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Original Research Article

Performance of a Triangular Rubber Tracked Tractor in Paddy Fields

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Abstract: Tracked tractors have been commonly used on paddy fields to overcome soft soil problem. However, triangular-shaped rubber-tracked tractors with high clearance has not been properly tested. The objective of the research was to evaluate the performance of a triangular, rubber-tracked tractor used in paddy fields. This tractor was tested in typical paddy field conditions at MARDI Seberang Perai. The prime mover was attached with a rotary tiller. The performance tests include measuring the soil bearing capacity before and after machine disturbance, machine work rate per hectare and the effective field capacity. The fuel consumption was also recorded. Results showed that the tracked tractor obtained an effective field capacity of 0.576 hr/ha with average fuel consumption of 20 liters/ha. The lightweight tractor also contributed in producing less ground effects, combined with the use of low ground contact pressure tracks, that caused minimal soil disturbance that would affect the soil hardpan layer. The tractor had enough power to move in typical paddy field condition, with no soft soil problems. The tractor was able to turn 360 degrees within a small area, which made it suitable for working in paddy fields. This prime mover has potential to be used in paddy fields.

Keywords: triangular rubber tracked tractor; low ground contact pressure; machine performance; soft soil; paddy mechanization

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1. Introduction

Tractors have been used for land preparation in the Malaysian paddy production. Land preparation is fully mechanized, be it using 2-wheel or 4-wheel tractors. Omar *et al.* (2019) reported that there are 10,000 units of tractors used in Malaysian paddy production, with 30% of it are 4-wheel tractors. From this percentage, 83% is owned by private service providers while the remaining 17% is owned by government agencies.

Although mechanization has helped increase the productivity of paddy production, it has also been blamed to cause soft soil condition. Soft soil condition is defined as a condition with high compressibility and low strength, with a hardpan layer of less than 0.3 MPa at 30 cm soil depth (Kim, 2010; Nordin *et al.*, 2014; Rendana *et al.*, 2017). Soft soil condition is caused by the extensive use of heavy field machinery which damages the soil hardpan layer (Ahmad *et al.*, 2014; Ahmad *et al.*, 2015). The soil hardpan layer is required in paddy fields to support the weight of field machinery, other than to prevent water leakage (Hemmat & Taki, 2003).

Soil hardpan layer damage is claimed to be caused by the usage of high ground contact pressure pneumatic rubber tyres (Vial *et al.*, 2020). This type of tyres has small contact area to the ground surface, and when using tractors and combine harvesters with total mass of more than 5tons, hence creating big pressure to the soil surface (Taghavifar & Mardani, 2013).

An alternative to reduce this problem is to use tracks replacing rubber pneumatic tyres. Agricultural tracks provide better traction performance and mobility, and reduces soil compaction (Fukushima *et al.*, 2019; Zhao *et al.*, 2020). There are several options of agricultural track configurations that are available such as full tracks, half-tracks and 4 half-tracks or quad-tracks. From these configurations, there are two types of track material used, which are rubber tracks or steel tracks.

A different type of tracked tractor has been recently imported into Malaysia. This uniquely designed tractor is equipped with full tracks, except that the full tracks are triangular shaped. The oscillating crawler units is claimed to have better stability on uneven ground surface (Fukushima *et al.*, 2019). This type of machine has not yet been fully tested scientifically and technically in Malaysian paddy fields, hence requires a specific experiment.

The objective of this paper is to evaluate the machine performance in terms of machine performance, slippage and soil bearing capacity.

2. Materials and Methods

2.1 Machine Description

The tractor is a fully tracked tractor with a power rating of 60 kW (80 hp) at a rated engine speed of 2400 rpm. The tractor is powered by a direct-injection, vertical, water-cooled, four-stroke turbodiesel engine. The tractor is 3.7 m long and 1.65 m wide. The tractor is equipped with a rubber track system that is driven by a drive sprocket attached at the rear end of the chassis. The rubber track is triangular shaped with 6 rollers and two idlers. Weight ballast of 120 kg was attached to the front end of the tractor. The overall weight of the tractor is 2600 kg. A rotary tiller with was attached to the tractor. The working width of the implement was 203 cm (80 in rotary tiller). The tillage depth was measured manually using a steel ruler from the soil surface to the tillage disturbance area.

Table 1. Tractor specifications.

Item	Description
Brand	Wong
Model	NF802
Power Rating kW (Hp)	60 (80) at 2400 RPM Engine Speed
Power Take-Off (PTO) speed	720RPM at 1000 RPM Engine Speed
Engine type	direct-injection, vertical, water-cooled, four-stroke turbodiesel
Implement width, cm	203
Total weight, kg	2600
Overall length, m	3.69
Overall width, m	1.65
Fuel Tank Capacity, liters	75

Figure 1. The triangular rubber tracked tractor attached with a rotary tiller.

2.2 Experimental Setup

The experiment was conducted at MARDI Seberang Perai using a paddy field area of 10 ha consisting of sandy loam soil. The type of soil and tillage depth was recorded. The test plots had no events of soft soil problem. Machine workrate per hectare was measured using a stopwatch. The effective field capacity was measured using the time consumed for real work and lost for other activitiies such as turning,loading or unloading and adjustment depending on field have been used.

Effective field capacity (ha/hr),

$$S = \frac{A}{T_P} + T_1 \quad (1)$$

where

A=Area covered (ha)

T_p= Productive time (hr)

T_l=Non-productive time (hr)

The fuel consumption was measured by filling up full tank of the tractor before tillage work. After completing a number of hectares, amount of fuel used was measured by how much fuel is refilled into the tank. The amount of fuel used in liters, divided by the number of hectares covered, gives the fuel consumption in litre per hectares (l/ha).

Slippage, or wheel slip can be defined as the ratio between the actual travel speed of the vehicle and the theoretical travel speed of its wheel. The theoretical speed of the wheel was measured by measuring the distance of the wheel when rotating for a number of ten revolutions on tarmac. This value was then compared with the actual travel speed, by measuring the distance of the wheel after rotating ten revolutions on paddy soil.

Soil conditions were evaluated by the soil penetration or soil compaction. Readings of soil compaction were taken before and after the passage of the tractor, at the beginning, halfway, and at the end of the test area, with 3 replicates for each sampling area. Two types of soil compaction data were taken, which were soil compaction after passage of tractors' tracks and no disturbance which acted as the control data. The soil strength was measured up to 80 cm depth using a soil cone penetrometer (Penetrologger, Eijkelkamp, The Netherlands) with a base area of 323 mm^2 (ASABE, 2009). Tracks soil disturbance data was taken. No disturbance data was also taken as control. The machine sinkage was also measured. The results from the soil compaction were analyzed using ANOVA (SAS, 2015).

3. Results and Discussions

3.1. Machine Performance

Table 1 shows the results obtained from the experiment. The tillage depth was roughly 40cm using the full working width of the implement, 203 cm. The measured effective field capacity using this tractor was 0.576 hour/hectares, which is considered fast if compared to most rear half-tracked tractors that are commonly used. The use of a wide rotary tiller showed effectiveness of the tillage work. The fuel consumption is average, using 20 liters for one hectare of land. This is mainly caused by the machine operated by MARDI operators and the soil condition of the experimental plot. Better fuel consumption is expected, done by a skilled and experienced operator with better soil conditions, at a range of 10–15 liters per hectare in typical paddy field conditions.

Table 2. The summary results for machine performance.

Performance Evaluation	Results
Tillage depth (cm)	40
Working width (cm)	203
Effective field capacity (hr/ha)	0.576
Fuel consumption (l/ha)	20

3.2 Slippage

Slippage is important in assessing the tractive efficiency and optimal settings of a prime mover. Slippage is used as an indicator to determine the correct tractor weight ballast and operating speed, which can result in not only efficient performance, but also fuel efficient. The slippage of between 3–5% is targeted. It was observed that the slippage on farm roads is 4.25%. In paddy fields, without the implement, the slippage is still within the targeted range, 4.15%. However, when fixed on the rotary tiller, the slippage dropped to 2.39%. Although not within the targeted range, the quality of tillage is excellent. The operation was smooth and easy to handle by the operator. During operation, there were times when the front end of the tractor was tilted upwards. Although this does not affect the performance of the tillage, but it might cause visibility and handling problems to the operator. This can be solved by installing enough ballast when more draught force is required.

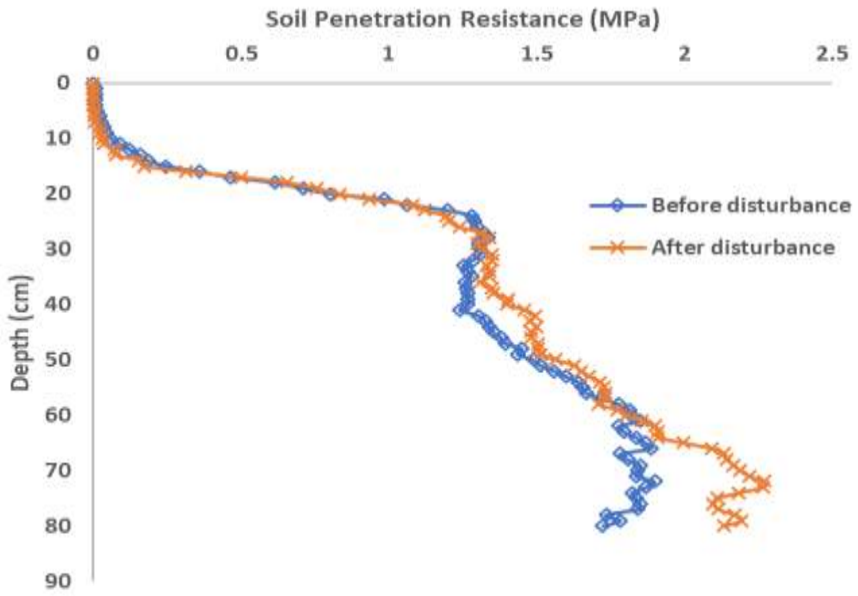
Table 3. The summary for slippage.

Condition	Slippage,% (Standard Deviation)
Farm Road	4.25 (1.5)
Paddy field (without rotary tiller)	2.39 (2.3)
Paddy field (with rotary tiller)	4.15 (2.5)

3.3 Soil Bearing Capacity

The soil effects after tractor disturbance was not significant (t = 0.30, p = 0.763). This showed that the low ground contact pressure of the tracked tractor has minimal effect on typical paddy fields. Although the working depth of the machine is 40 cm, the graph shows that there is no significant damage to the soil strength at 0–40 cm. This tractor will be useful for fields that are currently without any soft soil condition, as results here show no significant effects.

Figure 2. Soil penetration resistance of machine before and after disturbance.



4. Conclusions

The tracked tractor was tested in typical tillage conditions on paddy fields. The tracked tractor showed impressive results, obtaining an effective field capacity of 0.576 hr/ha with average fuel consumption of 20 liters/ha. Feedbacks from tractor operator were positive, although the tractor requires some training to operate, due to the use of tracks instead of wheels. Maneuverability of the tractor was excellent, able to turn 360 degrees within a small area, which makes it perfect for paddy field cultivation. The tractor had enough power to move in typical paddy field condition, with no soft soil problems. The low weight of the tractor also contributes in producing less ground effects, combining with the use of low ground contact pressure tracks. This prime mover has potential to be used in paddy fields.

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Conflicts of Interest: The authors declare no conflict of interest.

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