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DOES SOIL COMPACTION AFFECT OIL PALM STANDING BIOMASS?

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ABSTRACT

Soil compaction could be either desirable or detrimental to plant growth, depending on the severity of compaction. The compaction treatments applied in this study on a coastal alluvial soil, Bernam series (Typic Endoaquepts) *had resulted in significant reduction of oil palm total standing biomass in compacted plots. The oil palm total above-ground standing biomass comprising of fronds and trunk in the control plots was significantly higher than the compacted plots by 12%. Even though there was no significance difference in trunk heights, the palms were taller in 4T plots (tractor with 4 t trailer weight). Palms in compacted plots exhibited a significantly smaller trunk diameter, lower trunk dry weight and reduction in the frond dry weight by about 9%, 8% and 6%, respectively. The total green frond number, total leaf area and leaf area index (LAI) were not significantly different ($p \leq 0.05$) between the treatments. Total green frond number per palm was 33 to 35 fronds per palm. The LAI averaged more than 5 for all treatments implying compaction did not hinder photosynthesis process. Hence, the changes in soil physical properties such as bulk density, porosity, available water and hydraulic properties were considered not limiting to palm growth as they adapted well to the compaction treatments.*

Keywords: oil palm, standing biomass, trunk, frond, leaf area index, compacted soil.

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INTRODUCTION

Plant response to compacted soil varies due to the changes in soil structure, bulk density, porosity, moisture characteristics and water content of the soil. The relationship between texture and structure determine how compaction will effect plant growth. Machinery compaction increases mechanical resistance and the bulk density of the soil, while reducing porosity and hydraulic properties. It results in alteration of movement and retention of water in the soil system. Since compaction reduces aeration porosity, it would lead to a reduction in O_2 diffusion particularly when soils are saturated. Plants could probably respond to compacted soils by a reduction in biomass of both the roots and shoots (Chan *et al*., 2006; Mari and Changying, 2008).

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The requirements for labour in Malaysian oil palm plantations have escalated as planting areas have increased to 5.64 million hectares (MPOB, 2016). Various machines have been introduced to reduce labour reliance, as well as to improve productivity. However, mechanised field operations could contribute to gradual degradation of soil's physical properties leading to detrimental effects on crop productivity (Zuraidah *et al*., 2015a; Chan *et al*., 2005).

Effect of soil compaction on plants growth can be manifested in various forms such as stunting in growth, delayed emergence, narrow leaf structures, small grain heads, curled leaf edges and symptoms similar to bacterial wilt or chlorosis with limited recovery from the manifestation (Petersen *et al*., 2004; Taylor, 1971). Compaction can also cause physiological malfunctions resulting in inefficient use of essential resources (Richard *et al*., 2004). DeJong-Hughes *et al*. (2001) studied the more serious adverse effect of soil compaction on water flow and storage. However, some plant species *e.g.* perennial grasses (Clark *et al*., 2003) have a greater ability to overcome the mechanical stress.

In this study, the influence of soil compaction on growth of oil palm standing biomass is quantified in terms of frond (leaf) production, leaf area, petiole cross-section, trunk growth and total dry matter production. Plant growth is assessed in terms of dry weight which provides an estimate rate of photosynthesis, while the proportion of total dry matter in different plant parts reflects the distribution of photosynthetic products. Crop growth rate is the total dry matter produced per hectare per year, or the net photosynthesis productivity. It is very much dependent on planting density. Leaf dry matter is estimated from rate of leaf production during the period, and mean leaf dry weight. However, the number of fronds on a palm depends partly on harvesting and pruning practices. Dry matter used for vegetative growth has a fairly high heritability and sensitive to fertiliser levels. In particular, the cross-sectional area of the petiole appears to be a sensitive indicator for vegetative growth. The dry matter produced by the palm is partitioned into bunches and male inflorescences, trunk, fronds and roots (Fairhurst and Hardter, 2003). Similar to other crops, vegetative growth has priority over reproductive growth. Excess assimilates will be partitioned into reproductive growth, *i.e.* fruit bunches (Henson, 2006).

The alterations of soil physical properties due to the compaction treatments in this study was published earlier. The treatments had significantly increased the soil bulk density, available water content, as well as percentages of mesopores and micropores. On the other hand, the compaction treatments had resulted in reduction of the soil porosity, percentage of macropores, hydraulic conductivity and infiltration rate (Zuraidah *et al*., 2015a). Hence, only the effects of compaction treatments on above-ground vegetative growth oil palm are to be discussed in this article.

The main objective of this study is to evaluate the effects of compaction due to mechanisation on the performance of oil palm planted in Bernam soil series (*Typic Endoaquepts*). The study was carried out under field conditions to allow natural processes, such as fluctuating rainfall, wet and dry seasons, over a six-year period under actual plantation management practices except for the compaction treatments.

MATERIALS AND METHODS

Study Site

The study was carried out on a flat coastal terrain of Bernam soil series (*Typic Endoaquepts*), located at 4° 00'20.96268"N and 100° 50'18.66199"E, Bagan Datuk, Perak, Malaysia. The trial area had been planted with GH300 DxP planting materials according to standard estate practice with planting density of 148 palms per hectare. The compaction treatments were commenced when the palms were about 7-year old and this study was completed in six years. All other field operations at the trial site were conducted manually according to the standard estate practice.

Experimental Design

Soil compaction was monitored under controlled traffic conditions. The treatments were combination of 3 trailer weights and three transportation frequencies.

The three trailer weights were: (i) tractor without trailer (0T), (ii) tractor with 2 t trailer weight – normal trailer load (2T) and (iii) tractor with 4 t trailer weight (4 t).

The three transportation frequencies were: (i) one round monthly (1R), (ii) two rounds monthly (2R) and (iii) three rounds monthly (3R).

There was no vehicle traffic in the control plots. Each treatment block covered about 4.4 ha. The treatment plots were arranged in blocks (3 × 4) and replicated five times. A total of 60 experimental plots (15 control plots and 45 treatments plots) covered about 22 ha plantation area. Details of the experimental plot are as described in the previous paper by Zuraidah *et al*. (2015a).

Oil Palm Vegetative Measurements

As destructive methods could not be employed widely; non-destructive methods using correlations between dry weights and simple measurements, were adopted enabling repeated data collection on the same palm at different times. The non-destructive methods incorporated weight of fronds and trunk. Oil palm vegetative measurements were done twice a year according to the method described by Fairhurst and Hardter (2003). This was done to monitor the vegetative growth of oil palm in terms of leaf production, leaf area, petiole cross-section, trunk growth and total dry matter production.

The measurements were taken from the 16 recording palms per plot. Frond 17 from the selected palms was used for the leaf area measurements. The number of leaves (fronds) in each spiral of individual palm was counted. The mean total number of leaves (fronds) (g) was then calculated. The number of leaflets on one side of the rachis (n), including rudimentary leaflets at the base and fused leaflet at the tip were recorded.

Rachis length (rl) was measured from point of insertion of the lowest rudimentary leaflet to tip of rachis. Six undamaged leaflets from each rank at the mid-point of rachis were selected. The length and mid-width of each leaflet were then measured and the product of length x mid-width were calculated. The petiole width and depth were measured at point of insertion of lowest rudimentary leaflet by using a calliper. Petiole cross-section (*P*) is the product of petiole width x depth. The trunk height was measured from the ground level to the base of frond 33. The trunk diameter (*d*) was measured at about 1 m above-ground level after removing the old leaf bases using a large calliper.

The estimation of dry matter in vegetative growth was done following Fairhurst and Hardter (2003):

Dry weight of trunk

(i) Trunk dry weight (*T* kg).
$T = u \times S$ kg yr^{-1}
S is the trunk density *i.e.* the weight of dry matter per unit trunk volume which depends on palm age (*y*, in years).
$S = (0.0076y + 0.083)$ kg dm^{-3}

Volume increased (u dm^{-3}).
$u = \pi d^2 \times h/4 = $ dm^{-3}
d is the trunk diameter.
h is the trunk height increment *i.e.* the difference of trunk height (yearly).

Dry weight of leaves

(i) The mean leaf dry weight , *W* (kg)
$W = (0.102P + 0.206)$ kg
P is the petiole cross-section: $P = petiole\ width \times depth$

(ii) Total dry weight $= g \times W$ kg yr^{-1}
g is the total number of green leaves (fronds).

Total vegetative dry matter increment

(i) Vegetative dry matter increment (V kg palm^{-1} yr^{-1}).
$V = T + g \times W$ kg palm^{-1} yr^{-1}
T is the trunk dry weight.
g is the total number of green leaves (fronds).
W is the leaf dry weight.

Leaf area

(i) Relative leaf area (*rla*),
$rla = 2n \times b$
n is number of leaflets on one side of the rachis, and
b is the mean product of length x mid-width of the six leaflets.

$$b = \frac{(Length \times Mid - width)\ of\ 6\ leaflets}{6}$$

(ii) Total leaf area per palm (A m^3):
$A = rla \times g$ m^3

(iii) Total leaf area per hectare, *LA*:
$LA = A \times D$ palms ha^{-1}
D is the planting density (palms ha^{-1}).

(iv) LAI is the ratio of total leaf area to ground area.
$LAI = LA / 10\ 000$

Statistical Analysis

Data were analysed to determine significant trends between treatments. Comparisons were made using Tukey's test in conjunction with an analysis of variance (ANOVA) (post-hoc analysis) to find means that are significantly different from each other.

RESULTS AND DISCUSSION

Oil Palm Standing Biomass

The estimation of total dry weight of an oil palm stand in the field can be described by the term 'standing biomass'. Standing biomass, comprising of fronds and trunk was assessed using the non-destructive method developed for oil palm. The compaction treatments caused significant reduction in oil palm standing biomass. *Figure 1* shows that the oil palm above-ground total standing biomass comprising of fronds and trunk in the control plots at 341 kg palm^{-1} was significantly higher ($p \leq 0.05$) by about 12% compared to those of compacted plots which had a mean of 305 kg palm^{-1}. However there were no significant difference between the compaction treatments, as well as between the three transportation frequencies.

Oil Palm Trunk Parameters

The above-ground biomass accumulation occurs predominantly in the oil palm trunk. Therefore, the trunk measurements parameter including height and diameter is best used to determine the effect of compaction treatment on the palm growth.

Different trailer weights and wheeling frequencies did not manifest a significant influence on palm height (*Figure 2*) although the palms in 4T treatments plots were taller compared to other treatments. However, the impact of the compaction treatments could be seen on both, the diameter and dry weight of the oil palm trunk. Compared to control, the palms in compacted plots exhibited significantly ($p \leq 0.05$) smaller trunk diameter by about 9% (*Figure 3*) and hence, lower trunk dry weight by about 8% (*Figure 4*). There was no significant difference ($p \leq 0.05$) between the three transportation frequencies effects on both the trunk diameter and trunk dry weight.

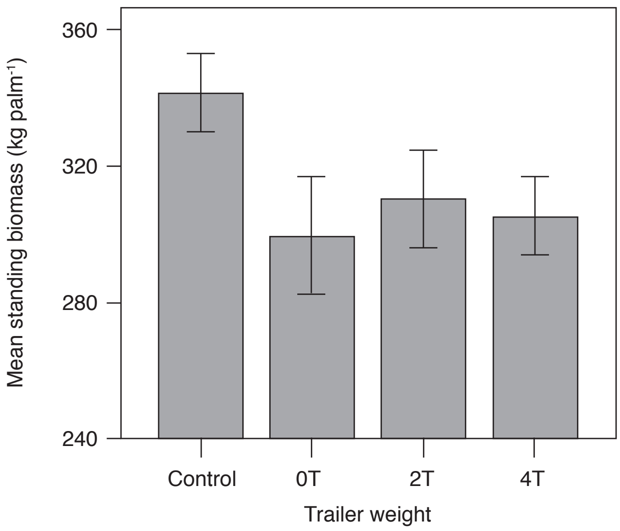

Figure 1. Effect of trailer weights on oil palm standing biomass.

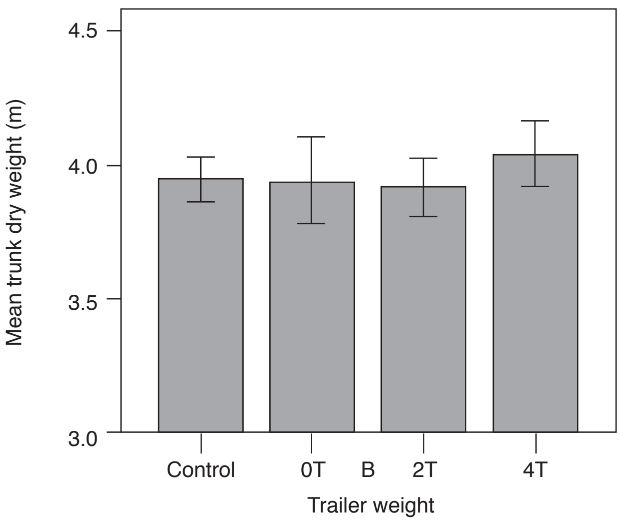

Figure 2. Effect of trailer weights on trunk height.

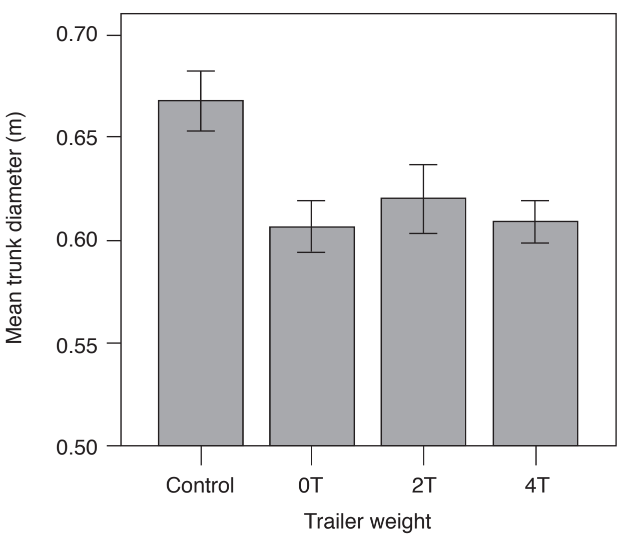

Figure 3. Effect of trailer weights on trunk diameter.

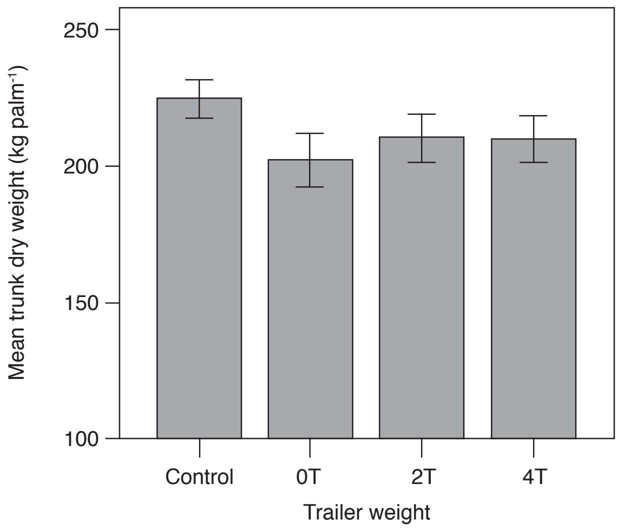

Figure 4. Effect of trailer weights on trunk dry weight.

Oil Palm Frond Vegetative Parameters

Palms in compacted plots show a significant reduction in the frond biomass by about 6% as compared to control (*Figure 5*). The successful growth of plants depends on maintenance of a balance in growth and function between roots and shoots. Lower frond biomass occurred probably in response to the lower root biomass produced in the compacted plots (Zuraidah *et al*., 2015b). There was no significant difference in frond dry weight ($p \leq 0.05$) in the compaction treatment plots with transportation frequency increment from 1R to 3R. The impact of trailer weights ($F=2.893$) was greater at $p \leq 0.05$ than the transportation frequency ($F=1.110$) in influencing the growth of oil palm fronds.

The total green frond number, total leaf area and leaf area index (*LAI*; the ratio between total leaf and

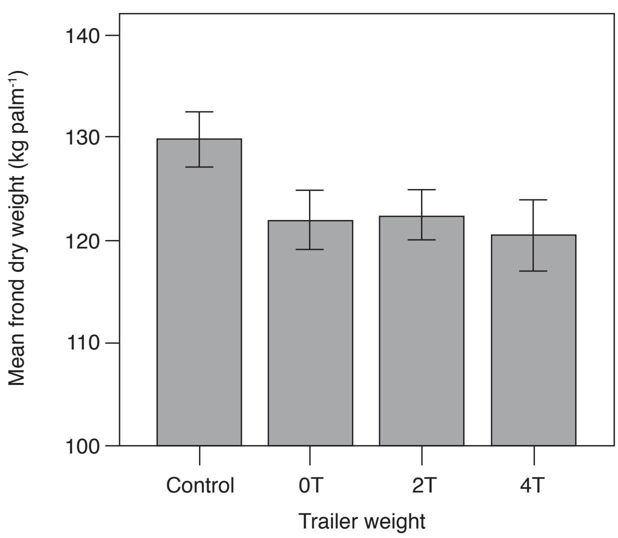

Figure 5. Effect of trailer weights on frond dry weight.

ground surface area) were not significantly different ($p \leq 0.05$) between the treatments. The total green fronds number was about 33 to 35 fronds per palm, which was slightly less than the recommended total of 35 to 40 fronds per palm (Ng *et al*., 2003). Furthermore, the compaction treatments did not affect the total leaf area per palm, varying from 340 to 360 m^2 $palm^{-1}$. Consequently, it was reflected in the *LAI* value obtained which was greater than 5. Nevertheless, the optimum *LAI* value for maximum oil palm yield is site-specific and dependent on several environmental factors such as sunshine, temperature, soil nutrient and moisture as well as planting material. The *LAI* values have been reported to vary between 5 and 7 (Helmut *et al*., 2003).

CONCLUSION

Compaction of coastal soils such as Bernam series caused significant reduction of oil palm standing biomass due to significant reduction in frond biomass, trunk diameter as well as trunk biomass. However, palm height, total green frond number, leaf area and *LAI* were not significantly influenced by the treatments.

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