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Design and Development of Power Operated Rotary Weeder for Rice

Kipoo Kiran Singh Mahilang[1], Swapnil Choudhary[2*], V. M. Victor[1], Naresh[2] and Khilendra Kumar Sonboier[3]

[1]Department of Farm Machinery and Power Engineering, SVCAET&RS, IGKV Raipur, India.
[2]Department of Farm Machinery and Power Engineering, COAE&T, CCSHAU, Hisar, India.
[3]Department of Agriculture Process and Food Engineering, SHIATS, Allahabad, India.

Authors' contributions

This work was carried out in collaboration between all authors. Authors KKSM and VMV designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SC and Naresh managed the analyses of the study. Author KKS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Weeds are serious problem in all crops but they are even more so in "kharif" crops. For weed problem several study and research work has carried out for its effective control and measure by various cultural, chemical and mechanical method. The present study on design and development of power operated rotary weeder for mechanical control of weeds in rice includes the designing and fabrication of engine operated mechanical weeder considering the optimum shape, size and location of weeding tools/cutting blade. The weeder was provided with a 1.30 kW petrol start-kerosene run engine as prime mower. The power is transmitted from engine to ground wheel or traction wheel and to cutting unit was operated by means of belt and pulley. For cutting unit 3 hubs each containing 2 standard L – shaped blades were fitted on rotary shaft. Two ground wheels were provided made up of two different diameter rings to make the operation smooth and prevent jerks. In addition to the traction wheels, a rear gauge wheel was provided for

**Corresponding author: E-mail: fmpswapnil@gmail.com;*

the depth adjustment of cutting unit. After fabrication, the power weeder was tested under field condition. It was found that the power weeder has field capacity of 0.14 ha/h with 91% weeding efficiency and 60% field efficiency. The operational cost was found to be Rs 808.42 per ha.

Keywords: Weeder; uplift pressure; weed dynamics; lugs; weeding efficiency.

1. INTRODUCTION

Weeds are probably the most ever-present class of crop pests and are responsible for marked losses in crop yields. Of the total losses caused by pests, weeds have a major share (30%). They reduce the crop yield and deteriorate the quality of produce and hence reduce the market value of the turnout. Therefore, management of weeds in all agro-ecosystems is imperative to sustain our crop productivity and to ensure the food security to the burgeoning population [1].

Weed management is one of the tedious operations in agricultural production. Because of labour costs, time and tedium, manual weeding is unfavourable. Weeds compete with crop plants for nutrients and other growth factors and in the absence of an effective control measure, remove 30 to 40 per cent of applied nutrients resulting in significant yield reduction [2]. Delay and negligence in weeding operation affect the crop yield and the loss in crop yields due to weeds in upland crops varying from 40 to 60 per cent and in many cases cause complete crop failure [3].

The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeders are most effective in both dry land and wet land [4]. Majority of Indian Farmers use hand-hoe for weeding which requires 40-60 labourers for weeding one hectare of land [5]. Manual weeding requires huge labour force and accounts for about 25 per cent of the total labour requirement which is usually 900 to 1200 man hours/hectares [6].

Mechanical weeding is preferred to chemical weeding because weedicide application is generally expensive, hazardous and selective. Besides, mechanical weeding keeps the soil surface loose by producing soil mulch which results in better aeration and moisture conservation. Keeping in view of the above facts, an engine operated weeder was designed, developed and tested in field.

2. MATERIALS AND METHODS

2.1 Design Considerations

The development of weeder was initiated with considering the condition of field & soil, weed and crop. A machine was designed by keeping in mind the various agronomical requirement of crop like spacing of crop (20 cm) and height of the crop (20 cm) from the ground level. Machine should be simple in design and it should easy to operate. Cost of the machine should be low so that it can be easily repairable by farmer or village artisan. Crop variety is an important parameter which influences the mechanical weeding operation since the growth factor and foliage varies for each variety. The soil parameters like soil type, moisture, bulk density and cone index influencing mechanical weeding of different crops were identified and measured.

2.2 Cutting Unit

Commonly three types of blade geometries are used as blades for weeders and tillers namely, L-shaped blades, C-shaped blades and J-shaped blades. The C-shaped blades have greater curvature, so they are recommended for penetration in hard field and better performance in heavy and wet soils. The J-shaped blades are used for loosening, destroying the soil surface compaction and giving better ventilation to the soil, generally used for tilling hard and wet soils whereas L-shaped blades are the most common widely used for the fields with crop residue, removing weeds [7,8].

In this weeder for cutting unit three sets of L-shaped blades were used on rectangularity sleeved hub containing two blades on each hub were fitted on rotary shaft at a distance of 200 mm apart. The rotary shaft was made of 10 mm dia and 500 mm long MS rod. The blades were bolted with 6 mm bolts and nuts on rectangularity sleeved hub. The rotary shaft is supported by MS plate which is made adjustable for setting of the complete cutting unit and the plate fixed in the engine frame.

2.3 Power Unit

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 0.5 kgf/cm^2. The speed of operation of the weeder was considered as 0.7 m/s to 1.0 m/s. Total width of coverage of cutting blades was in the range of 50 to 70 cm. The depth of operation was considered as 2 to 3 cm, transmission efficiency is 80%. The power required is calculated by following formula [9].

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

Where, P_d is power requirement in HP, SR is soil resistance (0.5 kgf/cm^2), d = depth of cut (5 cm), w is effective width of cut (39 cm), v is speed of operation (1 m/s) and η_t is transmission efficiency (75%).

Hence, power requirement is estimated as

$$P_d = \frac{0.5 \times 5 \times 39 \times 1}{75} \times \frac{1}{0.75} = 1.73 \text{ HP or } 1.29 \text{ kW}$$

Hence, A petrol engine (Honda GK 100) of 97.7 cc (1.3 kW), 4-stroke, Air Cooled, Single Cylinder was used as a prime mover.

2.4 Power Transmission System

Gearbox was purchased from the local market. Gearbox encompassed transmission unit's viz. shafts on the two ends and it has a reduction of 10:1. A coupling is used in between the engine and gearbox to transmit the power from engine to gearbox unit by joining both the ends of the shafts in coupler and is bolted by three sides. Since, the shaft of the gearbox rotates in reverse direction so crossed belts were provided to rotate the cutting units (rotary blade) and the ground wheel in forward direction.

Two four inch pulleys were attached on the gearbox shaft on either side and from left side of the gearbox power is transmitted to the 12 inch pulley fixed on the mid shaft after that power is transmitted from 2 inch pulley to the 8 inch pulley which is fixed on the ground wheel shaft and required 25 rpm is provided for the ground wheel. From right side the gearbox power to 2 inch pulley fixed on the cutting unit shaft directly with the help of V-belt which rotates the cutting unit belts and pulleys were used to transmit power from the engine to the ground wheel and the cutting unit (rotary blades).

2.5 Design of Components

2.5.1 Ground wheel axle shaft

This is the main component of the power operated rotary weeder. It consists of shaft, on which maximum load was rest on its periphery and bush. It was designed by considering that the axle must be able to bear the load of the machine and to accommodate the wheel, bush, pulleys and other adjustments.

2.5.2 Design of ground wheel axle shaft

The power weeder was operated by a 1.4 HP (97 cc) SI engine. So, the torque developed can be determined by the equations given below [10]:

$$BHP = \frac{2\pi NT}{4500} \qquad (2)$$

Where, BHP is available horsepower of engine (1.4 HP), N is rpm of the shaft (25 rpm) and T is torque developed at shaft in kg-m.

From equation 2:

$$T = \frac{1.4 \times 4500}{2 \times \pi \times 25} = 40.107 \text{ kg} - \text{m} = 4010.7 \text{ kg} - \text{cm}$$

From shear force and bending moment diagram the section C is subjected to maximum bending moment. Therefore the value of this bending moment can be determined by the equations given below [10]:

$$M = \frac{W}{2}\frac{L}{2} \qquad (3)$$

Where, M is maximum bending moment in kg cm, W is weight of machine (65 kg) and L is distance between the two bearings A and B (20 cm).

From equation 3:

$$M = \frac{65}{2} \times \frac{200}{2} = 325 \text{ kg cm}$$

Assuming permissible shear stress as 760 kg/cm^2 for axle shaft of steel, the diameter of shaft can be calculated by the equations given below [10]:

$$d = \sqrt[3]{\frac{16(T^2 + M^2)^{0.5}}{\pi f_s}} \quad (4)$$

$$d = \sqrt[3]{\frac{16(4010.7^2 + 325^2)^{0.5}}{\pi \times 760}} = 2.42\ cm = 24.2\ mm$$

However, for safety 25 mm diameter was taken for ground wheel axle shaft. Further the length of the axle shaft taken as 720 mm to accommodate the wheel on both side.

2.5.3 Ground wheel

2.5.3.1 Uplift pressure on the wheel

Assuming the flooded soil as a liquid with specific weight 'γ' the upward thrust developed at the bottom of a wheel of radius 'r'=262.5 mm and width 'b' = 50 mm sinks 50 mm in the puddle soil, then upward thrust can be calculated by equation given below [11].

$$\mathrm{Q = specific\ weight \times volume\ of\ soil} \quad (5)$$

$$\mathrm{Q} = \mathrm{b}\gamma\left[\mathrm{r}^2\cos^{-1}\left(\frac{\mathrm{r-h}}{\mathrm{r}}\right) - \mathrm{r} - \mathrm{h}\sqrt{2\mathrm{rh} - \mathrm{h}}\right] \quad (6)$$

Where, Q is upward thrust in kg, b is width of wheel (5 cm), γ is specific weight of flooded soil, r is radius of wheel (26.25 cm) and h is sinkage of wheel (5 cm).

By substituting the values in equation 6:

$$\mathrm{Q} = 50.00001\left[(26.25)^2\cos^{-1}\left(\frac{26.25-5}{26.25}\right) - 26.25 - 5\sqrt{(2\times26.25\times5)-5}\right] = 1.5\ \mathrm{kg}$$

The calculated uplift pressure on the wheel was 1.5 kg, which was appropriate for the designed cage wheel.

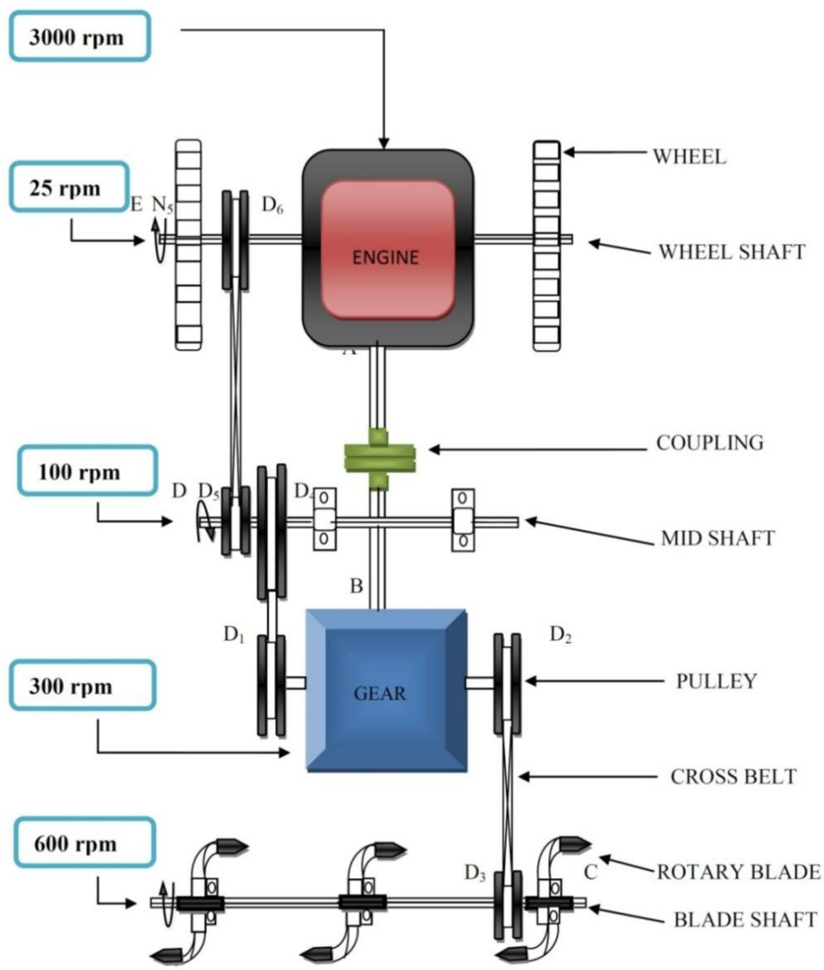

Fig. 1. Schematic diagram of power transmission system of rotary weeder

2.5.3.2 Optimum lug spacing

The ground wheel should be designed to run at a maximum slip of 30 per cent at which the lug spacing required for a wheel with radius 262.5 mm, lug sink age 30 mm and minimum shear spacing 60 mm is given by equation [12]:

$$L_1 = \frac{2}{(1-i)}\left[r\cos^{-1}\left(\frac{r-h}{r}\right) - r\sqrt{1-\left(\frac{r-h}{r}\right)^2} \times \frac{S}{2}\right] \qquad (7)$$

Where, L_1 is lug spacing in mm, i is maximum slip (30%), r is radius of wheel (26.25 cm), h is sinkage of wheel (5 cm) and S is minimum shear spacing (6 cm).

By substituting the value in equation 7:

$$L_1 = \frac{2}{(1-0.3)}\left[26.25 \times \cos^{-1}\left(\frac{26.25-5}{26.25}\right) - 26.25\sqrt{1-\left(\frac{26.25-5}{26.25}\right)^2} \times \frac{6}{2}\right] = 18\ \text{cm}$$

The optimum lug spacing will be 18 cm. Apart from this; the lug spacing should be such that it does not clogged by the soil.

Considering above values, two traction wheels were fabricated, using 10 mm diameter MS rod. The wheels were fabricated using two different rings outer 450 mm and inner 530 mm in between which lugs of MS flat dimensions 35×5 mm 9 in numbers were welded on the rim at 180 mm spacing. MS rods of 10 mm dia and 240 mm long in outer ring and 200 mm long in inner ring, 3 numbers in each ring were welded as spokes on the central hub. The 100 mm long hub was made up of MS pipe to suit the 1inch shaft, as the external axle of the ground wheels. The lugs were designed in between the rings was of 'V' shaped for better traction of the wheels in the field during operation. The reason behind using two different diameter rings was to make the field operations smooth and prevent jerks due to undulating field.

2.5.4 Gauge wheel

A gauge wheel is attached to the rear of the frame for depth adjustments of the rotary blades. An iron wheel of diameter 152.4 mm was used for this purpose. The 105 mm dia bush is provided in which four numbers of spokes of 60 mm each are fixed for better strength of wheel The gauge wheel shaft has adjustment for raising and lowering the gauge wheel so as to alter the depth of cutting and weeding by the rotary blades.

2.5.5 Frame

In order to accommodate the power unit, gearbox, transmission system and cutting unit it was decided to have frame of overall dimension of 600 mm in length and 200 mm in width. The frame is made from 35×35×5 mm MS angle section. Also strips of MS plate size of 115×32 mm were welded in between the angle iron as braces and support.

Fig. 2. Developed rotary weeder

Fig. 3. Developed rotary weeder during field operation

2.5.6 Handle

Two handles are provided at the rear of the machine which was attached to the main frame. Handles are made of 25 mm MS conduit pipe with plastic grip at the ends. With the help of handles machine can be steered and depth of tilling can also be controlled. A throttle lever is provided on one side of the handle to control engine speed.

3. RESULTS AND DISCUSSION

The machine was designed, fabricated and tested at the Department of Farm Machinery and Power Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India. The machine has a effective width of cut, 39 cm and a field capacity of 0.14 ha/h or 1.5 ha/8 working hours of the day at operating speed of 3.6 km/h. Average field efficiency was 60 %. It was observed that the machine worked satisfactorily for weeding. The cost of the prototype machine was Rs. 34524. The machine is economically viable with fuel consumption limited to 3 litres per day. Even, when there was standing water the machine performance was not satisfactory due to presence of hard soil beneath the water level. The bigger wheel provided better stability during operations and also some of the weeds were cut and buried due to the actions of lugs. The energy consumed by the developed power weeder was found 779.935 MJ/ha for weeding operation in wetland rice.

3.1 Weed Dynamics

The data presented in Table 1 shows that weed population before weeding operation was 245 which reduced to 22 after weeding operation by developed power weeder. The weeding efficiency of the developed power weeder was 91 %. Basically, three types of weeds were found in the field i.e. Grasses, sedges and broad leaves. It was found that the broad leaved weeds dominated over grasses and sedges in the experimental plot. 81 grasses, 66 sedges and 98 braod leaves were found before the weeding operations. However, it reduced to 7 grasses, 6 sedges and 9 broad leaves after the weeding operations.

Table 1. Weed dynamics

S. no.	Types of weeds	No. of weeds before weeding in 1 m^2	No. of weeds after weeding	Weeding efficiency (%)
1.	Grasses	81	7	91.3
2.	Sedge	66	6	90.9
3.	Broad leaves	98	9	90.8
	Total	245	22	91

4. CONCLUSION

The developed power operated rotary weeder was operated by 1.3 kW petrol start-kerosene run engine. It was tested in the experimental plot and observed that the machine worked satisfactorily. The field capacity and field efficiency of machine was 0.14 ha/h and 60% respectively. The larger wheels provided better stability during operation and due to presence of lugs in the wheel some weeds were also cut and buried. The operational cost was found to be Rs. 808.42.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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