The Potential of Palm Oil Mill Effluent for Improving the Water Infiltration Rate in Lateritic Soil

N F A Rashid¹, N Zulkifli², A Yaacob³, S K Yong³, J Kassim⁴

¹ Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Perlis Branch, Arau Campus, 02600 Arau, Perlis, Malaysia
² Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA Melaka Branch, Jasin Campus, 77300 Merlimau, Melaka, Malaysia
³ Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
⁴ Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor Malaysia

Corresponding author’s e-mail address: nurfirdaus@uitm.edu.my

Abstract. Poor soil drainage of the lateritic soil is due to its clayey texture and high bulk density. Palm oil mill effluent (POME) may be administrated to increase the water infiltration rate and improve the drainage of the lateritic soil. The share farm of the Faculty of Plantation and Agrotechnology, UiTM Jasin was treated with various volume of POME for 16 weeks by using Completely Randomized Design (CRD). Overall, treatment of POME did not increased water infiltration rate. The bulk density of the lateritic soil that was treated with POME is suitable for agriculture. Treatment 1 (2L) gave 68 mm/hour of water infiltration rate and 1.25 g/cm³ of bulk density with 0.570 and 0.451 of p-values respectively which is acceptable with the consideration of cost benefits, cost inputs, and profit to the industry. The results shown were not significant might be due to types and soil textures, duration for the research to be completed, and also climate change factors.

Keywords: POME, rate, Soil Drainage, Bulk Density, Lateritic Soil

1. Introduction

Increasing population is now becoming the problem to humanity with concerns over food security. The decreasing availability of prime land for agriculture has impacted the capacity to grow food for human consumption. In order to sustain ample food supply, the marginalized land including lateritic soil can be utilized for plantation of food crop.

Lateritic soil have high bulk density, clayey in texture, and poor drainage. Soil drainage is one of the factors that ensure excellent growth and yield of plants. Stagnation of water especially during rainy season may cause rotting of the root system and severely impact the basal stem. Generally, high bulk density leads to poor infiltration rate of water in soil. Therefore, it is vital to improve the water infiltration rate in lateritic soil in order to ensure a better health for the plant growth. The application of palm oil mill affluent (POME) to lateritic soil may overcome this problem is and allows planting of food crop.

Malaysia is the second largest producer for oil palm in the world [1,2]. The production processes of palm oil produces an abundant amount of liquid waste such as POME. Besides that, POME sludge is
also produced in huge amount that requires treatment and disposal [3]. However, POME may improve pH stabilization and speed up water infiltration rate of the aggregated soil [4,5].

2. Materials and Methods

2.1. Treatment of lateritic soil
This experiment was conducted in the share farm of the Faculty of Plantation and Agrotechnology, UiTM Jasin. Lateritic soil with a texture of a silty clay loam was treated with various volume of POME (i.e., 2L, 4L, 6L, and 8L) for 16 weeks using the Completely Randomized Design (CRD). (i.e., 2L, 4L, 6L, and 8L). All treatments were conducted in triplicates.

2.2 Determination of Infiltration Rate
Double ring infiltrometer method was the common method used to measure water infiltration rate in field by using Annex 2 water infiltration test. There were two rings needed with smaller diameter (30 cm) and larger diameter (60 cm) for inner and outer ring respectively. The rings were hammered about 8cm deep without changing any physical disturbance to the soil such as plough as it will affected the results. The vegetative growth needs to be removed manually to prevent the obstacle for the down speed of water level measurement [6]. The smaller ring was hammered with assist of the drive plank by using hammer. Then, the bigger ring was hammered with the same height of the inner ring. Water was poured until the depth of approximately 70-100mm. The inner and outer level of water should be in the same height. The water that was between the two rings were to prevent the water from spread and promote the inner ring to have lateral movement of water [7]. The clock time were taken and recorded. Then, the water infiltration rate were calculated by using this formula:

$$\text{Water infiltration rate} (\text{mm/hour}) = \frac{\text{Water level reading}}{\text{Time difference (min)}} \times 60 \text{ min}$$ (1)

2.3 Method of Bulk Density
Metal cylinder was used for this experiment to be calculated as the volume of soil for before and after dry weight. An empty metal cylinder was weight by using weight balance. The metal cylinder was then placed and drive into the ground and make sure that the metal cylinder had fully covered with the soil sample before carefully dig out from the ground. The metal cylinder with the soil sample was weight and the data was recorded. Next, dry them at 105°C in the oven for 24 hours. The soil sample was cooled before recorded the data again. The calculation by using this formula:

$$\text{Bulk density} (\frac{g}{cm^3}) = \frac{\text{Weight of oven dry soil (g)}}{\text{Volume of soil (cm3)}}$$ (2)

3. Results and Discussions

3.1 Infiltration rates
These are the results before and after of water infiltration rate under lateritic soil. Sharing letters (a, b or c) shows there is no significant different.

| Treatment | Volume of POME (L) | Water infiltration rate (mm/hour) |
|-----------|-------------------|---------------------------------|
|           | Before            | After                           |
| T1        | 2                 | 24a                             | 68b                             |
| T2        | 4                 | 26a                             | 42c                             |
| T3        | 6                 | 16a                             | 84a                             |
| T4        | 8                 | 22a                             | 80a                             |
These results were analysed with 5% significant different. Although there were no significant different, Table 1, show that the treatments did increase the water infiltration rate in the lateritic soil. This result is supported by [8], whereby, a proper POME application could improve soil physical properties including in Melaka soil series such as improve its infiltration rates from 90mm/hour to at minimum rates 48mm/hour.

Figure 1. Water infiltration rate (mm/hour) of lateritic soil treated with various volume of POME (T1 – 2L, T2 – 4L, T3 – 6L, T4 – 8L)

The Figure 1 shows that the water infiltration rate of the lateritic soil was increased with treatment of POME. The best rate of POME application is determined by referring to the standard range of water infiltration needed for plantation or agricultural purpose (Table 2). A water infiltration rate of greater than 50 mm/hour is considered as high water infiltration rate and is an ideal range for healthy growth of plants. Therefore, the best POME treatment recommended to the plantation industry is Treatment 1 (2L) as it achieves the most ideal rate of 68 mm/hour. The water infiltration rate of soil with Treatment 2 (4L) was 48 mm/hour. Although it is acceptable, the water infiltration rate for Treatment 2 is less cost effective than that of Treatment 1. The water infiltration rate for Treatment 3 (6L) and Treatment 4 (8L) with 84 mm/hour and 80 mm/hour, respectively were too high and the excessive POME may cause leaching of the lateritic soil. The high rate of POME input for both treatments are not cost effective.

Table 2. Standard range of water infiltration rate for plantation or agricultural purpose

| Water infiltration rate | Range (mm/hour) |
|-------------------------|-----------------|
| Low                     | Less than 15    |
| Medium                  | 15 to 50        |
| High                    | More than 50    |

Sources: Food and Agriculture Organization of the United Nations, FAO (1985) - Soil and Water

3.2 Bulk density

The following results were based on the Tukey's test from IBM SPSS Statistics 24 with one-way ANOVA analysis. These are the results before and after of bulk density under lateritic soil.
### Table 3. Results before and after POME application towards bulk density

| Treatment | Bulk density before (g/cm³) | Bulk density after (g/cm³) |
|-----------|----------------------------|---------------------------|
| T1        | 1.49<sup>ab</sup>          | 1.25<sup>a</sup>          |
| T2        | 1.46<sup>a</sup>           | 1.18<sup>a</sup>          |
| T3        | 1.53<sup>c</sup>           | 1.30<sup>a</sup>          |
| T4        | 1.51<sup>b</sup>           | 1.27<sup>a</sup>          |

Figure 2. The effects of POME application towards bulk density (before and after)

There were no significant different with 5% analysis for the after POME application in the lateritic soil. But, in the other hand, the Table 4.3 and Figure 4.3, show that the POME application did reduce the bulk density in the lateritic soil. Generally, water infiltration rate and bulk density were interrelated. Water infiltration rate increase, due to low bulk density. This statement can be supported by [9] as through their report on research study on water infiltration rate in native soil showed that high bulk density lead to poor water infiltration rate in soil.

### Table 4. Range for bulk density to root growth based on soil texture

| Soil texture | Ideal bulk density for plant growth (g/cm³) | Bulk density that restrict root growth (g/cm³) |
|--------------|---------------------------------------------|-----------------------------------------------|
| Sandy        | <1.60                                       | >1.80                                        |
| Silty        | <1.40                                       | >1.65                                        |
| Clayey       | <1.10                                       | >1.47                                        |

Sources: Food and Agriculture Organization of the United Nations, FAO (1985) - Soil and Water
The decrease in bulk density shows that another objective of this research is also achieved. The best rate that could be recommended is Treatment 1 (2L). This is because by referring to the standard range of bulk density (Table 4) needed for plantation or agricultural purpose, for clayey texture, the ideal range for plant growth is less than 1.10 g/cm$^3$, while bulk density that will restrict root growth is more than 1.47 g/cm$^3$. Based on Figure 4.4, all the bulk density (1.25, 1.18, 1.30, and 1.27 g/cm$^3$ respectively to treatments) could be accepted as they were less than 1.47 g/cm$^3$. By taking cost benefit, ideal bulk density, and easier management for the industry, Treatment 1 (2L) is the best among the rest as it can help to reduce the cost input especially the cost of POME, transportation of POME, and labour cost to be considered as to smooth the plantation or agriculture management.

4. Conclusions
Findings from this study conclude that application of POME fulfilled the objectives of the research study by increasing the water infiltration rate and reducing the bulk density in the lateritic soil. Related to the research objectives, the water infiltration rate range needed for healthy plant growth is more than 50 mm/hour. Treatment 1 (2L) gave 68 mm/hour which is considered as one of the best condition of water to infiltrate Without contributing to flooding issue to the plantation or agriculture area. The bulk density range that is excellent for penetration of roots, nutrients and water uptake is 1.10 to 1.40 g/cm$^3$ for clayey soil. Treatment 1 (2L) gave 1.25 g/cm$^3$ is considered as ideal bulk density for plant growth in lateritic soil with high clayey texture. Other treatments might fulfilled the range as well, but by taking the cost benefits, cost inputs, and economical values, Treatment 1 (2L) is recommended to be the best for the rate of POME treatments. Therefore, the rate that can be used for the industry is 20,000 L per 10,000 m$^2$ (1 hectare) of plantation or agriculture area for lateritic soil with high clayey soil condition. Different rate of POME will give different outcomes on the parameters that were measured. In addition, time taken for the experiment conducted, the type of soil texture, and changes in climate need to be considered as they can influence the results obtained. This is because, longer research duration contributes to more significant results. Apart from research duration, the rate of POME applications in lateritic soil will be differ to peat soil, alluvial soil, and also sandy soil as the soil texture and structure are different. Therefore, more researches should be done to get the suitable rate of POME applications based on the requirement of soil themselves.
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References
[1] Singh, R.P., Ibrahim, M. H., Esa N., and Iliyana, M. S. (2010). Composting of waste from palm oil mill: a sustainable waste management practice. Reviews in Environmental Science and Bio/Technology, 9(4), 331–344.
[2] Zahrim, A. Y., & Asis, T. (2010). Production of Non Shredded Empty Fruit Bunch Semi-Compost. Journal - The Institution of Engineers, Malaysia. 71(4), 11-17
[3] Kanakaraju, D., Metosen N. S., and Nori, H. (2016). Uptake of Heavy Metals from Palm Oil Mill Effluent Sludge Amended Soils in Water Spinach. Journal of Sustainability Science and Management. 11(1), 113-120
[4] Stamatiadis, S., Werner, M., and Buchanan, M., (1999). Field assessment of soil quality as affected by compost and fertilizer application in a broccoli field (San Benito County, California). Appl. Soil Ecol. 12, 217–225.
[5] Nwoko, C. O., Onoh, C. P., Ogunyemi, S. (2012a). Plant Nutrient Recovery Following Palm Oil Mill Effluent Soil Amendment In A Maize (Zea Mays) Grown Screen House Experiment. Int’l Journal of Agric. And Rural Dev. 15 (2), 1109 – 1118
[6] Jagdale, S., Dagadu, Nimbalkar P. T. (2012). Infiltration Studies of Different Soils under Different Soil Conditions and Comparison of Infiltration Models with Field Data. International Journal of Advanced Engineering Technology. 3, 1: 154-157
[7] Food and Agriculture Organization of the United Nations, FAO (1985) - Soil and Water retrieved by oct 2018 http://www.fao.org/3/r4082e/r4082e03.htm
[8] Wood, B. J., Pii, L. K. R, and Rajarainam, J. A. (1979). Palm Oil Mill Effluent Disposal on Land. Applied Science Publishers Ltd, England.
[9] Hartsig, T., and Szatko, A. (2012). Performance Assessment Of Two Stormwater Best Management Practices For Infiltration, Water Quality, And Vegetative Growth. A Report Completed For The City Of Omaha, Nebraska
[10] Phang, K. Y., & Lau, S. W. (2017). A Survey on the Usage of Biomass Wastes from Palm Oil Mills on Sustainable Development of Oil Palm Plantations in Sarawak. doi:10.1088/1757-899X/206/1/012091