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Comparative Assessment of using Fuel Flow Meter and Graduated Cylinder in Measuring Tractor Fuel Efficiency Parameters during Ridging Operations

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Abstract*: The use of energy during tillage operations is inevitable to boast agricultural mechanization for food production. In this study, field experiments were carried out to assess the comparison of using fuel flow meter and graduated cylinder measuring devices in determining tractor fuel efficiency parameters (hourly and tilled area fuel consumptions) during ridging operations. An experimental plot of 138 m by 50 m (6900m^2) area was cleared and divided into three blocks of nine sub-blocks. Each of the blocks was marked out in 2 m by 50m for different treatments. Alleys to the plot of dimensions of 1m by 50m were provided. Prior to ridging operations tillage operations such as ploughing and harrowing were carried out. The equipment and tractor used for the ridging operations were DFM 100CD fuel flow meter, 1000 litres graduated cylinder, disc plough and Swaraj 978FE. Soil-implement-machine parameters (tractor forward speed, ridging height, width of cut), time and tractor fuel efficiency parameters (hourly fuel consumption (FC_h) and tilled area fuel consumption (FC_{ta})) during ridging operations were determined. The field test data gotten were analysed statistically by paired t Test. The graphical hourly fuel consumption comparison between fuel flow meter and graduated cylinder showed a close alignment and a good relationship of very high coefficient of determination (R^2 = 0.9999). Additionally, comparison using paired t Test showed that there is no significant different statistically between fuel flow meter and graduated cylinder measurement at 95 and 99 % confidence levels, because the $t_{calculated}$ is less than the t_{table}. Similarly, the graphical illustration of the tilled area fuel consumption comparison between fuel flow meter and graduated cylinder displayed a close alignment and a good relationship of very high coefficient of determination (R^2 = 0.9999). Furthermore, comparison using paired t Test revealed that there is no significant different statistically between fuel flow meter and graduated cylinder measurement at 95 and 99 % confidence levels, because the $t_{calculated}$ is less than the t_{table}. Hence, recommended that the fuel flow meter and the graduated cylinder are efficient for measuring tractor fuel efficiency parameters (hourly and tilled area fuel consumption) during ridging operations.*

Keywords— Fuel flow meter, Graduated cylinder, Hourly fuel consumption, Ridging operation, Tilled area fuel consumption, Tractor

1. INTRODUCTION

Ridging is a tillage operation carried out after ploughing and harrowing operations. Ridge is a long mound of tilled soil typically between two furrows with a precise shape, its length depends on the size and layout of the field while the width and height of the ridge depend on the implement adjustment and size of the disc used [1]. Ridging has been defined by Nkakini and Fubara-Manuel [2] as tillage operation planned for heaping up tilled soil from two sides to form long stripes of mounds having furrow in between. This is majorly for undulating, flat and low-lying flat fields that are susceptible to being wet and/or any other topography can be used. The permanent raised ridges are flat and usually 30 to 61 cm (12 to 24 inches) wide and 10 to 16 cm (4 to 6 inches) high and the operation is accomplished with the help of tillage implement called ridger [3].

There are different heights and configurations of ridges, they are mainly determined by the type of crop to be planted, type of soil, depth of ridger cut in the soil and tractor forward travel speed. The effect of the last three parameters on the amount of fuel consumed during ridging operation on a sandy loam soil in a humid tropical environment [3].

It has been observed in literature, for each of tillage operations (ploughing, harrowing and ridging) fuel consumption rates rises linearly with time and area covered [4]. Igoni et al. [3] in their study found that increase in tractor forward speed and ridging height increase fuel consumption. The traditional tillage pattern needs a smaller amount fuel and time for tillage operation compared to circuitous and straight alternation pattern that would reduce the cost of production [5].

According to Udo and Akubuo [6] there are two different methods of measuring fuel consumption in agricultural field machinery. These consist of the introduction of an instrument to the machine to measure draught, fuel flow and other parameters under soil-bin (controlled) condition, and the other method is to measure fuel consumption in field operations by fixing supply tank fuel meter and depend on the operator to keep records. These aforementioned methods create different types of data with the first method usually present more useful and reliability of the results with respect to the machine design parameters [7], and many more of the environmental variables

and machine features which affect actual on-farm fuel consumption were considered the second technique.

Study by Fathollahzadeh et al. [8] revealed that flow-time diagram points out that some important and operative factors on the spot upsetting fuel consumption during tillage operations differ continuously in the field. There by, recommended that the speedy fuel consumption data and positioning system may perhaps be adapted to develop fuel consumption map. A number of approaches to measure the suitability of fuel consumption of tractor engine have been adopted by several researchers such as Fathollahdeh, et al. [8,9]; Grisso et al. [10]; Rahimi-Ajdadi and Abbaspour-Gilandeh [11]; Spagnolo et al. [12]; Jokiniemi et al. [13]; Tayel et al. [14]; Leghari et al. [15,16], Shafaei et al. [17]; Oyelade and Oni [18]; Nkakini et al. [19,20]; Igoni et al. [21]; Igoni et al. [3]; Ekemube et al. [22]. These include: Direct method, cylindrical fuel container branched, Flow meters sensors, two flow sensors, Series sensors, volumetric system, instrumentation package and transducer system, and transparent fuel level indicator.

Ridges are of different heights and configurations, mainly determined by the type of crop to be planted, type of soil, depth of ridger cut in the soil and tractor forward travel speed [3]. The effect of the last three parameters on the amount of fuel consumed during ridging operation [3]. But different methods have been employed to measure tractor fuel consumption during tillage operations but there is dearth of information in literature on the comparative assessment of the use of fuel flow meter and graduated cylinder in measuring tractor fuel consumption. Therefore, the objective of this study is to compare the use fuel flow meter and graduated cylinder in tractor fuel utilization efficiency during ridging operation, by determining appropriate measuring device.

2. MATERIALS AND METHODS

2.1 Study Area Description

This experimental area map is shown in figure 1. The experiment was carried out on May 11th, 2021 at the Rivers Institute of Agricultural Research and Training (RIART) farm at Rivers State University, Port Harcourt, Nigeria (latitude of 4° 49′ 27″ N, and longitude of 7° 2′ 1″ E). The experimental design used in this study is group balanced block design (GBBD). A farm size of 138 m by 50 m (6900 m2) was divided into three plots of 9 sub-plots each. Each sub-plot of 50m by 2m was marked with a 1m alley. The sub-plot was provided for different treatment options and with a space of 2 m between each block and 1 m at the sides of the outer blocks.

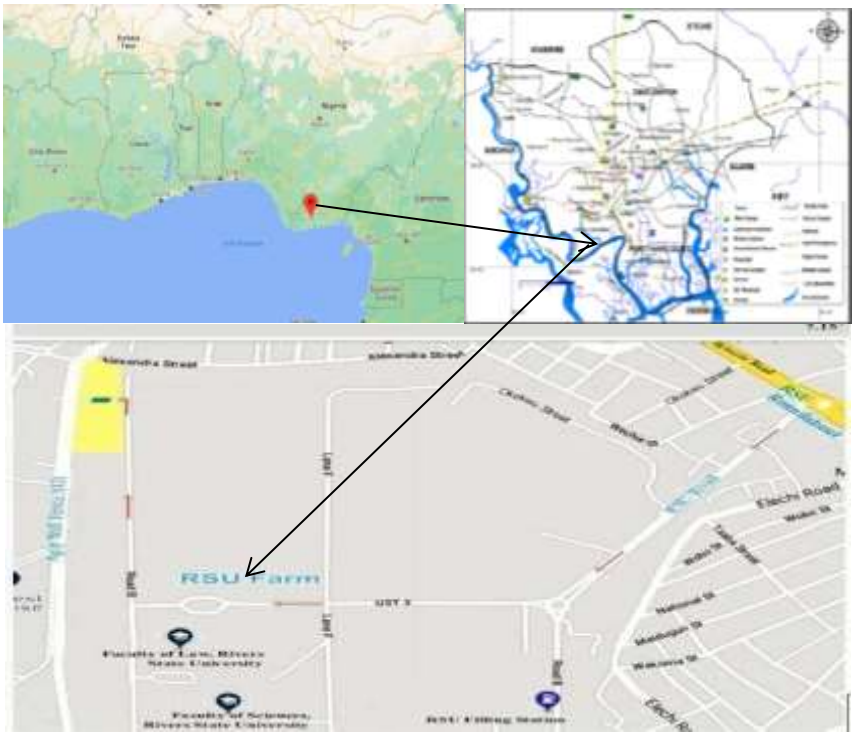

Figure 1: Map of Nigeria, Port Harcourt Metropolis and River State University (Source: Googgle Map, 2021).

2.2 Tractor and Implement Specifications

The tractor specifications are shown in Table 1, implement specification in Table 2 and fuel flow meter specification in Table 3. Also, their images are displayed in plates 1. 2, and 3 respectively.

Table 2 Tractor Specifications

Parameter	Description
Model	Swaraj 978 FE
Drive	2 Wheel drive
Engine horse power	72 hp
Lifting power	2200 kg
Hitch	3-point CAT III
Front tyres	7.5 - 16 ,8 – ply
Rear tyres	16.9 - 28,12 – ply
Width	2030 mm
Weight	3050 kg
Manufacturer	Swaraj
Country	India

Plate 1: The Swaraj 978 FE Tractor (Swaraj, India)

TABLE 2: DISC RIDGER SPECIFICATIONS

Parameter	Description
Number of Disc	4
Working Depth (mm)	330
Frame Width (mm)	2500
Width of Cut (mm)	1000
Disc Diameter (mm)	711.2
Disc Spacing (mm)	1000
Estimated weight (Kg)	506
Tractor Required Power (Hp)	65 – 80
Model	SD
Manufacturer	Baldan Implementos Agricolas
Country	Brazil

Plate 2: 2-Row Disc Ridger

Table 3: Fuel Flow Meter Specifications

Parameter	Description
Model	DFM 100CD
Nominal fuel pressure (MPa)	0.2
Maximum fuel pressure (MPa)	2.5
Minimum kinematic viscosity (mm^2/s)	1.5
Maximum kinetic viscosity (mm^2/s)	6.0
Infiltration size in liquid (mm) no more than	0.08
Minimum supply voltage (V)	10
Maximum supply voltage (V)	45
Maximum current consumption (mA) for Unom 12/24 V	50/25
Operating temperature (^oC)	-40……+85 / -20…….+60
Ingress protection rating (IP Code	54
Manufacturer	Technoton Engineering
Country	Belarus

Plate 3: DFM 100CD Fuel Flow Meter (Technoton Engineering, Belarus) used in this Study

Plate 4: 1000 ml Graduated Cylinder

2.3 Methods

Preceding ridging operation, soil core was used for obtaining the soil sample from the depth of 0 – 10, 10 – 20 and 20 - 30 cm respectively at random in the field to determined textural classification of the soil and moisture. The collected soil samples were taken to the laboratory for analysis. The parameters such as textural classification of the soil was determined by hydrometer method and the gravimetric (i.e., oven dry method) was used for soil moisture content determination.

The disc ridger was attached to the tractor and levelled using the top links of the tractor in order to reduce parasitic forces. Then, ridging heights were determined by setting the level control of the lifting mechanism (three-point linkage height) to lower the disc ridger to the desired ridging height. Tractor forward speeds were determined by selecting a particular gear that gave the desired speed. This was done in a practice area in advance for each test plot to maintain the desired treatment. The ridging height measurement was done by placing the meter rule from furrow bottom to the surface of the ridged land, while the width of cut was measured by placing a steel tape from one side of the furrow wall to the other end. Time was determined with a stopwatch set at zero before each operation.

Fuel consumption was determined in two methods. These are direct method (topping up the tank) and digital method (use of fuel consumption flow meter) of determining fuel consumption. During the direct method process, the tractor fuel tank was filled to the brim before and after each operations test was performed. The measurement of fuel consumption was taken using 1000 ml graduated cylinder to top up the fuel level in the tank after each operation test. Therefore, the volume of fuel consumed per time taken for the operation was recorded. Similar method has been used by Shah *et al*. [23]; Oyelade and Oni 18; Nkakini *et al*. [19, 20]; Igoni *et al*. [3, 21] Ekemube *et al*. [22], and Nkakini and Ekemube [24]. The digital method of measuring the quantity of fuel used was adopted to determine tractor fuel consumption. During this process, the use of DFM fuel flow meter was employed to measure fuel consumption. The metre was mounted on the fuel line between the tractor's fuel tank and the pump. At the end of each test operation the data was taken from the fuel flow meter as display information, switching is performed by light touch to the top cover of fuel flow meter by iButton key. Similar method has been adopted by Sumer *et al*. [25]; Spanolo *et al*. [12]; Lopez-Vazquez *et al.* [26]; Ivanov [27]. Mathematically, hourly and tilled area fuel consumptions were deduced by expression in Equations (2 and 3) [17]:

$$FC_h = \frac{T_{fc}}{h} \quad (1)$$

Where:
FC_{wh} = Fuel consumption per working hour (L/h);
T_{fc} = Tractor fuel consumption, L;
h = Working hour,

$$FC_{ta} = \frac{10T_{fc}}{V \times W \times E \times h} \quad (2)$$

Where:
FC_{ta} = Fuel consumption per tilled area, L/ha;
T_{fc} = Tractor fuel consumption, L;
V = Forward speed, Km/h;
W = Implement width, m
E = Implement field efficiency, %;
h = Working hour h.

2.4 Statistical Analysis

The paired t-Test of two samples assuming equal variance was used to compare the graduated cylinder and fuel flow meter data. This was to determine if the means measured are totally different and if the difference are away from what is attributed to chance or experimental error and difference was considered as significant at $t_{computed} > t_{table}$ (95 and 99 % confidence) levels as given in equation (3).

$$t = \frac{\sum D/N}{\sqrt{\frac{\sum D^2 - \left(\frac{(\sum D)^2}{N}\right)}{(N-1)(N)}}} \quad (3)$$

Where:
$\sum D$ = summation of the differences;
$\sum D^2$ = summation of the squared differences;
$(\sum D)^2$ = summation of the differences squared;
N = number of samples.

3 RESULTS AND DISCUSSIONS

3.1 Soil textural class

The particle size distribution (PSD) analysis of a 102g air-dried soil before tillage operations indicated soil particles of various sizes, including sand (9.60 %), silt (8.80 %) and clay (83.60 %) in the soil. Result showed that the soil texture was loamy sand according to the United State Department Agriculture (US DA) textural classification of soil (Figure 2).

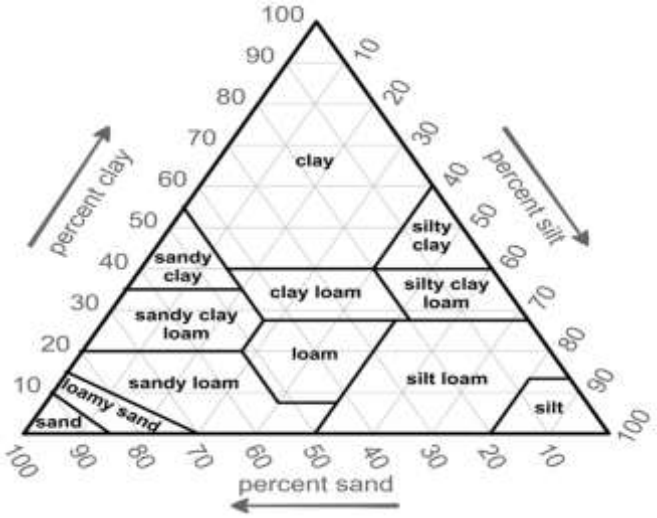

Figure 2: USDA Soil Texture Triangle

3.2 Hourly fuel consumption

Table 1 shows the field test results of height, h, speed (V), width of cut (W) and hourly fuel consumption (FC_h).

Table 1: Hourly Mean Results of Field Test Performed during Ridging Operation

Parameters				
h, m	**V, Km/h**	**W, m**	**FC_h (M), L/h**	**FC_h (G), L/h**
0.10	5.00	1.00	3.30	3.26
	7.00	1.00	4.27	4.18
	9.00	1.00	4.38	4.29
0.20	5.00	1.00	4.78	4.73
	7.00	1.00	6.11	6.06
	9.00	1.00	6.26	6.22
0.30	5.00	1.00	7.15	7.10
	7.00	1.00	8.86	8.79
	9.00	1.00	9.40	9.33

h = height (m), V = velocity, W = width of cut (m), FC_h (M) = hourly fuel consumption measured with flow meter (L/h), FC_h (G) = hourly area fuel consumption measured with graduated (L/h).

Comparison of hourly fuel consumption measured with fuel flow meter and graduated cylinder during ridging operations was present graphically in Figures 3 and 4 respectively. The graphical analysis (Figure 3) showed a close association of the curves of the fuel flow meter and graduated cylinder fuel consumption of the tractor. The devices – the fuel flow meter and graduated cylinder computed data (Table 1) align closely, showing that they were almost equal. insignificance. The graphical observation of the plot of fuel flow meter data against graduated cylinder data has a high correlation with the graduated cylinder data obtained from the ridging operation with R^2 value of 0.9999. When the means of the fuel flow meter and graduated cylinder output capacities were compared statistically, it was revealed that there is no significant difference between the means at 5 and 1% levels of significance, since the calculated "t" value (0.20) is less than the table "t" value (2.306 and 3.355 respectively.

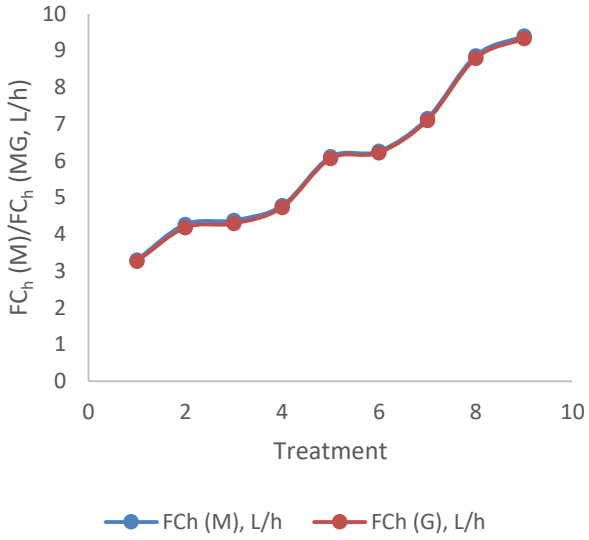

Figure 3: Hourly FC Measurement Accuracy of Fuel Flow Meter versus Graduated Cylinder during Ridging

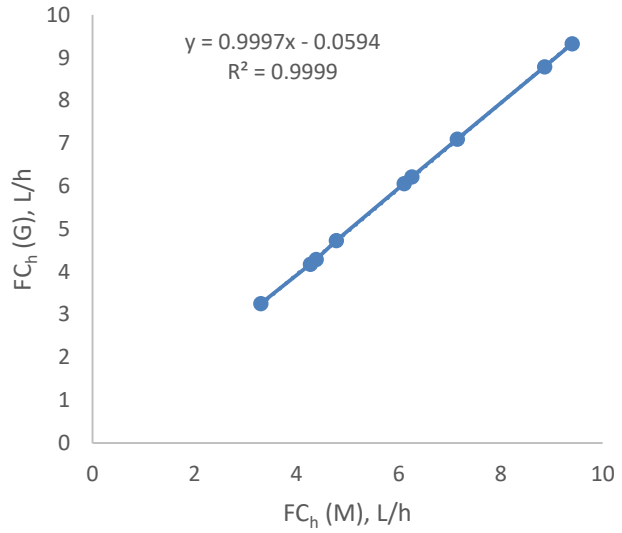

Figure 4: Hourly FC Measurement of Flow Meter versus Graduated Cylinder during Ridging

3.3 Tilled area fuel consumption

The tilled area field test results of height, h, speed (V), width of cut (W) and hourly fuel consumption (FC_h) are shown in table 2.

Table 2: Tilled Area Mean Results of Field Test Performed during Ridging Operation

Parameters				
h, m	**V, Km/h**	**W, m**	**FCta (M), L/h**	**FCta (G), L/h**
0.10	5.00	1.00	6.27	6.15
	7.00	1.00	6.80	6.66
	9.00	1.00	6.90	6.81
0.20	5.00	1.00	9.03	8.92
	7.00	1.00	9.72	9.66
	9.00	1.00	9.99	9.87
0.30	5.00	1.00	13.46	13.38
	7.00	1.00	14.61	14.49
	9.00	1.00	14.93	14.81

h = height (m), V = velocity, W = width of cut (m), FC_{ta} (M) = hourly fuel consumption measured with flow meter (L/h), $FC_{ta\ (G)}$ = hourly area fuel consumption measured with graduated (L/h).

The graphical comparison of tilled area fuel consumption measured with fuel flow meter and graduated cylinder during ridging operation was presented graphically in Figures 5 and 6. The graphical analysis displayed a close association of the curves from the fuel flow meter and graduated cylinder fuel consumption of the tractor (Figure 5). Moreover, the trend lines produced by the data from flow meter and graduated cylinder aligned together showing insignificance difference.

Furthermore, the results showed that the fuel flow meter and the graduated cylinder have high correlation coefficient close to unity for fuel consumption measurement. As presented in Figure 6, it was observed that the fuel flow meter has a high correlation with the graduated cylinder data obtained from the ridging operation with R^2 value of 0.9999. Based on the statistically comparison of the means of the fuel flow meter and graduated cylinder output capacities, it was shown that there is no significant difference between the means at 5 and 1% levels of significance, since the calculated "t" value (0.35) is less than the table "t" value (2.306 and 3.355 respectively).

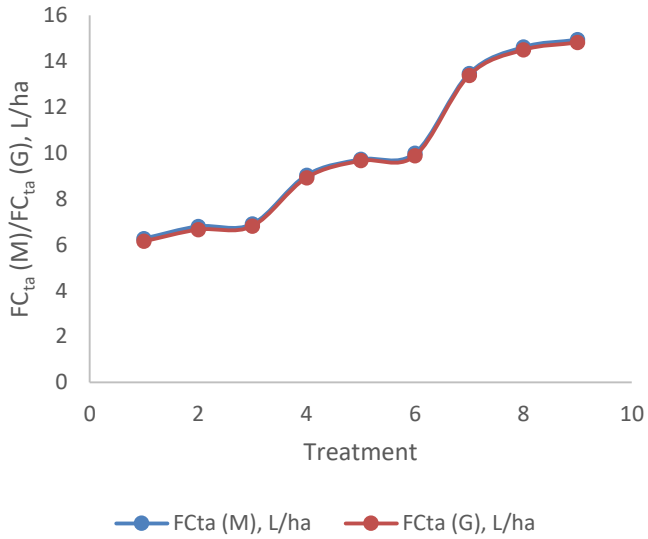

Figure 5: Tilled Area FC Measurement Accuracy of Fuel Flow Meter versus Graduated Cylinder during Ridging

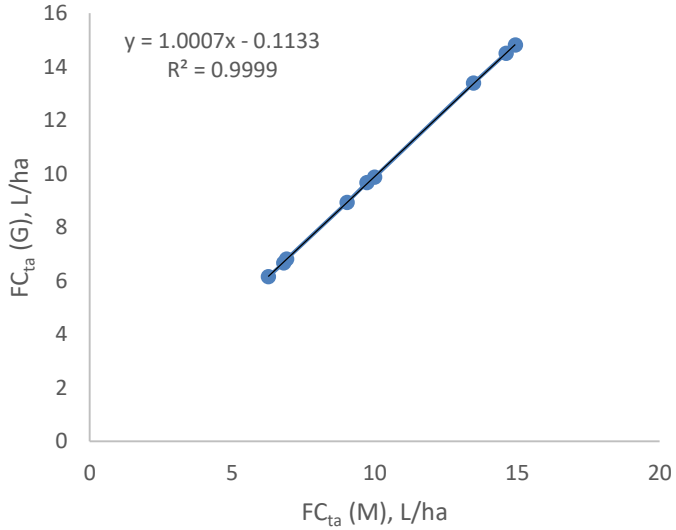

Figure 6: Tilled Area FC Measurement of Flow Meter versus Graduated Cylinder during Ridging

4. CONCLUSION

This study had assessed the comparison of tractor fuel efficiency parameters measured with fuel flow meter and graduated clinder during ridging operation. The following conclusions support the obtained results:

i. There is no significance difference among the data gotten from fuel flow meter and graduated cylinder for hourly fuel consumption;
ii. There is no significance difference among the data gotten from fuel flow meter and graduated cylinder for tilled area fuel consumption; and
iii. Any of the preferable devices used for this study could be used in measuring fuel consumption during ridging.

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