Effect of Forward Speed and Soil Type in Massey Ferguson Tractor (Model 290) Performance

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Abstract

This study was conducted by the faculty of Agriculture - University of Nile Valley during winter 2018/2019 to study the effect of three tractor forward speeds (5,7 and 9 km/h) on the performance parameters of the tractor (the draft force, wheel slippage, fuel consumption, field capacity and field efficiency). Tractor performance test was carried out when linked to three implements, which are disc plow, a disc harrow and ridger. The study was carried out on two different locations, location one has a sandy clay soil while location two has a clay texture. The results showed that the draft force, wheel slippage, effective field capacity and fuel consumption increased with an increase in speed. The disc plow with speed (9 km/hr) recorded the highest values of draft force and wheel slippage, while the ridger recorded the lowest values of these parameters for the same speed, except for effective field capacity. The ridger with speed (9km/hr) recorded the highest values of effective field capacity, while the disc plow recorded the lowest values of this parameter for the same speed. The Three implements with speed three (9 km/hr) recorded different values of fuel consumption. The statistical analysis showed that, the effect of forward speed was significant at a 1% level, while the effect of the implementing type showed no significant differences. The experiment was arranged in a completely randomized block design with three replicates.

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Introduction

Agricultural tractors and equipment play an important role in increasing production through timeliness of agricultural operations and increased cropping intensity. In developing countries, the number of tractors and modern agricultural machinery was well increased; there is also a growing awareness among the developing nations for the role of agricultural mechanization in increasing agricultural productivity and improving rural life. (Roozbeh, and Khani, 2020).

Farmers can save significant money and energy if they use field operation plans that provide adequate crop care with minimum fuel consumption. Effective application of research and development in agricultural machinery can only be realized from Commercial production, i.e., there should be transition from technically viable.

Commercial production, i.e., there should be transition from technically viable innovations to commercially successful ventures (Askari, and Khalifahamzehghasem, 2013; Jokiniemi, *et al.*, 2012). Moldboard, disc, chisel, rotary "and subsoiled Plows are used as main implements for primary tillage operation. Therefore, an agricultural tractor with implements has a significant role in the agricultural sector (Gatea, 2013).

Draft force, energy and fuel requirements for agricultural implements have been recognized as essential when attempting to correctly match on agricultural implement and tractor. The need for tillage implement is one of the factors, which determine the size of use–age tractor and determine quantity of usage of energy in an operation (Jalel *et al*., 2021). Proper selection and matching of agricultural machinery can reduce the quantity of energy required for each implement. Other factors are the machine performance and the time needed for the machine to accomplish operation. Therefore, it is important to select the machine or machines to carry out the specific operation with minimum cost of energy and in the required (Kudabo and Gabdamosi, 2012).

The tillage processes areas considered one of the most important processes in agriculture, as it gives suitable conditions for root growth, which in turn supports the growth of plants, as it reduces soil resistance, increases the ventilation process and eliminates weeds (Gatea, 2013).

Conservation tillage plays an important role in reducing production costs, reducing runoff, increasing soil organic matter "and water infiltration rate. Disc plow play a prominent role in tillage and under certain conditions, they are reported to be advantageous over +other implements used for the same purpose, as they roll into the soil instead of sliding (Abdallah *et al.*, 2014). Disc Plow can be used in adverse soil condition and because of rolling action, their unit draft is low if under adverse soil conditions. Disc Plow as primary tillage implements is used for the initial major soil working operations (Adewoyin and Ajav, 2013).

Different speeds affected the soil aggregation as higher percentage of small soil aggregates were obtained at lower forward speeds than higher forward speeds (Karimiinchebron *et al*., 2012). Keeping in view the need to evaluate the existing tillage tools and the importance of disc plow as initial soil working operations implement, it was decided to study the effects of forward speed on the performance of the disc plow (Musa *et al.,* 2012).

Slippage is defined as the relative reduction in movement in the direction of travel at mutual contact surface of a traction or transport device and the surface, which supports it. Slippage can also be considered as a reduction in actual vehicle travel speed when compared to the theoretical speed that should be attained from the speed of the tire or track surface (Leghari *et al.,* 2016; El-mowla, *el al.,* 2019).

There are many factors affecting slippage such as, draft, load, speed, soil condition"and type, wheel slippage increases with increasing the load (Moeinfar *el al.,* 2014). The slippage is decreasing with increasing speed, also slippage increasing with increasing draft and moisture content (Rashidi *el al.,* 2013).

Fuel is the source of energy for every farm-mechanized operation. It plays a major role in every tractor’s life. Fuel Consumption rates increase linearly with time and area covered for each tillage operations plowing, harrowing and ridging). The application of appropriate tillage pattern during tillage operation reduces fuel consumption and tilling time (Jokiniemi. *et al*., 2012.).

Soil moisture content texture, bulk density, and shear strength contribute to energy requirements during tillage operations. Also, some parameters in tillage operation affecting fuel consumption of tractors were type and structure of soil, climate, tractor type, tractor size, and tractor-implement relationship. Similarly, in the literature, factors that fundamentally affect fuel consumption by tillage equipment use is the increment in power used by increasing the speed, width of cut, soil strength, moisture content"and the depth of cut (Namdari *et.al.,* 2011). However, the depth and forward speed have more influence on tractor's fuel Consumption. The objectives of the study were to (i) determine the tractor rear wheel slippage when using three different tillage implements which are disc plow, disc harrow and ridger with different speeds, (ii) to determine the tractor efficiencies for different speeds and (iii) to measure the fuel consumption for different speeds

Materials and Methods

The experiment was carried out at two locations during the winter seasons of 2018 and 2019. At food security Project (5 km north of Atbara – River Nile state - Sudan) and at of the Atbara River Project (10 km southeast Atbara – River Nile state - Sudan). Both projects at latitude 17.71799 -N and longitude 34.0024 -E, and were cultivated in the previous season by fodder sorghum. Soil samples from the two locations were taken from depth 0-15, 30 - 15 cm by an auger. The moisture contents calculated on a dry weight basis were changed from 20 to 22%. The average of moisture content was 21%.The soil of the experiment in the first location (food security Project - atbra) is generally sandy clay soil and in the second location (Atbara River Project) is generally clay soil. Some physical and chemical characteristics of the soil in the two locations are shown in Tables 1 and Fig 1.

Massey Ferguson Tractor (80hp) model 290 for general purpose (Tables 3) was used in the experiment as a power source for drafting tillage implements, Disc plough, Offset disc harro and ridger implements (Tables 2and Fig 2) Measuring cylinder of a (1000 ml) was used for refilling the tractor fuel tank, to determine fuel consumption rate during each treatment (MASSEY FERGUSON, 2006).

A completely randomized block design with three replicates was applied. Three implements (Disc plow, Offset disc and Rieger), Three plowing speeds (5, 7 and 9 km/h). The wheel slippage was measured at all treatments.

Measurement Measurement of Wheel Slippage (Travel Reduction %)

The travel reduction (Slippage) of the tested Tractor was determined by marking the wheel at a portion tangent to the ground surface. Then distance travel in 10 revolutions with load and without load was marked and measured. (Kudabo and Gabdamosi, 2012). The travel reduction was calculated using the formula (1):

$$\text{Slippage\%} = 1 - \frac{\text{actual distance traveled (without loaded) (m)}}{\text{theoretical distance traveled (with load) (m)}} \quad ...1$$

Machine Draft and Drawbar Power Requirements (kW)

Draft requirement of the plow was measured with a hydraulic dynamometer was attached to a horizontal chain between two tractors to measure the draft. Two wheel drive tractor (Massy Ferguson model 290), of 80 hp was used as a rear (towed) on which the implement was mounted ؛ whereas the front tractor (Massy Ferguson (4x4), 120 hp was used to pull the towed tractor with the attached implement through the strain gauge dynamometer. The towed tractor was working on the neutral gear but the implementation in the operating position; Dynamometer readings were averaged over a distance of 200 to 300 meters (two runs across the field). On the same field, the implementation was lifted from the soil and the rear tractor was pulled to record and save the idle draft. The difference between the two measurements was the net drawbar power for the implement under study conditions. (Ranjbarian *et al.,* 2017). The power could be estimated according to the following formula (2):

$$\text{Drawbar power (kW)} = \frac{\text{Draft (kN)x plowing Speed } \left(\frac{\text{km}}{\text{hr}}\right)}{3.6} \quad ....2$$

Fuel Consumption Measurement (L/hr)

The fuel tank of the MF-290 tractor was filled up to its top level before field testing. After field testing, the tractor engine was stopped and the fuel tank was refilled up to the same level as the graduate cylinder to determine the quantity of diesel fuel needed to refill the tractor tank up to the same level. (Dahab *et al.*, 2021), Fuel consumption per hectare in each plot was calculated by the method described and calculated as follows formulas (3) and (4).

$$\text{The fuel consumption rate } \left(\frac{\text{L}}{\text{hr}}\right) = \frac{\left(\text{Reading cylinder } \frac{\text{ml}}{1000}\right)}{\text{Area of plot } \frac{\text{m2}}{4200}} \ldots \quad (3)$$

$$\text{The fuel consumption rate } \left(\frac{\text{L}}{\text{hr}}\right) = \frac{\left(\text{Reading cylinder } \frac{\text{ml}}{1000}\right)}{\text{time requried to cover plot (hr)}} \ldots (4)$$

Measurement of Field Capacity (ha/hr)

a) Field capacity includes the following; Actual field capacity Is defined as the actual rate of coverage by the machine based upon the total field time, expressed as ha/hr. Actual Field capacity in ha/hr was calculated as following a formula (5):

$$\text{Actual Field capacity } \left(\frac{\text{ha}}{\text{hr}}\right) = \frac{\text{Area covered (ha)}}{\text{Time taken (hr)}} \ldots \ (5)$$

b) Theoretical field capacity (Kepner, 1982): Theoretical Field capacity in ha/hr was calculated as follows:

$$\text{Theoretical Field capacity}\left(\frac{\text{ha}}{\text{hr}}\right) = \frac{\text{working width (m)} * \text{Speed } \left(\frac{\text{km}}{\text{hr}}\right) * \ 1000 \text{ (m)}}{4200 \text{ (m2)}} \ (6)$$

Measurement of Field Efficiency

Field efficiency is defined as the rate of actual field capacity to the theoretical field capacity expressed as percentage. Field efficiency was calculated as a follows formula (7):

$$\text{Field efficiency \%} = \frac{\text{Actual Field Capacity}}{\text{Theoretical Field Capacity}} \ x\ 100 \quad \ldots (7)$$

Table 1. Some physio-chemical characteristics of the soil

Soil type	Depths cm	EcE	Caco	CoMg	Na	pH	Sand	Silt	Clay	Textural class
Soil 1	0-15	0.397	7.53	3.03	0.13	6.7	0.1	0.67	1.003	Silty clay
	15-30	0.97	7.5	3.13	0.1	6.7	0.1	1	1.004	
Soil 2	0-15	0.6	8.9	9	2.5	8.57	9	26	60	clay
	15-30	3.5	9.3	8	6.2	8.2	38	16	41	

Soil 1: Food security - Atbara project
Soil 2: Atbara river project

Figure 1. Test location, Food security - Atbara project

Table 2. Some specifications of implements

Specifications	Disc plow	Offset disc harrow	Rider
Mark	Super - AF	GIAD	GIAD
Make	Brazil	GIAD	GIAD
Width of cut	97cm	150cm	210cm
Number of units	3	2x7	4
Hitching	3point linkage	3- point linkage	3point linkage
Tractor power requirement	50 kw	50 kw	50 kw

Figure 2. Disc plow and Rider implements

Table 3. Technical specifications of the tractor

name	Massey Ferguson
Model number of cylinder	8480 Dyna VT, 6
Engine cubic capacity	8.4 L
Normal engine power at 2000 rpm	213 kW
Maximum engine power at 2200 rpm	231 kW
Maximum engine torque	1280 Nm
Idle speed	800 rpm
Maximum engine speed rate at no load	2250 rpm
Cooling system	Water-cooled
Rear tire and inflation pressure	Michelin 650/85 R 38 and 1.2 bar
Front tire and inflation pressure	Michelin 600/70 R 28 and 1.4 bar
Weight with full tank	8500–9200 Kg
Length and width	5.068 M, 2.550 M
Height at roof	3.197 M
Maximum and minimum clearance from axel	0.335 M, 0.477 M

Source: Massey Ferguson (2006)

Results and Discussions

Effect of Forward Speeds, Draft force (KN)

Table 4 and Figure 3 show that the average draft force of the different implements (disc plow, disc harro and ridger) in soil 1 (Sandy clay) the food security Atbara Project) and soil 2 (clay soil - Atbara river Project) with a used tractor (80 hp).

The result illustrates that, the average draft of the disc plow in soil 1 was 11.4 kN, while in soil 2 was 11.9 kN as shown in (Table 4) The average draft of disc harrow in soil 1 was 10.9, but in soil 2, 11.1 kN (Table 4). The mean draft of ridger in soil 1 was 9.98 kN, while in soil 2 was 10.16 kN.

Table 4. Effect of different forward speeds and soil on Implement draft force (kN) at the different soils

Implements	Soil 1				Soil 2			
	Sp1	Sp2	Sp3	Mean	Sp1	Sp2	Sp3	Mean
Disc plow	10.3	11.6	12.3	11.4 a	11.3	12	12.5	11.9
Disc harrow	10.3	11.3	10.5	10.9 a	10.3	12	11	11.1 a
Ridger	9.8	9.76	10.4	9.98	9.8	10.2	10.5	10.16a

Means with the same letters are not significantly different
Soil 1: Food security Project.
Soil 2 :Atbara River Project.
Sp1 :Speed one (5 km/hr).
Sp2: Speed two (7 km/hr).
Sp3: Speed three (9 km/hr).

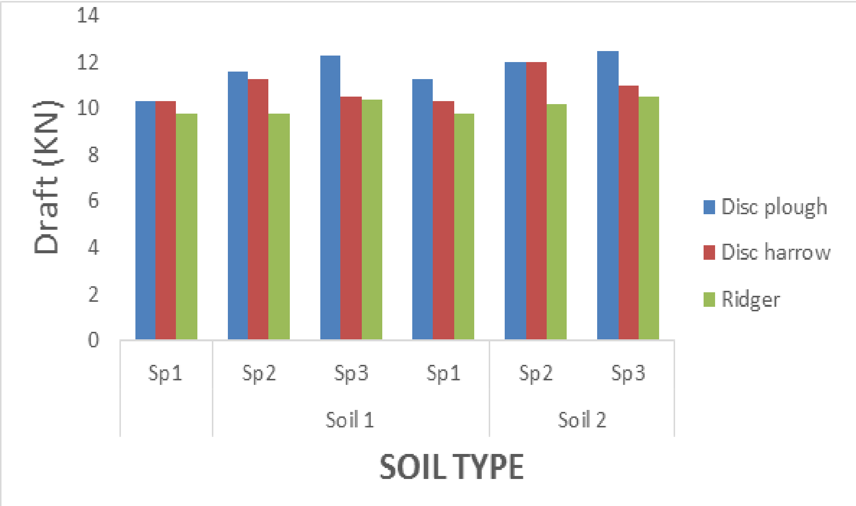

Figure 3. Effect of different forward speeds and soil on implementing draft force (KN) at the different soils

Effect of Forward Speeds and Two Different Soils on Wheel Slippage (%)

Table 5 presented the values of rear wheel slippage for different implements (disc plow, disc harrow and ridger) in soil 1 and soil 2 when using tractor power of 80 hp. The result illustrated that the mean values of slippage of disc plow in soil 1 was 11.56%, while in soil 2 was 11.9%. (Table 5). The average value of slippage of disc harrow in soil 1 was 9.93, while in soil 2 was 11.13. The mean value of slippage of ridger in soil 1 was 10.8while in soil 2 was 11.06 (Table 5).

It was clear that, the disc plow recorded significant difference in average wheel slippage of the three implements in both soil 2 and soil 1. The ridger recorded the lowest values of slippage. This may be due to the higher draft forces exerted by the weight of the implement. These results in agreement with (Gatea, 2013).

The forward speed three (Sp3) recorded the highest average slippage followed by speed two (Sp2) and speed one (SP1) in both soil 2 and soil 1 except the ridger in soil 2 Figure 3. This result confirmed the findings (Gatea, 2013).

Table 5. Effect of different forward speeds and two different soils on wheel slippage as a percentage (%)

Implements	Soil 1				Soil 2			
	Sp1	Sp2	Sp3	Mean	Sp1	Sp2	Sp3	Mean
Disc plow	10.2	11	13.5	11.56 a	10.2	12.5	13	11.9 a
Disc harrow	10.4	10.8	11.2	9.93 a	10.1	11.8	11.5	11.13 a
Ridger	9.3	10	10.5	10.8	10.4	11	11.8	11.06 a

Means with the same letters are not significantly different.
Soil 1: Food security Project.
Soil 2 :Atbara River Project.
Sp1 :Speed one (5 km/hr).
Sp2: Speed two (7 km/hr).
Sp3: Speed three (9 km/hr).

Effect of Forward Speed and Tractors Power on Effective Field Capacity (ha/hr) at Two Different Soils

Table 6 presented that the values of effective field capacity of different implements (disc plow, disc harrow"and ridger) in soil 2 and soil 1. The result showed that, the mean values of effective field capacity of disc plough in soil 1 was 0.45 ha/hr. and ha/hr. while in soil 2 it was 0.4 ha/hr The average values of effective field capacity of disc harrow in Soil 2was 0.78 ha/hr, while in soil 1 it was 0.85 ha/hr.

The average values of effective field capacity of ridger showed that in soil 1 it was 1.2 ha/hr, while in soil 2 it was 1.23 ha/hr. (Table 8).

It was clear that the ridger implement resulted in the highest average effective field capacity in both soils, followed by disc harrow and disc plow. These results may be attributed to utilize its full width of the machine and time according to lost time is the most difficult variable to evaluate in relation to field capacity (Moeinfar *et al.*, 2014).

Effect of Forward Speeds and Soils Types on Fuel Consumption (l/hr.)

Table 7 and Figure 4 showed the average fuel consumption (L/hr) of the implements (disc plow, disc harrow"and ridger) in soil 1and soil 2 The results showed that, the mean values of fuel consumption (l/hr) of disc plough in soil 2 was 3.95 l/hr while in soil 1 was 3.45 l/hr. The average of fuel consumption value of disc harrow in soil 2 was 7.19 l/hr, while in soil 1 was 7.64 l/hr (Table 7). The mean valueof fuel consumption of ridger in soil 1 was 7.86 l/hr, while in soil 2 was 8.18 l/hr.

It can be observed that the ridger was resulted in the highest mean values of fuel consumption in both soil 2 and soil 1 (Table 7). This may be due to accelerated engine speed. The disc harrow, required more fuel per hour due to accelerated engine speed.

It can be observed that, speed three Sp3 recorded the highest values of fuel consumption followed by speed two (Sp2) and speed one (Sp1) in both soil types Table7 and Figure 6 This is an agreement, an increase in speed was accompanied by an increase in fuel consumption (Ranjbarian *et al.*, 2017).

Table 6. Effect of different forward speeds and two different soils on Effective field capacity (ha/hr)

Implements	Soil 1				Soil 2			
	Sp1	Sp2	Sp3	Mean	Sp1	Sp2	Sp3	Mean
Disc plough	0.54	0.45	0.37	0.45 a	0.44	0.39	0.37	0.4 a
Disc harrow	0.77	0.86	0.81	0.85a	0.81	0.76	0.79	0.78a
Ridger	1.2	1.2	1,2	1.2 a	1.2	1.4	1,1	1.23a

Means with the same letters are not significantly different
Soil 1: Food security Project.
Soil 2: Atbara River Project.
Sp1: Speed one (5 km/hr).
Sp2: Speed one (7 km/hr).
Sp3: Speed one (9 km/hr).

Table 7. Effect of different forward speeds on fuel Consumption (L/hr)

Implements	Soil 1				Soil 2			
	Sp1	Sp2	Sp3	Mean	Sp1	Sp2	Sp3	Mean
Disc plow	2.54	3.45	4.34	3.45a	3.54	4.15	4.17	3.95a
Disc harrow	4.17	9.06	9.71	7.64a	3.11	8.76	9.71	7.19a
Ridger	4.17	9.56	9.81	7.86a	5.18	9.56	9.81	8.18a

Means with the same letters are not significantly different.
Soil 1: Food security Project.
Soil 2: Atbara River Project.
Sp1: Speed one (5 km/hr).
Sp2: Speed two (7 km/hr).

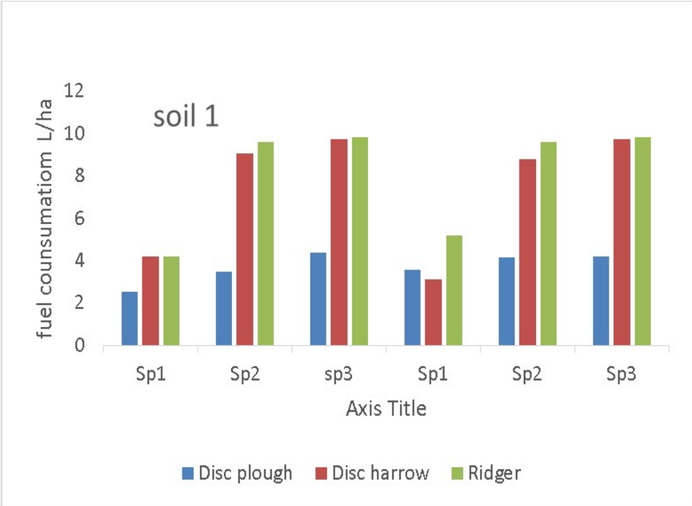

Figure 4. Effect of different forward speeds and tractors power on fuel Consumption (l/hr) at two different soils

Conclusions

Draft force, slippage, and effective field capacity and fuel consumption. Increased with an increase in forward speed. The disc plow recorded the highest average draft and slippage in both soils compared to the disc harrow and ridger. The ridger recorded the highest average effective field capacity compared to the disc plow and disc harrow.

Conflict of Interest

The authors declare that they have no competitor or conflict of interest.

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