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Effect of Palm Oil Mill Solid Waste and Bioneensis Biofertilizer on Carbon Organic, P-Available, and Mustard Growth in Ultisol Soil

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Abstract: ***This research was conducted in the Greenhouse and Research and Technology Laboratory of the Faculty of Agriculture, University of North Sumatra from May to September 2023. This study used Randomized Group Design (RAK) with 2 treatment factors and 3 replications. The first factor is palm oil mill solid waste (solid) consisting of 4 treatment levels, namely: (S0) control without palm oil mill solid waste (solid), (S1) palm oil mill solid waste (solid) 15 tonss/ha, (S2) palm oil mill solid waste (solid) 30 tonss/ha, (S3) palm oil mill solid waste (solid) 45 tons/ha. The second factor is Bioneensis biofertilizer (B) with 3 levels, namely: (B0) control without Bioneensis biofertilizer, (B1) 4 tons/ha, and (B2) 8 tonss/ha. The parameters observed were soil C-organic, soil P-available, number of leaves and mustard weight. The results showed that the application of palm oil mill solid waste (solid) significantly increased soil C-organic, soil P-available, number of leaves and mustard weight. The application of Bioneensis biofertilizer significantly increased soil C-organic, soil P-available and the number of mustard leaves. Their interaction significantly increased soil P-available.***

Keywords: Bioneensis biofertilizer, Mustard (*Brassica juncea* L.), Palm oil mill solid waste (solid), Ultisol

1. Introduction

Ultisols are among the most targeted agricultural soils in Indonesia because they occupy the largest area after Inceptisols. The distribution of Ultisol in Indonesia reaches 45,794,000 ha or about 25% of the total land area of Indonesia. Ultisol soil in Indonesia has not been handled properly, Ultisol soil still has shortcomings to be used as agricultural land, namely the low nutrient content caused by the intensive leaching process. The addition of organic matter to Ultisol soil is one alternative in order to improve the physical, chemical and biological properties of the soil (Antonsius *et al.*, 2018) [1]

Palm oil mill solid waste (solid) is one of the solid wastes as a by-product of the processing of fresh fruit bunches (FFB) in palm oil mills into crude palm oil (Anom and Armaini, 2016). The main nutrients of palm oil mill solid waste include nitrogen (N) 1.47%, phosphorus (P) 0.17%, potassium (K) 0.99%, calcium (Ca) 1.19%, magnesium (Mg) 0.24% and organic carbon 14.4%. Palm oil mill solid waste (solid) has considerable potential to be utilized as an organic soil conditioner. Palm oil mill solid waste (solid) contains high nutrients and organic matter. The high content of protein, fat and cellulose triggers one of the microorganisms to grow well in this waste (Imran and Mustaka, 2020). Palm oil mill solid waste (solid) can also be a soil improver, expected to increase the carrying capacity of the soil for the availability of organic matter and nutrients for plant growth (Ginting *et al.*, 2017) [2].

Biofertilizers can be defined as inoculants made from living organisms that function to add certain nutrients or facilitate the availability of soil nutrients for plants. Bioneensis is the result of research innovation from PPKS researchers that aims to increase oil palm productivity. Bioneensis is a biofertilizer formulation from a consortium of indigenous bacteria in the oil palm root (rhizosphere). Bioneensis contains N-fixing, P-solubilizing and IAA (indole acetic acid) producing microorganisms that function as plant growth promoting bacteria that can associate with plants originating from around the root (rhizosphere), leaf surface (phyllosphere) or from plant parts (endophytes). The composition of bioneensis biological fertilizer consists of *Azospirillium sp, Azotobacter sp, Bacillus sp, Pseudomonas sp* and *indole acetic acid* producing bacteria (Putra, 2022) [3].

Mustard is a vegetable commodity that has commercial value and good prospects. Apart from the climatological aspect, technically and economically it is also very supportive, so it has the feasibility to be cultivated in Indonesia. In addition, this vegetable is a type of vegetable that is favored by all groups of society. Demand for mustard greens is always increasing along with the increase in population and awareness of nutritional needs. (Haryanto *et al.*, 2006). Data from the Central Statistics Agency (BPS) shows that mustard production in Indonesia was 706,305 tonss in 2022. And decreased 2.9% compared to the previous year (727,467 tonss) [4]

Based on the advantages of palm oil mill solid waste material (solid), the researcher is interested in knowing the extent of the effect of solid palm oil mill solid waste and Bioneensis biofertilizer on C-organic, P-available and mustard growth on Ultisol soil [5].

2. Materials and Menthods

2.1 Place and time of research

This research was conducted in the Greenhouse of the Faculty of Agriculture, University of North Sumatra, Medan. Then continued with the analysis of soil chemical properties at the Research and Technology Laboratory of the Faculty of Agriculture, University of North Sumatra in May to September 2023.

2.2 Tools and materials

The tools used in this research are hoe, digital soil analyzer tester meter, sieve, paddle, label, camera and stationery. The materials used are Ultisol soil, palm oil mill solid waste, Bioneensis biofertilizer, mustard seeds, polybags, NPK fertilizer, and water.

2.3 Experimental method

The method used is experimental method with factorial randomized group design (RAK) with 2 factorials. The first factor is solid palm oil waste with 4 levels of treatment. The second factor is the application of bioneensis biofertilizer with 3 levels of treatment. Thus in this study there were 4 x 3 combinations or 12 treatment combinations.

Factor I is solid palm oil waste consisting of 4 treatment levels, namely:
- S0 = No treatment (Control)
- S1 = Palm oil waste (solid) 15 tonss/ha (75 g/10 kg soil)
- S2 = Palm oil waste (solid) 30 tonss/ha (150 g/10 kg soil)
- S3 = Palm oil waste (solid) 45 tonss/ha (225 g/10 kg soil)

Factor II is bioneensis consisting of 3 treatment levels, namely:
- B0 = No treatment (Control)
- B1 = 4 tonss/ha (20 g/planting hole)
- B2 = 8 tonss/ha (40 g/planting hole)

Thus, there were 12 treatments with 3 replications so that a total of 36 experimental units were obtained.

Data were analyzed using variance analysis, if the results of variance analysis showed a significant effect, then continued using Duncan's multiple range test (DMRT) at the 5% level.

Parameters observed in the soil were soil C-organic and soil P-availability. And in plants, namely the number of leaves and plant weight.

3. Results and Discussion

3.1 Carbon Organic

The application of palm oil mill solid waste (solid) and Bioneensis biofertilizer had a significant effect on increasing soil C-organic, while the interaction of the two had no significant effect on increasing soil C-organic. The results of the mean difference test are in Table 1.

Table 1: Average C-organic Content of Ultisol Soil in the Treatment of Palm Oil Mill Solid Waste (Solid) and Bioneensis Biofertilizer

Palm oil mill solid waste (solid) (S)	Bioneensis Biofertilizer (B)			Average
	B0	B1	B2	
	(Control)	(4 tons/ha)	(8 tons/ha)	
	.....%.....			
S0 (Control)	0,5	0,58	0,57	0,55a
S1 (15 tons/ha)	0,83	1,17	1,51	1,17b
S2 (30 tons/ha)	1,53	1,61	1,74	1,63c
S3 (45 tons/ha)	1,9	1,73	2,41	2,01d
Average	1,19a	1,27ab	1,56c	

Notes: Numbers followed by the same letter in the same row and column are not significantly different atthe 5% level according to the *Duncan Multiple Range Test.*

In Table 1. it can be seen that the soil organic carbon content of different treatments. The provision of palm oil mill solid waste S3 (45 tons/ha) has the highest soil C-organic content among other treatments. Increased soil C-organic levels also occurred in the S1 (15 tons/ha) and S2 (30 tons/ha) treatments. The S0 treatment (control) is significantly different from S1 (15 tons/ha), S2 (30 tons/ha) and S3 (45 tons/ha).

The provision of palm oil mill solid waste (solid) has a very significant effect on increasing soil C-organic. The treatment of giving solid waste of palm oil mill (solid) with a dose of 45 tons/ha of soil has the highest increase in soil C-organic from 0.21% to 2.41%. This is due to the very high C-organic content of palm oil mill solid waste compost (solid) which is 31.15% so that the provision of palm oil mill solid waste (solid) can increase soil C-organic. The occurrence of an increase in soil C-organic content is because the solid waste of palm oil mills used is one of the main sources of organic matter. This is in accordance with the results of research by Syukur and Indah (2006) in Wijayanti (2008), that the application of solid palm oil mill solid waste can increase soil C-organic content. The more organic matter added to the soil, the greater the increase in C-organic content in the soil. The addition of organic matter such as palm oil mill solid waste (solid) to the soil is caused by organic matter added to the soil that has undergone a decomposition process.

The application of Bioneensis fertilizer also causes an increase in soil C-organic content. Treatment B2 (8 tons/ha) has the highest soil C-organic content than B0 (control). Treatment B1 (4 tons/ha) also had higher soil C-organic levels than treatment B0 (control).

Bioneensis fertilizer contains *Azospirillium sp, Azotobacter sp, Bacillus sp, Pseudomonas sp* and indole acetic acid producing bacteria. Pseudomonas sp and Bacillus sp bacteria are soil microorganisms that have many benefits, among others, as nutrient providers. This is in accordance with Afandi *et al.*, (2015) which states that carbon is a food source for soil microorganisms, so the presence of C-organic in the soil will spur the activities of microorganisms so as to increase the process of soil decomposition and also reactions that require the help of microorganisms, such as P dissolution, and N fixation.

3.2 P Available

The main text for your paragraphs should be 10pt font. All body paragraphs (except the beginning of a section/sub-section) should have the first line indented about 3.6 mm(0.14").The results of the analysis of variance showed that the application of palm oil mill solid waste, Bioneensis fertilizer and the interaction of the two had a significant effect on increasing soil P-available. The results of the mean difference test are in Table 2.

Table 2: Average Levels of P-available in Ultisol Soil in the Treatment of Palm Oil Mill Solid Waste (Solid) and Biofertilizer Bioneensis

Palm oil mill solid waste (solid) (S)	Biofertilizer Bioneensis (B)			Average
	B0 (Control)	B1 (4 tons/ha)	B2 (8 tons/ha)	
	.....ppm.....			
S0 (Control)	1,58a	7,75c	12,00d	7,11
S1 (15 tons/ha)	2,90ab	12,21d	9,67c	8,26
S2 (30 tons/ha)	3,65b	7,69c	26,53f	10,13
S3 (45 tons/ha)	1,96ab	7,96c	20,48e	12,62
Average	2,52	8,90	17,17	

Notes: Numbers followed by the same letter in the same row and column are not significantly different at the 5% level according to the *Duncan Multiple Range Test.*

Table 2. shows that the application of palm oil mill solid waste and Bioneensis fertilizer has a very significant effect in increasing P-available levels in Ultisol soil. The highest P-available levels were found in the S2B2 treatment and the lowest P-available levels were found in the S0B0 treatment.

The addition of palm oil mill solid waste (solid) to the planting media causes P-availability to also increase if it is decomposed properly. This is in accordance with Imran and Mustaka, (2020) which states that in palm oil mill solid waste (solid) there is Aspergillus niger and A. fumigatus. A. niger has the ability to decompose complex compounds such as cellulose into simple carbon compounds and is also able to dissolve phosphate absorbed in the soil into phosphate available for plant absorption. Poerwidodo (1992) also said that palm oil mill solid waste (solid) contains nitrogen which activates the working properties of phosphorus elements, although palm oil mill solid waste (solid) has a low phosphorus element, but it should be noted that plants given nitrogen will absorb more phosphorus than plants without nitrogen, because nitrogen is able to stimulate root growth in absorbing phosphorus.

The increase in soil P-availability was 5 times that of the initial soil P-availability. This was coused by Bioneensis biofertilizer which contains *Azospirillium sp, Azotobacter sp, Bacillus sp, Pseudomonas sp* and indole acetic acid-producing bacteria. According to Hasannudin and Gonggo (2004), to overcome low soil P-availability is to utilize free-living soil microbes that have the ability to dissolve fertilizer P and soil P, such as phosphate solubilizing bacteria. Bacillus sp and Pseudomonas sp are phosphate solubilizing bacteria that function to dissolve P bound by other elements.

3.3 Number of Leaves

The provision of solid palm oil waste (solid) has a significant effect on the number of mustard leaves. While the provision of Bioneensis fertilizer and the interaction of the two had no significant effect. At MST 1 to 5 the provision of Bioneensis fertilizer gives no real effect, but at MST 4 to 5 the provision of Bioneensis fertilizer gives a real effect on the number of leaves of mustard plants. The interaction between palm oil mill solid waste (solid) and Bioneensis fertilizer gives no real effect. The results of the mean difference test in Table 3.

Table 3: Average Number of Leaves of Mustard (*Brassica Juncea* L.) 1-5 weeks after planting in the Treatment of Palm Oil Mill Solid Waste (Solid) and Bioneensis Biofertilizer

MST	Palm oil mill solid waste (solid) (S)	Bioneensis Biofertilizer (B)			Average
		B0 (Control)	B1 (4 tons/ha)	B2 (8 tons/ha)	
		.....strands.....			
1	S0 (Control)	0,00	1,00	2,33	1,1a
	S1 (15 tons/ha)	1,33	1,67	2,00	1,67ab
	S2 (30 tons/ha)	3,33	2,67	3,00	3,00c
	S3 (45 tons/ha)	3,33	3,33	3,00	3,22c
	Average	2,00	2,17	2,58	
2	S0 (Control)	0,67	2,67	3,67	2,33a
	S1 (15 tons/ha)	2,33	3,00	3,33	2,89ab
	S2 (30 tons/ha)	4,33	3,67	4,00	4,00c
	S3 (45 tons/ha)	4,33	4,33	4,33	4,33c
	Average	2,92	3,42	3,83	
3	S0 (Control)	2,67	5,00	5,33	4,33a
	S1 (15 tons/ha)	5,67	6,00	5,67	5,78b
	S2 (30 tons/ha)	6,33	6,00	6,33	6,22bc
	S3 (45 tons/ha)	5,33	6,33	6,67	6,11bc
	Average	5,00	5,83	6,00	
4	S0 (Control)	3,33	8,00	7,33	6,22a
	S1 (15 tons/ha)	9,67	11,00	9,67	10,11b
	S2 (30 tons/ha)	9,33	13,33	10,00	10,89c
	S3 (45 tons/ha)	10,33	11,33	10,33	10,67bc
	Average	8,17a	10,92ab	9,33c	
5	S0 (Control)	4,00	9,67	8,33	7,33a
	S1 (15 tons/ha)	12,00	14,33	13,00	13,11b
	S2 (30 tons/ha)	11,33	17,00	12,00	13,44c
	S3 (45 tons/ha)	11,67	13,67	13,00	12,78bc
	Average	9,75a	13,67c	11,58ab	

Notes: Numbers followed by the same letter in the same row and column are not significantly different at the 5% level

according to the *Duncan Multiple Range Test.*

Table 3. shows that the provision of palm oil mill solid waste (solid) causes an increase in the number of leaves. The highest number of leaves in MST 1 was found in S3 (45 tons/ha) and the lowest was S0 (control). In the 2nd MST, the highest number of leaves was in S3 (45 tons/ha) and the lowest was in S0 (control). In the 3rd MST, the highest number of leaves was in S2 (30 tons/ha) and the lowest was in S0 (control). The highest number of leaves in MST 4 was found in S2 (30 tons/ha) and the lowest in S0 (control). And at MST 5, the highest number of leaves was in the S2 treatment (30 tons/ha) and the lowest was in S0 (control).

The increase in the number of leaves of mustard plants is relatively in line with the increase in the dose of palm oil mill solid waste (solid) but the highest number of leaves is found in the highest dose treatment. This is in accordance with Tambun *et al.,* (2022) which states that the provision of solid decanter waste from oil palm has an effect on mustard growth. It is suspected that solid is able to supply sufficient nitrogen for plant growth needs. Palm oil mill solid waste (solid) contains 3.52% nitrogen so that it becomes a factor that affects plant growth. Nitrogen nutrients spur the process of cell division so that plant growth is getting better.

Bioneensis biofertilizer has a very significant effect on the 4th to 5th MST. In the 4th MST, the highest average number of leaves was found in B1 (20 g) and the lowest was found in B0 (control). While in the 5th week of planting, the highest average number of leaves was found in B1 (20 g) and the lowest was found in B0 (control).

In Bioneensis biological fertilizer there are IAA (indole acetic acid) producing bacteria. Idris*et al.,* (2007) states that IAA is a natural auxin group phytohormone and acts as a plant growth promoter (ZPT) because it regulates many physiological processes, such as cell division and differentiation and protein synthesis. The content of IAA in small amounts can have a major effect on plant growth and production. IAA can be produced by certain microorganisms and can also be produced by plants that can affect the physiological processes of plants.

3.4 Weight of Mustard

The application of palm oil mill solid waste (solid) had a very significant effect on the weight of mustard plants while the treatment of Bioneensis biofertilizer and the interaction of the two had no significant effect. The results of the mean difference test are in Table 4.

Table 4: Average Weight of Mustard (*Brassica juncea* L.) in the Treatment of Palm Oil Mill Solid Waste (Solid) and Bioneensis Biofertilizer

Palm oil mill solid waste (solid) (S)	Bioneensis Biofertilizer (B)			Average
	B0 (Control)	B1 (4 tons/ha)	B2 (8 tons/ha)	
	.....gram.....			
S0 (Control)	1,67	38,00	27,67	22,44a
S1 (15 tons/ha)	77,33	105,67	107,33	96,78b
S2 (30 tons/ha)	110,33	127,00	98,00	111,78bc
S3 (45 tons/ha)	96,00	141,00	153,00	130,00c
Average	71,33	102,92	96,50	

Notes: Numbers followed by the same letter in the same row and column are not significantly different at the 5% level according to the *Duncan Multiple Range Test.*

Table 4. shows that the provision of palm oil mill solid waste is able to increase plant weight. The provision of palm oil mill solid waste S3 (45 tons/ha) significantly increased the highest plant weight among the palm oil mill solid waste treatments. The plant weight of S2 treatment (30 tons/ha) and S1 treatment (15 tons/ha) were statistically similar. However, the S0 (control) treatment was significantly different from S1 (15 tons/ha), S2 (30 tons/ha) and S3 (45 tons/ha).

The weight of mustard was relatively in line with the increase in the dose of palm oil mill solid waste compost (solid), the highest mustard weight was found in the highest dose treatment. The use of organic matter in the form of palm oil mill solid waste (solid) in the soil is beneficial to accelerate the activity of microorganisms, thereby increasing the speed of decomposition of organic matter and accelerating the release of nutrients. Organic material can also be used to increase plant metabolism, which has an influence on mustard weight. Ginting *et al.,* (2017) stated that the nutrient content contained in palm oil mill solid waste (solid) provides sufficient nutrient intake that supports the rate of plant growth which will ultimately increase mustard weight.

Bioneensis biofertilizer contains microbes that are able to produce active compounds that play a role in providing/ decomposing nutrients. The activity of microorganisms can also increase the soil's ability to store water, so that nutrients are more easily absorbed by plants. Hardjowigeno (2003) said that the application of biological fertilizers has a very important influence in improving the chemical and physical properties of soil, one of which is providing nutrients for plants and helping to increase the soil's ability to retain water.

4. Conclusions and Suggestions

4.1 Conclusion

1) Application of palm oil mill solid waste (solid) at a dose of 45 tons/ha gives the best results in increasing soil C-organic, soil P-available, mustard weight, and number of leaves.
2) Application of Bioneensis fertilizer at a dose of 8 tons/ha gives the best results in increasing soil C-organic and soil P-available. While the dose of 4 tons/ha gives the best results in increasing the number of mustard leaves.
3) The interaction between palm oil mill solid waste (solid) and Bioneensis fertilizer with a dose of 30 tons/ha of palm oil mill solid waste (solid) and 8 tons/ha of Bioneensis fertilizer, namely S2B2, gives the best results in increasing soil P-provision.

4.2 Suggestion

The application of palm oil mill solid waste (solid) and Bioneensis fertilizer has not significantly affected the chemical properties of the soil and the growth of mustard plants because the nutrient content has not met the nutrient needs of mustard plants. So it is necessary to conduct further research with higher treatment doses.

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