufficient organic matter to the soil for the availability of nutrients for green mustard growth, supported by the improvement of the soil's physical properties. Improved soil properties such as bulk density and porosity will balance the availability of water and air in the soil system. This fact will provide both sufficient nutrients and water for green mustard growth.

The shoot fresh weight is an important indicator that reflects the growth and development of plant tissue, which is determined by the water and nutrient content in plant cells. Manuhuttu *et al*. (2014) suggested that shoot fresh weight is not only a key variable in assessing plant growth but also plays an important role in determining economic production, especially in food crop products, such as green mustard which has high commercial value.

Different results were reported by Jasminarni *et al.* (2021) where shoot weight did not show a significant difference in the treatment of various doses of tithonia compost. They predicted that the dense nature of tithonia compost could need longer to decompose in the soil.

CONCLUSION

The application of tithonia compost at a dose of 15 ton ha^{-1} demonstrated the highest improvement of selected physical properties of soil, designated by the reduction of bulk density and increase in soil moisture content, total pore space and soil permeability. Adding 15 ton ha^{-1} lowered bulk density by 26.7% and increased soil moisture by 20.0%, total pore space by 21.35% and soil permeability by 65.95% compared to control. The application of tithonia compost at the rate of 5 ton ha^{-1} provided sufficient improvement of soil physical properties and nutrient availability for green mustard yield, indicated by the increase in 32.77% of shoot fresh weight. The findings of the study are significant for the green mustard cultivation in Ultisols for sustainable agriculture system.

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