COMPARATIVE ANALYSIS OF FUNCTIONAL FEATURES OF TWO DIFFERENT AGRICULTURAL TRACTORS (MF 178 AND X750)

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ABSTRACT
The tractor remains a very important machine in agriculture due to its ability to provide mechanical power to farm implements both on and off the farm. The choice of a tractor based on field performance can be very challenging due to limited information with regards to performance on the field. With a desire to provide some information on the field performance of Massey Fergusson's MF 178 and YTO's X750, Field tests were conducted on a soil that is predominantly sandy loam with an average moisture content of 3.18 % and bulk density of 1.01 g/cm^3 at Sambawa farms, Kaduna. The field parameters evaluated were the fuel consumption, operating speed, wheel slip, draft of implement, effective field capacity, theoretical field capacity, field efficiency, volume of soil disturbed and drawbar power during ploughing and harrowing operations. The data collected was subjected to Duncan's Multiple Range Test at 0.05 % significance levels. From the results, there was significant difference in the field performance of the two tractors. The MF 178 was however found to have a field efficiency of 86.75 % against 74.07 % of the X750. The X750 equally consumed more fuel during both ploughing and harrowing operations by 1.67 L/ha or 2.21 L/h. The MF 178 was then adjudged to give a better performance based on the data analyzed and on the standpoint of operational efficiency and economy.

Keywords:Tractor, Field Performance, Ploughing.

1. INTRODUCTION

The tractor has become a major source of farm power in man's quest to satisfy world hunger thus gradually replacing human power in the field of agriculture thereby saving labour and time in land preparation, food production as well as processing and thus saving cost (Al-Suhaibani *et al.,* 2010; Bellis, 2013; Danfoss, 2013).

Land preparation is one of the most energy demanding operations in agriculture, it involves soil cutting, turning and pulverizing and thus demands high energy, hence the need to optimize tractor performance in order to utilize the available energy. This energy utilization depends on many factors such as soil type and condition, operating depth and speed, and hitch geometry (Sirelkatim *et al*., 2001).

Due to the cost of energy, efficient energy utilization is of great importance to agricultural engineers and tractor owners thus, optimization of tractor performance is a necessity because it will help in minimizing the fuel consumption and energy loss. Ahaneku *et al*.(2011) stated that ownership of a tractor and associated equipment can involve a substantial investment and hence, improper choice of tractor size can be costly because a very small tractor (lower horse power) can result in long hours of field work, excessive delays and premature replacements, while a too large tractor (higher horse power) can result in excessive operating and overhead costs (Summer and Williams, 2007).

Several factors affect the selection of a tractor and its associated implements. These include soil type, crop type, climatic condition, cost of production, size of field and cultural practices such as tillage system. According to Ahaneku *et al.* (2011), the selection and matching of tractors with implements depends on the availability of information about the capacity of the tractor and implements as well as the likely load to be imposed on the tractor. Thus, draft requirements will vary with implement size, soil type, speed of operation and depth of operation. Therefore, for effective tractor-implement matching, there is the need to ascertain actual field efficiencies and draft requirements along with other indices of tractive performance (Bukhari *et al.,* 1988).

Sirelkatim *et al.* (2001) stated that agricultural tractor efficiency relies on better tractive effort which can result from increasing the area of contact between the tractor wheels and the soil surface, and reducing the wheel slippage. This will reduce tractor power losses and the amounts of fuel used and consequently allow covering more lands in a given time. Thus, the decision to provide the farm with a new or second hand agricultural tractor is regarded as a responsible task, with little or no room for errors (Pawlak, 2001).

This research work was therefore carried out to compare the field performances of MF 178 and X750 on a sandy loam soil.

2. METHODOLOGY

This research work was carried out on a sandy loam soil at the Sambawa Farms, along Kaduna - Zaria expressway in the north western state of Kaduna, Nigeria. The two tractors whose field performances were evaluated and compared are the MF 178 and YTO X750. The specifications of the tractors are given in Table 1. The implements used for the trials were tractor mounted disc plough and disc harrow. The specifications of the matching implements are given in Table 2. Each tractor was tested on an area of 0.030 hectares (10 x 30 m) laid side by side in a randomized complete block design (RCBD) with three replications (ASABE, 2011; Ashaye, 1983; Ingle, 2011).

Table 1: Specifications of tested tractors

TRACTOR MODEL Specification	MF 178	YTO X750
Engine Power (hp)	73	73
Type of Engine	4-cylinder	4-cylinder
Type of Fuel	Diesel	Diesel
Type of Steering System	Power-assisted	Power-assisted
Type of Injector Pump	In-line injector	In-line injector
Firing Order	1-3-4-2	1-3-4-2
Fuel Tank Capacity (L)	107.9	102
Lifting Capacity (kg)	1927	1800
Rated Engine Speed (rpm)	2200	2400
Type of Cooling System	Water-Cooled	Water-Cooled
Country of Manufacture	Pakistan	China
Front Tyres (size)	7.50 – 16	7.50 – 16
Inflation Pressure (psi)	24	24
Rear Tyres (size)	16.9 – 30	14.9 – 30
Inflation Pressure (psi)	17	17
Weight (kg)	2739	2320

Source: (ASABE, 2011; Ingle, 2011).

Table 2: Specifications of matching implements

Specifications	Disc Plough	Disc Harrow
Implement type	Mounted	Mounted
Overall length (mm)	1800	2200
Overall width (mm)	1500	1700
Number of bottom/blades	3	24
Width of cut (mm)	1310	1080
Diameter of disc (mm)	605	-
Diameter of blade (plane), mm	-	510
Diameter of blade (notched), mm	-	505

Source: (ASABE, 2011; Ingle, 2011).

2.1. Measurements

2.2. Operating Speed

To measure the operating speed, time was recorded when each tractor travelled a distance of 20 m during each operation. The operating speed was then evaluated as a ratio of the distance covered (20 m) to the time recorded.

2.3. Travel Reduction (Wheel Slip)

The travel reduction was determined as follows: a mark was made on the tractor drive wheel with coloured tapes and allowed to move forward. The distance covered after 10 revolutions under no load and load conditions on same surface were measured and expressed mathematically as expressed in equation 1:

$$TR = \frac{A-B}{A} \times 100\ \% \quad (1)$$

Where: TR = Travel Reduction (%); A = Distance covered at every 10 revolutions of tractor drive wheel at no load (m); B = Distance covered at every 10 revolutions of tractor drive wheel with load (m)

2.4. Fuel Consumption

The fuel required for each tillage operation was determined by filling the tank of each tractor to full capacity before and after each test. The amount of fuel required to refill after working on each test plot is the fuel consumed during the test.

2.5. Effective Field Capacity

The effective field capacity was evaluated using the relation given in equation 2:

$$S = \frac{A}{T} \quad (2)$$

Where: S = Effective Field Capacity (ha/h); A = Area covered (ha); T = Time (h)

2.6. Theoretical Field Capacity

The theoretical field capacity was evaluated using the relation given in equation 3:

$$TFC = \frac{S \times W}{10} \quad (3)$$

Where: TFC = Theoretical field capacity (ha/h); S = Speed (km/h); W = Width (m)

2.7. Field Efficiency

The field efficiency gives an indication of the time lost in the field and the failure to utilize the full working width of the machine. It was calculated from the test data as given in equation 4:

$$E_f = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \text{x } 100 \quad (4)$$

Where: Ef = Field efficiency (%)

2.8. Volume of Soil Disturbed

The volume of soil disturbed (m^3/h) was calculated by multiplying the field capacity with the depth of cut. This is given by the relation in equation 5(Al- Suhaibani *et al.*, 2010):

$$V = 10000SD \quad (5)$$

Where: V = Soil of Volume Disturbed (m3/h); S = Effective Capacity (ha/h); D = Depth ofcut (m).

2.9. Drawbar Power

Drawbar power was evaluated using the relationship between draft and speed as expressed in equation 6.

$$\text{Drawbar Power} = \frac{\text{Draft (kN)} \times \text{Operating Speed (km/h)}}{3.6 \text{ (constant)}} \quad (6)$$

2.10. Draft of Implement

Draft was measured with the aid of equation 7 developed by Al- Suhaibani *et al.* (2010).

$$UD = \beta0 + \beta1D + \beta2D2 + \beta23\ S + \beta4S2 + \beta5DS \quad (7)$$

Where: UD = Unit draft (N mm-1 or N/tool); D = Tillage depth (cm); S = Travel speed (Km h-1); β0, 1, 2,3,4,5 = Regression coefficients

2.11. Data and Analysis

All data collected were subjected to Duncan's Multiple Range Test using the statistical package SPSS Statistics 20 for windows.

3. RESULTS AND DISCUSSIONS

The results from the field test performed by the two tractors are given in Tables 3 and 4. While the result of the soil analysis tests carried out on the soil is presented in Table 5.

Table 3: Average resultsof parameters from field test performed on MF 178 and X750 during ploughing operation

Parameter	Tractor Model	
	MF 178	X750
Travel reduction (%)	05.86	08.47
Width of cut (cm)	110.0	120.0
Depth of cut (cm)	10.00	08.00
Speed of operation (km/h)	05.50	07.20
Effective field capacity (ha/h)	0.720	0.800
Theoretical field capacity (ha/h)	0.830	01.08
Operation time (h/ha)	1.390	01.25
Field efficiency (%)	86.75	74.07
Draft force (kN)	6.730	08.16
Fuel consumption (L/ha)	10.00	11.67
Fuel consumption (L/h)	07.12	09.33
Soil of volume disturbed (m^3/h)	720.0	640.0
Drawbar power (kW)	10.28	16.32

Table 4: Average results from field test performed on MF 178 and YTO X750 during harrowing operation

Parameter	Tractor Model	
	MF 178	X750
Travel reduction (%)	05.40	06.70
Width of cut (cm)	205.0	212.0
Depth of cut (cm)	04.00	03.50
Speed of operation (km/h)	08.00	08.00
Effective field capacity (ha/h)	01.20	01.20
Theoretical field capacity (ha/h)	01.64	01.64
Operation time (h/ha)	0.830	0.830
Field efficiency (%)	73.17	73.17
Draft force (kN)	05.19	05.34
Fuel consumption (L/ha)	03.33	05.00
Fuel consumption (L/h)	04.00	06.00
Soil volume disturbed (m^3/h)	480.0	420.0
Drawbar power (kW)	11.53	11.87

Table 5: Soil physical properties

Variables	Soil Characteristics
% Sand	79.08
% Clay	13.0
% Silt	7.92
Texture class	Sandy Loam
Bulk density (g/cm^3)	1.01
Soil moisture content (%)	3.18

The soil was found to be predominantly sandy – loam with average moisture content of 3.18 % and bulk density of 1.01 g/cm^3. Tables 6 and 7 show that there is significant difference at 0.05 levels according to Duncan's Multiple Range Test with regards to these parameters and hence there is significant difference in the performance of both tractors. However, each test parameter is discussed as thus:

Fuel Consumption

The fuel consumption rates of the test tractors are depicted in Figures 1 and 2.

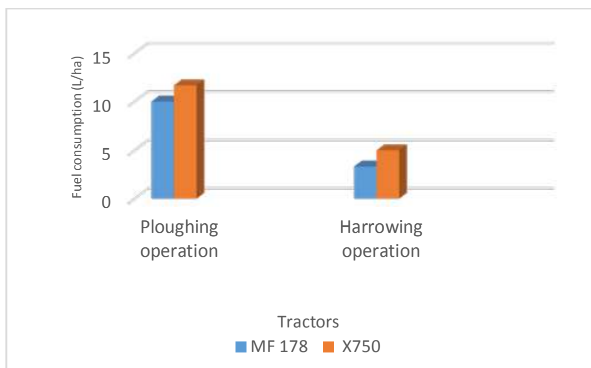

Fig. 1: Fuel consumption of test tractors in litres per hectare

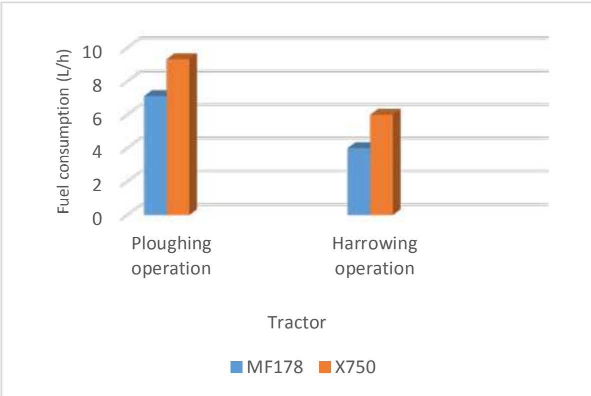

Fig. 2: Fuel consumption of test tractors in litres per hour

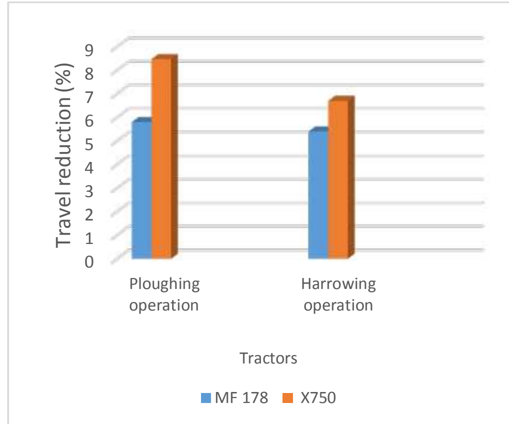

Fig. 3: Travel reduction of test tractors

Figure 1 shows the consumption rate in litres per hectare while Figure 2 shows the consumption rate in litres per hour. Ploughing operations consumed more fuel than harrowing operations for both tractors. The average consumption rate of both tractors is not significantly different as earlier shown in Tables 6 and 7. This is in agreement with the findings of Ahaneku *et al*. (2011) on the comparative evaluation of three models of Mahindra tractors. They reported that the fuel consumption parameter did not show any significant difference when operated at the same condition. However, tractor model X750 consumed more fuel i.e 1.67 L/ha or 2.21 L/h more during ploughing operation and 1.67 L/ha or 2 L/h more during harrowing operation. This could be attributed to its higher speed of travel with higher travel reduction.

Travel reduction (Wheel slip)

Travel reduction tends to affect the traction efficiency of tractive devices. Figure 3 depicts the results of the travel reduction obtained from the field test of MF 178 and X750.

Tractor model X750 consistently gave the higher values of travel reduction or wheel slip during both ploughing and harrowing operations. High values of travel reduction tends to lead to an increase in fuel consumption as useful energy is lost doing little or no work. Hence tractor model X750 is more likely to consume more fuel than MF 178.

Operation time

Time taken to accomplish a task is very vital in production. Results of time taken by test tractors to cover the same area were earlier shown in Tables 3 and 4. Both tractors covered the harrowing operations at the same time while the X750 had a slightly better time than the MF 178.

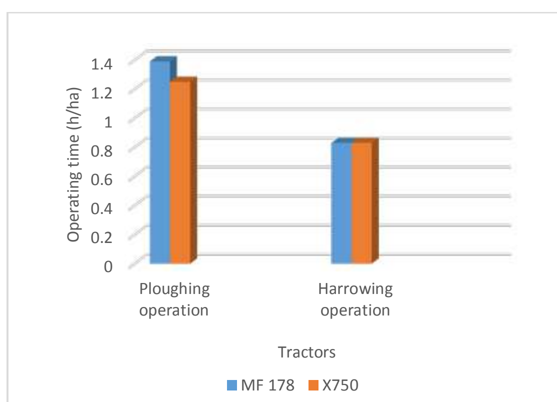

Fig. 4: Operation time of test tractors

Soil volume disturbed

Soil disturbance has been reported as one of the two major factors that determine the performance of tillage implements (Bukhari *et al*., 1988). Soil volume disturbed is a function of the effective field capacity and depth of cut. Comparing the performance of both tractors in terms of soil disturbance as illustrated in Figure 5, tractor model MF 178 achieved a slightly higher soil disturbance than the X750 in both field operations.

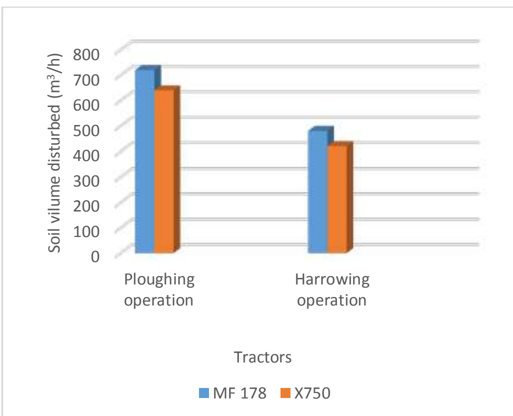

Fig. 5: Soil volume disturbed by test tractors

Field capacity

Field capacity is the other major factor as reported by Bukhari *et al*. (1988) that helps in determining the performance of tillage implements. The field capacity of a machine depends on its width, speed and efficiency of operation. Tractor model X750 achieved a slightly higher field capacity as shown in Figure 6 during the ploughing operation but MF 178 achieved a better field efficiency.

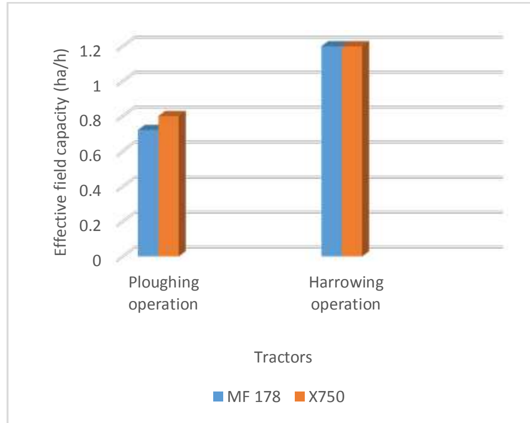

Fig. 6: Effective field capacity of test tractors

Draft of implements

Draft of implements is a function of speed of operation and depth of cut. Figure 7 illustrates the draft (drawbar pull) of both test tractors during ploughing and harrowing operations.

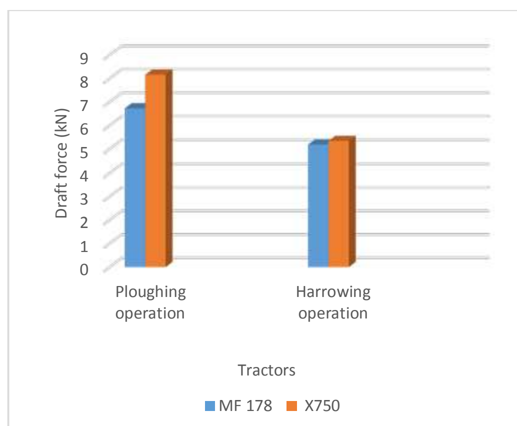

Fig. 7: Draft force of test tractors

Draft recorded during ploughing operations were consistently higher than those of harrowing irrespective of tractor model. The X750 experienced a higher draft. It should be noted that draft recorded were measured with the aid of the equation developed by Al-Suhaibani *et al*. (2010).

Drawbar power

Drawbar power is a function of draft and operating speed. Figure 8 shows the drawbar power of the test tractors recorded during the field operations.

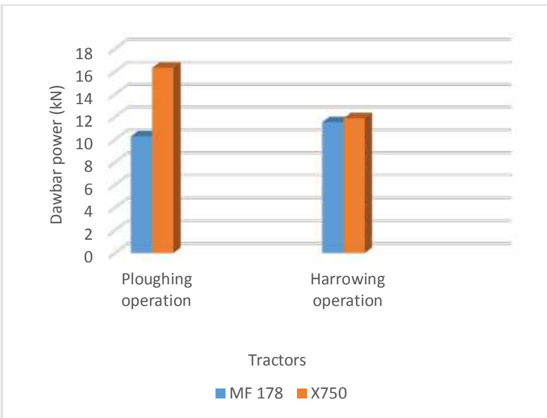

Fig. 8: Drawbar power of test tractors

The drawbar power of X750 was higher than that of MF 178 for both ploughing and harrowing since a large drawbar pull and high speed will result in a large drawbar power as seen with the X750. Drawbar power recorded were higher than those of draft of implements which is essential for doing work.

Field efficiency

Field efficiency is the ratio of the effective field capacity to the theoretical field capacity. It is an indication of time lost in the field and the failure to utilize the full working width of the machine (Ahaneku *et al*., 2011). Hence it represents the amount of work actually done by the machine. Figure 9 illustrates the field efficiency of the test tractors during ploughing and harrowing operations. The MF 178 exhibited a higher field efficiency than the X750 during the ploughing operations.

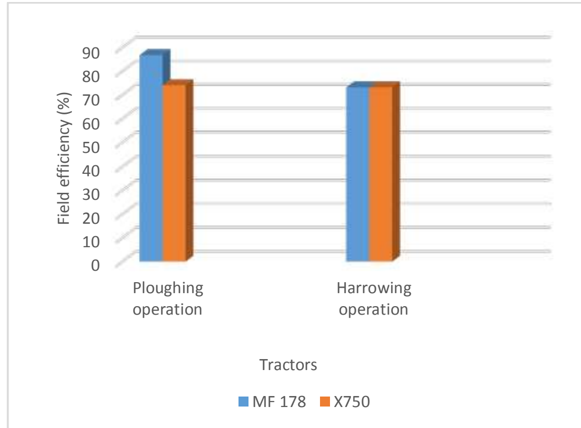

Fig. 9: Field efficiency of test tractors

4. CONCLUSION

It was discovered that there was significant difference in the field performance of the tested tractors. This result can be attributed to the fact that both tractors were tested under identical conditions. However, the MF 178 exhibited a better fuel economy and field efficiency. With the high cost of diesel to run tractors, this will indeed reduce the cost of operation especially during ploughing operations where more energy is required being a primary operation. Also, a more efficient tractor must be able to exhibit a small wheel slip in order to do more work and reduce fuel wastages. This was also exhibited by the MF 178.

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