Performance Evaluation of Power Tiller in Bauchi State Nigeria

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Abstract
The research work involves performance evaluation of Power Tiller in the Savanna agro-ecological zone of Nigeria. Bauchi State Agricultural Development Programme's farm was used as the study area having satisfied the condition for a small scale farm in a developing economy. The Power Tiller speeds was measured using stopwatch and a measuring tape, width of cut of the machine was measured using measuring tape, soil moisture content was obtained using a laboratory oven drier and the depth of cultivation and fuel consumption was measured using a graduated dip stick. The results obtained were from the following field parameters: effective field capacity, field efficiency, fuel consumption, speeds of operation, depth and width of cut. These parameters were determined from field work and laboratory experiment and the basic operations considered during the field operations were ploughing and rototilling. The field efficiency obtained was 47 and 48 percent for ploughing and rotovating with effective field capacity of 0.04ha/hr. and 0.06ha/hr. respectively. The fuel consumption was 1.3L/hr. and 1.6L/hr. for ploughing and rotovating at a depth of 9cm and 5.5cm when the soil moisture contents were 6.3 and 8 percent respectively. The result shows that the machine is suitable for small scale farmers in Savanna Agro-ecological zone.
Keywords: Power Tiller, Performance Evaluation, Effective Field Capacity, Field Efficiency

1.0 Introduction

The choice of mechanical, animal or manual power for any work in the farm revolves round on the relative cost of the different forms of power for doing unit of work for the particular type under consideration (Sankaran and Mudaliar, 1984). This is related to the size of the farm and influenced by the intensity of cultivation. Where cultivation is of an intensive type, tillage and other operations are done frequently and the power unit is kept engaged for a large part of the year even with small units of cultivation. The power chosen can be used economically, only if it is used with as few idling days in the year as possible (Ishola and Adeoti, 2004).

The performance of agricultural machines is assessable by the rate at which an operation is accomplished and by the quality of the output (Yohanna and Ifem, 2009). Field machine task or capacitive performance is the rate at which it can cover a field while performing its intended function or useful work. It is usually measured by the rate of work in hectares per hour (Kaul and Egbo, 1985).

Power tillers were re- introduced in Nigerian agriculture in 2001 by Watershed Initiatives Nigeria by importing few units for Sawah rice production technology (Ademiluyi and Oladele, 2008). The role of farm power in the development of agricultural is something of paramount importance. The total area under cultivation and the timeliness and efficiency of accomplishing crop husbandry tasks is strongly influenced by the amount of available farm power and its efficient use. The increased usage of farm power for cultivation creates further demand for related agricultural machinery for harvesting and storage and generates employment opportunities in the agricultural service and industry (Kong et al.,1983). It is therefore important to seek information concerning available farm power and its application in various agricultural activities (e.g soil preparation, sowing, weeding, spraying, harvesting, processing, etc.) this information is also of great importance for planning exercises as it influences the design and implementation of future policies. Non-availability of matching equipment for different farm operations limits the versatility of the power tillers. Implements initially offered with the power tillers included rotavator attachment, trailer and in some cases a plough and ridger. The initial introduction of power tillers was without a complete range of matching equipment (Kathirvel et al,, 2000).

The Power Tiller is a multipurpose two wheel tractor designed suitably for use in paddy fields, dry fields, vegetable gardens and hilly land with a little inclination. It can be used for ploughing, rototilling and harrowing in paddy fields as well as harvesting, drilling, ditching, transportation (Ademiluyi et al., 2008). It can also be extensively used as a stationary power source for small scale drainage and irrigation, spraying, grain threshing, cotton ginning, flour milling and feeder cutting (Ademiluyiet al., 2008).

The concept of using power tiller drawn wheeled multipurpose tool carrier was introduced newly as it is a development over the animal drawn wheeled tool carrier. Though, the initial cost of equipment is slightly high, it offers several advantages like timeliness in farm operation, quality and precision of work, increased work rate, efficient utilization of machine power, reduction in human drudgery and allow for year round use due to its multipurpose utility. The popularity of these models among farmers is limited. The multipurpose tool carrier can be used for different operations like ploughing, harrowing, tillage etc. by attachment with suitable implements.

The efficient machine management requires accurate performance data on the capability of individual machine

in order to meet the projected work and to form balanced mechanization system by matching the performance of separate items of equipment (Witney, 1988).
The Bauchi State government imported One Thousand Seven Hundred (1700) pieces of the machines and distributed to farmers and Civil Servants in the State and there is no available data from field operations under local conditions to compare the degree of field efficiency fuel consumption and effective field capacity aimed at evaluating the performance of the machine.

2.0 Materials and Methods
Bauchi State is situated between latitude 9^{0}30' and 12^{0}30'N and longitude 8^{0}50' and 11^{0}E of Greenwich Meridian. The rainfall ranges from 600 mm in the extreme Northern part of the State and 1300 mm in the Southern part of the State (Jahun, 2011).
The equipment used for the field operations includes Stopwatch, Measuring tape, Weighing balance and Air tight containers. The Stopwatch was used for time and motion study of machine operations to determine power tiller field speed of operations and activity times of power tiller operations. The field area operated by the power tiller combination was determined using measuring tape. Soil samples were collected at 30 cm depth and immediately taken to the laboratory for moisture content analysis using air-tight containers. The weighing balance was used to weigh oven-dried soil samples from the operated fields.
2.1 Machine Speeds of Operations
The speeds of operations for power tiller were measured in kilometers per hour. Ten measurements of the times it took the power tiller to travel along the field row length during an operation was taken and averaged. Using the average of these measurements, the time-distance relationship was converted to kilometers per hour as reported by (Jahun, 2011).

$$\frac{Meter}{Row} = \frac{Row}{Avetime\,(mins)} \times \frac{60\,mins}{hr} \times \frac{kilometers}{1000} \qquad (1)$$

2.2 Machine Fuel Consumption
Fuel consumed by Power Tiller during an operation was measured using a fuel gauge stick. The fuel gauge stick was read before and after an operation. The difference between the two readings divided by the area operated upon was the total fuel consumed for the operations in litres per hectare (Gupta and Kumar, 2001).
2.3 Soil Moisture Content
Soil samples were taken before and from freshly ploughed and rotovated field immediately after an operation and was placed in tins provided with air-tight covers. The air-tight tin covers were immediately weighed in the field with an accurate weighing balance and later taken to the laboratory for oven drying at 110^{0}C for 24 hours as reported by (Gwarzo, 1990). The loss of weight after drying divided by the original weight of individual soil sample multiplied by hundred determines the moisture content of the soil samples on the wet basis as shown below.

$$mc = \frac{m_i - m_f}{m_i} X\ 100 \qquad (2)$$

Where,
$m_c =$ Moisture Content, Percentage.
$m_i =$Mass of Sample before drying (kg)
$m_f =$Mass of Sample after drying (kg).
2.4 Tillage Depth
Machine depths of operation for tillage (ploughing and rotovating) were measured in centimeters immediately after each tillage operation. A graduated measuring stick made to penetrate tilled soil was used to measure ploughing and rotovating depths. The depths of tilled soil was measured for thirty (30) times at different points along the ploughed and rotovated field and then averaged to the soil depth of each tillage operation.
2.5 Effective Field Capacity
The capacitive performance of an agricultural machine measure the field area covered per unit of time. This capacity performance termed effective field capacity was given by (Gwarzo, 1990) as shown below.

$$C = (T_c) = \frac{SW_g}{10} \qquad (3)$$

Where,
$C =$ Effective field capacity, $\frac{ha}{h}$
$T_c =$Theoretical field capacity, $\frac{ha}{h}$

$S =$ Field speed, $\frac{km}{h}$

$W =$ Machine Width, m

$e =$ Field efficiency, decimal

3.0 Results and Discussions

The speeds of operation of the machine during ploughing found to be 1.1km/hr which is within the designed speed range of (0.5-1.3km/hr.). The effective width of cut of the machine was found to be 0.8m. The field efficiency during the ploughing operation was 47% which is within the range of field efficiency of 50-60 % as reported by (Singh and Vasta, 1998). The effective field capacity was found to be 0.04 ha/hr. which is below the theoretical effective field capacity of 0.088 ha/hr. which might be due to the nature of the soil and the skill of the Operator. The average fuel consumption of the machine obtained from the field operation for ploughing operation was 1.11L/hr. which is slightly above the designed fuel consumption of 1.0 L/hr. as shown in the Table 1 below.

The field performance for rotovating operation was obtained as shown in Table 2 below. The effective operating time was 8.2hr/ha and effective width of cut of the machine was 0.9m. On the other hand, the effective field capacity are 0.15 ha/hr and 0.11 ha/hr for Biemo1 and Adugyma; while the average time of operation are 7.92 hr/ha and 8.9 hr/ha respectively for the locations in Ghana. The difference in effective field capacity obtained at Shaba- Maliki (0.089 ha/hr) and Ejeti (0.047 ha/hr) was due to the variation in the average time of operation, the operational time at Ejeti (21.7 hr/ha) almost doubles that of Shaba-Maliki (13.15 hr/ha). This shows that the turning time, time to clearing of clogs/trash from the machine was greater at Ejeti, also the operator's capability and ease of handling the machine plays another role there. Ejeti field was grass fallow. Delay and other interruptions was found to be 1.2hr/ha. The effective field capacity and field efficiency of the power tiller during rotovating were 0.06ha/hr. and 48% respectively. Ademiluyi and Oladele, (2008) in their comparism of field efficiency in Nigeria and Ghana obtained the average values of 93 and 92% for field efficiency at Ejeti and Shaba-Maliki respectively. In Ghana the field efficiency of VST SHAKTI 130D1 power tillers Biemson1 and Adugyma were 80.52% and 82%. This may be due to the fact that the nature of soils in these locations. The soils are generally more clayey than what obtains in Nigerian locations of Ejeti and Shaba- Maliki. The work rate is high enough to guarantee the quality of work done and ensures the fuel economy on farmers' plots. The values obtained during the study demonstrate the lack of mastery of the tiller which was introducing as new machine in Bauchi State. This shows that the power tiller is efficient for the operation in terms of work rate, quality of work done, fuel economy and ease of management on farmer's small farm holding. The theoretical field capacity was found to be 0.13hr/ha. The rotovating speed of the machine was 1.4km/hr. All the values obtained are within the range as reported by (Singh and Vasta, 1998).

Sahay et al., (2009) study on the prototype oscillatory tillage implement having 25 cm tool width operated up to 15.3 cm depth in dry, untilled field conditions. However, the same implement operated only up to 7.4 cm depth in non-oscillatory mode of operation. The volume of soil handled per unit time, fuel consumption and tillage performance index were higher (94.88 $m^3 h^{-1}$, 2.70 $l h^{-1}$ and 2.99, respectively) with prototype oscillatory tillage implement working at average 15.3 cm depth of operation as compared to the same implement working in non-oscillatory mode of operation.

Veerangouda et al., (2009) on their study on development and evaluation of multipurpose tool carrier for power tiller observed that the tool carrier was operated at an average working speed of 2.0 km per hour for tilling operation with the average depth of operation of 5.15 cm. The average draft of the unit was found to be 70.0 kg. The theoretical and actual field capacity of the tool carrier was found to be 0.30 ha/ h and 0.20 ha/h respectively. The field efficiency is calculated by considering the theoretical field capacity and actual field capacity. The field efficiency was observed to be 66.66 per cent. The average fuel consumption was observed to be 1.05 litres per hour for tilling operation. The cost of operation was observed to be Rs.231.86 per hectare for tilling operation. The tool carrier was operated at an average working speed 2.2 km per hour for harrowing operation with average depth of operation of 4 cm. The average draft of the unit was found to be 60 kg. The theoretical and actual field capacity was observed to be 0.033 ha/h and 0.23 ha/h respectively. The field efficiency of the power tiller operated multipurpose tool carrier was observed to be 69.88 per cent for harrowing. The average fuel consumption was observed to be 0.95 litres per hour for harrowing operation. The cost of operation was observed to be Rs.201.20 per hectare for harrowing operation (Mahabudul Alam, 1981). There was a significant difference between the two conditions based on the study areas both in Nigeria and Ghana and the results obtained in Bauchi State as the study area.

Table 1: Performance of Power Tiller during Ploughing Operation

Parameters	Average
Effective Width of the Machine	0.8
Speed of Operation (km/hr)	1.1
Effective operating Time (hr/ha)	9.2
Delay and other interruptions (hr/ha)	2.7
Theoretical Field Capacity (Cth) ha/hr	0.088
Effective Field Capacity (Ce) ha/hr	0.04
Field Efficiency (%)	47
Fuel Consumption (L/hr)	1.6

Table 2: Performance of Power Tiller during Rotovating Operation

Parameters	Average
Effective Width of the Machine (m)	0.9
Speed of Operation (km/hr)	1.4
Effective operating Time (hr/ha)	8.2
Delay and other interruptions (hr/ha)	1.2
Theoretical Field Capacity (Cth) ha/hr	0.13
Effective Field Capacity (Ce) ha/hr	0.06
Field Efficiency (%)	48
Fuel Consumption (L/hr)	1.3

4.0 Conclusions

The performance evaluation of Power Tiller studied showed that during ploughing and rotovating the effective field capacity, fuel consumption and field efficiency were within the range as stipulated by the manufactures'.
The light weight Power Tiller is favourable factor for working in wet and dry land conditions of the study area, it does not sink in wet rice pardy fields and creates least disturbance to soil structure compared with standard tractors. It is considered more appropriate alternative than animal drawn implement and tractors that are sometimes not available during the peak period of land preparation in Bauchi State. It is hope that the know-how and adoption would be increase by mastery of use by the operators and mechanics and lead to local manufacture of spare parts locally and open up for employment opportunities for many Nigerians as obtainable in other part of the World.

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