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Effect of Tire Lug Height, Forward Speed and Cast Iron Ballast on Tractor Performance

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ABSTRACT

The study was conducted at El Rahad Agricultural Scheme (Block 8) Sudan, during the period Feb.-May 1996 where the soil is a heavy cracking clay. The objective of the study was to improve the performance of the tractor when worn tires were used. The performance of the tractor، wheel slippage, fuel consumption and field capacity of the tractor were measured. Three levels of tire lug height were used, namely, 35 mm (new tire), 20 mm (medium worm tire) and zero mm (fully worn tire). Four levels of cast iron ballast were used, namely, zero, 63, 126 and 252 kg were distributed between rear tires. Moreover, three levels of tractor forward speed (5.6, 6.9 and 10.6 km/hr) were employed. The results indicated that there was a significant improvement in tractor performance when using worn tires through the use of cast iron ballast on the rear wheels. It was found that tires with zero mm lug height and 252 kg cast iron ballast decreased tractor wheel slippage and fuel consumption by %34and 18%, respectively, and increased tractor field capacity by 16.2% Moreover, when tires with 20 mm lug height and 252 kg cast iron ballast were used, the slippage and fuel consumption were decreased by 41.7% and 18.2%, respectively, and tractor field capacity was increased by 14.5%. The tractor with tires lug height of 35 mm and 252 kg cast iron ballast, decreased slippage and fuel consumption by 22% and 11.5%، respectively, and increased tractor field capacity by 13.5%.

INTRODUCTION

Field preparations are the most energy consuming of all other operations. This depends on many factors, such as soil type and condition, depth of tillage, speed of operations, tractor tires wear and hitch geometry. Hence, the reduction of energy loss in tillage operations depends upon proper matching of the tractor and implement. Tire failure consumes fuel and causes loss of working time Proper selection of tire load, inflation pressure and working speed raises the tractor productivity. Fortunately, these parameters can be controlled through proper management and field adjustment. Most tires used in Sudan are imported، and hence the prices of new tires are high. Under such conditions machinery owners tend to use second-hand tires.

The total engine power available for conversion into useful pull is generally in excess of the tractive capacity that can be developed between the traction device and the soil. The annual fuel losses due to inefficiency of pneumatic tires and improper transmission, amount to millions of dollars (Gill and Vanden Berg, 1968). Soil-pneumatic tire interaction continues to be an inefficient process. A conservative estimate of annual fuel loss in the U.S. due to poor tractive efficiency of farm power units is 575million liters (Wulfsohn, 1987).

Some of the most common parameters which may influence pneumatic tire performance are lug height, lug spacing, lug angle, tread width, tread curvature, and lug shape (Taylor, 1974). Watyothea and Salokhe (2001) reported that power of the modified wheels reached a peak at about 30-40% wheel slip depending on the circumferential angle and lug spacing. The average wheel slip at the peak tractive efficiency was about 34% for all circumferential angles and lug spacing. Studies conducted by Reed and Shields (1950) indicated that lower lug height improved tractive efficiency, and that smooth tires (fully worn tires) were more efficient than lugged tires but they developed lover maximum pull.

Gee-Clough *et al* (1977) found that under British field conditions the coefficient of net traction was lower and tractive efficiency higher for smooth tires at 20% slip than for lugged tires. They found that the coefficient of rolling resistance increased with the increase in lug height Taylor (1974) reported that in six soils tested, tires with treads performed better than smooth ones. Upadhyaya *et al*. (1989) developed traction prediction equations for radial ply tires using both traction mechanics and dimensional analysis techniques as a guide. They found that in addition to tire geometry, loading, and soil parameters, soil-tire contact length and contact area were important parameters, which influence the tractive ability of pneumatic tires.

Vasey and Naylor (1959) found that smooth tires did not develop sufficient pull in a stubble-covered clay soil, and that in plowed soil regular lug pattern was superior to an irregular pattern, and that slightly curved lugs were superior to straight lugs. Liljedahl *et al*. (1979) indicated that when traction conditions were good, the largest improvement in tractor performance could be made by simply adding more weights to the tractor drive wheels.

Gloker (1984) reported that the usual average values of slippage coefficient for different soils were 5 to 10% for concrete, 10 to 20% for agricultural soils, and 25 to 30% for sandy vary widely conditions, such as soil uzzé2zecuaCent. Barger *et al*. (1967) and Domler and Willon (1978) reported that several factors lower the tractive efficiency, among which are steering, rolling resistance, slip, friction and deflection of the traction device, load to power ratio and speed of travel. This study was focused on evaluating the effects of ballasting, forward speed and tire lug height on tractor performance.

MATERIALS AND METHODS

The experiments were carried out at El Rahad Agricultural Scheme Block 8), Sudan, during the period between February-May 1996, where the soil is heavy cracking clay. The performance of a 2WD (two-wheel drive) tractor was evaluated with respect to slippage, fuel consumption and field capacity. Treatment were tire lug height, rear wheel cast iron ballast and forward speed. Three levels of tire lug height (zero, 20 and 35 mm), four levels of rear wheel cast iron ballast (zero, 63, 126 and 252 kg) and three levels of forward speed (5.6, 6.9

and10.6 km/h) were used. A medium-sized tractor (Fiat 66-80) was used for all experiments. A trailed offset disc harrow consisting of 24-disc blades each 63.5-cm in diameter used in these experiments. The disc harrow was adjusted to maintain a constant depth of 14 cm. To determine fuel consumption, a separate graduated tank was used on the tractor. The tank was provided with a two -pipe line, one of these pipes directed the fuel to the injection pump and the other was used to return back the excess fuel that came from the atomizers to the tank. The fuel consumed was calculated directly by subtracting the quantity of fuel in the tank before operation from the quantity left after the operation. Tractor rear wheel slippage could be calculated as the percentage loss of forward speed of the tractor, or the percentage loss of tractor wheel revolution without load compared with wheel revolution with load. The formula used for calculating slippage was as follows:

Slippage=100 (Velocity without load-Velocity with load)/velocity without load. Experimental plots of 0.5 feddan (l feddan = 0.42 ha) were used to calculate the tractor field capacity (feddan/hour). The formula used to calculate the tractor field capacity was as follows:
Tractor field capacity = (Total experimental area (ha)/total operating time (hr).

Other factors which were kept constant in all the experiments were engine r.p.m. which was kept at 2200, soil moisture content at 17% - %19 and tire inflation pressure at 2.1 kg/cm^2. Radial-ply tires with 8 plies were used. The completely randomized design with 4 replications was used.

RESULTS AND DISCUSSION

The effects of tire lug height on tractor wheel slippage, fuel consumption and field capacity are shown in Table 1. The results indicated significant differences between treatments (P=0.5). A high percentage of slippage was obtained when the tire lug height approached zero cm, and the lowest percentage of slippage occurred when the tire lug height was 20 cm. Furthermore, the results showed significant differences in engine fuel consumption when using different tractor tire lug heights. When using tires with zero-cm lug height (smooth) the tractor consumed the highest . amount of fuel (0.6I gal/fed.), while it consumed the lowest amount (0.48 gal/fed) when using tires with 20-cm lug height. The large quantity of fuel consumed when using smooth tires was mainly due to the high values of tractor slippage. These results partially agreed with those of Raghaven *et al*. (1976) and Kepner *et al*. (1972).

Table l. Effect of tire lug height on tractor performance.

	Tractor performance		
Tire lug height (cm)	Slippage (%)	Fuel consumption (gal/fed)	Field capacity (fed/hr)
35	29.40	0.57	2.82
20	19.48	0.48	3.07
00	33.54	0.61	2.63

Moreover, the tractor tire lug height significantly affected the tractor field capacity. In such a way that the highest field capacity (3.07 fed/hr) occurred when the tractor tire lug height was 20 cm, and that the lowest (2.63)fed/hr) was obtained when the tractor tire lug height approached zero. The main reason for these results is the tractor wheel slippage, since as slippage increases field capacity decreases.

The effects of tractor forward speed on tractor performance (tractor wheel slippage, fuel consumption and field capacity) are shown in Table 2. The results showed significant differences in tractor performance when using different levels of forward speed. The percentage of wheel slippage increased as tractor forward speed increased. At a speed of 10.6 .km/hr، tractor wheel slippage was 30.01% and the least percentage of slippage (24.47%) was found when the tractor forward speed was 5.6 km/hr. These results are in line with the findings of Domler and Willon (1978) who indicated that the load to power ratio, and speed of travel are the main factors affecting maximum tractive efficiency. The study indicated that as the tractor forward speed increased, the engine fuel consumption increased, due to increasing rate of wheel slippage. At 10.6 km/hr tractor forward speed, the engine consumed 0.59 gal/fed of fuel, and at the speed of 5.6 km/hr it consumed 0.53 gal/fed. Also, tractor field capacity was directly affected by the forward speed. It was observed that field capacity increased with increasing rate of tractor forward speed, and it was 3.63 fed/hr when the tractor speed was 10.6 km/hr.

Table 2. Effect of tractor forward speed on tractor performance.

	Tractor performance		
Forward speed (km/kr)	Slippage (%)	Fuel consumption (gal/fed)	Field capacity (fed/hr)
5.6	24.47	0.53	2.31
6.9	27.18	0.55	2.59
10.6	31.01	0.59	3.63

The effects of rear-wheel ballasting cast iron on tractor wheel slippage are shown in Table 3. The results showed significant differences in slippage when using different levels of cast iron ballast. The lowest tractor wheel slippage (22.92 %) occurred when cast iron ballast of 252 kg was used, while the highest slippage value (33.76 %) was obtained when no cast iron ballast was used. The reduced slippage can be attributed to the improved traction due to using cast iron ballast. Also, it is quite evident from Table 3 that the increased cast iron ballast progressively decreased tractor slippage and fuel consumption, and increased tractor field capacity. These findings agreed with those of Barger *et al*. (1967) who reported that the maximum tractive efficiency of the tractor occurred when the driving wheels slip between 10 and 15%.

Table 3. Effect of tractor cast iron ballast on tractor performance.

	Tractor performance		
Cast iron ballast (kg)	Slippage (%)	Fuel consumption (gal/fed)	Field capacity (fed/hr)
0	33.76	0.61	2.61
63	28.90	0.57	2.77
126	24.62	0.53	2.93
252	22.92	0.51	3.06

The combined effects of cast iron ballast and tire lug height on tractor performance are shown in Table 4. The results indicated that cast iron ballast had a significant effect on tractor performance. The tires with zero lug height and 252kg cast iron ballast decreased slippage and fuel consumption by 34% and 21 8%, respectively and increased field capacity by 16.2%. Moreover, when the tractor was operated with 20-cm tire lug height wheels and 252kg cast iron ballast slippage and fuel consumption were decreased by 41.7% and 18.2%, respectively and field capacity was increased by 14.5%. Furthermore, when the tractor was operated with 35-mm tire lug height and 252kg cast iron ballast, slippage and fuel consumption were reduced by 22% and 11.5%, respectively, and field capacity was increased by 13.5%. Therefore, the tractor with 35mm tire lug height was found to develop lesser performance, and this could be due mainly to the longer lug height, which impeded motion and consequently increased slippage. It was clear that as dead loads (i.e ballast) were increased on the tractor rear wheels, traction between tires and soil increased, and therefore tractor performance was improved.

Table 4. Combined effects of cast iron ballast and tractor tire lug height on tractor performance.

	Tire lug height (mm)								
	35			20			Zero		
Cost Iron Ballast(kg)	Slip (%)	Fuel Cons. (gal/fed)	Field capa. (fed/hr)	Slip. (%)	Fuel Cons. (gal/fed)	Field capa (fed/hr)	Slip (%)	Fuel cons. (gal/fed)	Field capa. (fed/hr)
0	33.60	0.61	2.63	26.86	0.55	2.82	40.81	0.67	2.38
63	30.66	0.58	2.79	19.92	0.49	2.97	36.13	0.63	2.55
126	28.10	0.56	2.84	15.49	0.45	3.20	20.28	0.58	2.75
252	26.19	0.54	3.04	15.66	0.45	3.30	26.92	0.55	2.84

In conclusion, the tractor with tire lug height of 20mm produced good traction between tires and soil, therefore increasing tractor performance. Tires with 35mm lug height (new tire) developed lesser tractor performance compared to those with 20mm lug height, due to the longer lugs, which increased the slippage. Addition of different levels of cast iron ballast on the rear wheels of the tractor improved performance, and therefore smooth tires (zero cm lug height) could be effectively used. Generally, attaching cast iron ballast on rear wheels at different levels of tire lug height increased the performance of the tractor by increasing tractor field capacity and reducing fuel consumption.

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