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Soil Physical Properties and Oil Palm Plant (Elaeis guineensis Jacq.) Growth Applied with Solid Waste of Palm Oil Mill

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ABSTRACT

The growth of oil palm plants, such as height, additional fronds, and stem diameter, depends on the soil condition and its physical properties. Good soil physical properties will support the growth of oil palm plants. On marginal lands such as ex-mining land and sub-soil soil that has poor soil physical properties, improvements must be made. Thus, palm oil cultivation on ex-mining land or subsoil land can grow well. This research aims to study solid application to various soil conditions to improve the growth and physical properties of oil palm plants. The land applied by solid is an ex-mining land subsoil land. Meanwhile, the land with flat topography has not been degraded as a control. The data analysis carried out is an orthogonal contrast test, between control with solid application and without solid application, between solid application with without solid, between among solid application (ex-mining and subsoil land), between among without solid application (ex-mining and subsoil land). The research result shows that soil physical properties and plant growth applied with solid are better than without solid, lower bulk density value, higher total pore space and water holding capacity, taller plant growth, higher palm branches quantity, larger stem diameter. Solid application in ex-mining is lower than solid application on sub-soil, with lower water holding capacity value and lesser palm fronds addition. Without solid application on ex-mining sites, the results are worse than no solid application on sub-soil, with lower water holding capacity and lower plant height. Control is better than solid and without solid applications, higher plants, higher addition of frond quantity, and larger stem diameter.

Keywords: *Soil physical properties, Solid, Marginal land, palm oil*

1. INTRODUCTION

Solid is one of the solid wastes from palm oil mill processing. The potential of solid is enormous to be utilized. Every Palm Oil Mill (PKS) produces solid waste with an average of 20 tons/day/factory, depending on the quantity of palm oil processed. Solid produced in palm oil processing reaches 5-6%. Today, there are 183 palm oil mills in Riau province (Kemenperin, 2020). If every factory produces an average of 20 tons of solid/day, the production will obtain 3,660 tons of solid every day.

Solid has quite good physical and chemical properties. Characteristics of solid shaped like mud and dark black, with these characteristics one does not need to compost it for plant application. Solid chemical content includes Nitrogen, Phosphorus, Potassium, Magnesium, and Calcium. (Pahan, 2008).

Providing organic substances such as solids to the soil can rectify its physical, chemical, and biological properties. Stevenson (1982) reveals that soil organic matter is one of the materials for forming soil aggregates which contributes as an adhesive material between soil particles to unite into soil aggregates so that organic substance is essential in forming the soil structure. The effect of organic matter provision on the land structure is highly connected with the soil texture applied. In a lump of heavy clay, a change occurs in coarse and firm lumps structure to a more delicate structure, with a moderate to a substantial degree of structure. Organic components such as humic acid and fulvic acid, in this case, act to cement clay particles by forming clay-metal-humus complexes. Organic substance is expected to change the soil structure from single grain to compound grain in sandy soil. It increases the degree of structure and size of the aggregate or increases the structure class from fine to medium or coarse (Scholes *et al*., 1994).

Organic matter is also an energy source or food for many microorganisms living within the ground—the more organic matter in the soil, the tremendous amount of microorganisms in the soil. Indirectly, microorganisms within the ground will rectify the soil's physical and chemical properties. Secretory materials from soil microorganisms can bind soil particles into larger aggregates. These large soil aggregates can store groundwater in the delicate pores between soil particles for the plant to use. In addition, soil organic matter also invites more extensive soil microorganism activities, such as earthworms. The activity of earthworms within the soil can rectify soil structure by making channels or holes within the ground so that soil's aeration and infiltration becomes better (Atmaja, 2017).

Soil's physical properties highly affect a plant's yield and growth. The condition within the soil can determine root penetration within the ground, water retention, aeration drainage, and plant nutrient. Soil's physical and drainage properties also affect soil's chemical and biological properties (Hakim *et al.* 1986).

Based on the above description, solid waste from palm oil processing mills has enormous potential to rectify solid physical properties and oil palm plant growth. Solid waste can be used as mixed material in palm oil growing media in ex-mining land and subsoil land, including marginal land. Solid waste is expected to increase the soil's carrying capacity for oil palm plant growth as a soil improvement agent. Regarding using ex-mining land

and sub-soil for oil palm planting, it is necessary to research "Soil Physical Properties and Oil palm plant (Elaeis guineensis Jacq.) Growth Applied with Solid Waste".

This research aims to investigate solid application in various soil conditions to improve the physical properties and growth of the oil palm plant.

2. RESEARCH METHOD

2.1. Research Site

The research site was determined using purposive sampling based on areal conditions, ex-mining land, subsoil land, and flat topography that has not been degraded as a control. The research was conducted from November 2017 until November 2018 in Banjar Benai Village, Benai Subdistrict, Kuantan Singingi Regency.

2.2. Materials and Tools

The materials used were oil palm seeds ready for planting at the age of 12 months (DXP, Marihat), 600 g per tree Rock Phosphate (RP) fertilizer for planting holes, NPKMg+Borate (13:6:27:4+0.65) with the dosage of 3,25 kg per tree in 1 year divided into four applications, solid, and empty oil palm bunches (TKKS).

The tools used are ring sampler, soil drill, digital scale, beaker glass, pycnometer bottle, acetone, thermometer, sieve, oven, desiccator.

2.3. Research Method

The research was carried out experimentally on the ex-mining field, subsoil land, and control (undegraded flat ground), e.g.:

1. Control: land with flat topography and has not been degraded.
2. Solid application on ex-mining land.
3. Solid application on subsoil land.
4. Without solid application on ex-mining land.
5. Without solid application on subsoil land.

The soil sample collection was carried out in three repetitions for every treatment, and thereby the total sample derived was 15 units in this research. Sample collection for vegetative observation was carried out as many as thirty repetitions for each treatment so that the total sample was 150 units. Later on, the data were analyzed using a completely random design and orthogonal test to compare treatments.

2.4. Data Analysis

The data of plant's physical properties and growth were analyzed using completely random design with the model of:

$$\mathbf{Y_{ijk} = \mu + \tau_i + \varepsilon_{ij}}$$

Where:

Y_{ijk}= Observation results from the experimental unit in the treatment

μ = Common average score

τ_i = Treatment effect

ε_{ij} = Effect of error on experimental unit in treatment

Afterward, it was conducted orthogonal contrast test consisting of 3 groups, i.e., control, solid application, and without solid application. In this study, the contrasts that are tested and are orthogonal to each other are:

K1: Between controls with solid and without solid application.

K2: Between solid and without solid application.

K3: Between solid applications (on ex-mining and sub-soil soils).
K4: Between each other without solid application (ex-mining and sub-soil).

3. RESULT AND DISCUSSION

3.1. Soil's Physical Properties

The orthogonal contrast test showed that the bulk density was significantly different between solid and without solid applications and between solid applications on ex-mining and subsoil land. The other is total pore space between solid and without solid applications and between solid on ex-mining and sub-soil land. Water holding capacity between applications using solid and without solid, between applications using solid on ex-mining land and sub-soil, between without solid on ex-mining land and sub-soil. The soil physical properties that have been tested for contrast are presented in Table 1.

Table 1. *Bulk Density,* Total Pore Space and Water Holding Capacity applied to solid and without solid land

Contrast	***Bulk density*** **(g/cm^3)**	
K1	1.48	1.45^{tn}
K2	1.29	1.61*
K3	1.16	1.42*
K4	1.58	1.65^{tn}
	Total Pore Space (%)	
K1	42.23	41.45^{tn}
K2	43.59	39.31*
K3	45.49	41.68^{tn}
K4	41.90	36.72*
	Water Holding Capacity **(%)**	
K1	25.13	26.43^{tn}
K2	29.59	23.27*
K3	23.73	35.45*
K4	18.22	28.32*

Remark: *showing orthogonal contrast is significantly different at the 5% level.
K1, K2, K3, and K4, respectively, are the contrast between control with solid and without solid applications, between solid and without solid applications, between solid applications (ex-mining and sub-soil), between without solid applications (ex-mining and subsoil).

Bulk density value in solid application area is lower (1.29 g/cm^3) than without solid (1.61 g/cm^3). This result is because the solid applied contains organic matter, reducing the soil volume weight. According to Stevenson (1989), the effect of organic matter on bulk density is through the mechanism of aggregate formation. Organic matter can affect soil aggregates through 3 mechanisms, i.e.:

1) Organic matter as a binder for clay particles cohesion through H-bonding and coordination with polyvalent cations. Humic and fulvic acids contained in organic matter can form clay-metal-humus complex bonds.
2) The mucus of organic matter envelops soil particles and binds them through cementing.
3) Soil particles are tied through physical binding by bonding fungal hyphae and plant roots.

There is an interaction of solids with a soil's particle; as a result, the ground structure becomes looser and will enlarge pores spaces. According to Wiskandar (2002), adding organic matter will increase total pores within the soil and decrease soil bulk density.

Solid is also an energy source for macro and microorganisms within the soil, indirectly rectifying the soil structure. According to Tian *et al.* (1997), adding organic matter into soil will increase soil microbiology activity and land population. The microbiological activity contributes to the humification and mineralization process (nutrient launching); even more, it is responsible for rectifying soil structure, which eventually decreases soil's bulk density.

The bulk density value of solid application on the ex-mining field (1,16 g/cm^3) is lower than solid application on subsoil land (1,42 g/cm^3). This result is because subsoil land has higher clay content and lower organic matter. The content of the clay fraction is presented in Table 2. Sutedjo (2002) conveys that the deeper the ground goes, soil mass density will also increase due to the low organic matter content.

Table 2. Clay Fraction (%) in the land applied using solid and without solid

Type of Land	Clay Fraction (%)
Control	23,33
Solid application on ex-mining	5,33
Solid application on Subsoil land	38,67
Without Solid on ex-mining land	6,67
Without Solid on subsoil land	26,00

The total value of pore spaces in solid application land is higher (43.59%) than without solid (39.31%). The total of pores space is affected by soil organic matter. The solid application will increase soil's porosity because of the creation of soil's aggregate. Solid interacts with soil particles to make the structure lose and enlarge pore spaces. The solid decomposition process will result in humic and fulvic acid, creating complex bonds of clay-metal-humus (Stevenson, 1989).

The total value of pore spaces without a solid application on ex-mining is higher (41.90%) than without solid in subsoil land (36.72%). This result is because soil texture on ex-mining field land contains a high sand fraction (89.33%), presented in Table 3. The sand fraction has spaces between particles so that pores' total is also higher. According to Dariah *et al.* (2003), the land dominated by a sand fraction will flow water faster (higher infiltration and permeability capacity) than the soil dominated with dust and clay fraction. This condition is because of coarse sand fraction size.

Table 3. Sand Fraction (%**)** in the land applied using solid and without solid

Type of Land	**Sand Fraction (%)**
Control	64.00
Solid application on ex-mining	82.67
Solid application on Subsoil land	42.67
Without Solid on ex-mining land	89.33
Without Solid on subsoil land	56.67

The value of water holding capacity in solid application treatment is higher (29.59%) than without solid (23.27%). Solid application has a C-organic content of 4.83%, which at the same time increases the humus content in the soil. According to Handayanto (1998), organic matter supplied to the soil will rot and demolish the process, generating humus. Sarief (1985) also states that humus is hydrophilic. Hence, it can increase water retention within the soil and increase water retention properties. According to Muslimin *et al.* (2012), soil organic substance has higher pores quantity than soil's mineral particles, meaning that the absorption surface area is broader. Consequently, the higher the organic matter within soil, the higher the groundwater content and availability.

The value of water holding capacity in solid application treatment on ex-mining soil (23.73%) is lower than solid application in sub-soil (35.45%). One of the factors determining the value of water holding capacity is the percentage of soil's fraction content (sand, dust, and clay). Ex-mining land applied using solid in this study is dominated by the sand fraction, 82.67%, while the sub-soil that has been applied solid is only 42.67%. While the subsoil land applied using solid is only 42.67%. Likewise, the value of water holding capacity in the treatment without solid ex-mining land (18.22%) was lower than without solid sub-soil (28.32%). The fraction of sand on ex-mining land without solid is 89.33%, while sub-soil without solid is 56.67%. According to Sarief (1985), the high fraction of sand will form macropores with low water holding capacity. The coarser the soil texture, the greater the soil's ability to hold water. It is supported by Pairunan *et al.* (1985), stating that clay can store more water than sand because clay not only has a large surface area but is also negatively charged so that most of the water in the pores with the shape of a water film will be attracted to the clay surface. Next, Dixon (1991) adds that clay particle has a negatively charged surface area. This side will bond positively, and a water molecule will finally bond strongly to its surface. This property makes the soil with clay texture have high storing water capability.

3.2. Oil palm plant Growth

The orthogonal contrast test showed that the plant heights differed significantly between solid and without solid applications, between without solids in ex-mining land and sub-soil, between control and solid applications, and without solids. The addition of palm fronds occurred between solid and without solid applications, between solid applications on ex-mining land and solid applications on sub-soil, between control and solid and without solid applications. The growth of oil palm plantations that have been tested for contrast using solid and without solid application areas are presented in Table 4.

Table 4. Plant height, the addition of oil palm fronds, and stem diameter in solid and without solid applied land

Contrast	Plants' Height (cm)	
K1	229.45	220.77*
K2	228.02	213.51*
K3	227.27	228.78tn
K4	202.38	224.63*
	Addition of palm fronds in 1 year	
K1	34.80	27.13*
K2	28.09	26.16*
K3	26.74	29.43*
K4	26.43	25.90tn
	Stem Diameter (cm)	
K1	52.47	35.74*
K2	37.57	33.91*
K3	38.80	36.35tn
K4	32.83	35.00tn

Remark: *showing orthogonal contrast was significantly different at the 5% level. K1, K2, K3, and K4, respectively, are the contrast between control with solid and without solid applications, between solid and without solid applications, between solid applications (ex-mining and sub-soil), between without solid applications (ex-mining and subsoil).

Plant height in the solid application was taller (228.02 cm) than without solid (213.51 cm). Solid can improve soil physical properties and contain high organic substances and nutrients. The solid waste used has also been decomposed, and the macro and micronutrients contained in the solid waste are available for plants, especially nitrogen nutrients, which can stimulate the growth of oil palm plant height. According to Pahan (2008) and Rachman *et al.* (2008), solid contains high nutrients and organic substances, its application to oil palm plants can improve the soil's physical, chemical, biological properties, and increase plant growth.

Plant height without solid on ex-mining soil is lower (202.38 cm) than without solid on sub-soil (224.63 cm). This height is due to the high sand fraction in the ex-mining land without solids (89.33%) and the low C-organic content, as presented in Table 3. According to Brata and Nelistya (2008), the high sand fraction will decrease nutrient content, especially N.

Plants in control were taller (229.45 cm) than the solid application and without solid application (220.77 cm). The soil physical properties on the control land have not been degraded and are better, so the nutrient absorption for oil palm plants is also better, especially N nutrients. According to Rosita *et al.* (2007), nitrogen contributes crucially to a plant's height growth because the function of this nutrient itself is to form the plant's vegetative parts and stimulate the acceleration of vegetative growth itself.

The addition of fronds quantity in 1 year of observation on solid applications (28.09 fronds) was more than without solids (26.16 fronds). The nutrients available in the planting media alone cannot meet the plant's nutrient needs. According to PPKS (2010), the availability of nutrients is a very influential factor in plant growth, especially on cell enlargement, which affects the leaves' quantity. Nutrients in the solid waste can meet plant needs and increase soil organic matter content. Sutarta et al. (2000) state that solid waste contains nutrients that influence plant growth, especially cell enlargement, affecting the leaves' quantity.

The addition of fronds in 1 year of observation on ex-mining solid applications (26.74 fronds) was less than that of solid applications on sub-soil (29.43 fronds). This result is presumably because the leaching of nutrients in ex-mining solid applications is more significant. The sand fraction is still high at 82.67% (Table 3) so that nutrients are very easy to leach. According to Hanafiah (2005), the more porous the soil, the easier it will be for roots to penetrate, and the easier it will be for water and air to circulate, but the water will be more accessible to lost from the soil and vice versa.

The addition of oil palm fronds in 1 year of observation on the control (34.80 fronds) was more than the solid and without solid application (27.13 fronds). This addition is because the soil conditions under control are better and have not been degraded, such as on ex-mining land and sub-soil. As a result, nutrient absorption is also better, especially N, P, and K. Plants need these nutrients as essential elements and as a constituent of protein and chlorophyll, which has an essential role in increasing plant growth, including the leaves quantity. According to Lingga (2005), one of the fundamental elements plant needs is nitrogen. This element is needed to produce proteins and other essential materials in forming new cells and contribute to forming chlorophyll.

The stem diameter in the solid application is larger (37.57 cm) than without solid (33.91 cm). This yield resulted from the nutrients in the solid stimulating cell division process so that the plant growth rate can work well. According to Vitta (2012), to accelerate root development, nutrients must stimulate the cell division process and plant metabolism to encourage the rate of plant growth, including the flourishment of stem diameter.

The stem diameter of the oil palm plant in control (52.47 cm) was more significant than the solid and without solid application (35.74 cm). This yield is because the soil conditions under control are better and have not been degraded so that the available nutrients are sufficient for weevil diameter development and metabolic processes and the accumulation of simylates to work correctly. According to Jumin (1992), the stem is an area for accumulating plant growth, especially young plants. Proper nutrients can boost photosynthesis rate in producing photosynthate, thus helping stem weevil formation.

4. CONCLUSION

Soil physical properties and plant growth applied with solid are better than without solid application, and the bulk density value is lower. Another result is that the total pores space and water holding capacity is higher, taller plants, additional fronds, and larger stem diameter. Solid application on the ex-mining field is worse than solid application on subsoil land. The water holding capacity value is lower and lesser in addition to fronds. Without solid application on subsoil land, the water holding capacity is lower, and the plant's height is lower. The control is better than solid application, and without solid application, the plant's height is taller, more additional fronds yield, and larger stem diameter.

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