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Research Paper

Design and Fabrication of a Rigid Tine Cultivator

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ABSTRACT: *Soil cultivation is an activity through which humans become directly involved in the management of the lives and life cycles of certain plants. Soil pulverization has been energy consuming work in farming operations. Therefore, an implement which can loosen soil effectively for easy penetration of plant roots and water is necessary. A rigid tine cultivator was designed and fabricated in the Department of Agricultural and Bio-Environmental Engineering, the Federal Polytechnic, Ado-Ekiti. Locally sourced materials were used in the fabrication which consists of seven tines mounted on a rigid tine shank and attached to a rigid frame. It was coupled to a tractor through the three point linkage during operation and depth of penetration is controlled by the hydraulic lever. Field test results showed that fuel consumption was 7.6L/ha, effective field capacity was 0.96ha/hr, depth of penetration was 0.74cm, theoretical field capacity was 1.8ha/hr, and field efficiency was 53.7%.*

KEYWORDS: *Tine cultivator, soil cultivation, fabrication*

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I. INTRODUCTION

Soil tillage consists of breaking the compact surface of earth to a certain depth and to loosen the soil mass, to enable the roots of the crops to penetrate and spread into the soil. Also tillage breaks soil, enhances the release of soil nutrients for crop growth, destroys weeds and enhances the circulation of water and air within the soil (Parmar and Gupta, 2016). Cultivator is a mechanical implement for breaking up the soil and uprooting weeds (Raut *et al.,* 2014). A cultivator is also an agricultural implement for breaking up the soil and uprooting weeds. Cultivators are secondary tilling implements that means, farmers use cultivators after the land had been ploughed. Farm machinery is a key driver of agricultural productivity. The motivation to mechanize farming activities is influenced primarily by a desire to increase food security for a family, increase household income or improve quality of life (Kepner *et al.,* 1987). The importance of land cultivation to the growth and development of crop cannot be overemphasized. A well pulverized soil is important for the better growth of plants and good yield. However, the primitive methods of land tillage, of using hand tools is slow, tedious and ineffective to meet food security demands of food production in Nigeria. The imported rigid tine cultivator is expensive, which is not affordable to local farmers. It therefore necessary to develop a locally and indigenous cultivator for alternative means of pulverizing hard soil which characterized Nigeria soil. A cultivator performs functions intermediate between those of plough and the harrow. Destruction of weeds is the primary function of a cultivator. Rigid tine cultivators are those that do not deflect during tillage operation on the field. The tines are bolted between angle braces, fastened to the main bars by sturdy clamps and bolts. The spacing of the bolts is changed simply by slackening the bolts and sliding them to the desires position. Rigid tine cultivator are mounted on the front and rear toolbars, the spacing between the times can easily be adjusted without getting the times choked with the stubbles of the previous crop or weed growth. A pair of gauge wheel is used for controlling the depth of penetration. No springs are available with these cultivators. These cultivators are available in single row and double row. There are five shanks in single row cultivator and nine shanks in double row cultivators. These shanks are made of special alloy steel SG iron. This cultivator has the feature of easily adjustable row width as per the requirement is as shown in figure 1.

Figure 1: A rigid tine cultivator

II. METHODOLOGY

A. Design Consideration

The design of a rigid tine cultivator is based on the following considerations,

1. Simple and efficient: The machine is simple in design using locally available materials to ensure effectiveness in tillage operations.
2. Durability: Mild steel material is used to provide durability in order to overcome corrosion and deformation.
3. Strength and Rigidity. The machine should be strong and rigid enough to break soil into lumps and fine tilt.
4. Components parts can easily be dismantled for replacement, maintenance and repair.

B. Design Feature

The developed rigid tine cultivator consists of the following components:

i. Frame: The frame is the skeletal structure which holds the whole parts of the implement together and to which the point of attachment to the tractor three-point linkage is welded. The design factors considered in the determination of the material required for the frame are the weight and strength. It is rectangular.

ii. Shank: The shank is the part of the rigid tine cultivator that holds the tine firmly. The material selected for this part requires high strength and durability to withstand shock and vibrations during operation.

iii. Tine: This is the part of the rigid tine cultivator that enters into the soil and pulverize the soil, it has a sharp/pointed edge that enters into the soil.

iv. Bolt and nut: All the parts of the cassava harvester were coupled together with the means of bolt and nut at the respective joint.

v. Point of attachment (3-point linkages): The point of attachment is the point at which the implement is coupled/hitched to the tractor through the three point linkages which is coupled with the procedure LEFT - RIGHT – TOP.

C. Design Analysis.

The following parameters were obtained by design calculation:

i. The weight of the implement
ii. Power requirement of the implement
iii. Draft requirement of implement

i. Determination of weight of the implement.

The weight of the implement is a very important consideration in the implement design of the implement as it a determinant of the magnitude of weight that is exacted on the frame members and also influences the durability, firmness and physical outlook of the implement to avoid physical disfiguration. They were obtained as thus:

Weight of frame = 75.38kg

Weight of shank (7) =11.53kg × 7= 80.71kg

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Weight of tine (7) =0.29kg×7=2.04kg
Weight of u-bolt (14) = 0.692kg×14=9.69kg
Weight of 3-point leakage = 6.917kg
Weight of lock bolts = 0.458kg×3=1.37kg
Weight of tine bolts (21) = 0.025kg×21=0.53kg
Weight of 3-point hitch brace = 4.335kg
Total weight of implement = (75.38+80.71+2.04+9.69+6.92+1.37+0.53+4.33) kg×10 =180.97×10 = 1809.7N

ii. Determination of implement power requirement

The relationships in the equation
Power = (draft+ weight) × speed
= 27000+1809.7) ×12×1000÷3600
Where,
Draft = 27000
Speed = 12km/hr
Weight = 1809.7N
Power = (28,809.7) ×3.3
= 32970.855W
= 44Hp

iii. Determination of implement draft

Draft = soil resistance × width of implement × cutting depth
Where,
soil resistance = 0.12×10^6N/m (Lomling and Mori, 2015).
Width of implement = 1.5m
Cutting depth = 0.15m
Draft = $0.12 \times 10^6 \times 1.5 \times 0.15$
= 27000N

iv. Draft requirement of a rigid tine cultivator

Draft is the force that is requires pulling the implement through a horizontal distance of travel (Mehta *et al.*, 2014). The draft requirement was measured by using a pre-calibrated load cell with a digital indicator. The draft requirement for tilling tools is a function of operating speed and depth is an important criterion for the evaluation of tillage tools in field and/or laboratory conditions (Deshpande *et al.*, 2015). The formula is:

Draft (N) = Soil resistance x width of implement x cutting depth (Sapkale *et al.*, 2011).

v. Power Requirements of a Rigid Tine Cultivator

The power requirement by the implement is very important from the point of view of the design and the user. This helps to determine which tractor that match the implement. Power requirement for the operation of the implement was calculated by the following formula:

Power requirement, (KW) = draft (KN) x speed (m\s) (Sapkale, 2011).

D. Fabrication Procedure

Most of the parts of the rigid tine cultivator were fabricated in the workshop of the Department of Agricultural and Bio-environmental Engineering, The Federal Polytechnic, Ado-Ekiti. The U-bolt used to fasten the Shank and tine assembly to the frame was bought out as well as bolts and nuts.

The frame which supports every other component was fabricated using 50 mm thick mild steel square pipe of length 1500 mm and width 450 mm making it rectangular in shape. The shank was fabricated using 100 mm thick mild steel flat bar of length 150 mm which was bent at the 100 mm mark at angle 35^0. The tine was fabricated using 100 mm mild steel flat bar pointed at the end which engages the soil. The tine is then mounted on the shank. The tine and shank assembly is reproduced to make up seven gangs. The seven gangs is fastened to the frame using U-bolt and a mild steel flat plate. The gangs are spaced 375 mm apart at both front and rear end. Three-point linkage was fabricated through which the implement would be attached to the tractor.

E. Testing of the Rigid Tine Cultivator

Trial tests (3) were conducted to ensure the effectiveness of the implement in breaking and preparation of the soil for agricultural purposes without any form of damages to d soil texture and formation.

A well mechanized farm around the school premises was sited and used for the soil preparation the implement was coupled to the tractor appropriately through the three point linkages from the left link to the right link and to the top link and was conveyed to the farm. A 100m by 50m ploughed land was marked out for the cultivation (further breaking of the soil) operation.

The tractor mounted with implement was position at the start of the marked area, the implement was lowered into the soil and was driven through the ploughed land at the required speed to the top end of the marked area the implement was raised up at the top end of the marked area and a U-turn movement was made to position the implement at the top end of the marked area. The procedure was also repeated 3 more times for further loosing and breaking of the soil clods. Some test parameters were determined which includes the effective capacity, theoretical field capacity, field capacity and fuel consumption use.

i. Determination of fuel consumption

Fuel consumption can be estimated by determining how much fuel is being used for a particular field operation and compare it to average usage. This measurement can be completed by filling the fuel tank of the tractor before and after a field operation, noting the number of hectares covered. The number of liters used, divided by the number of hectares covered, and it was given in liters per hectare (l/ha).

Where,

Tank capacity=75L
Height of tank=55.5cm
Initial level of fuel=29cm
Final level of fuel=26.75cm
Fuel consumed= $75 \times \frac{0.05}{55.5}$=0.068$l$
Length of strip=20m
Width of implement=1.5m
Number of trip=3
Area covered=length of strip × width of implement × Number of trip
$=20 \times 1.5 \times 3 = 90m^2$

Fuel consumption $\frac{l}{ha}=10000 \times \frac{0.068}{90} =$7.6l/ha 2

ii. Determination of theoretical field capacity

The theoretical field capacity of a farm machine is the rate at which at which a machine would perform its functions if there were no interruptions – no clogging, turning, slowing or filling of hoppers, that is, the number of hectares that can be worked per hour.

Theoretical Field Capacity = $\frac{width(m) \times speed\ (^m/_s) \times 36}{10000}$ 3

where,

Width = 100m
Speed of cultivating operation = 5 m/s
TFC = $100 \times 5 \times \frac{36}{10000}$ 4
=1.8ha/hr

iii. Determination of effective field capacity

This is the number of hectares that can be worked per hour.

C = $\frac{\text{Total Area (ha)}}{\text{Total Time}}$ (ha/hr) 5

Where,

Area covered = 20 $\times$ 1.5 $\times$2= 90 m^2
Time of operation = 33.6sec
C = $\frac{A \times 3600}{10000 \times t}$ (ha/hr.)
= $\frac{90 \times 3600}{10000 \times 33.6}$
= 0.96 ha/hr.

iv. Determination of field efficiency

Field efficiency is the rate of effective field capacity and theoretical field capacity expressed in percentages. Field efficiency is used to determine the effectiveness of the cultivating operation. It is expressed in percent.

Field Efficiency = $\frac{\text{effective field capacity}}{\text{theoretical field capacity}} \times 100$ 6
= $\frac{0.96}{1.8} \times 100$
= 53.6 %

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v. Determination of depth of operation

Depth of penetration for the rigid tine cultivator was determined using depth measuring probe together with a measuring tape. The depth measuring probes was horizontal pushed with minimal force through the soil until it reached hard surface, it's a hand switch making it different to push the probe again. The foldable rule is placed horizontal on the soil surface to intercept the probe after which it is drawn out of the soil and the depth read using measuring tape.

III. RESULT AND DISCUSSION

A. Fabricated machine

The fabricated rigid tine cultivator is shown below in plate1

THE FABRICATED RIGID TINE CULTIVATOR IS SHOWN BELOW IN PLATE1

Plate1: The Fabricated rigid tine cultivator

i. Description of the machine components

The developed rigid tine cultivator consists of the following components:

a. Frame: The frame is the skeletal structure which holds the whole parts of the implement together and to which the point of attachment to the tractor three-point linkage is welded to. The design factors considered in the determination of the material required for the frame are the weight and strength. It is rectangular in shape.

b. Shank: The shank is the part of the rigid tine cultivator that holds the tine firmly. The material selected for this part requires high strength and durability to withstand shock and vibrations during operation.

c. Tine: This is the part of the rigid tine cultivator that enters into the soil and pulverize the soil, it has a sharp/pointed edge that enters into the soil.

d. Bolt and nut: All the parts of the cassava harvester were coupled together with the means of bolt and nut at the respective joint.

e. Point of attachment (3-point linkages): The point of attachment is the point at which the implement is coupled/hitched to the tractor through the three point linkages which is coupled with the procedure LEFT - RIGHT – TOP.

ii. Mode of operation

The implement was coupled to the tractor through the three point linkages, by the order of left, right and top link after that it was powered by hydraulic lever for lowering and lifting of the implement above the ground and it was then driven to the field by the tractor, on getting to the field, the tine of the rigid tine cultivator will cut the ground, hydraulic lever was used to lower the implement and also place the implement at appropriate angle for

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better performance, after that the drag forces of the tractor makes the implement cultivator will perform perfectly.

B. Test Result of the Implement

The results obtained from the field test of the rigid tine cultivator are used to determine the table below:

Table 5: Table showing test result of the implement

S/N	Parameter	Value
1	Fuel consumption	7.2 *l/ha*
2	Theoretical field capacity	1.8 ha/hr
3	Effective field capacity	0.96 ha/hr
4	Field efficiency	53.9 %
5	Depth of penetration	0.74 cm

C. Discussion

i. Fuel consumption: The fuel consumption is lesser than the one obtained from rigid tine cultivator fabricated at Natural Resources and Life Science University of Vienna which was 18.29 l/ha but more than the on obtained from the tractor operated cultivator produced by filipovic *et al*., (2004), at Agricultural Engineering. This may also be due to the fact that the soil is soft during the period of testing and the quantity of the soil carried by the implement during the operation.

ii. Effective field capacity: The field capacity obtained is lesser than rigid tine cultivator produced by Maheshwari *et.al.*, (2004) which was 2.5 ha/hr.

iii. Field efficiency: Field efficiency is lower than tractor operated rigid tine cultivator produced by Maheshwari *et.al.*, (2004) which was 65%.

iv. Depth of penetration: The average depth of penetration obtained was lower than the one obtained from TEK cultivator which was 0.96 cm. This was also due to the time of testing of the machine.

IV. CONCLUSION

A rigid tine cultivator was designed and fabricated in the Department of Agricultural and Bio-Environmental Engineering, The Federal Polytechnic, Ado-Ekiti. Locally sourced materials were used in the fabrication which consists of tine to dig the ground, gauge wheel it is used for controlling the depth of penetration, frame and three-point linkage. Test results showed that fuel consumption was 7.6L/ha,effective field capacity was 0.96ha/hr, depth of penetration was 0.74cm, theoretical field capacity was 1.8ha/hr, and field efficiency was 53.7%.

V. RECOMMENDATIONS

i. The rigid tine cultivator gives an undesired soil pattern when used on an unplugged soil therefore it is recommended to use the implement on an already ploughed land for better breaking of clouds.

ii. Further testing of the rigid tine cultivator should be carried out in a well prepared field beginning from field preparation.

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