eISBN 978-967-16145-1-8

Konvensyen Kebangsaan Kejuruteraan Pertanian Dan Makanan 2019
21 Mac 2019, Wisma Tani, Kementerian Pertanian Malaysia, Putrajaya

MSAE2019-AMA24

Soil Compaction Effects of Rubber -Wheel Tractors and Half -Track Tractors in Rice Cultivation

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Abstract

As the machinery being operated in the field, the damage to the soil is obvious, which common damages appears mainly to the top soil layer such as increase in soil compaction and may create the 'soft soil' spot. However, the magnitude and the level of the damaged soil layer is challenging to quantify over the spatial distribution of the area. The study is focusing on comparing the level of soil compaction between rubber-wheeled tractor (RWT) and half-track tractor (HTT) during tillage operation using a rotovator implement in rice production. The widely used of HTT feared to cause damage to the soil hardpan as compared to common RWT type. A field study was conducted at Tunjang, Wilayah II – Jitra, Kedah with total area of 3.4 ha. More than 4000 data set of the soil pressured was measured using the soil penetrologger throughout two main growing seasons; wet and dry. The statistical analysis using T-test across all stages and operations revealed no significant different between the RTT and HTT on the soil compaction at the top soil layer (0-20 cm). However, the overall pressure from HTT is slightly higher than RWT, but below than threshold values of 1.4 MPa, thus may not limiting the root growth of the rice plant.

Keywords: tillage, soil compaction, paddy, hardpan

Introduction

Intensive and fully mechanized application across the rice production timelines have been proven as an effective machinery toolset to conduct most critical operation such as land preparation, planting, crop care and harvesting. In one hand, utilization of proper machinery type and selection is important for cost effective and most efficient farming operation (Robert et al., 2005). On other hand, from agronomic point of view the utilization of heavy machinery and continuous application over the years may damage the soil structure (Angers and Caron, 1998; Horn and Smucker, 2005) by introducing the compaction layer or introduce a 'soft soil' spot or a pothole, thus may damage the machinery during the operation (Bill Cotching, 2009) or limit the crop growth. Although some farmers claim that the damage from HTT is more severe than RWT, the scale and the magnitude is not well documented. HTT may provide a better alternative since during typical operation it would produce higher field capacity than RWT (Mohd Shahabudin Ismail, 2011).

Soil penetration resistance is highly depending upon to the soil moisture content (Ayers and Perumpral, 1982; Henderson et al., 1988). In some cases, the soil penetration resistance would increase during the drought season in rice production (Samson et al., 2002). In contrast, the resistance will be less during wet season. However, the level of the soil compaction might be different due to different soil type and structure (Soil Compaction Handbook, 2011). To apply heavy machinery usage in rice field, hardpan layer force should exceed reading 0.3 Mpa (Mohd Nadzim Nordin et al., 2014). In addition, according to the Cairns et al. (2011), the soil penetration resistance of 1.4 MPa is sufficient to inhibit root system expansion for rice plant. However, the ability of soils to withstand compaction is related to soil properties such as soil moisture, texture, organic matter content and clay mineral type (Hamza and Anderson, 2005; Tekeste et al., 2008). Compaction influences soil strength, aeration and water flow, creating inter-related stresses which may act simultaneously to influence root growth and distribution (Chen et al, 2014).

This study was therefore undertaken in order to evaluate the impact of the soil pressure due to implementation of two type of tractors during tillage operation in rice cultivation. The results was expected to help the local authorities to provide a guideline of RWT and HTT operation to avoid more soil damage that might affect soft soil in long term.

Materials and Methods

Study Area

This study has been carried out at Wilayah II – Jitra, Kedah, at three different locations with a combined area of 3.4 ha (Table 1). Each site location was divided by two sub plots equally. One subplot designated for HTT and the other is for RWT tractor. The site coordinates, the tractor path and speed, the soil sampling locations and compaction measurement points were recorded manually and using the GPS unit (Trimble Juno 3b) with 3-5 m accuracy. All sites received water from the open canal irrigation system, gravity flow. The soil textures were classified as clay and silty clay soil.

Tillage Operation and Test Procedure

The field tests were carried out using two tractors with the similar specification, however, fitted with different types of running gear. The main technical specification of these tractors and their running gear are given in Table 2. The soil was previously tilled up to 0.40 m and second tillage up to 0.20 m depth using rotorvator implement on both tractors. The field tests were carried out on soil previously tilled to compare the effect of two types of tractors HTT and RWT. This land preparation involved two operations which were primary tillage (PT) and second tillage (ST). This data collection for land preparation held on 23 September 2016 until 19 October 2016. There were three locations observed and each location was divided by two plots for side-by-side comparison and operation. Data collection of the soil had collected before, after and during tillage operation. Data collection for the soil before tillage was collected as a control. After the tillage operation, the hardpan of the soil was measured from time to time and table in this paper.

Penetration resistance measurement

The penetration resistances of the soil were measured using digital penetrologger (Model: Eijkelkamp), with on 30° cone and base area 3.3 cm^3 driven into the soil at constant rate about 3 cm/s speed. The soil penetration resistance was measured in the tracks left by each tractor in operation PT, ST and before tillage (BT: before tillage, which had no traffic). For each plot, including the control area, 20 point for penetrometer reading with 3 replications for each point were taken in increments of 1 cm at depth of 0.0-0.40 m. As a result 4320 datasets were collected (3 locations x 2 subplots per location x 20 sampling points per subplot x 3 measurements per sampling points x 3 stages (before and after every tillage operation) x 2 seasons (wet and dry) x 2 different tractor). The measured dataset from the data logger then were transferred in the text file (ASCII format). Then the datasets were further analysed using the Microsoft Excel software for graphical comparison, descriptive statistics and statistical T-test at 95% confidence interval.

Results and Discussion

The mean values of soil resistance of BT, PT and ST were compared as shown in Figure 3. Soil compaction induced by agricultural practices is caused by external forces shearing and compressing the soil particles together to reduce porosity, increase strength and restrict root growth. Overall, the analysis of the T-test comparison across tillage practices and test plots shows that no significant difference of the soil compaction level between HTT and RWT (p-value = 0.0583, t-stat =1.8944, T-Critical = 2.57). If the hardpan of the soil at shallow depth, the machinery difficult to get into the field as it potentially stuck deep in the soil.

Overall, the hardpan layer was found to be in between 0.25-0.30 cm (Figure 4). The compaction pressure increases with the increase of the soil depths (0-0.9 MPa) as in Figure 4, regardless the tractor's operation stages. However, the pressure values were reduced after second tillage operations at both depths 0-10 and 10-20 cm of the soil profiles, and either with HTT or RWT operations. This is very important from an agronomic perspective as softer soil structure is needed to facilitate the root growth of the rice plant. The pressure measurement before tillage for both types of tractor is almost similar, thus shows that the site shared similar soil characteristics. Over the tillage operation, the resistances were reduced drastically, especially on RWT sites. In contrast, HTT introduced slightly high soil compaction to the soil after first and second tillage operations. The compaction level may not severe effect as at 1.4 MPa is the threshold value limiting the root growth (Cairns et al, 2011). HTT type may provide better solutions for problematic area where the traction is superior to the RWT and better farm efficiency. For long run effect it might build fake soil hardpan (hardpan at shallow depth) or soft soil.

Conclusions

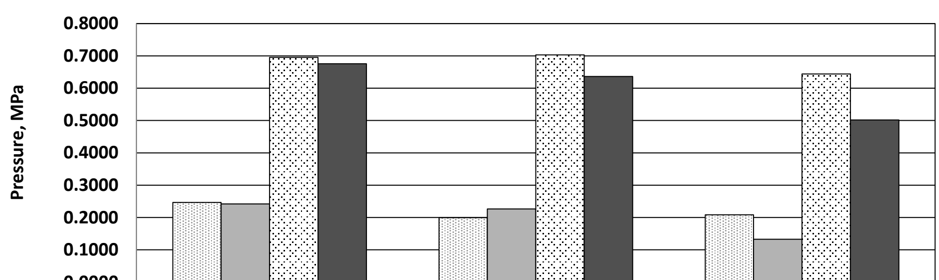
Overall, there is no significant difference on the level of soil pressure introduced by two different tractor types; HHT vs. RWT. However, HTT pressure reading was slightly higher than RWT. A long term monitoring for spatially distributed of the soil compaction is recommended since the compaction layer could be differ from one season to another due to different management practice, climatic condition, soil moisture content and irrigation schedule over the growing season.

Table 1: Site location information

Location	Coordinate	Area (ha)	Water Irrigation Type
1	N 6.3184 to N 6.3191 E 100.3616 to E 100.3639	1.1560	Open canal
2	N 6.2811 to N6.2816 E 100.3295 to E 100.3315	0.7836	Open canal
3	N 6.2729 to N 6.2732 E 100.3451 to E 100.3472	1.4881	Open canal

Table 2: Tractor specification.

Specification/Tractor type	Rubber-Wheeled Tractor	Half –Track Tractor
Brand	Massey Ferguson	
Model	Massey Ferguson 185	
Maximum engine power (HP / kW)	75 HP (55.9 kW)	
Engine RPM	1701	1143
Implement width, m	2.2	
PTO rpm	540 rpm	
Gear Selection	Low, 4	High, 1
Total weight	2510	4130
Total contact area pressure (kPa)	**272**	**111**



	Before Tillage	Primary Tillage	Second Tillage
HTT (0.00-0.10 m) Average	0.2467	0.1994	0.2083
RWT (0.00-0.10 m) Average	0.2422	0.2267	0.1328
HTT(0.10-0.20 m) Average	0.6950	0.7028	0.6439
RWT (0.10-0.20 m) Average	0.6756	0.6361	0.5017

Figure 3. Compare of mean value before tillage (BT), primary tillage (PT), second tillage (ST) for depth 0.0m -10m and 0.10-0.20m

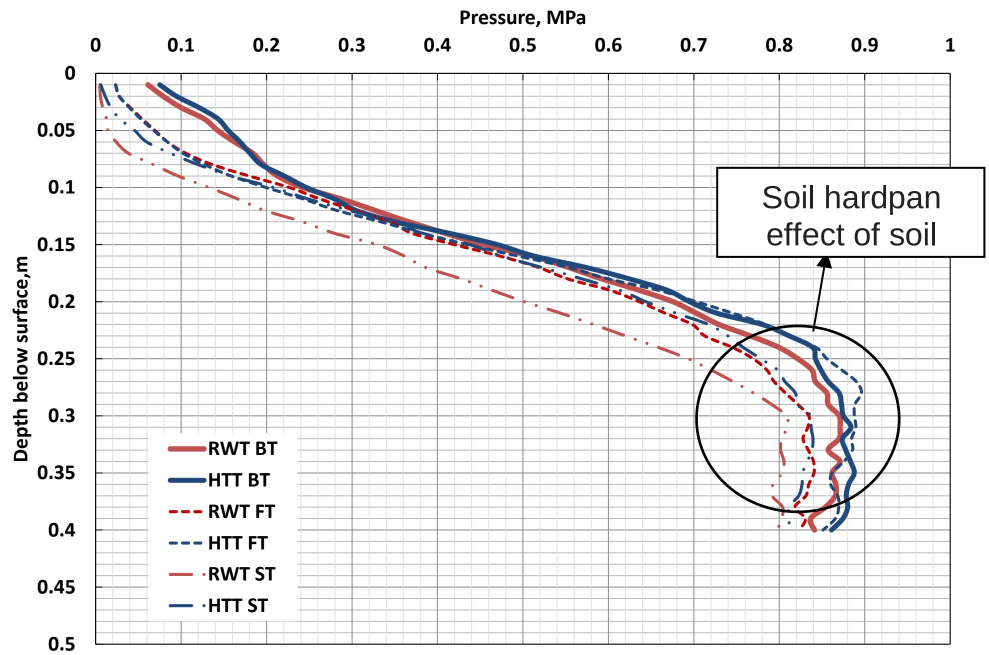


Figure 4. Compare of mean value RWT and HTT at operation before tillage (BT), first tillage (FT) and second tillage (ST) for depth 0-40cm. In the side-by-side comparison test, all three penetrometers were reasonably consistent.

Acknowledgements

The authors gratefully acknowledge the support and funding from Ministry of Higher Education through Fundamental Research Grant Scheme (FRGS) (Vote: 5540087), Muda Agricultural Development Authority (MADA) (Ref. #: MADA(C5)303105(43)), and the contributions and help from Mr. Ahmad Shukri Saad and his team from MADA, and Nurul Azimah Wagiman during data collection.

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