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DESIGN AND FABRICATION OF AN ENGINE POWERED ROTO-WEEDER

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ABSTRACT

The need for an effective weeding equipment suited for the tropics to reduce time loss, labour and operational cost cannot be overemphasized. To this end, an engine-powered, manually operated roto-weeder employing the principle of a rotary tiller and adapted to operate on a deltaic terrain was designed, fabricated and tested in an experimental field. The weeder is powered by a 1.45hp petrol engine with an operating speed of 1130 rpm and equipped with 16 L-shaped standard cutting blades. The depth and width of cut of the blades are 3 and 350mm respectively. At the time of the machine test, the field location had well-drained soil classified as sandy loam with compositions of 76% sand, 7.28% silt and 15.95% clay. The moisture content was 18%wb. Field tests conducted showed weeding field capacity 0.037ha/hr and weeding efficiency 90%. The performance evaluation of the roto-weeder at the tested average operating speed of 0.036m/s were: standard deviation, (SD) 118.84 and coefficient variation (CV) 1.73. These results show the weeder to be effective and efficient. The weeder is simple and locally fabricated. The cost of producing the roto-weeder was estimated at about 275 US Dollars (₦35,000.00).

KEYWORDS: Manually operated, engine-powered, roto-weeder, design.

1. INTRODUCTION

Plants that grow in places where they are not required (i.e. weeds) have caused much problems in agricultural practices particularly in the tropical regions of the world. They remain the most important crop production constraint, competing seriously with crops for nutrients, thereby reducing productivity. In the tropics, especially the Niger Delta region of Nigeria, where, incessant rainfall throughout the year results in fast growing tall weeds, which are detrimental to crop growth and yield. Sharma et al (1997) stated that the presence of weeds in direct-seeded upland paddy rice is the cause of yield reduction within the range of 42- 65 percent.

Weeding is inevitable for a proper crop management in the tropical region. Hence various weeding practices such as biological, chemical, cultural, thermal, mulching and mechanical weeding have been introduced, with various reported levels of success. According to Odigboh and Ahmed (1980) weeding constitutes about 75-90% of farm labour in Nigeria. This is because weeding is mainly traditional, which is strenuous, time consuming and labour intensive.

In most of the tropical countries, small-and medium-scale farmers use the traditional short-and long-handle hoes for weeding and these have stood the test of time (Oladipo, 1997). However, the use of hoes and cutlasses in weeding is limited by time and money (Kamal and Babatunde, 1999). Manually operated weeders with field capacities greater than that of the traditional long-handle hoes have been employed in weeding, but are found to be ineffective (Rangasamy et al., 1993; Kamal et al., 1991) as cited in Kamal and Babatunde (1999). This prompted the need for the design and development of several engine-powered weeders for tropical agriculture. An engine-powered rotary weeder for wetland paddy was developed by Viren and Ajav (2003), but had difficulties of maneuverability and was not easily affordable by peasant farmers. Ariyentine (2004) developed a Chinese internal combustion engine-powered weeder; an innovation motivated as a result of problems encountered in cultivating 5 acres (2ha) with system of rice intensification (SRI). Researchers that had made attempts in this direction are; Manuwa and Olofinkua (2009) developed and tested a low-cost mechanical weeder for environmental preservation.

Oni (1990) developed an ox-drawn straddle-row rotary weeder. Aderele and Braide (1992) developed and tested a motorized mechanical weeder. Onwuji (1997) developed a mechanical weeding hoe. Olukunle and Oguntunde (2006) developed and tested a row-crop weeder as cited in Manuwa and Olofinkua (2009).

The objective of the work is to design and fabricate an engine driven roto-weeder for row crops on a deltaic terrain, test the weeding efficiency in order to evaluate its performance.

2. MATERIALS AND METHODS

2.1 Design Principles and Considerations

The following factors were considered in the design of the machine:

a) Soil resistance properties to tillage implement draft.
b) Materials selection in terms of cost, availability of parts, overall weight, durability, safety, affordability and depth of cut.
c) The transmission mechanism and the best engine power for the operation.
d) The fundamental engineering principles.

The functional parts of the weeder were designed using basic engineering principles.

2.2 Description of the Roto-weeder

The roto-weeder comprises the following components: chassis, frame, handle, engine, rotary blades, wooden engine seat, sprockets, chain, shaft, ground wheel and gauge wheel (cutting depth adjuster) (Fig.1and plate 1).

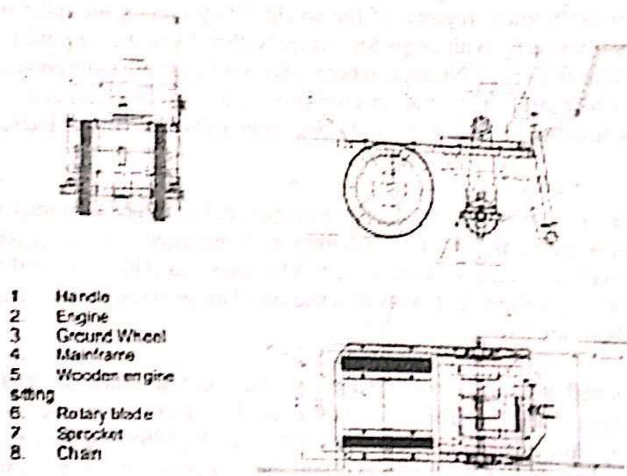

Fig. 1. Autographic view of the component parts of the roto weeder

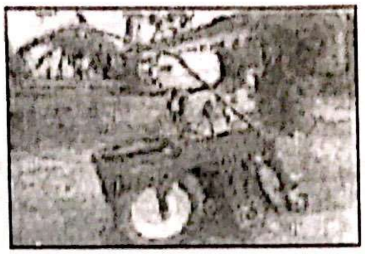

Plate 1: Roto weeder

The chassis consists of a main frame and a supporting frame with wooden engine seat. The wooden seat served as an absorber of vibration and reduces excessive noise. Attached to it is a wide spread rubber material that prevents the operator from cut-off soil slices and weeded materials. The frame (made up of mild steel angle bar of cross section 50 x 50mm) provides points of attachment for all parts of the weeder. At the front of the weeder, two ground wheels with pneumatic tires are fitted. And mounted behind the two sides of the ground wheels are V-shaped short frames where the rotary shaft blade is attached.

The rotary blade consists of a ground-wheel driven rotating horizontal shaft connected to the set of 16 blades arranged at an angle of 15^0 to vertical axis. The blades are L-shaped and fastened to a hollow shaft with bolts and nuts. These blades are the cutting unit of the weeder which are made with replaceable hardened mild steel.

The handle of the machine is made from hallow shaft. It is fitted to the main frame. The outer diameter and length of the handle are 22 and 1000mm respectively. It is adjustable to any position that suits the comfort of the operator.

The power transmission system is made up of a driving 80mm-diameter sprocket and a driven 140mm-diameter sprocket with 23 and 69 numbers of teeth respectively. By this arrangement, the engine speed is reduced to 1103rpm at the ground wheel. The 22mm-diameter shaft is made of steel. A sprocket is fitted to the shaft at one end with a key. The chain length is 600mm.

The two ground-wheels are equipped with pneumatic tires, and fixed to two short mild steel shafts of diameter 20mm. At the rear end of the weeder is gauge wheel provided for depth adjustment of the cutting unit. Depth adjustment is achieved through a 254 x38mm cross-section rubber-coated iron wheel fitted to the gauge wheel and operating on the principle of the screw jack. The machine, which operates on the principle of a rotary tiller, is powered by a small internal combustion engine (prime mover). The power required for weeding operation is expended in cutting, throwing out the cut-off weed with soil and moving the machine. The light-weighted internal combustion engine has a rated output of 1.45hp and a speed of 1103rpm.The engine seats on a wooden board, which acts as a vibration damper.

2.3 Design Theory

The roto-weeder is designed on the principle of the rotary tiller. In operation, the rotary blades undergo two types of motions - rotary and translational forward motions.

2.3.1 Design of Shaft Diameter

The shaft diameter was obtained from the relationship (Shingley, 1989).

$$ds = \left[16\sqrt{\frac{(K_m M)^2 + (K_t x T)^2}{\pi fs(perm)}}\right]^{\frac{1}{3}} \quad (1)$$

Where: k_m = combined shock and fatigue factor for bending; K_t = combined shock and fatigue for torsion (twisting); T = applied torque, N/m; $fs_{(perm)}$ = permissible shear stress N/m^2; ds = diameter of the shaft, m; using this diameter of 20mm was obtained.

2.3.2 Power Requirements

There are three major powers involved during operation, which are:

- Power needed for cutting or soil deformation, Nd
- Power expended on machine motion, Nm
- Power expended throwing out of soil and weeds, N_T

Thus, total power expended for cutting operation is denoted by N and obtained from the relationship. (Berezovsky and Petrov, 1988)

$$N = Nd + Nm + N_T \quad (2)$$

Since the machine is hand-push type, power expended on machine motion is discarded, i.e. $N_m = 0$
Therefore total power required is

$$N = Nd + N_T \quad (3)$$

Where: Nd = power expended on soil deformation; N_T = power expended throwing out of soil and weeds; N = 1.63kW.

In the weeding operation, losses are encountered due to friction arising from rotary parts such as chain, sprocket teeth and bearing. Therefore, factor of safety 1.5 is considered to take care of the losses.

$$Power(N) = \frac{6.63}{1.5} = 1.0867kW \quad (4)$$

The horse power of the machine for effective drive is obtained from the relationship.

$$Hp = \frac{power}{0.75} \quad (5)$$

$$Hp = \frac{1.0867}{0.75} = 1.45hp$$

2.3.3 Required number of blades

The number of blades attached to the weeder shaft was calculated from the relationship.

$$n = \frac{2\pi R}{L\max} \quad (6)$$

Where: R = radius of the rotary shaft, m; L max = the distance covered by the blade, m; n = the number of blades, n = 16.

2.4 Field Tests

The field test was conducted in order to determine the performance of the roto-weeder in terms of weeding capacity (ha/hr), weeding efficiency (%) and the depth of cut (mm). Fig. 2 shows the field test of the roto-weeder.

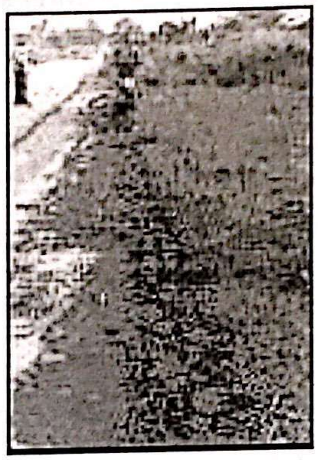

Fig. 2. Field performance test of roto-weeder

2.4.1 Field Conditions

The machine was tested in the experimental plots of the Department of Agricultural and Environmental Engineering, Rivers State University of Science and Technology, Port Harcourt. The field plot was on a flat land without crops. The experimental field of area 4.0×2.5m was marked in six rows. During the time of testing the location had well-drained soil classified as sandy loam with composition of 76% sand, 7.28% silt and 15.95% clay. The moisture content was 18%wb. There were three main species of weeds present, which were; *sidealba, trichosma zeylanicum and ipomea spp.*

2.4.2 Test Procedures

The roto-weeder was powered through the internal combustion engine and started the weeding process at one end of the rows of the field. The lengths of the rows were determined with a tape rule. The weeding operation for evaluation of the locally fabricated weeder was demonstrated on the marked out field. The effective area of coverage of 13m^2 was determined using a measuring tape. The time used in weeding the weeds was determined with a stopwatch. Time was recorded in weeding the area of the field. There were six field text runs. The average expended times in weeding and turning were 110.2s and 5.8s.

The depth of cut was also randomly measured with a steel rule. Before and after weeding, weed samples were collected from 1-m squares in three replications. The field capacity was calculated from the relationship.

$$\text{Field capacity } (F_c) = \frac{A}{T_p + T_1} = ha/hr \qquad (7)$$

Where: A = area covered, ha; T_p = productive time, hr; T_1 = non-productive time, hr.

The weeding efficiency was calculated from the relationship.

$$(W_f) = \frac{W_1 - W_2}{W_1} x\ 100 \qquad (8)$$

Where: W_1 = number of weeds before weeding (no/m^2); W_2 = number of weeds after weeding (no/m^2).

The effective width and designed width of cuts were measured by using a tape rule.
The angle of cut was calculated from the relationship.

$$\text{Sin}\ \phi = 1 - \frac{a}{R} \qquad (9)$$

Where: ϕ = angle of cut in degree; a = depth of cut, mm; R = radius of rotary shaft, mm.

The maximum thickness of soil slice was calculated from the relationship (Odigboh, 1979).

$$\delta \max = X_Z \text{ Cos } \phi \qquad (10)$$

Where: δ max = thickness of the soil slice.

The effectiveness of the weeder was calculated as coefficient of variation from the relationship:

$$CV = \frac{SD}{M} x100\% \qquad (11)$$

Where: SD = Standard Deviation of weeding operation and is calculated from the relationship:

$$SD = \frac{\sum(x-m)^2}{n} \qquad (12)$$

Where: X = the number of weedings in the samples; N = number of samples collected.

3. RESULTS AND DISCUSSION

The engine powered roto-weeder that was designed and fabricated is presented in Fig.1. The weeder was tested on sandy loam soil. Table 1, shows the major components of the weeder.

Table 1: Specification of the engine powered roto-weeder

(1) Type	-	Walking behind type
(2) Over all dimensions		
Length	-	1056mm
Width	-	405mm
Height	-	706mm
Main frame length	-	70mm
Main frame width	-	40.5mm angle of 50x50mm
Support frame	-	36 x 32mm mild steel
Vertical supporting frame	-	52mm
(3) Prime Mover		

Type	-	Honda
Type of Cylinder	-	Single
Stroke	-	6 times
Bore	-	50mm
Displacement volume	-	1.4hp
Compression ratio	-	600 ℓ /min delivery volume
Power speed	-	1130rpm
(4) The power transmission system		
Chain length	-	600mm
Sprocket diameter larger size (shaft)	-	140mm
Sprocket diameter smaller size (single)	-	80mm
Number of teeth for larger sprocket	-	69
Number of teeth for smaller sprocket	-	23 Pitch diameter - 15.87mm
(5) Cutting unit		
Type	-	Rotary
Blade type	-	L – shaped blade
Number of blades	-	16
Width of cut	-	350mm
Depth of cut	-	3mm
Diameter of shaft	-	20mm
(6) Ground clearance	-	150mm
(7) Wheels	-	Two ground wheels
	-	One gauge wheel at rear end
Type of tire	-	Hollow tube type

Table 2 shows that there is no significant difference in the standard deviation (SD) and the coefficient of variation (CV) at different rows of weeding operations. The little variation in the values of SD and CV is an indication of uniform weeding efficiency of the weeder in the tested field runs. The results show that the average weeding efficiency was 90%.This efficiency is attributed to the moisture content of 18%wb of the soil. Another factor is the unploughed condition of the field test which deterred the blades cutting ability. The table shows the average depth and width of cuts of 3mm and 350mm respectively. The average field capacity of the weeder is 0.037ha/hr. The weeding time per row in the field test, were 105s, 109s, 102s,106s, 108s and131s bringing the average time taken for weeding the rows to be 110.2s. The weeding speed per row, were 0.037m/s, 0.036m/s, 0.037m/s, 0.037m/s, 0.037m/s and 0.039m/s bringing the average weeding speed to 0.036m/s for the same plot. The non-productive times, (i.e. time lost during turning) per row were 4s,6s,5s,6s,8s and 6s bringing the average non-productive time to be 5.8s.The effectiveness of the weeder is considered high at the operating time of 131s, followed by 108s but considered low at operating time of 105s. The field capacity and weeding efficiency were influenced by the forward speed of the weeder, that is, they increased with increase in operating speed. The result trend and efficiencies were similar to that of Manuwa and Olofinkua (2009), where field weeding capacity was 0.035ha/hr and weeding efficiency 96% under moisture content level of 10%db of sandy clay loam soil. Though little improvement was noticed on the weeding efficiency of Manuwa and Olofinkua (2009) over 90% of the weeder developed by Nkakini et al., (2009). This little difference is as a result of moisture content of 10%db level and the present state of the soil condition during the period of the field test.

Olukunle and Oguntunde, (2006) obtained field capacity of 0.075ha/hr and an average field efficiency of 90% for a row crop weeder. The differences in field capacity may be as a result of the width of the machine being 50cm (500mm) and the possible soil condition where the weeder was tested.

The cutting angle of the blades was calculated to be 45^0. The number of the cutting blades and the maximum thickness of cut were calculated to be 16 and 0.0078mm respectively.

Table 2: Field test data for the roto-weeder

Operational items	No of Weeding rows						Average
	1	2	3	4	5	6	
Time taken for each rows (sec)	105	109	102	106	108	131	110.2
Average speed per row (m/s)	0.037	0.036	0.037	0.037	0.037	0.039	0.036
Turning time (sec)	4	6	5	6	8	6	5.8
Field capacity (ha/hr)	0.035	0.037	0.036	0.036	0.036	0.037	0.037
Depth of cut(mm)	2.99	3.10	3.19	3.20	3.21	3.21	3.00
Width of cut(mm)	320	334	394	350	350	350	350
Weeding efficiency (%)	87.80	91.10	92.10	92.10	92.11	92.12	90
SD	118.96	118.51	118.86	118.84	118.86	118.85	118.84
CV (%)	1.74	1.74	1.72	1.80	1.73	1.74	1.73

4. CONCLUSION

The engine powered roto-weeder was designed, constructed and evaluated. This is to facilitate the mechanization of the laborious manual weeding operation associated with a smallholder farmer. From the experimental field test runs, the developed weeder provides a practical means for mechanical weeding with field capacity of 0.037ha/hr, weeding efficiency of 90%, width and depth of cuts 350mm and 3mm respectively. The weeder performance was high at average operating speed of 0.036m/s with standard deviation (SD) and the coefficient of variation (CV) of 118.84 and 1.73% respectively. The operation of the weeder does not require skilled labourer. However, maintenance of the prime mover requires experienced mechanic. The engine powered roto-weeder would be viable for medium scale farmers.

Enhancing mass production of this roto-weeder could lead to replacement of the traditional hoes and cutlasses which dominate small and medium-scale farming in the tropics.

The cost of the weeder is estimated at ₦35,000.00 ($275).

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