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Machinery systems management of walking tractor (power tiller) for rice production (*sawah*) in Nigeria

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Abstract

The study examined the performance and evaluation of a 10 kW two wheel tractor (power tiller) and determined the cost of using power tiller in *sawah* rice production technology in Nigeria. The study was carried out in Bida area, Niger state, where the *sawah* rice production was disseminated by Watershed Initiative in Nigeria (WIN 2001). Some of the parameters assessed during the field test included average speed of operation, average wheel slip/travel reduction, average draught of implement and fuel consumption. Field efficiencies determined were 93 and 92% at Eject and Shaba-Maliki respectively. Assessment of soil parameters before and after the operation showed that the power tiller with the attached tillage tool had improved the soil structure. The cost of operation over five years of usage was determined and it was therefore concluded that the power tiller is a better alternative to animal drawn equipment for small-scale farmers.

Key words: Field test, power tiller, production cost, *sawah* rice production.

Introduction

"Small tractors" have been viewed by their promoters as an appropriate though underdeveloped stage in the dynamic process of agricultural mechanization. According to Pollard and Morris [6], the term "small tractors" is understood as applicable when the following attributes characterize a particular tractor: simple construction using mass produced components, assembling or fabricating as much as possible locally; safe and easy operation and maintenance, reasonably rugged construction and reliable performance, improved performance (quality and quantity of work) compared to that of a pair of oxen and low initial cost within the cash or credit reach of a "small farmer". For the purpose of this paper, two-wheel tractors are classified as small tractors.

Two-wheel tractors are sometimes called by other names such as single axle tractor, hand tractor, walking tractor, walk-behind tractor, etc. [7]. The two-wheel tractor with different attachments (implements) can accomplish many kinds of farm work like tillage, planting, harvesting and transportation. When a tillage implement is attached to a two-wheel tractor, it is called power-tiller. There are many types of two-wheel tractors such as: mini tiller type (1.5-2.2 kW), traction-type (2.9–4.4 kW), dual type (3.7-5.2 kW), drive type (5.2-10.3 kW) and Thai type (5.9-8.8 kW) [7].

Two-wheel tractors are grouped either as professional farm use tractors called agricultural tractors, or hobby-use tractors called garden tractors, mini tillers, etc. The required total life of a hobby-use tractor has been said to be about 150 hours in northern developed countries that is an average of 15-25 hours of use per year. This was determined from the view point of a common office worker using the machine less than two hours every weekend during the four weeks or so in each of spring and autumn, amounting to about 10 years life on the average [7].

In the case of a professional tractor for a small-scale farmer who holds about one hectare of double-cropped land, for example, the durability has been estimated to be equivalent to 200-250 hours of operation every year under a full-load condition for several years' life. If the tractor is used for contract operation, it is expected to withstand at least 500-600 hours of use per year. This is based on the expectation of 8-10 hours operation per day for one month in each of two farming seasons per year. On the whole the professional two-wheel tractor is expected to have a minimum life of about 2000 hours [7]. Further classification of single axle tractors can be done based on their dimensions and their field performance (Table 1).

The demand, production and concentration of two-wheel tractors have been of particular significance in certain countries of Asia, especially those in which low land rice is a major crop. Data for some of these countries are presented in Table 2. It has been observed that the power available per unit over most of Africa, for example, is about 0.04 kW/ha, while that in most developed countries, with yields per unit area of between 3 and 5 times greater, is in excess of 0.6 kW/ha (Fig. 1). Therefore it was suggested [8] that in order to achieve reasonable productivity in developing areas such as Africa, a tenfold increase in power, to 0.4 kW/ha is necessary. To increase the available power by the introduction of more people or animals was considered unlikely to be feasible since in either case a rise in productivity could be encountered by an increased food demand.

Fossil fuelled agricultural machinery offers a technically feasible way of providing additional power. The size of the average family holding in many developing countries is of the order 2 to 5 hectares, with 3 hectares as an appropriate average figure. Such a holding would therefore require a power input of 1.2 kW to provide the level suggested [2]. It is therefore the opinion of many that due to the economic level of majority of farmers in developing countries like Nigeria, in transforming from the presently predominant hand-tool technology to a full blown large-scale engine power technology, there has to be an appropriate intermediate technology. In the past this has been viewed as the animal draft technology. However, the introduction of two-wheel tractors (power-tillers) in many countries is proving to be a better and more appropriate intermediate technology for the arguments put forward earlier.

In the past three to four years, there has been an influx of two-wheel tractors into Nigeria and the demand has particularly been increasing in a place like Niger State where its use for the cultivation of low land rice is increasingly becoming popular.The objectives of this study are to i) determine the production cost of using power tiller for *sawah;* ii) determine the profitability of using power tiller for *sawah* and iii) come up with appropriate management approach that will bring in the optimum application of power tiller for *sawah*.

Methodology

Description of the equipment: The power-tiller or walking tractor, as it is sometimes called is a single-axle (two-wheel) tractor. This particular one is of Indian made and the model is VST-SHAKTI 130 DI with 10 kW (13 hp) rated power, diesel engine of 2400 rpm rated crankshaft speed. The engine is single cylinder horizontal 4 strokes, water cooled and hand-cranking type. The driving wheels are of two types: the pneumatic type for normal traction and the steel or cage wheel for wet puddling.

Field layout and operations: The performance evaluation of the machine was carried out in wet puddling on two different rice field located at Shaba-Maliki and Ejeti village near Bida on a clayey loamy, sandy soil, under the guinea savannah ecology of Nigeria. Bida is 137 m above sea level and lies on longitude 6°01'E and latitude 9°06'N in Niger State of Nigeria.

The 600 mm tine cultivator was attached to the power tiller and it was used for puddling of the field before the transplanting of the rice was done. Fashola *et al.* [3] have a detailed description of the *sawah* system on farmers' fields. Some of the parameters assessed during the field test included average speed of operation, average wheel slip/travel reduction, average draught of implement and fuel consumption. The soil properties monitored included soil moisture content, bulk density, porosity, penetrometer resistance/cone index and shear strength. The core technique was used in obtaining samples for bulk density measurement, soil penetrometer and shear vane readings were determine *in situ*. Soil samples were obtained at various depths of 7 cm intervals, soil laboratory tests were all performed using standard procedures [5].

Cost determination: Cost calculations for mechanized farm operations are almost similar everywhere. Usually there are basic assumptions and few other adjustments are made to suit the particular needs and locality. For example, while in some countries taxes are paid on agricultural machines and implements, in Nigeria they are tax-free.

Costing of mechanized operation can be done either on an hourly basis or a hectare basis. The former is only meaningful when accurate records of the time (machine hours) are available. In Nigeria, 34.7% of the operator's time was spent in doing unproductive work 31.2% of these representing avoidable delays [1]. It would be unfair and inaccurate to add this idling time to the overall time for carrying out an operation. Moreover, the farmer is more interested to know how much it will cost him to farm a unit area so as to compare it with the yield per area.

Generally, the factors involved in the calculation of operating costs of farm machinery can be grouped under two main titles – fixed and variable factor or costs.

Fixed factors include the factors whose cost must always be taken into account whether the machinery is in operation or not. They are related to machine ownership and represent a form of financial discipline, to make sure that the business does in-fact pay-off capital investment within a reasonable period. They are depreciation (on tractor and on implement), interest on investment, taxes, insurance and shelter.

Many ways have been put forward for calculating depreciation. These include the inventory method, the straight line method, sum of the years' digits method and the sinking fund method [4]. After reviewing these methods, it was found that, for the Nigerian condition, the straight line method was most appropriate. The equation used was: Depreciation = Initial cost of machine/ Expected total hours of use.

Variable factors are the remaining operating costs that depend on particular operations and are directly proportional to the machinery usage. They include labour (operator and mechanic), spares, fuel and lubricants.

Labour – The usual daily rate for skilled workers like operators and mechanics increases from ₦500 in 2002 to ₦700 in 2006 per day, but it is very uncommon to employ mechanics on a daily wage basis; instead they are paid whenever their services are needed in a case of sudden breakdown.

Fuel– The variables that have direct influence on the fuel consumption for any operation are speed of operation and soil properties (texture and moisture) and skill of operator. Fuel cost per ha can be given as $F = (f \times p)/C$, where F = fuel cost/hectare (ha), f = fuel consumption rate (l/h), p = cost of fuel (l), C = rate performance of machine or machine capacity (ha/l).

The operating cost of power tiller was determined based on its annual use for a period of five years usage. The cost per year was calculated by the relation:

$$C = \frac{(FC)}{100} P + H \frac{(R\&M)}{10^4} + L + O + F$$

where C = annual cost, FC = annual fixed cost, % (interest + taxes + depreciation); this value is of ten rounded off at 16%, P = purchase price, H = hours used per year, R&M= repair and maintenance cost, % per 100 h of use, L= labour cost per year, O = oil cost (often 10% of fuel) per year and F = fuel cost per year.

Results and Discussion

The summary of the field tests, effects of the tillage tool on some soil physical properties and the operating cost of power tiller are

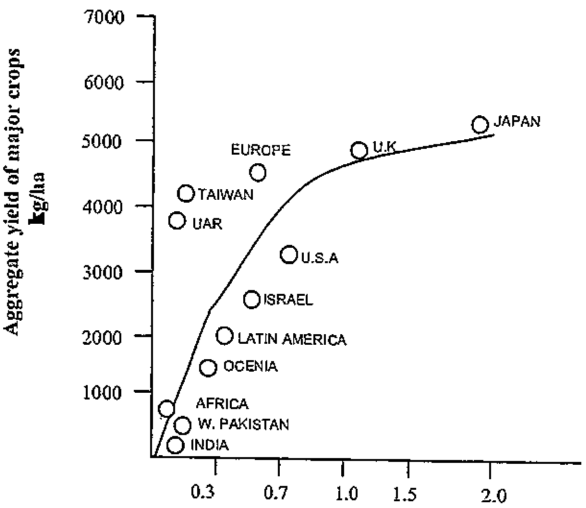

Figure 1. Relationship between yield and power input [2].

presented in Tables 3-6. The average values of 93 and 92% were recorded for field efficiency at Ejeti and Shaba-Maliki respectively. 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 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) (Table 3) almost doubles that of Shaba-Maliki (13.15 hr/ha) (Table 4). 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 while Shaba-Maliki was cultivated with dry season tuber crop. Ejeti therefore had more grown weeds than Shaba-Maliki. Same value was obtained for draught at both locations, the average fuel consumption of the machine at both sites with other parameters assessed conform with derivation of basic desiring of small tractors [2].

It was observed (Table 5) that the bulk density increased with depth, both before and after operation but the bulk density reduced after the operation. Porosity measured immediately after operation at different depths showed an improvement down the depth. This indicates a positive condition for the flow of water and air through the soil profile and minimum resistance to root growth and proliferation. The power tiller with the attached tillage tool has improved the soil moisture content, reduced shear strength and penetration resistance respectively as evident in Table 5.

The operating cost of power tiller (Table 6) was determined based on the annual usage and farm size for agricultural purpose. It was evident that the operating cost per annum increases yearly till the year 2005 also the area of coverage and the number of days worked based on 4 hours per day usage. For the five years of operation, the highest area of coverage was recorded in 2005, while the same year recorded highest cost of repair and maintenance. The first three years recorded same volume for repair and maintenance cost until the break down that occurred in 2005 while it was a bit lesser in the subsequent year.

The price of diesel varied between ₦45 per litre to ₦90 per litre between 2002 and 2006, this also added to the increase in the cost of production yearly. Never the less comparing the income, based on hiring services, there was shortage in 2002. This might be because the operator was yet to be familiar with the machine, he could not make maximum use of the machine to cover much area. For example in 2002, 80 hrs of operation covered 5 hectare while twice the area was covered in 2003 in 120 hrs, the operator was able to save 40 hrs. After 2003 there was a gradual increase in the revenue generation as the hiring rate increases slightly with other factor of production.

Conclusions

Having determined the production cost of using power tiller for *sawah* for a period of five years at Ejeti and Shaba-Maliki village, it is obvious that the power tiller is capable of primary and secondary tillage operations and is most suitable for operations in hilly regions, wet conditions and for small holdings. Given the right set of implements and attachments, the power tiller is capable of performing most of the field operations in the intensive cultivation of *sawah* rice production.

The light weight of power tiller is a favourable factor for working in wet and dry land conditions of *sawah* fields, it does not sink in wet paddy fields and creates least disturbance to soil structure. In view of the advantages, it has been decided that greater thrust be given to the use of power tillers as it is relatively cheaper than tractors and farmers can afford to invest their money in it. Power tillers are considered appropriate alternative for most farmers in developing countries like Nigeria given their common average size of farm and economic situation. It is also believed that the performance of the power tillers may vary appreciably on the positive side with increasing adoption and mastery of use by owners, operators and mechanics. Mass adoption will also certainly lead to local manufacture of most components giving rise to employment opportunities for many people.

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Table 1. Main characteristics for two-wheel tractor.

Category	Overall dimension L*W*H (Mm)	Track width (mm)	Clearance	Mass (kg)	Maximum traction (kN)	Speed (km/h)	Power (kW)	Engine
I	1500x410x1000	315	150	45-60	0.3-0.5	1.55	2.7-4	2- or 4-cycle gasoline or diesel
II	830-530x1800x1230	400-700	200	75-148	0.6-1.2	1-12.6	5-7	4-cycle gasoline or diesel
III	1900x560x800x2680x960x1250	400-750	200 546[1]	175-465 5.47[1]	1.37-3.7 3.91[1]	1-16.3	8-10.2	

[1]Parameters for a clearance two-wheeled tractor of special design [1]. Source: catalogues from manufactures from Europe and Asia and publication on special design.

Table 2. Average annual demand for agricultural tractors in 1993-1995.

Country	Power tillers (Two-wheel)	Tractor (Four-wheel)
Bangladesh	4,300	700
India	5,400	131,700
Indonesia	80,000	600*
Rep. of Iran	10,000	15,000
Nepal	100*	800*
Pakistan	1,700*	31,100
P.R. of China	1,100,000	84,000
Philippines	2,800	400
Rep. of Korea	90,000	8,400*
Sri Lanka	8,600*	2,000*
Thailand	76,000	6,200
Total	1,379,200	280,900

*Computer estimates
Source: Regional Network for Agricultural Machinery National Institutes

Table 3. Field performance test of VST SHAKTI 130 DI power tiller at Ejeti.

Parameter	Plot I	Plot II	Plot III	Average
Slippage (%)	10.53	10.53	10.53	10.53
Effective field capacity (ha/hr)	0.0393	0.0460	0.0558	0.0470
Theoretical field capacity (ha/hr)	0.0416	0.0492	0.0605	0.0504
Field efficiency (%)	94.44	93.55	92.13	93.37
Working speed (km/hr)	2.66	2.66	2.66	2.66
Draught (kN)	1.73	1.73	1.73	1.73
Fuel consumption (L/ha)	9.35	10.94	13.28	11.19
Fuel consumption (L/hr)	0.367	0.503	0.741	0.537
No of rounds of operation	1	3	3	
Area of land (ha)	0.02941	0.03860	0.0372	0.0350
Average time of operation (hr/ha)	25.45	21.74	17.92	21.70

Table 4. Field performance test of VST SHAKTI 130DI power tiller at Shaba Maliki.

Parameter	Plot I	Plot II	Plot III	Average
Slippage (%)	10.53	10.53	10.53	10.53
Effective field capacity (ha/hr)	0.1416	0.0559	0.0689	0.0888
Working speed (km/hr)	2.66	2.66	2.66	2.66
Theoretical field capacity (ha/hr)	0.1517	0.0606	0.0763	0.0962
Field efficiency (%)	93.37	92.17	90.34	91.96
Draught (kN)	1.73	1.73	1.73	1.73
Fuel consumption (L/ha)	11.98	13.30	13.46	12.91
Fuel consumption (L/hr)	1.696	0.743	0.927	1.122
No of rounds of operation	1	3	3	
Area of land (ha)	0.02254	0.02857	0.03565	0.02892
Average time of operation (hr/ha)	7.06	17.89	14.51	13.15

Table 5. Effect of tillage tool on some soil physical properties (M.C. moisture content, B. D. bulk density, C. I. penetrometer resistance/cone index, S.S. shear strength).

Depth	Before operation					After operation				
(cm)	M.C. (%)	B.D. (g/cm³)	C.I. (N/m²)	S.S. (MPa)	Porosity (%)	M.C. (%)	B.D. (g/cm³)	C.I. (N/m²)	S.S (MPa)	Porosity (%)
0 – 7	34.47	1.26	24.12	0.022	52.5	39.54	1.36	0	0	48.7
7-14	19.54	1.65	37.90	0.014	37.7	29.59	1.53	3.45	0.006	42.3
14-21	16.92	1.80	93.02	0.060	32.1	19.40	1.67	15.16	0.010	37.0

Table 6. Annual use of power tiller.

Year	Total annual use (hr)	Total annual coverage (ha)	R&M cost per annum (₦)	Cost of fuel per annum (₦)	Total cost of operation per annum (₦)	Hiring cost per annum (₦)
2002	80	5	10,000	2,722.5	27,554.75	15,000.00
2003	120	10	10,000	6,050	32,855	40,000.00
2004	160	16	10,000	11,616	51,338	80,000.00
2005	220	25	35,000	25,606	132,466	175,000.00
2006	120	22	32,444.50	23,958	81,178	154,000.00