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Machinery Compaction Effects on Physical Properties of Bernam Series in an Oil Palm Plantation

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Abstract: Problem statement: Introduction of mechanisation in oil palm (*Elaeis guineensis*) plantations could result in soil compaction and cause soil degradation. This could be a serious problem in the future due to increase in size, weight and transportation frequency of machines used. Objectives: This trial was carried out to evaluate the effect of different trailer weights and transportation frequencies on the soil physical properties of Bernam series soil. **Approach:** The treatments were a combination of three trailer weights and four transportation frequencies. At the end of 6 years of the experiment, soil samples were taken for soil physical properties characterisation at 0-10, 10-20 and 20-30 cm depths. **Results:** After six years of soil compaction treatments, the results showed that the mean soil bulk density increased and the porosity decreased annually. However, the mean soil bulk density was still less than 1.0 g cm^{-3}. The mean soil bulk density decreased with increasing soil depth, but porosity and available water increased with soil depth. The 3 rounds per month transportation frequency for all trailer weights and 2 rounds per month for the 4 tonnes trailer weight significantly affected the soil physical properties. **Conclusion:** Generally, the results indicated that the 6 years of compaction treatments did not cause serious soil compaction that could alter the soil physical properties for this particular soil type.

Keywords: Soil compaction, oil palm plantation, soil physical properties, Machinery use

INTRODUCTION

Soil physical properties include soil texture, structure, porosity, soil density, drainage and surface hydrology. These properties have an important influence on plant growth and development as they determine the ease of root penetration, water availability and gaseous exchange in the soil. Despite fertilizer application, use of improved crop varieties and control of pests and diseases, crop productivity cannot be sustained if a soil's physical condition deteriorates. The impact of soil compaction from the wheel traffic of heavy machines contributes to gradual alteration of soil physical properties which could reduce soil productivity. A study by Peralta *et al.*[1] indicated that good management of soil physical characteristics improves yield and fertilizer utilization.

The Malaysian palm oil industry is very much dependent on labour for routine field management activities such as harvesting, weeding, fertilising and others. Mechanisation has been introduced to oil palm plantations since early 1980s, not only to overcome labour shortage but also to improve production efficiency. Research and development has enhanced the introduction of various mechanised in-field equipment such as fresh fruit bunch collector, infield transporters

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as well as a loose fruit collector, mechanical spreaders for fertilizer application and mechanised sprayers for applications of herbicides and pesticides.

The introduction of mechanisation has increased land to labour ratio in oil palm plantations, but machinery used in the field could have negative effects on the soil properties and hence crop productivity especially with the use of heavy machinery. The severity and the extent of soil compaction resulting from mechanisation in oil palm plantation is not extensively researched. Richard *et al.*[2] and Hamza and Anderson[3] found that compaction induced by vehicle traffic has adverse effects on soil properties such as bulk density, soil strength, mechanical impedance, porosity and hydraulic properties (infiltration rate and hydraulic conductivity).

The objective of this study was to evaluate the severity and effect of compaction on the following soil physical properties: Soil Bulk Density (SBD), porosity and Available Water (AW).

MATERIALS AND METHODS

The trial was carried out at Melentang Estate, Bagan Datok, Perak. The soil is a flat coastal terrain of Bernam series soil (fine, mixed, isohyperthermic)[4]. The rainfall in this location is about 1400 mm a year. The soil textural classification is clay having about 50% clay, 30% silt and 20% sand. The mean SBD and particle density were found to be 0.8 and 2.45 g cm^{-3} respectively, with a mean soil porosity of 67%. The trial area was planted in 1996 with GH300 DxP materials according to standard estate practice. The compaction trial was started in 2002 when the palms were about 7 years old. All field operations at the trial site, such as fertilizer applications, FFB evacuation and weeding were carried out manually according to standard estate practices.

The treatments were a combination of three trailer weights and four transportation frequencies. The three trailer weights were 0T (tractor without trailer), 2T (tractor with 2 tonnes trailer weight) and 4T (tractor with 4 tonnes trailer weight). The four transportation frequencies were 0, 1, 2 and 3 rounds per month with no vehicle traffic in the control plots. Each treatment block was 4.4 ha in size with each replicated five times. A total of 60 experimental plots (15 control plots and 45 treatment plots) resulting in a total area of 22 ha.

Undisturbed soil samples were taken by using a split tube sampler with sampling rings. The height and diameter of the sampling rings was 5 cm. The sampling depths for soil physical properties characterisation were 0-10, 10-20 and 20-30 cm. Soil sampling was done at 3 locations in treatment plots and two locations from the 'harvesting path' (under and between the wheels tracks) and one from the 'frond pile path'. For the control plots, soil sampling was done at two locations only-one from the 'harvesting path' and one from the 'frond pile path'. Soil sampling was done twice a year for determination of soil bulk density, porosity and available water. Soil bulk density and particle density were determined using the core method[5]. Bulk density is the ratio of a mass of dry soil (oven-dried at 105°C to constant weight) to its total volume. Soil porosity was derived mathematically from bulk density and particle density. The soil moisture properties were determined by using ceramic plates to obtain pF-curves. The soil moisture was forced out of the soil samples by increasing the pressure in the extractor until equilibrium was reached. The moisture content between field capacity and the permanent wilting point is known as the plant available water.

RESULTS

Six years of compaction treatment produced significant changes in SBD in the Bernam Series soil. The annual mean SBD showed no significant annual increase (Fig. 1). However, the mean SBD increased with increasing trailer weight with a significant increase for the 3 rounds per month treatment as shown in Table 1. Both 0 and 2 tonnes trailer weights treatments showed no significant effects on mean SBD for the one and two monthly rounds transportation frequency but was significantly higher for 3 rounds per month. The mean SBD for the 4 tonnes trailer weight increased significantly with increasing transportation frequency and produced the highest mean SBD for 3 rounds per month with an increase of about 10.5% more than the control. The locations under and between the tracks at 0-10 cm depth (Fig. 2) were the most affected wherein the bulk density decreased with increasing soil depths,

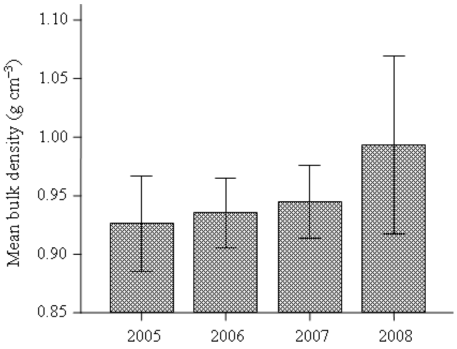

Fig. 1: Mean soil bulk density over 4 years (2005-2008)

Table 1: Effects of trailer weight and transportation frequency on soil physical properties

Treatment		Soil physical properties		
Trailer weight (tonnes)	Frequency (rounds)	Bulk density (g cm^{-3})	Porosity (%)	Available water (cm cm^{-3})
Control	Control	0.86a	64.90a	10.83a
0T	1R	0.83a	66.12a	10.83a
	2R	0.82a	66.53a	11.14a
	3R	0.94b	61.63b	11.95a
2T	1R	0.85a	65.31a	11.10a
	2R	0.85a	65.31a	11.46a
	3R	0.92b	62.44b	11.28a
4T	1R	0.87a	64.49a	11.33a
	2R	0.93b	62.04b	10.37a
	3R	0.95b	61.22b	11.04a

Means followed by the same letter are not significantly different at $p<0.05$

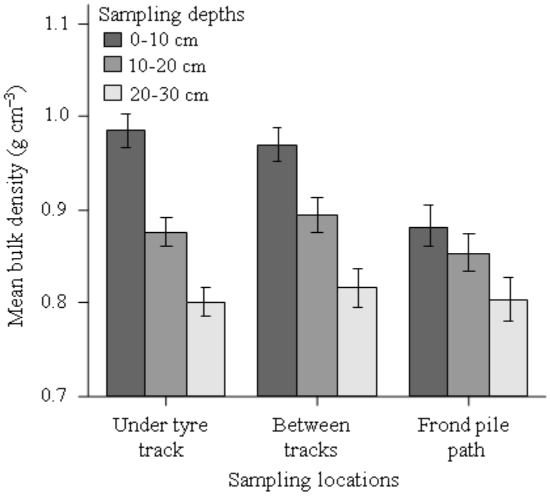

Fig. 2: Mean soil bulk density at different sampling locations and depths

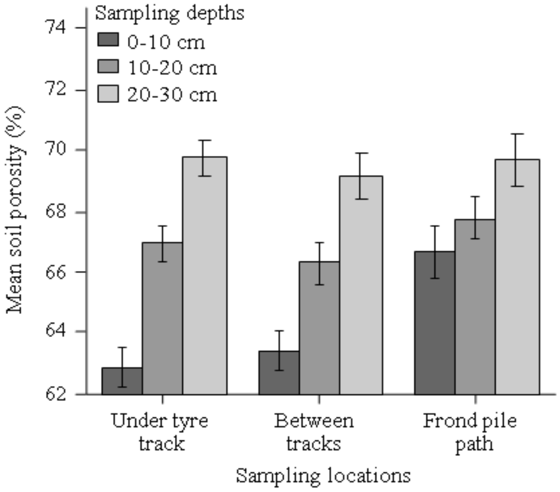

Fig. 3: Mean soil porosity at different sampling locations and depths

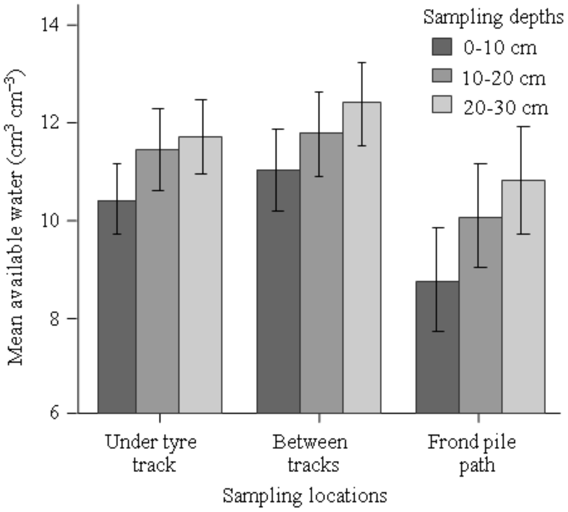

Fig. 4: Soil available water at different sampling locations and depths

but it was still less than 1.0 g cm^{-3} and well below the root-limiting critical range[6]. The different trailer loads used were not sufficient to affect the SBD at depths below 10 cm and the critical stress to cause maximum compaction below the surface was not reached with the trailer loads used in this study.

A reduction in mean soil porosity was expected to be inversely correlated to the mean SBD as it was derived mathematically from bulk density. The mean soil porosity decreased with increasing trailer weight and decreased significantly at 3 rounds per month as shown in Table 1. Both 0 and 2 tonnes trailer weights treatments showed no significant effects on mean soil porosity for transportation frequencies of 1 and 2 rounds per month but significantly lower at 3 rounds per month. For the 4 tonnes trailer weight, the mean soil porosity was significantly reduced with increasing number of transportation frequency and resulted in the lowest mean soil porosity at 3 rounds per month which was about 5% lower than the control. Porosity increased significantly with soil depth for all locations except in the frond pile path due to less soil disturbance in this location. The most affected area was the 0-10 cm depth (Fig. 3).

Table 1 also shows that mean Soil Available Water (SAW) was unaffected by different trailer loads and transportation frequency. Soil available water was higher at the sampling locations under the tyre track and between the two tracks compared to the frond pile path (Fig. 4). As SBD increases, porosity decreased as a result of reduction in the size of macropores. This would then increase the amount of micropores that will retain more water in the soil.

DISCUSSION

Adrian *et al*.[7] also found that compaction increased available water content at 0-10 cm depth by 24-59% when compared to non-compacted soil. At both 0-10 and 10-20 cm depths of non-compacted soil the SAW was lower than that of compacted soil.

Optimum bulk densities of soils depend on soil texture. Typical soil bulk densities range from 1.0-1.7 g cm^{-3}, in soils with varying clay and water contents[6]. Generally, soils with low bulk density possess better physical conditions. Zhang *et al*.[8] reported that a small four-wheel tractor (900 kg) caused significant soil compaction in the top soil (20 cm). Increased frequency of traffic resulted in more detrimental soil conditions. Adrian *et al*.[7] studied the effect of ground based logging on soil physical properties and reported that soil bulk density at 0-30 cm depth increased by 27% from 0.63-0.83 Mg m^{-3} in the most compacted portions of traffic lanes. Total soil porosity decreased by 10-13% with compaction and available water holding capacity increased.

Large pores are essential for water and air movement in soil and are primarily affected by soil compaction. Porosity is often significantly reduced after years of planting. Available Water Capacity (AWC) is much greater for silt loam soil than sandy loam soils. Sands have very low AWC[9,10]. AWC in soils is in the order clayey soils > loamy soils > sandy soils. In most field conditions, soil moisture increases with depth. Increasing soil bulk density reduces available pore space for air and water in the soil at a given depth.

CONCLUSION

After six years of soil compaction, the annual mean soil bulk density and porosity increased and decreased respectively. The soil bulk density and porosity in the frond pile path was lowest and highest respectively due to less soil disturbance and organic matter returns from frond decomposition. Mean soil porosity and available water were higher with increasing soil depths. The mean available water was higher in where tyre track moved and between the two tyre tracks where the soil was compacted. These results indicated that in 6 years, the treatments did not cause serious and deleterious soil compaction that could subsequently affect the soil physical properties in the oil palm plantation on Bernam series soil.

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