
DEVELOPMENT AND PERFORMANCE EVALUATION OF A MANUALLY OPERATED SINGLE ROW MULTI-PURPOSE WEEDER

Aminu Saleh^{1,*}, Akande F. B², Ishola T. A³

¹Department of Agricultural and Bio-Resources Engineering, Institute for Agricultural Research,
Ahmadu Bello University Zaria

²Ladike Akintola University of Technology, Ogbomosho

³University of Ilorin

Email: salehaminu@gmail.com*, bukola@gmail.com, ishola@gmail.com

*Corresponding author: Aminu Saleh

DOI: <https://doi.org/10.67203/sp.ICESID.2026>

ABSTRACT

Weed control is one of the major problems in agricultural production. Most of the peasant farmers in Nigeria use manual weeders in cultivating, a process that is costly, labour intensive and time consuming. Manual weed control does not also give the farmer adequate returns to enable him breakeven. It is, therefore, necessary to design a weeding mechanism that could minimize the human effort and provide efficient work output for the peasant farmer. This study focus on designing, construction and evaluation of a multi-purpose hand-pushed weeding machine that could eliminate the challenges of manual weeding under different field and soil conditions. Materials selected for the construction of the multi-purpose weeder are durable and locally available, easily replaced if damaged and at affordable cost. They include mild steel plate (3mm, 5mm), 30 mm circular (hollow) pipes, 10 mm diameter steel rod, 10 mm bearings, 10 mm square rod, 17 mm bolt and nuts and 400 mm diameter steel and pneumatic wheels to suit different soil conditions. The developed weeder was evaluated in the experimental farm of IAR with impressive results. It works well in loamy (27.42% moisture content) and sandy soils (25.65% moisture content) and requires less labour force compared to the conventional manual hoes. It has an average weeding efficiency of 84.7%, 0.0129ha/hr effective field capacity, 0.019ha/hr theoretical field capacity and 68% average field efficiency. Results obtained also shows a 100% plant damage efficiency (i.e. no plants damaged). The average cost of the weeder is N46, 200:00.

Keywords: Manual weeding; hand-pushed weeder; weeding efficiency; field efficiency

1. INTRODUCTION

One of the major problems in crops and vegetables production in Nigeria is weed control. Weeds may be broadly defined as plants growing where they are not wanted. They are probably the most ever-present class of crop pests and are responsible for marked losses in crop yields. Besides reducing crop yield, weeds deteriorates the quality of produce and hence reduce the market value of the produce. Weeds competes with the crops for nutrients, space, light and water. Numerous studies have documented negative effects of weed competition on crop yield. Results of such studies shows that crop losses measured under weedy conditions for maize was between 55 – 90 % (Chikoye *et al.*, 2004), 40 – 80 % for sorghum (Ishaya *et al.*, 2007), 40 – 60 % for cowpea (Olowe *et al.*, 1987) and 50 – 100 % for rice (Dadari and Mani, 2005).

Management of weeds is, therefore, imperative to sustain crop productivity and to ensure food security to the ever-increasing population. Weed control is the process of limiting weed infestations such that crops could be grown profitably and efficiently. It is the combination of the techniques of prevention, eradication and control to manage weeds in a crop, cropping system, or environment. Weed managers recognize that field's cropping history, grower's management objectives, available technology, financial resources, and a host of other factors must be combined to make good management decisions; Tisdell, (1988) and Rana and Rana. (2016).

Weeding could be done manually, mechanically, biologically or by means of agro-chemicals. Hand weeding is the predominant weed control practice on smallholder farms in Nigeria and most of Sub-Saharan Africa (Vissoh *et al.*, 2004). It is the oldest method and consists of hand-pulling, hand slashing and hoeing of weeds. Smallholder farmers spend 50 – 70 % of their total labour time in hand

weeding (Chikoye *et al.*, 2007). Another study of African agriculture also confirmed that weeding took up more days in the field than any other operation (IFAD, 1998). Several constraints that limit the effective use of hand weeding, including limited cash for hiring labour and none availability of hired labour during peak periods (Johnson, 1995). Labour supply in rural areas has been significantly reduced in many African countries migration to urban areas (Bisikwa *et al.*, 1997). This necessitates use of mechanical means of weeding to eliminate the challenges of physical exhaustion that is usually associated with manual weeding; Yadav and Pund (2007).

Mechanical weed control, on the other hand, refers to any technique that involves use of farm equipment to control weeds. Implements used vary from simple hand tools to multiple tractor drawn implements; Rana and Rana. (2016). Most existing mechanical weed control machines are drawn by tractors. Peasant farmers who are in the majority today do not have access to credit facilities and cannot afford to buy or hire the agricultural machinery to enhance their farming capabilities. It, thus, becomes necessary to develop and construct a weed control equipment that would depend on minimum human efforts for its motion, but could weed at a greater speed and efficiency than human beings, hence, the objective of this study.

2. MATEIALS AND METHODS

Materials to be used for the construction of the multi-purpose weeder are; 3 mm and 5 mm mild steel, 30 mm circular (hollow) pipes, 10 mm diameter steel rod, 10 mm bearings, 10 mm square rod, 17 mm bolt and nuts and 400 mm diameter steel and pneumatic wheels to suit different soil conditions. The bases for these materials were their durability and availability, ease of replacement if damaged and light in weight for safety and ease of transportation. Their cost is also affordable to a local fabricator and medium scale famer. In its construction, the multi-purpose weeder was made in such a way that it is easy to operate and maintain while the components could easily be dismantled for replacement of parts. Traction on the wheels has also been considered for proper movement on different soil conditions. Other materials used were weighing scale, oven, soil sampler, measuring tape, steel rule and a stop watch.

2.2 Description of the Multi-Purpose Weeder

The multi-purpose weeder constitutes a frame, steel and pneumatic wheels (to suit different types of soil), tin cultivator, furrower and a weeding blade that could optimally operate under different soil conditions as shown in Figure 1. Appendix A show the Orthographic View of the Multi-Purpose Weeding Machine.

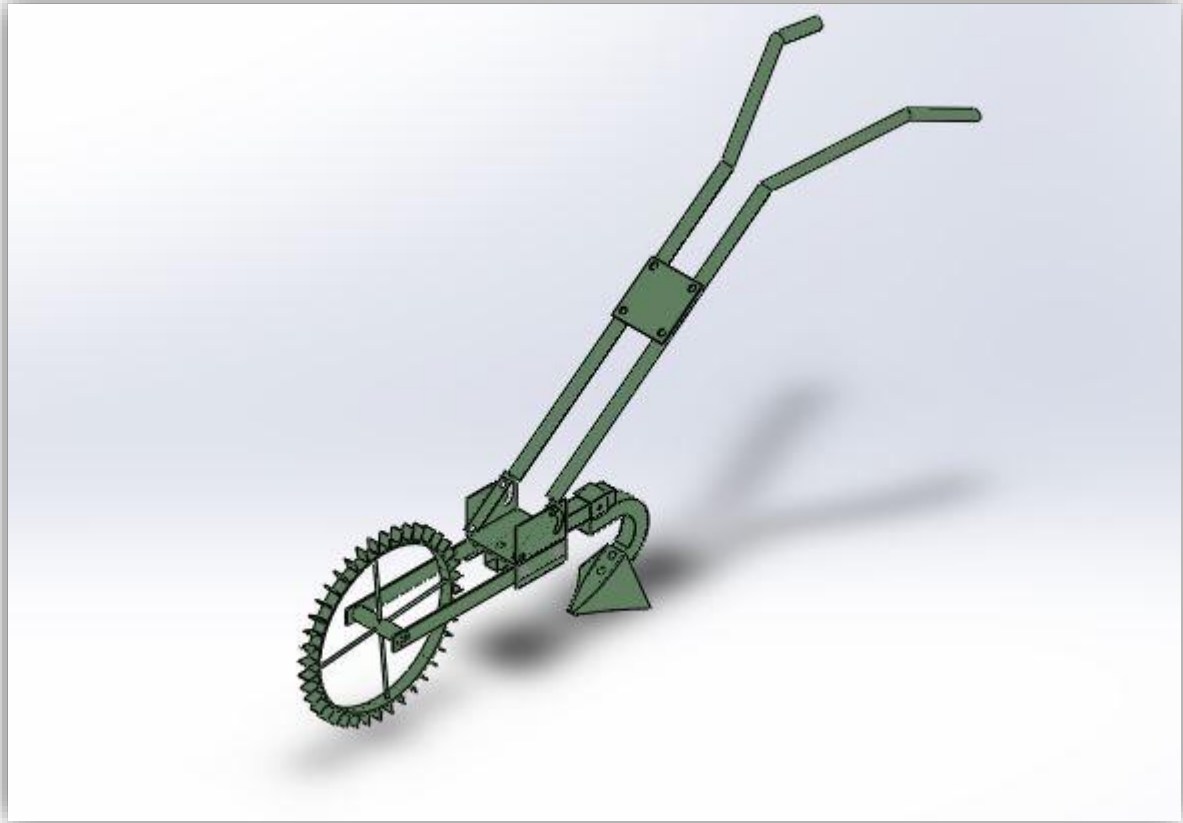


Figure 1: Pictorial View of the Developed Multi-Purpose Weeder

- i. **Frame** - The frame is the skeleton/structural component on which all the components of the weeder were built, supported and attached. It was made from 3 mm mild steel rod. All the components mounted on it were attached with bolts and nuts for ease of transport and replacement of defective parts.
- ii. **Wheels** - The weeder has two different wheels; pneumatic (moulded and tubless) and steel wheels (Figure 2). Both are of the same diameter (400 mm) and are not used simultaneously but one at a time depending on the type of soil.
- iii. **Handle** - The handle was constructed using 30 mm diameter circular (hollow) pipe. Ergonomic and anthropometric aspects were considered in such a way it suit variety of users. It was attached to the frame to control and direct the weeder on the field.
- iv. **Tine cultivator** - The tin cultivator was made from 10 mm diameter steel rods which were flattened at its base and supported at the top by a mild steel metal sheet. It was meant to work on a stony and rooted soils (Figure 3).
- v. **Furrower** - The furrower was made from a 3mm mild steel metal to form a typical sweep furrow of 18×18 cm (Figure 4).
- vi. **Weeding blade** - The weeding blade which forms the integral part of the weeder was made from 5 mm mild steel plate. It's dimensions are 20×20 cm. It has a sharp blade which is used to cut, slice and pulverize the soil for effective weeding.

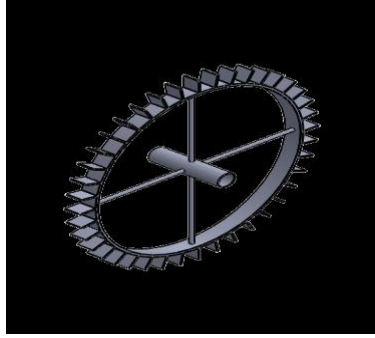


Figure 2: Steel Wheel

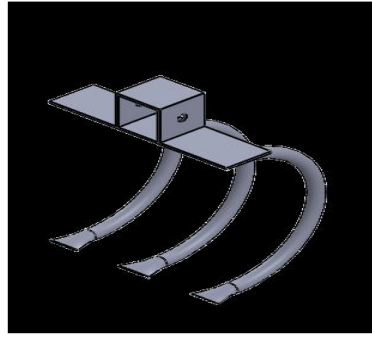


Figure 3: Tine Cultivator

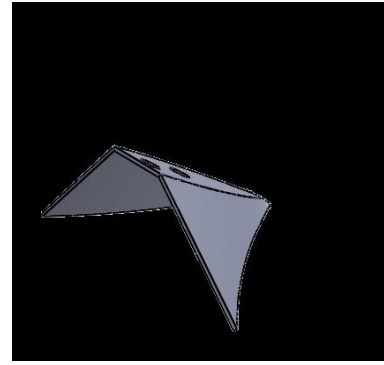


Figure 4: Furrower

2.3 Experimental site

The study was conducted in the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria between March and December 2025. While construction was done at the departmental workshop, the multi-purpose weeder was tested at the experimental farm of the Institute for Agricultural Research (IAR). The plots with sandy and loamy soils were used to test the weeder.

2.4 Determination of the Weeder Performance

The test for the weeding performance parameters was carried out on the field size of $2 \times 1\text{m}$. The average performance parameters of the multi-purpose weeder such as weeding efficiency, plant damaged, effective field capacity, theoretical field capacity and field efficiency of multi-purpose weeder were determined and evaluated through the following expressions:

- i. **Weeding efficiency** – This is the ratio of the numbers of weeds removed by the weeder to the number of weeds in a unit area before weeding and is expressed as a percentage. It was expressed using equation (1) as suggested by Madhusudhana (2015).

$$\text{Weeding efficiency (\%)} = \frac{W_1 - W_2}{W_1} \times 100 \quad (1)$$

where:

W_1 = Number of weeds counted per unit area before weeding operation

W_2 = Number of weeds counted in same unit area after weeding operation.

- ii. **Plant damage** – Plant damage is the ratio of the number of plants damaged after weeding operation to the number of plants before the weeding. It is expressed in percentage.

$$\text{Plant Damage (\%)} = \left(1 - \frac{q}{p}\right) \times 100 \quad (2)$$

where:

p = Number of plants in a row before weeding = 29,

q = Number of plants in a row after weeding = 29.

- iii. **Effective field capacity** – Effective field capacity is the actual average rate of coverage by the weeder based upon the total field time. It is a function of the rated width of the weeder, the percentage of rated width actually utilized, speed of the travel and the amount of field time lost during the operation. Effective field capacity is expressed in ha/h (Kepner *et al.*, 1978).

$$\text{EFC} = \frac{A}{T_p + T_i} \quad (3)$$

where:

EFC = Effective field capacity, ha/h

A = Actual area covered, ha

T_p = Productive time, h

T_i = Non-productive time, h

- iv. **Theoretical field capacity** - Theoretical field capacity of the weeder is the rate of field coverage that would be obtained if the weeder were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width. It is expressed in ha/h (Kepner *et al.*, 1978):

$$\begin{aligned} TFC \\ = \frac{W \times S}{10} \end{aligned} \quad (4)$$

where:

TFC = Theoretical field capacity, ha/h

w = Width of cut, m

s = Speed of operation, km/h

- v. **Field efficiency** – Field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage. It includes the effect of time lost in the field and failure to utilize the full width of the weeder.

$$\eta_e = \left(\frac{EFC}{TFC} \right) \times 100 \quad (5)$$

where:

η_e = Field efficiency, %

EFC = Effective field capacity, ha/h

TFC = Theoretical field capacity, ha/h

- vi. **Bulk density of soil** - The bulk density of soil was determined by core cutter method. The core sampler of the soil of known volume was collected and weighed. The soil bulk density was mathematically determined as the ratio of the mass of soil to volume of soil:

$$\rho = \frac{M}{V} \quad (6)$$

where:

ρ = Bulk density, g/cm³

M = Mass of the soil, g

V = Volume of the soil, cm³

- vii. **Moisture content of soil** – The moisture content of the soil was determined by oven drying method. Soil samples were taken from three different points on the field. The samples which weight 400 g, 398 g and 405 g were kept in the thermostatically controlled oven at a temperature of 105°C for 24 hours. The dried soil was again weighed and the moisture content is determined as:

$$M_c = \frac{W_w - W_d}{W_d} \times 100 \quad (7)$$

where:

M_c = Moisture content, (% db)

W_w = weight of moist soil, g

W_d = weight of dry soil, g

- viii. **Effective working depth** – The depth of cut of the weeder with different blades was measured in the field by measuring the depth of soil layer tilled by the blade in a row. The depth of the weeding was measured by measuring rule in different rows at different places. Average of five observations was taken as depth of weeding and expressed in cm.

- ix. **Effective working width** – The width of cut of the machine with different blades was measured in the field by observing the strip of soil and weeds cut in a row.

3. RESULTS AND DISCUSSION

3.1 Bulk density and moisture content of the soil

The average bulk densities of the sandy and loamy soils collected from three different points of the fields were determined to be 1.21 g/cm³ and 1.70 g/cm³, respectively. The average moisture contents of the areas were also found to be 25.65 and 27.42 % (Tables 1 and 2).

Table 1: Bulk Density and Moisture Content of the Soil (Sandy Soil)

Samples	Weight of wet (g)	Weight of dry (g)	Moisture content on dry basis (%)	Bulk density (g/cm ³)
A	400	317.0	26.18	1.22
B	398	320.0	24.38	1.20
C	405	320.4	26.40	1.21
Average	401	319.0	25.65	1.21

Table 2: Bulk Density and Moisture Content of the Soil (Loamy Soil)

Samples	Weight of wet (g)	Weight of dry (g)	Moisture content on dry basis (%)	Bulk density (g/cm ³)
A	408	326.1	27.21	1.72
B	410	325.5	27.46	1.69
C	409	325.7	27.58	1.70
Average	409	325.8	27.42	1.70

3.2 Effective working width and depth

The effective working width and depth were determined in three different spots on the field using all the three attachments of the weeder. Results obtained (Table 3) shows that the working widths of the three implements were determined from three different attachments (tin cultivator, weeding blade and furrower) were 20 cm, 19.30 cm and 17.09 cm respectively. This shows that the furrower has a wider coverage than the other attachments. Similarly, the average effective working depth for three attachments were 3.85 cm, 4.11 cm and 6.87 cm respectively (Table 4). This indicated that the tin cultivator which penetrates deeper into the soil has the tendency of uprooting stubborn weeds and those that has deeper tap roots. Deeper seed bed also means tendency to allow more water and air circulation, hence provides more conducive environment for crop growth.

Table 3: Working widths-of-cut of the Multi-Purpose Weeder

Trial/Implement	Tin cultivator	Weeding Blade	Furrower
	(cm)		
1	20	19.4	17.3
2	20	19.2	17.10
3	20	19.4	17.21
Average	20	19.3	17.09

Table 4: Effective Working Depth-of-cut of the Multi-Purpose Weeder

Trial/Implement	Tine cultivator	Weeding Blade	Furrower
	(cm)		
1	3.84	4.11	6.32
2	4.10	4.00	7.10
3	3.60	4.23	7.21
Average	3.85	4.11	6.87

3.3 Weeding efficiency

The test for the weeding efficiency was carried out on the field size of $2 \times 1\text{m}$. The ratio of weeds counted before and after the weeding was 85.7:1. The cumulative average weed population of the three trials was 600 before weeding operation while weeds left after the exercise was an average of 7 for both attachments (Table 5).

Table 5: Average Weed Population

Trial/Implement	Tine cultivator	Weeding Blade	Furrower
	(No.)		
1	598	601	602
2	599	600	600
3	603	598	598
Average	601	599	600

The weeding efficiency was computed using Equation (1) given as:

$$\text{Weeding Efficiency (\%)} = \frac{600 - 7}{600} \times 100 = 98.83\%$$

3.4 Average Effective field capacity

The average effective field capacity was determined from Equation (3) after weeding $3 \times 1.5\text{m}$ (0.00045ha) within an average of 1min 57secs (0.0325 hours) for both attachments. The average time used for turning and adjustment was 10 sec (0.00266hours).

$$\text{Average EFC} = \frac{0.00045}{0.0325 + 0.00266} = 0.0129\text{ha/hr}$$

3.5 Theoretical field capacity

The theoretical field capacity of the multi-purpose weeder was determined computing the rate of weeder coverage at its 100% rated width. Average width of cut of the three implements was 0.19 m from Table 3 while the average speed of operation of the three implements was 1.008km/h. Thus, from Equation (4), the theoretical field capacity was determined as:

$$\text{TFC} = \frac{0.19 \times 1.008}{10} = 0.019\text{ha/h}$$

3.6 Average Field efficiency

The average field efficiency of the weeder was computed from Equation (5) as:

$$\eta_e = \frac{0.0129}{0.019} \times 100 = 67.9\% \approx 68\%$$

3.7 Plant damage efficiency

The plant damage efficiency was calculated using Equation (2). After weeding three different rows of about 10 m length each, it was discovered that no plant was damaged by both attachments (number of plants before and after weeding = 29). This shows a 100% plant damage efficiency. Therefore, the plant damage efficiency is calculated thus;

$$\text{Plant Damage (\%)} = \left(1 - \frac{29}{29} \times 100\right) = 0$$

4 CONCLUSION

A hand-pushed multi-purpose weeder that could use three different weeding attachments for effective weeding operation has been designed and developed. From the results obtained during the

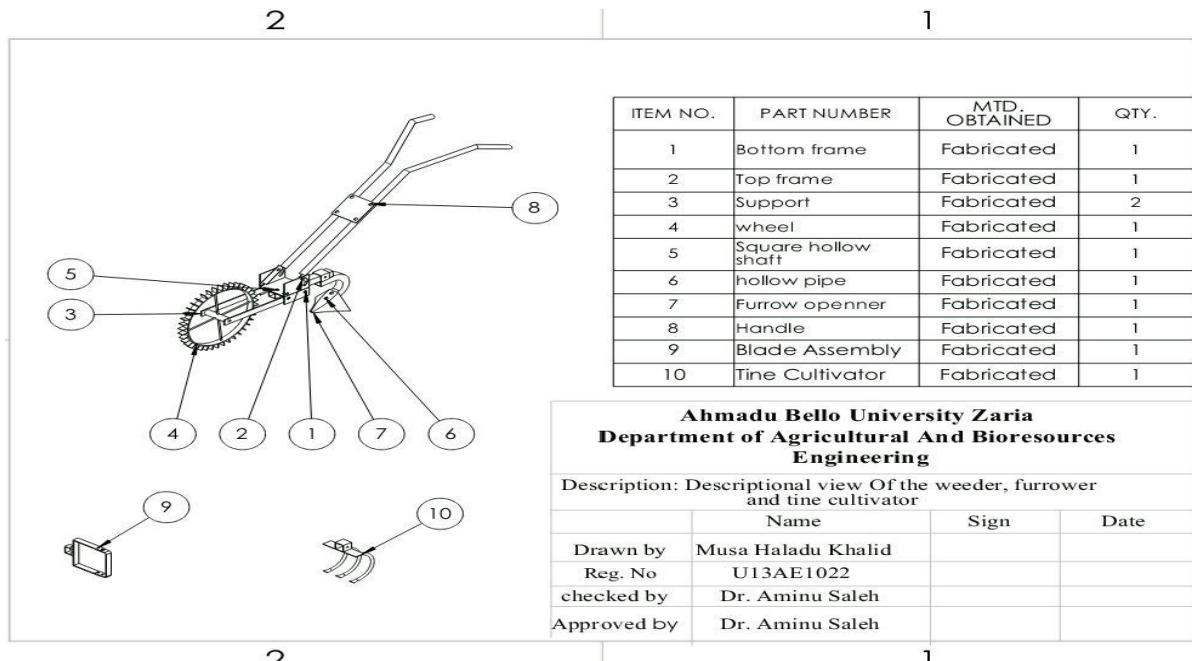
performance evaluation, it was observed that the weeder is light in weight which makes it easy to be pushed with less effort, save time and energy and effective in its output. It could, thus, promote the living standard of peasant farmers by reducing the drudgery involved in weeding. The multi-purpose weeder could also be used on a flat soil or between furrows if the soil moisture is within its acceptance range. It has a weeding efficiency of 84.7% with no plant damage during the weeding trials conducted. The average cost of the multi-purpose weeder is N46, 200:00.

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APPENDIX A

Orthographic View of the Multi-Purpose Weeding Machine



Bill of Engineering and Material Evaluation

S/N	Description	Quantity	Rate(N)	Amount (N)
1	3mm mild steel	Quarter length	-	4500
2	5mm flat bar	One length	-	4500
3	Bolt and nut	20 pieces	150	3000
4	10 mm iron road	0.75 of a length	4000	2000
5	Cutting disc	One disc	2000	2000
6	Electrode	1 pack	2000	2000
7	10 mm Bearing	Two	2500	5000
8	30 mm Round pipe	One length	3500	3500
9	Pneumatic tyre	Complete set	3000	3000
10	Square road	½ length	4000	2000
11	Paint	⅓ gallon		2500
12	Transportation	-		5000
13	Miscellaneous			3000
14	Labour (10% Sub-Total)			4,200
15	Total			N46,200