

Development and Performance Evaluation of a Row-Crop Mechanical Weeder

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Abstract: Weed control is a major problem for peasant farmers in Nigeria. Majority of these farmers do control weed using hand tools like hoes and cutlasses and so on. Though, this method proves useful yet it is very demanding of labour and full of drudgery. This is further compounded by the low interest shown by the youth in agriculture in the last one-decade or so. To solve this problem, an engine powered row crop mechanical weeder was designed, fabricated and tested at the Federal University of Technology, Akure, Nigeria. The main features of the weeder were: a 5 hp Internal Combustion (IC) petrol engine as prime mover, power transmission system, three sets of weeding blades, main frame and ground wheels. The overall width, length and height of the weeder are: 0.32, 0.85 and 0.65 m, respectively. The width of cut of the machine was 0.24 m, while the speed of the cutting blades was 800 rpm. The average fuel consumption of the engine was 0.7 L h⁻¹ at maximum speed. Field tests showed that under moist field condition, the weeding efficiency was 95% and effective weeding capacity was 0.053 ha h⁻¹. The cost of producing the model weeder was estimated at about US\$ 285 in 2007.

Key words: Mechanical weeder, efficiency, field capacity, cost, farmer

INTRODUCTION

Weeds have always been problems in the cultivation of crops as they lower yields and quality of yields. Weeds reduce yields by competing with crops for water, nutrient and sunlight. Weeds also may directly reduce profits by hindering harvest operations and producing chemicals that are harmful to crop plants (allelopathy). Biswas *et al.* (2000) have shown that weeds cause between 50-70% reduction in crop yields.

Also, weeds left uncontrolled may harbour insects and diseases and produce seeds and rootstocks, which infest the field and affect future crop. Weeds can also be potential carriers of infections, fungus and other diseases, which can contaminate the crops. Large numbers of weeds can also cause cereal to lodge. In spite of large expenditures for weed control, it has been estimated that losses in U.S. crops due to weeds left uncontrolled exceed USD 7.5 billion annually. Weed control is thus an essential part of all crop production systems.

Weeds pose very serious problems in the cultivation of crops in southwestern Nigeria where the vegetation is predominantly Forest regrowth (Agboola, 1979). The wet season covers the period between March and October with an annual average rainfall of about 150 cm.

Four methods of weed control have been identified (Robbins and Craft, 1962). The decision as to which method to adopt depends on several factors such as specificity of the weed problem, farm size, type of growing crops and availability of working labour, farm machinery and working tools (Mganilwa *et al.*, 2003).

In South-Western Nigeria, agricultural production derives its sources of power mainly from human and mechanical sources such as Internal Combustion (IC) engines including tractors (to a lesser extent). This suggests the use of hand tools that are time consuming, labour demanding and inefficient (in some cases) and full of drudgery. This of course explains, why there is acute shortage of food in the land and the farmers, who are supposed to be rich are very poor. This is the problem.

It is therefore, become imperative to mechanize the weeding process in order to solve or overcome the problems enumerated above. Researchers have made attempts in this direction (Aderele and Braide, 1992; Onwuji, 1997; Manuwa, 1998; Olukunle and Oguntunde, 2006).

Chemical weeding may soon become unpopular because it is not environmentally friendly. This is because chemical weeding has been found to introduce toxic substances into the environment.

Herbicides appeared not affordable and even uneconomical for small-scale farmers. The production of herbicides itself is a high technology process and a very reliable network is needed (Stevens, 2000). Mechanical weeding is an environmentally friendly method for controlling weeds.

Biswas *et al.* (2000) reported that mechanical methods would remain by far the most widely used means of weed control for years to come. Stevens (2000) reported that mechanical weeding is more likely to be sustainable than chemical weeding because it carries fewer risks (financial, health and environmental) and easier to maintain with existing skills and facilities.

Mechanical weeders range from basic hand tools to sophisticated tractor driven or self-propelled machines. Such weeders include cultivation tools such as hoes, harrows, tined implements, brush weeders, cutting tools like mowers and trimmers, as well as implements like thistle-bars that may do both (Bond and Turner, 2005). Custom-made basket or cage-wheeled weeders, with gangs of rolling wire cylinders, offer another way of dealing with seedling weeds in a friable soil (Bowman, 1997).

MATERIALS AND METHODS

The weeder was designed and constructed to research in crop rows. The main features of the weeder and their functions are following:

The mainframe: It was built of a rectangular hollow pipe (50×50×3 mm) with a length of 500 mm. A steel channel (50×30×3 mm) was welded to the frame, with brackets to hold the engine in place. The weeder blades shaft was mounted at the front of the frame.

Handle: The handle was attached to the main frame. This feature enables the operator to push or pull and also to direct the machine as the case may be during operation within the crop rows. The handle was made of hollow square section steel pipe with brackets. The handle also enables the operator to raise the cutting blades should stones, stumps be encountered.

Cutting blades: There are three sets of the cutting blades mounted on a shaft (constituting a gang) supported by the front of the main frame. Each gang has four L-shaped (80×48×8 mm) blades arranged in two orthogonal planes. The blades were made of steel and welded to a circular rigid plate 75 mm in diameter, 8 mm thick and carrying a

center-hole of 25 mm diameter for the blade shaft. The blades were bolted to the plate for adequate rigidity, support and easy maintenance. The cutting edge of the blades was beveled at an angle 30° to minimize the effort required in cutting the soil. Also, the arrangement of the blades was such that cutting was done progressively, one blade after the other. This of course help to minimize the power required to cut into the soil. The blades provide maximum cutting depth of 40 mm, which was deep enough cut and bury weeds and prevent re-growth. The width of cut was 240 mm.

Blades shield: A shield was necessary to cover the blades on the gang. The shield helps to direct the cut weeds and soil away from the operator so that he can concentrate on the job.

Transmission system: Power was transmitted to the weeding blades through belt and pulley arrangements. The choice was influenced by the relative availability and cost when compared with that of gear, chain and sprocket drive system.

Wheels: Two types of wheels were used: a single wheel in front of the machine behind the blades whose function were to control the depth of soil cut, parking and stability when the machine was not working, so that it does not rest on the blades. This wheel is capable of adjustment in the vertical direction. The other pair of wheels at the rear provide traction for the machine as the push or pull effort was applied.

Internal combustion engine: A commercial 5 hp petrol engine (Honda), engine speed (4200 rpm) was used as the power source. The quantity of fuel that goes into the engine was controlled with the engine throttle. This provides for speed variation.

Testing and performance evaluation: A field test was carried out to evaluate the performance of the prototype machine in terms of field capacity and the weeding efficiency that may enable us compare it with other similar machines. The test was conducted in a field planted with plantain at the Agricultural Engineering Departmental Research and Demonstration Farm of the Federal University of Technology, Akure, Nigeria. The soil was a sandy clay loam with average moisture content of 12% in the 0-100 mm depth during the period of the tests. The average penetration resistance of the soil was 350 kPa in the 0-20 cm depth of the soil. The plantains were planted

on the flat and in rows. The test procedures were similar to that reported by Migariwa *et al.* (2003). Tests were carried out in four rows of 6 m length each. Depth of cut was randomly measured by a steel rule. After weeding samples of cut and surviving weeds were collected from 1 m² field area and dried.

The weeding efficiency was calculated using the following Eq. 1:

$$E_w = \frac{W_1}{W_1 + W_2} \times 100 \quad (1)$$

Where:

E_w = Weeding efficiency (%)

W_1 = Weight of cut weeds

W_2 = Weight of survived weeds

The effective field capacity was determined using the following expression:

$$\text{Effective field capacity (S)} = W_e \times E_r \frac{10^4}{3600} (\text{ha h}^{-1}) \quad (2)$$

Where:

S = Average weeding speed (m sec⁻¹)

W_e = Effective weeding width (m)

E_r = Field efficiency (%)

RESULTS AND DISCUSSION

The prototype of the engine powered mechanical weeder that was designed and fabricated is presented in Fig. 1. The machine was more versatile than the type reported by Manuwa (1998). This was expected because the latter derived its power from human source and the former (this machine), engine powered. The machine was rugged and designed for easy maintainability. Bolts and nuts and screw fasteners were preferred to permanent fastening (welding) without sacrificing strength and rigidity.

The cutting blades on gang are presented in Fig. 2. The width of cut of the machine can be increased to close 100% within the capacity of the 5 hp IC engine still able to furnish the required power to do the research. Correspondingly the field capacity of the machine would increase.

The field capacity of the weeder was 0.035 ha h⁻¹. Field capacity was influenced by the forward speed to a point that is the field capacity increased with forward speed to a point (about 0.5 m sec⁻¹) when further increase in speed caused a reduction in the weeding efficiency. The forward speed ranged from 0.25-0.5 m sec⁻¹.



Fig. 1: The mechanical weeder



Fig. 2: Weeder blades on gang

The field efficiency was 96%. Effective weeding width was 0.24 m. Average depth of cut was 40 mm at average moisture content of 10% (db) of sandy clay loam soil.

The cost of a prototype of the machine was put at about US\$ 285. However, if the production were commercialized or mass-produced, it could be possible to have the unit cost reduced to about US\$ 200 depending on the scale of production.

CONCLUSION

A row-crop mechanical weeder has been designed, fabricated and tested and it is environmentally friendly because it does not pollute the environment in any way in its use for crop protection.

It is fuel-economic as its fuel consumption is 0.7 L h⁻¹ at maximum speed. Its efficiency was 95% and effective weeding capacity was 0.053 ha h⁻¹. If it were mass-produced, the cost would be affordable to local farmers.

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