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Design and Fabrication of Hand Guided, Self-Propelled Row Crop Mechanical Weeder

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Abstract

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost and low yield involved in agricultural production. Autodesk inventor was used to design the machine. The materials were sourced locally in the market. The mechanical Weeder comprises of frame, 3.5 Hp petrol engine, gear box, weeding blades (L and horizontal shape), support wheel, blades guard and handle. Overall dimensions of the weeder are height 1225 mm, length 905 mm and width 702 mm. It is observed that the height adjustment make it easy to operate and maneuver by any operator, the machine portability ease movement of the weeder from one location to another. Proper performance and evaluation is recommended for the weeder. Introduction of mechanical weeding in farming operation is seen as a means of reducing drudgery which serve as bottleneck in the management of weeds on farms and also importation bills obtained from the importation of weeding tools or herbicides. For this reason, there is need to encourage the development of locally made mechanical Weeder in Nigeria.

Keywords: Design, mechanical Weeder, blades, weeding.

1.0 Introduction

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost and low yield involved in agricultural production. In land preparation, the limit is primarily due to the intensity of the energy demanded for controlling the weed germination on farm lands, whereas for weed control; the duration of demand is likely to be more restricted. Weeds are therefore one of the most important crop production constraints in field crops during growth. Farmers generally expressed their concern for effective weed control measures to arrest the growth and propagation of weeds. Weed is an everyday term usually to describe a plant considered undesirable (Gavali et al.,2014).The word weed is commonly applied to unwanted plants in human-controlled settings, such as farm fields, gardens ,lawns, and parks. Weeds compete with the beneficial and desired vegetation crop lands. (Gavali et al., 2014). Weeds may be unwanted for a number of reasons .An important one is that they interfere with food and fiber production in agriculture, where in they must be controlled in order to prevent lost or diminished crop yields. Other important reasons are that they interfere with other decorative or recreational goals, such as in lawns, landscape architecture, playing fields, and golf courses. Similarly, they can be of concern for environmental reasons where by introduced species out-compete for resources or space with desired plants. Weeds have long been a concern, perhaps as long as humans have cultivated plants (Gavali et al., 2014). Nigeria is an Agricultural country, with 70% of the population depending on Agriculture as a means of sustenance. Majority of the farmers that farm still rely on hoes and cutlass old methods of weeding to remove weeds on their farms. In order to do away with drudgery, time consuming and making farming easy there is need for introduction of modern Agricultural technologies. To achieve food security and high yield production, good agricultural practices are required as well as proper weed management which is one of the most important practices to put in place. Weeds have more chances of survival when compare to crops and if its management and treatment is not carried out timely, the weeds takes over the farm land. The harm done by weeds is usually more than the harm caused by any other type of Agricultural pests.

The quest for removal of weeds on fields has brought about various methods of weed removal. Some of the methods used in the management of weed include but are not limited to manual, chemical, biological and mechanical methods.

Manual weeding is the commonest method in Nigerian Agricultural practice. The use of hand hoes and cutlass is effective and it is the most widely used weed control method. It is reported that manual weeding is labor-intensive, accounting for roughly 80% of the total labour required for producing food in Nigeria (Rajatet al,. 2017). Farmers using only hand hoes and cutlass for weeding would find it difficult to escape poverty, since this level of technology tends to perpetuate human drudgery and risk. The use of herbicides has possible effect on desert encroachment and other adverse impact on human lives and crop production (Rajatet al,. 2017).

According to Kumar et al. (2017), the mechanical method of weed control is the best method of weeding with little or no limitation because of its effectiveness. Though, the mechanical weeding machines are not common. Therefore, to complete weeding operation within the available period, farmers are left with the only option of manual weeding which is labour intensive and time taking. As the tractor operated weeders are not much available, are costly and are recommended for large farmland. Therefore this work aims to design, fabricate a hand- guided, gasoline-powered row crop mechanical weeder

Introduction of mechanical weeding into farming operation is seen as a means of reducing drudgery in the management of weeds on farms and also importation bills obtained from the importation of weeding tools or herbicides. For this reason, there is need to encourage the development of locally made mechanical Weeder in Nigeria. Hence, there is a need to develop a small weeding machine for small and large scale fields.

2.0 Materials and Method

2.1 Description of the Machine Components

Based on design values of different components, a hand guided, gasoline-powered row crop mechanical Weeder for maize, cow pea and soya beans was fabricated in the workshop of Farm Power and Machinery Department, National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. The engineering drawing was done with engineering application called Autodesk inventor, the overall design dimensions of the weeder are height 1225 mm, length 905 mm and width 702 mm. The materials were sourced locally in the market and taken into the centre's engineering workshop where the materials were machined and cut according to the working drawing dimensions and assembled with welding machine, bolts and nuts respectively. The mechanical Weeder comprises of frame, 3.5 Hp petrol engine, gear box, weeding blades (L and horizontal shape), support wheel, blades guard and handle.

2.1.1 Frames

The frame is the rigid component that support and carries other components of the machine which makes the machine stand without the operator holding it. It also helps the operator to operate the machine with ease and comfort.

2.1.2 Weeding Blades

This component carryout the main function of the Weeder, which is weeding of unwanted plants on the farm. Horizontal and L-shape blades were used as shown in Figure 1 and 2 respectively.

2.1.3 Height Adjustable Wheels

Two pneumatic tires were coupled on the horizontal welded hollow pipe connecting the two arm of the handle which is use for adjusting the height of the Weeder, the adjustment is ergonomically to all height of whoever want to operate the weeded.

2.1.4 Blades Guard

To avoid throwing of mud and stones towards operator and as a safety, a safe guard is fabricated covering the upper and lower rear sides of the blades of the rotary cutting units. All the side covers are made of 1.5mm mild steel plate both are fasten and supported with the means of bolts and nuts.

2.1.5 Handle

The handles are made of 25 mm mild steel pipe with plastic grip fitted at the ends with an accelerator control on the right hand of the handle. The overall length of handle is 1100 mm with two bends from point of attachment by bolt and nut in another 30 mm welded on the frame and have an adjustable height from ground level for the operators. The help of handles the machine can be maneuvered during operation or conveying from one place to another.

2.1.6 Gear box

The gear box is fashionable made of mild steel pipe and plate housing the worm gear and worm wheel with it output shaft that drives the weeding blades.

3.0 Design Consideration

In other to achieve maximum efficiency and effectiveness of the machine weight, shape, size of the machine and the soil properties were the factors carefully and critically considered to arrive at a workable and cost-effective design. Ergonomic considerations such height of the machine, material availability, affordability of materials, cost of maintenance, replaceable parts were also highlighted in the design and fabrication of the weeder.

3.1 Power requirement

Soil resistance, width of cut and speed of operation has a considerable effect on the power requirement of Weeder. For calculating power requirement of the Weeder, maximum soil resistance was taken as 0.75$\mathrm{Kgf/cm^2}$, machine efficiency is taken as 0.82%. The power required is calculated by formula; Aditya *et al*., (2016).

$$P = \frac{SR \times d \times w \times v}{75} \times \frac{1}{\eta} \qquad (1)$$

Where; P=power requirement in Hp, SR=Soil resistance (0.75 Kgf⁄ 〖cm〗 ^2), d=Depth of cut, w=Effectiveof cut, v=speed of operation (km⁄hr) and η = machine efficiency.

3.2 Power transmission system of worm and worm gear

In worm and worm gear arrangement, various proportion are considered with the axial pitch (Pa= 5.09) in mm as shown in Table 1 and 2 respectively (Khurmi and Gupta, 2005).

Table 1: Proportion of Worm

S/no	Particulars	Single and double threaded
1	Normal pressure angle (φ)	14½º
2	Pitch circle diameter for worm with integral the shaft	$2.35P_a$+10mm.
3	Pitch circle diameter for worm bored to fit over the shaft	$2.4P_a$+28mm.
4	Maximum bore for shaft	P_a+13.5mm.
5	Hub diameter	$1.66P_a$+25mm.
6	Face length (Lw)	P_a(4.5+0.02Tw)
7	Depth of tooth (h)	$0.689P_a$
8	Addendum(a)	$0.318P_a$

Table 2: Proportions for Worm Gear

S/no	Particulars	Single and double thread
1	Normal pressure (φ)	14½º
2	Outside diameter (D_{OG})	D_G +1.0135P_a
3	Thread diameter (D_T)	D_G + 0.636P_a
4	Face width (b)	2.38P_a + 6.5mm.
5	Radius of gear face (R_f)	0.882P_a +14mm.
6	Radius of gear rim (R_r)	2.2P_a +14mm.

3.3 Torque transmitted by input and output shafts

The torque transmitted by the input shaft is calculated using the relation

$$T = \frac{P \times 60 \times 10^2}{2 \times \pi \times N} \quad (2)$$

Where P = power (Kw), T = Torque transmitted by the input shaft (Nm)N = Revolution per minute.

The torque transmitted by the output shaft is calculated as given by the equation (Sirmouret al., 2018).

$$T_B = \eta \left(\frac{Z_B}{Z_A}\right) \times T_A \quad (3)$$

Where; T_B = torque on the output shaft, η = machine efficiency, Z_B = the number of teeth on output gear, Z_A = number of teeth on the input gear, T_A = input torque (Nm). The flowchart of the transmission of the mechanical Weeder is shown in figure 1

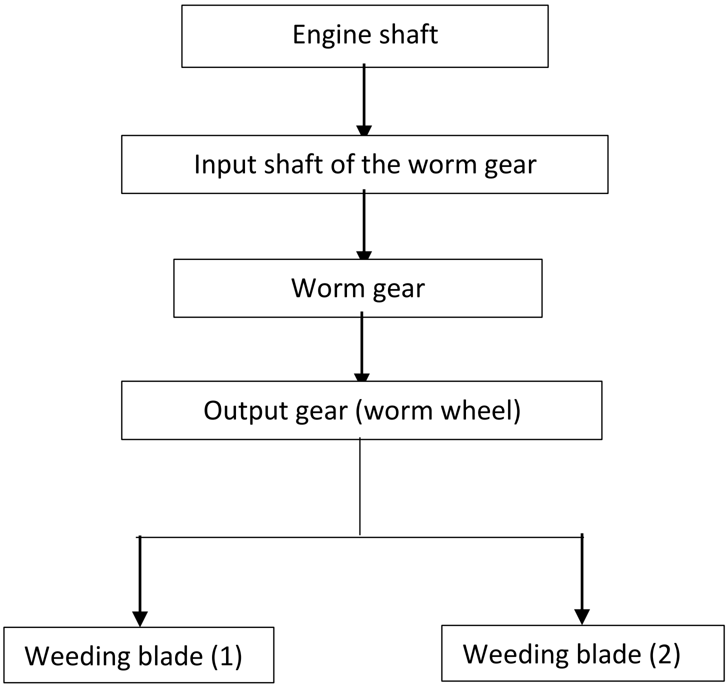

Figure 1: The power transmission of the mechanical Weeder

3.4 Diameter of the flexible shaft

For designing the rotor shaft, the maximum tangential force which can be endured by the rotor should be considered. The maximum tangential force occurs at the minimum of blades tangential speed is calculated by the following (Sirmour *et al.*, 2018).

$$K_s = \frac{C_S \times 75 \times N_C \times \eta_c \times \eta_z}{u} \quad (4)$$

Where, Ks = Maximum tangential force, N, Cs = Reliability factor (1.5) for non-rocky soils and 2 for rocky soils), Nc = Power of engine, Hp, η_c = Traction efficiency for the forward rotation of rotor shaft as (0.9), η_z = Coefficient of reservation of engine power(0.7-0.8), u = Minimum tangential speed of blades.

Tangential peripheral speed, u, can be calculated using the following equation:

$$u = \frac{2 \times \pi \times N \times R}{6000} \quad (5)$$

Where N = Revolution of rotor (rpm), R = Radius of Rotor (cm)

The maximum moment on the rotor shaft (Ms) is calculated with the equation (Sirmouret et al., 2018).

$$M_S = K_S \times R \quad (6)$$

Where, Ms = Maximum moment on the rotor shaft (Kg-cm), Ks = Maximum tangential force(kg) and R = Radius of Rotor (cm).

Allowable stress on the rotor is determined by;

$$\tau_{all} = \frac{0.577 \times K \times \sigma y}{f} \quad (7)$$

Where τ_{all} = Allowable stress on rotor shaft N/m^2, K = Coefficient of stress concentration (0.77), F =Coefficient of safety (1.5), σy = Yield stress.

By substituting the values in the equation the diameter of the shaft is calculated

$$D = \sqrt{\frac{16 \times M_s}{\tau_{all} \times \pi}} \quad (8)$$

3.5 Design of cutting blades

Considering parameters used in this study to give safe strength values to the fabricated blades during weeding operation. The calculation and assumed dimension are based on standard handbook of machine design were followed (Sirmour et al., 2018).

The soil force acting on the blade (Ke) was determine by the equation below:

$$K_e = \frac{K_S \times C_P}{i \times Z_e \times n_e} \quad (9)$$

Where; Ke = maximum tangential force N, Cp = coefficient of tangential as 0.8, i = number of flanges, Ze = number of blades on the flanges is, ne = Number of blades which act jointly on the soil by total number of blades. By solving eqn. 9, the soil force acting on the blade (Ke) was determined

Considering the shape of the blades, the bending stress (σ_{zg}), shear stress (τ_{skt}), and equivalent stress (σ_{zt}) can be calculated by the following equations (Sirmour et al., 2018)

$$\sigma_{zg} = \frac{6 \times K_e \times S}{b_e \times h_e^2} \quad (10)$$

$$\tau_{skt} = \frac{3 \times K_e \times S_1}{\left[\frac{h_2^1}{b_e} - 0.63\right] \times b_e^3} \quad (11)$$

$$\sigma_{zt} = \sqrt{\sigma_{zg}^2} + 4\tau_{skt}^2 \quad (12)$$

Where σ_{zg} = bending stress, MPa, τ_{skt} = shear stress, MPa and σ_{zt} = equivalent stress, MPa

3.6 Determining the blade width (W)

The assumption was that, the tilled soil mass is in the first half of the blade working depth and the maximum working depth was assumed to be 5 cm for mechanical Weeder in order to calculate the minimum blade width (W).

$$W = \frac{H_h}{\sin \beta} \quad (13)$$

and

$$\beta = 90° + \gamma - \alpha \quad (14)$$

Where, Hh = half of maximum working depth m, α = angle of blade rotation from the horizontal degree, β = angle of inclination of the blade from horizontal, degree, γ = cutting angle 45^0

Inclination angle (β) was determined and, angle (α) is also calculated using the equation below;

$$\alpha = \sin^{-1}\left[\frac{H - H_h + R}{R}\right] \quad (15)$$

Where, H = maximum working depth, R = Radius of rotor

Substituting the equation (15) into (14) inclination angle β is calculated.

3.7 Maximum force required to cut the soil for each blade (P);

$$P_{max} = PA \quad (N) \quad (16)$$

Where;

P = Maximum specific resistance of soil = 0.75 kg/cm2, A = Area to be disturbed, A = a × length of soil slice; and a = edge length of the blade, l = length of blade.

Cutting force per unit length of blade,

$$P_a = \frac{P_{max}}{l} \quad (N) \quad (17)$$

The orthographic projection and pictorial view of the mechanical Weeder are presented in Figures 2 and 3 respectively. The bill of engineering materials and technical specification are presented in Tables 3 and 4.

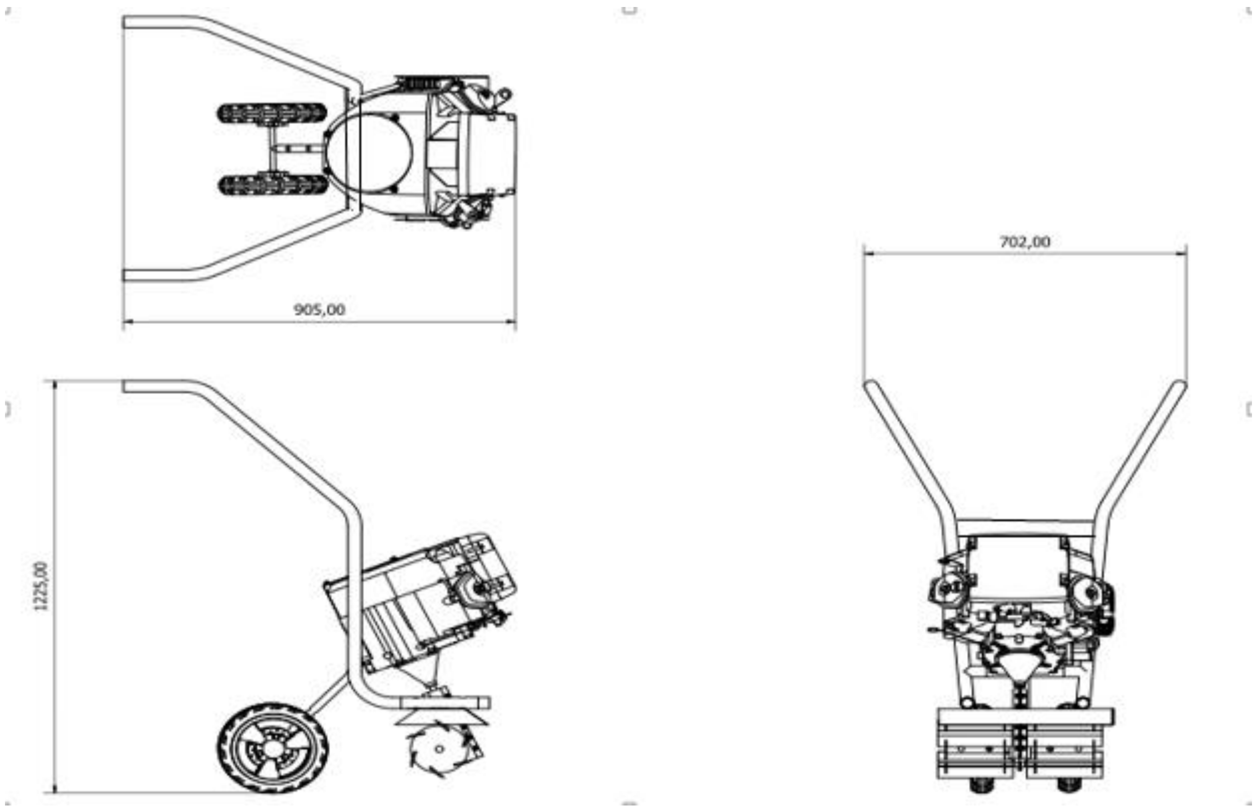

Figure 2: Orthographic projection of the mechanical Weeder

Figure 3: The pictorial view of the fabricated mechanical Weeder

Table 3. Technical Specification of the Mechanical Weeder

S/N	Particulars	Specification
1	Name and type	Hand guided, self-propelled row crop mechanical Weeder
2	Make and mode	Prototype
3	Power source	3.5hp, single cylinder, petrol, air cool Engine
4	Over all dimension	1225.00 x 905.00 x 702.00mm
5	Weight	20kg
6	Cutting unit and blade	Rotary type, "L" shaped and horizontal blades
7	Number of blades	2 nos. (1row x 2 blades per row)
8	Blade cutting length	35mm
9	Wheel	Two support wheel at the rail
10	Fuel tank capacity	1.1ltrs
11	Fuel	Petrol mixed with lubrication oil
12	Materials of blades	Mild steel for horizontal and "L" shaped blades
13	Weeding depth	30 – 100mm
14	Weeding width	142 – 284mm

Table 4. Bill of Engineering Measurement and Evaluation (BEME) of mechanical Weeder

S/N.	Component	Material specification	Qty	Rate (₦)	Amount (₦)
1	Main frame and handle	Galvanized Hollow pipe 25mm diameter	2 length	6,000	12,000
2	Prime mover	Petrol engine 3.5Hp	1 unit	85,000	85,000
3	Gear box	Mild steel pipe 4" and 2" diameter	12" each	5,000	10,000
4	Worm, worm gear and shaft	30mm and 80mm mild steel rod	1 set	45,000	45,000
5	Weeding	Mild steel plate 24" x 24" x 3mm	1 pc	5,000	5,000
6	Support wheel	Pneumatic tyre 9" θ	2 pcs	3,000	6,000
7	Coupling accessories	Bolts and nuts 10M and 13M	2 dozen each	2,000	4,000
8	Transportation of materials	Lump	-	3,000	3,000
				Total	**170,000**

Reference

Aditya Srmour.*et al.,* (2016). Design and development of single Weeder for rice, Agricultural Engineering (Farm Machinery and Power Engineering) Roll No. 220114010.

Khurmi, R. S., and Gupta J. K. (2005). Machine Design. First Multicolour Edition. Eurasia Publishing House (PVT) Ltd. Ram Nagar, New Delhi-110 055.

Kumar S., Kumar A., and Kumar S. (2017). Performance Evaluation of Developed

Manually Operated Rotary Weeder for Vegetable Crops. *Int.J. Curr. Microbiol. App. Sci.* 6(11): 4012-4019. DOI: https://doi.org/10.20546/ijcmas.2017.611.470.

Rajat Bhosale et al. (2017) "Design and Fabrication of Agricultural Rotary Weeder" International Journal of Scientific Research in Science, Engineering and Technology. Vol.3. Issue 2.

M. Gavali and S. Kulkarni "Comparative Analysis of Portable Weeder and Power Tillers in Indian Market" International Journal of Innovative Research in Science, Engineering and Technology. Vol. 3. Issue 4, April 2014.

Sirmour A and Verma A. Design and development of single row power Weeder for rice, Journal of Crop and Weed, 14(1): 163-169 (2018).

