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USE OF PALM OIL MILL EFFLUENT AND SLUDGE WASTE FOR IMPROVEMENT OF SOIL MECHANICAL STRENGTH

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Abstract

Using specific vegetation for shear strength enhancement is crucial for erosion control on the cutting slope. In this study, the effects of treated palm oil mill effluent sludge and chicken dung as soil amendments on the shear strength was determined by growing *Pennisetum setaceum* and *Digitaria setivalva*. On the cut slope, the vegetation effect towards the interaction of root-shear strength relationships was observed. The objectives of this study were (1) to evaluate the influence of palm oil mill effluent sludge on soil physical properties and root length density, (2) to measure the soil strength condition correlated to some soil physical properties. The Bungor series soil slope (Typic Kandiudult) was having a pH of 4.43, which was acidic, high exchangeable aluminum at 32.2 mg kg^{-1} and contained low of soil organic carbon at 0.43%, total N was 0.02%, available P at 0.17 mg kg^{-1} and trace elements such as Fe, Mn, Cu and Zn indicating <0.5 mg kg^{-1}, which was low fertility status. Therefore, the soil porosity and hydraulic conductivity in the dumping sludge> chicken dung> mixing sludge was significantly difference compared to the control in Pennisetum setaceum and Digitaria setivalva. Different trend was observed in bulk density; control> mixing sludge> chicken dung> dumping sludge and root length density (g m^{-3}) in Pennisetum setaceum and Digitaria setivalva; dumping sludge (389.69) (334.28) > chicken dung (271.80) (273.15) > mixing sludge (156.26) (138.43) > control (83.64) (76.69). The results showed that the dumping sludge application effectively enhanced vegetation growth of *Pennisetum setaceum* and *Digitaria setivalva* and increased in soil shear strength. The increased of soil shear strength was correlated to the increased of root length density (RLD) and rapid vegetation growth. There were statistically significant strong correlation identified in an organic amendments for all the treatments (R^2 = 0.92). Thus, these grass-soil interactions were significant in erosion control and improved soil shear strength.

Key words: *Pennisetum setaceum, Digitaria setivalva,* treated POME sludge, soil shear strength

Introduction

In Malaysia, annual precipitation was observed more than 4500 mm. The average high temperatures throughout the year might cause intense weathering processes and the formation of thick residual soil profiles. The effect of tropical climate and temperature becomes one of the important factors triggering the landslides to occur during and after a period of heavy rainfall. The shallow slides such as landslip normally occurred less than 4 m deep immediately after intense rainfall (Pradhan and Lee, 2010) and quite easily seen in Malaysia's climate condition. The difficulties on the selections of suitable vegetation planted on the slope surface might left the area bare and without any conservation practices. The cut slope was identified infertile and limit the plants grow because of most of the

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cut slope might expose the B horizon. The B horizon was infertile and needs soil amendments application. Application of soil amendments and types of vegetation grown on the slope surface was vital and only the fast growth species was selected.

The Organic amendments was vital in improving soil physicochemical status. Organic amendments produced from the oil palm waste was very potential to be used as an organic fertilizer including the palm oil effluent. According to Khairuddin *et al.,* (2017) stated that the sludge from palm oil mill effluent could be utilized as nutrients in soil after some processes and procedures were adopted. Nowadays, mostly chicken dung was frequent to be used as main organic amendments. The roles of organic amendment was to bind the roots and soil particles as a cementing agents to become more stable aggregates. The influence of soil physical properties towards the plant growth was vital and it's might create an equal effects if the fertility status was also being neglected. Soil Strength is one of the important soil physical properties to evaluate which correlated with water holding capacity (WHC) (Coppin and Richards, 1990). Shear strength could be measured using the direct shear stress methods and soil compaction analysis. Soil shear strength is a soil resistance to the breakdown of soil aggregate per unit volume that the soil aggregate can resist and sliding along the soil plane (Bell, 2013). The roots density would increase the soil strength and resistant from cracking or breakdown of the soil aggregates. High roots density and soil reinforcement effect together with the soil moisture depletion by evapotranspiration (Abernethy and Rutherfurd, 2000) improved the soil strength. Other factors were also correlated to the soil strength such as soil water holding capacity, soil texture and the types of mineral content form the different soil types or soil series. The objectives of the study were to determine the effects of palm oil mill effluent sludge on soil physical properties and root length density, and to determine the root-shear strength relationships.

Materials and Methods

Soil sampling site: The study site was located along the Persiaran UPM-MARDI where the horizon A, B and C of the soil profile was left bare without any vegetation cover. Horizon A and B from the soil profile was unable to provide adequate nutrients for plant establishment and amendments need to be done. There was no vegetation survived on Horizon C due to it was not classified as soil materials. Horizon C was exposed and more than 10 meter depth which identified as parent material and lacking of macro- and micronutrients for root development. The parent material was low in pH and compacted under dry condition because the soft rock might prevent roots penetration and water percolation (Hodge, 2010). The site was bare especially at horizon C and exposed to erosion due to the high rainfall events (2000-3000 mm/year) and temperatures ranging from 25.6 to 27.8°C throughout the year (Pradhan *et al.,* 2010). Most roads in Malaysia were constructed on the hilly areas where cutting and re-design the slopes gradient and surface becoming compulsory for new road development. Lacking of nutrients availability on horizon B of cut slope might affect vegetation growth and causes soil erosion, and in certain cases when the soil was saturated with water the landslip might occur and collapsed the profile.

Soil physicochemical analysis: Samples of Bungor soil series slope were obtained from nearby University Putra Malaysia (N 2.98343, E 101. 73806). The soil was left for a week to let the soil samples completing the air-dried process and sieved through a 2.0-mm sieve. The samples were prepared based on the analysis for pH, total nitrogen (TN), soil organic carbon (SOC), available phosphorus, using standard analytical methods (Johnson *et al.,* 2007). The pH was determined using 1:1 of soil:water ratio suspension pH meter. Soil shear strength was determined using the direct shear test method (Gan, *et al.,* 1988). The soil samples was cut and trimmed into 25 cm thick from the column boxes of 20 cm × 20 cm × 100 cm. The soil samples were cut at 25 cm intervals in each column boxes and carefully trimmed according to the size needed. The soil sample was inserted into a metal shear box before starting the measurement (Abou-Chakra and Tüzün, 1999). The angle of internal friction was determined by plotting the graph of shear stress against the normal stress from soil shear strength equation.

Experimental layout

The experiment was conducted in a complete randomized block design (RCBD) with five replications which was a One way ANOVA analysis. In each column box, a mixture of grass (*Pennisetum setaceum*) and fast growing grass (*Digitaria setivalva*) were transplanted in the ratio of 1:1. Both species were selected based on growth ability performance such as fast growth and high biomass production. The soil amendments were applied at every 2 weeks. The data was collected after 5 month of planting.

Statistical analysis

Data were analysed using analysis of variance (ANOVA), the one-way ANOVA was used as as the experimental design layout. All statistical analyses were compared at probability level of p > 0.05 using SAS Statistical Analysis System (SAS, 2007).

Results

Chemical properties of Bungor series soil: Table 1 shows pH, organic carbon, CEC and macronutrients availability before application of treatments. The Bungor soil series was inherently infertile, characterized by high acidity (pH = 3.32), CEC (2.23 meg/100 g soil) and organic carbon (0.94 %). Available P (6.04 %), Ca (0.06 mg kg^{-1}), K (0.05 mg kg^{-1}), Mg (0.08 mg kg^{-1}) and available P (6.04 mg kg^{-1}) were very high.

Physical properties of Bungor series soil: Fig. 1 shows that treatment with the dumping sludge (DP) gave the lowest bulk density in *Pennisetum setaceum* (PS) and *Digitaria setivalva* (DS) which was significantly different compared to the chicken dung, mixing pond (MP) sludge and control. The porosity status after treatments application, showed that the control and DP was significantly different compared to MP sludge and chicken dung Fig. 1.

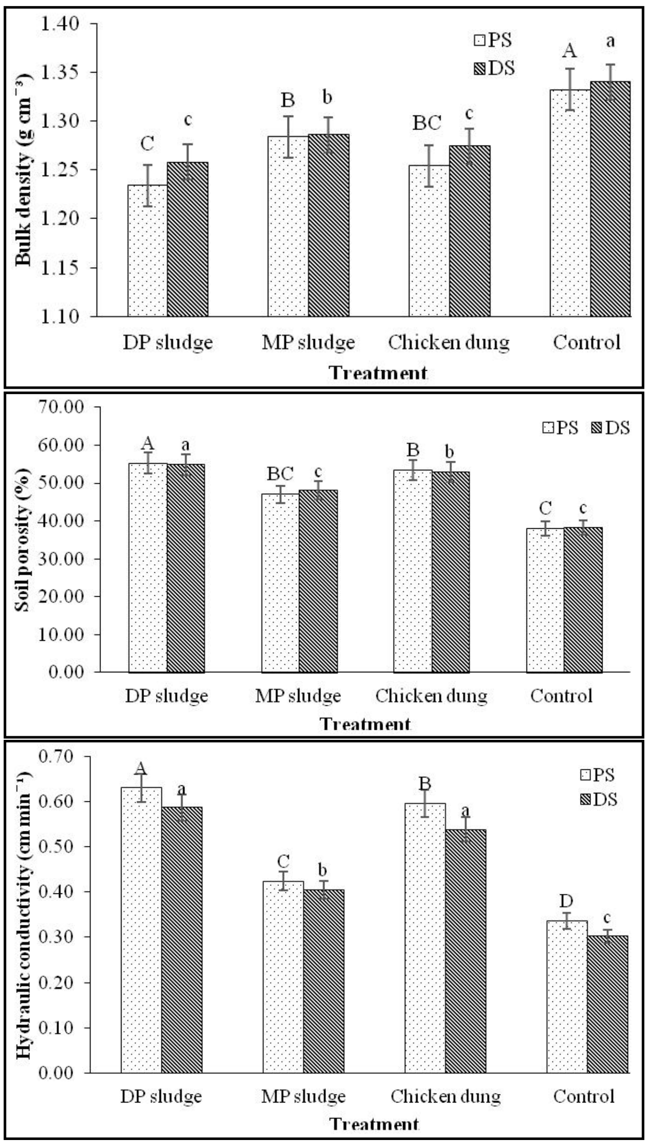

Fig. 1: Bulk density, porosity and hydraulic conductivity measurements after application of treatments (Means with the same letter are not significantly different at p<0.05).

Table 1: Chemical characteristics of Bungor soil series on a cut-slope at Persiaran UPM-MARDI, Universiti Putra Malaysia, Serdang, Malaysia.

Chemical properties	
pH	3.32
CEC (meq/100g soil)	2.23
Organic carbon (%)	0.94
Available P (mg kg^{-1})	6.04
Ca (mg kg^{-1})	0.06
K (mg kg^{-1})	0.05
Mg (mg kg^{-1})	0.08

The soil hydraulic conductivity Fig. 1 of *Pennisetum setaceum* (PS), the DP sludge (0.62 cm min^{-1}) and chicken dung (0.60 cm min^{-1}) was significantly different compared to the control (0.32 cm min^{-1}) and MP sludge (0.41 cm min^{-1}). Meanwhile, *Digitaria setivalva* (DS) showed that the DP sludge (0.59 cm min^{-1}) and chicken dung (0.57 cm min^{-1}) was no significant different. However, there was significantly different between the MP sludge (0.40 cm min^{-1}) and control (0.30 cm min^{-1}).

Root length density: Root length density (gm^{-3}) varied significantly (p>0.05) compared with all the treatments in *Pennisetum setaceum (PS)* and *Digitaria setivalva (DS)*, which showed the increasing trend following the control (83.64 g m^{-3}), (76.69 g m^{-3}) < MP sludge (156.26 g m^{-3}), (139.43 g m^{-3}) < chicken dung (271.80 g m^{-3}), (273.15 g m^{-3}) < DP sludge (389.69), (224.28). From Fig. 2, the DP sludge application increased root length density of Bungor series soil approximately

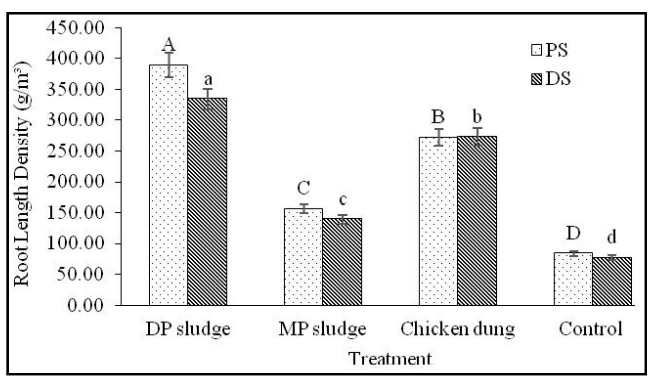

Fig. 2: Effects of DP sludge, MP sludge, chicken dung and control application of root length density on slope planting with *Pennisetum setaceum* (PS) and *Digitaria setivalva* (DS) (Means with the same letter are not significantly different at p<0.05).

between 60 to 70% compared to the control treatment.

Shear Strength characteristic: Fig. 3 shows that the soil shear strength results after application of treatments, indicating that there were significant different in all the treatments using *Pennisetum setaceum* (PS) and *Digitaria setivalva* (DS). But between *Pennisetum setaceum* (PS) and *Digitaria setivalva* (DS) in the same treatments pond, there was no significant different. Furthermore, the pattern had shown that the DP sludge was high in shear strength compared to the chicken dung, MP sludge and control. The roots growth applied with DP sludge and chicken dung amendments in *Pennisetum setaceum (PS)* and *Digitaria setivalva (DS)* had significantly affect the cohesion and angle of internal friction table 2 and Fig. 3. At the normal stress of 396.18 kN m^{-2} and 390.80 kN m^{-2} Fig. 3, the DP sludge amended with the Bungor series soil showed the cohesion (c) and angle of internal friction (ϕ) value at 21^o and 22^o, table 2 compared to the other treatments. On the other hand, the chicken dung possessed the normal stress of 354.50 kN m^{-2} and 354.31 kN m^{-2} Fig. 3 indicated a cohesion (c) and angle of internal friction (ϕ) at 23^o and 24^o which was lower than the MP sludge. The control treatment shows the lowest shear strength measurement in this experiment.

Relationship between Shear Strength and Root length density: Fig. 4 indicated that the results of four different treatments on the effect of roots reinforcement towards the shear strength of the soil. The *Pennisetum setaceum* (PS) and *Digitaria setivalva* (DS) treated with the palm oil mill sludge were significantly different in shear strength analysis correlated with the root length density (RLD). Increased in root length density (RLD) would increase the soil shear strength after application of treatments which improved the soil aggregate stability of the soil.

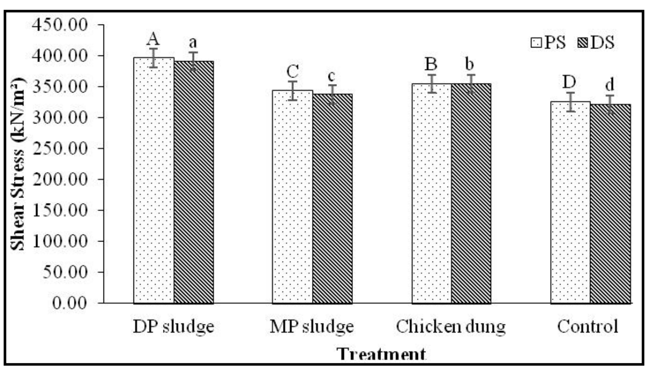

Fig. 3: Shear strength measurement after application of treatments. (Means with the same letter are not significantly different at $p<0.05$).

Table 2: Treatments indicated shear strength parameters.

Treatments	Angle of Internal Friction (ϕ)		Cohesion (c)	
	PS	DS	PS	DS
DP	21	22	75	80
MP	24	26	100	110
Chicken dung	23	24	95	90
Control	32	32	130	130

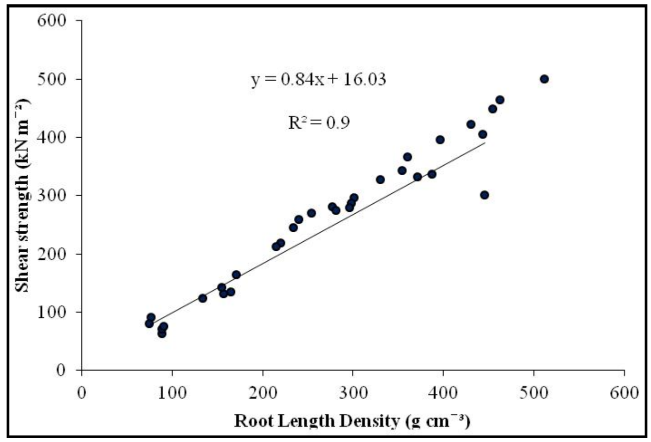

Fig. 4: Correlation between shear strength (kN m^{-2}) and root length density (cm cm^{-3}).

Discussion

Soil bulk density is correlated to soil compaction, which influenced by some soil physical and chemical characteristics such as soil texture, amount of organic matter in soils, constituent of minerals and porosity (Ghestem *et al.,* 2013). Bulk density is closely related to soil porosity also hydraulic conductivity within the soil profile. Soil porosity in the control, chicken dung, MP sludge and DP sludge increased and reduced the bulk density. Soil porosity is also correlated to water infiltration, water and nutrient absorption within soil and roots and ability to hold water (water holding capacity) (Bronick and Lal, 2005). There were many factors that could affect the soil hydraulic conductivity. Soil with higher percentage of clay indicated slow infiltration rate compared to the sandy soil. High bulk density and less soil pores may also cause low soil hydraulic conductivity (Osunbitan *et al.,* 2005). The addition of amendments in soil was associated with the increased of soil aggregation and macro-porosity, which lead in increasing of soil hydraulic conductivity (Eusufzai and Fujii, 2012).Khairuddin *et al.,* (2017) had mentioned that the root length density (RLD) correlated to the increased of soil shear strength. The present of roots resulted in increasing of soil shear strength (Khairuddin *et al.,* 2017). The high root length densities observed in this treatment enhanced the anchorage ability by strengthening the aggregates stability of the Ultisols. POME sludge could increase the soil water holding capacity (SWHC) with significant improvement on root growth (Isa *et al.,* 2017). Generally, Fig. 3 showed the shear strength results from the control treatment as low as 321 kN m^{-2} until 396.18 kN m^{-2} which was shown in the DP sludge treatment. The mechanical effects of the vegetation roots might enhance the soil shear stress and resistance to sliding, increased the soil strength of the soil profile; the angle of internal friction was small as compared to the soil treatments with low shear stress value. The low shear stress value might indicate high angle of internal friction which prone to sliding or collapsed. The effects of roots or vegetation on slopes would develop gradually over a period of time. The maximum rooting depth of vegetation that grow on the slope, would determine the degree of stabilization that vegetation could provide.

Conclusion

In conclusion the study had shown significant effect of an organic fertilizer application, amelioration strategies in achieving rapid and successful vegetation growth on the surface of the cut slope as a protection from raindrop impact was extremely important. Subsequent dumping pond (DP) sludge applications effectively established the vegetation growth, improved root elongation and densities distribution, sustained water holding capacity and fast slope coverage from erosion or surface runoff. Enhanced the root growth stimulated by the dumping pond sludge (DP) by supplying adequate nutrients had shown significant effect also on the shear strength and root length density (RLD) in this experiment after application of the treatments. The findings had confirmed that the nutrients from the dumping pond sludge (DP) enhanced vegetation growth and increased shear strength of the substrate.

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