Original Research Article

Design and Fabrication of Manually Operated Paddy Weeder

ABSTRACT:

A manual type operated weeder was designed and developed at the workshop of the Department of Farm Machinery and Power at BCKV, Nadia district, West Bengal, India. This Study was conducted to know the design features of manually operated weeders for paddy weeding. The weeder was made of locally available materials to reduce the cost of weeding. The weeder was tested at the experimental field of the Department of Farm Machinery and Power to evaluate its functional and economical parameters. The travel speed of this type weeder is 1.3 km/h. The weeding efficiency of weeder was found 65.6% to 74.2%. The average field capacity of the weeder was observed as 0.013 ha/h.

The field efficiency of this type weeder was found as 81.2%. The plant damage of this weeder was found as 2.96%. Operating cost of this type weeder is Rs. 3557.3/ha. Therefore, designed of this type weeder is the best in terms of cost of operation and it is more economical compared to other weeding operation.

Keywords: *weeder, uplift pressure, lugs, weeding efficiency, field efficiency, plant damage*

1. INTRODUCTION

India is the world's second largest producer of rice according to FAO report, 2021. Rice is mainly grown in rain fed areas that receive heavy annual rainfall and thus it is usually grown in a kharif season (Yerpude et al., 2015). It depends upon temperature of around 25°C and above and rainfall of more than 1000 mm (Yerpude et al., 2015). Agriculture in West Bengal is the means of livelihood of about 65% of the population of the state living in villages with over 95% as small and marginal farmers (Bag et al., 2011). Small and marginal farmers consist of over 95% of total farm population and they own near about 80% of cultivated land (Bag et al., 2011). The soils of West Bengal can broadly be classified into 8 categories viz (Bag et al., 2011).

i. Brown forest soils (Darjeeling and Jalpaiguri zone)
ii. Terai soils (Coochbehar, Uttar Dinajpur part zone),
iii. Tista – Mahananda alluvial soils (Coochbehar, Jalpaiguri part zone),
iv. Vindhyan alluvial soils (Bankura part, Hooghly part),
v. Gangetic alluvial soils (Howrah part, Nadia, Birbhum part zone),
vi. Deltaic and coastal soils (North 24-Parganas part, Midnapore part),
vii. Red soils (Midnapore, Birbhum part) and
viii. Lateritic soils (Midnapore, Birbhum part).

2. MATERIALS AND METHODS

2.1 Theoretical Design

The machine is light, simple in design, easy to operate, better to handle, reduce drudgery, can easily be manufactured from locally available materials (i.e.) galvanized iron pipe, mild steel bar and can be easily maintained. A manually operated weeder was designed for weeding of mechanical and manual transplanting of paddy. From the design point of view, cutting blades shaft were the important components of single row manual weeder for paddy.

2.1.1 Power requirement

Soil resistance had a considerable effect upon the power requirement of the weeder. Also, width of cut and speed of operation have major role in power estimation of weeder. A man can comfortably walk in the field at a speed of 1 to 1.2 km/h **(Pandey, 1994)**. The specific draft of soil vary 1.4-2 N/cm^2 for sandy soil, 2-5 N/ cm^2 for silty loam and 4-8 N/ cm^2 for clay loams and heavy clay soils **(Kepner *et al.*,1978)**.

We assume the following parameter for calculation of the power requirement:

i. Walking speed – 1.2-2 km/h (consider 2 km/h)

ii. Depth and width of cut – maximum depth 40 mm and width 130 mm.

The draft was calculated by the following expression;

$$P = w \times d_w \times R_s \quad \ldots \quad (1)$$

Where,

P = Draft of the weeder (kg)

W = width of cut (cm)

d_w = depth of cut (cm)

R_s = soil resistance (kgf/cm^2)

$$P = 13 \times 4 \times 0.5$$

$$P = 26 \text{ kg}$$

The power input required for weeding operation was calculated by considering the parameters like draft and traveling speed.

$$\text{Power input (hp)} = \frac{\text{Draft } (kg) \times \text{traveling speed } (\frac{m}{s})}{75} \quad \ldots \quad (2)$$

$$= \frac{26 \times 0.5}{75}$$

$$= 0.17 \text{ hp}$$

$$= 126.7 \text{ w}$$

2.1.2 Frame:

We consider a frame which has less complicated in design and strength of frame material. Frame was made using 740×150×250 mm MS angle iron. Plant height was considered to decide the clearance of frame from the ground, for less damage of plant during operation. The frame was able to hold all the components of weeder. It supports the adjusting shafts of cutting blades and also determine the width of the machine.

2.1.3 Handle:

It is fabricated from the galvanized iron pipe of 340 mm length. Ergonomi consideration was very important for less effort of human to operate this instrument (Fig.1). Handle grip was 36 mm diameter. 250 mm height of the adjusting handle from the ground surface is obtained with adjusting support**.** It transmits force to the rotary blades.

Fig. 1 Handle of the manually operated weeder

2.1.4 Handle Grip:

Cylindrical shape was more suitable for holding with maximum grip (Fig.2). Take diameter in which the middle finger not touches to palm and the grip should not more than the inside grip diameter. When the machine operated by man and women worker both then lower limit of diameter is 95th %ile of middle finger palm grip diameter and upper limit 5th %ile grip diameter inside of the female worker can be used.

Fig. 2 Handle grip of the manually operated weeder

2.1.5 Ground wheel:

Ground wheel is fabricated from mild steel bar of 250 mm diameter, 40 mm width and 12 mm thickness (Fig.3). 44 teeth of big sprocket and 16 teeth of small free sprocket are attached inside the ground wheel. Gear ratio is 3:1. 3 spikes are attached to the ground wheel. Total length of 3 spikes are 312 mm. The length of each spikes are 104 mm. The diameter of small hub shaft with the ground Wheel is 32 mm.

Fig. 3 Ground wheel of rotary weeder

2.1.6 Uplift pressure on the ground wheel:

When wheel move in flooded/muddy soil it sink and dislocate some volume of soil. This was uplift pressure which produced by the soil which was displaced through the wheel. When the upward thrust balances the normal load on the wheel, the wheel operates in the floating condition. The uplift pressure was calculated by following formula **(Mahilang 2013)**.

$$Q = b\gamma\,[r^2 \cos^{-1}(\frac{r-h}{r}) - r - h \times \sqrt{2 \times r \times h} - h] \quad \ldots \quad (3)$$

Where,

b = width of wheel, m

h = sinkage of the wheel, m

Q = upward thrust, kg

r = radius of wheel, m

By substituting the values in equation 3,

$$Q = .04 \times 0.00001[.125^2 \times \cos^{-1}(\frac{0.125-0.03}{0.125}) - 0.125 - .03 \times \sqrt{2 \times 0.125 \times .03} - .03]$$

$$Q = 1.7 \times 10^{-7}\ \text{kg}$$

2.1.7 Design of lugs:

The lugs are providing on the circumference of the ground wheel to obtain proper traction. The soil acceleration force was calculated using equation as given **Srivastava (2003)**.

$$F_{s1} = \frac{pg}{g} \times b \times d \times {v_o}^2 \frac{\sin\theta}{\sin(\theta + \propto)} \quad \ldots \quad (4)$$

Where,

F_{s1} = soil acceleration force, N;

B = width of penetration lugs, m;

D = depth at penetration of lugs, m;

v_o = forward speed of weeder, m/s

θ = tool lift angle, degrees

∝ = angle of forward failure surface, degree;

The sizes of lugs on wheel were selected as 25 mm width and 10 mm thickness. Lugs are welded perpendicular to ground wheel with 90º to soil surface. The bulk density of soil was 1500 kg/m³. It is assumed internal angle of friction as 36º, maximum forward speed as 2.5 km/hr. Angle of forward failure surface is calculated using formula:

$$\propto = \frac{1}{2}(90 - \varphi) \quad \ldots \quad (5)$$

∝ = 1/2 (90-36)

$\propto = 27^0$

$$F_{s1} = \frac{1500 \times 9.81}{9.81} \times 0.025 \times 0.018 \times 0.7^2 \frac{sin 90}{sin(90+27)}$$

$Fs1 = 0.36N$

Considering three lugs are in contact with soil, total soil acceleration force is given by

$$B_0 = 3 \times F_{s1} \quad \ldots \quad (6)$$

Where,

B_0 = Total soil acceleration force on wheel,

$B_0 = 3 \times 0.36$

$B_0 = 1.08N$

2.1.8 Cutting Blade:

It is made of cast iron. L-shaped blades are the most common widely used for the wet soil fields with crop residue, removing weeds {**(Bernacki et al., (1972) and Khodabakhshi et al., (2013)}**. The width and length of the blades are 130 mm and 100 mm respectively (Fig.4). The blades are sharpen at the lower end so it can penetrate into the soil at proper angle and desired depth during weeding.

Maximum expected length of soil slice,

$$L = \frac{v \times 2 \times \pi \times R}{U \times Z} \quad \ldots \quad (7)$$

$= \frac{0.68\times2\times\pi\times22.5}{0.871\times26}$

$=$ 4.2 cm

$=$ 0.04 m

Maximum force required to cut the soil for each blade, P_m

$P_m = {}_{p}A$ … (8)

$P_m = 0.50 \times 10.1 \times 1$

$P_m =$ 5.05 kg

Where,

V = forward speed

U = peripheral speed of rotor with radius R

P = maximum specific resistance of soil

A = area to be disturbed,

A = a × length of soil slice; and

A = edge length of the blade,

L = length of blade,

Z = no. of lugs

Fig. 4 Cutting blade

2.1.9 Power Transmission:

Chain and sprocket system will used for the power transmission to the ground wheel.

Speed reduction ratio (chain drive) $= \frac{44}{16}$

$=$ 2.75: 1

Where,

Big sprocket (Drive)	=	44 number of teeth
Small free sprocket (Driven)	=	16 number of teeth

Speed reduction was calculated based on the chain and sprocket available in the market.

Speed of chain drive was obtained by using the following equations:

$$V = r \times \omega \quad \ldots \quad (9)$$

$$0.684 = 0.125 \times 2\,\pi\, N_1$$

$$N_1 = 0.87 \text{ m/s}$$

$$N_1 T_1 = N_2 T_2 \quad \ldots \quad (10)$$

$$N_2 = 2.39 \text{ m/s}$$

Where,

N_1 = rpm of the driven sprocket

N_2 = rpm of the drive sprocket

T_1 & T_2 = No. of the driven & drive sprocket

ω = angular velocity

2.1.10 Length of Chain:

Length of chain can be determined by using the following formula according to the **Khurmi *et al.* (2005).**

$$L = \frac{P}{2}(T_1+T_2) + 2X + [\frac{P}{2}\text{cosec}\frac{180}{T1} - \frac{P}{2}\text{cosec}\frac{180}{T2}]^2 / X \quad \ldots \quad (11)$$

$$L = \frac{12.7}{2} \times (44+16) + 2\times340 + [\frac{12.7}{2}\text{cosec}\frac{180}{T1} - \frac{12.7}{2}\text{cosec}\frac{180}{T2}]^2 / 340$$

$$L = 1070 \text{ mm}$$

$$L = 1.07 \text{ m}$$

Where,

L = length of chain, mm

P = pitch of chain, mm

T_1 = no. of teeth on drive shaft

T_2 = no. of teeth on driven shaft

X = centre to centre distance between two sprockets, mm

Fig. 5 A view of newly developed rotary weeder

2.2 Testing Methods:

The following parameters were used for evaluate the performance of weeder for weeding operation in paddy crops.

2.2.1 Speed of travel:

For calculating the speed of travel, at first a particular distance was fixed and the time to cover this distance was noted. For measuring the speed of travel, the implement was started well before the first pole marker and it was ensured that the speed was uniform throughout the marked space. Then the implement was operated at that particular distance. A stop watch was used to record the time taken by the implement to travel the marked distance during operation. The speed of travel was calculated in terms of m/min or m/s.

2.2.2 Weeding efficiency:

It is the ratio between the numbers of weeds removed by weeder to the number of weeds present in a unit area in fig.6 and is expressed as %.

$$\text{Weeding efficiency (\%)} = \frac{W1-W2}{w1} \times 100 \qquad \ldots \qquad (12)$$

Where,

W_1 = No. of weeds counted per unit area before weeding operation

W_2 = No. of weeds counted in same unit area after weeding operation

Fig. 6 Counting of weeds in the field

2.2.3 Effective field capacity:

It is the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of travel and the amount of field time lost during the operation. It is expressed as ha/h.

Effective field capacity,

$$EFC = \frac{total\ area\ (ha)}{total\ time\ (h)} \quad \ldots \quad (13)$$

2.2.4 Theoretical field capacity:

It is the rate of field coverage that would be obtained if the machine were performing its function 100% of the time at the rated forward speed and always covered 100% of its rated width. It is expressed as ha/h.

$$TFC = \frac{w \times s}{10} \quad \ldots \quad (14)$$

Where,

TFC = theoretical field capacity, ha/h

w & s = width of cut, m & speed of operation, km/hr.

2.2.5 Field efficiency:

It is the ratio of effective field capacity to the theoretical field capacity, expressed as %. It includes the effect of time lost in the field and of failure to utilize the full width of the machine.

$$\eta_e = \frac{EFC}{TFC} \times 100 \quad \ldots \quad (15)$$

Where,

η_e = Field efficiency, %

EFC = Effective field capacity, ha/h

TFC = Theoretical field capacity, ha/h

2.2.6 Draft:

The draft required by the weeder was calculated by using following expression.

$$D = W \times d_w \times R_s \quad \ldots \quad (16)$$

Where,

D = Draft of a weeder, kg

W = Width of cut, cm

d_w = Depth of cut, cm

R_S = Soil resistance, kg/cm^2

2.2.7 Power requirement:

The power input required for weeding operation was calculated by considering the parameters like draft and traveling speed.

$$\text{Power input, (hp)} = \frac{Draft\ (kg) \times traveling\ speed\ (\frac{m}{s})}{75} \quad \ldots \quad (17)$$

2.2.8 Depth Adjustment:

A depth of operation control device was used with the weeder due to adjust the height and angle position of the handle to make it easy to operate for every one with different heights. This arrangement makes the weeder working in a stable depth with minimum and maximum as shown in Fig (7) & Fig (8).

Fig. 7 Minimum Weeding operation **Fig. 8 Maximum Weeding operation**

3. RESULTS AND DISCUSSION

This chapter deals with the result and discussion of the experiment conducted in order to fulfill the objective of the study. Performance parameters were measured i.e. weeding efficiency, field capacity, field efficiency, economics etc. are discussed in this chapter.

3.1 Working Performance of Manually Operated Weeder

The weeding test was performed on the farm of Jaguli Instructional Farm, B.C.K.V in Nadia district, West Bengal, India, Pin-741252. Five readings of travel speed were taken and average travel speed was calculated and used in the study. The average traveling speed was found to be 0.99 m/s. During testing it was observed that the traveling speed also depends on the parameters such as weight of the operator, height of the operator, and physical condition of the operator. Therefore, to avoid the error in result analysis the subjects of more and less equal weight and anthropometry were selected for the study.

The field capacity of the newly developed weeder was calculated by selecting the representative three sample plots of size 10 × 10 m. The field capacity was found out to be 0.048 ha/h, which was higher than the already available weeders. It was also observed that if the effective cutting width is reduced, the field capacity is also reduced. The field capacity of the newly developed rotary weeder was also superior as compared to the available local weeders.

The average weeding efficiency was found to be 92.5 %, which shows that the weeder is efficient. It was observed that the weeding efficiency depends on the root zone depth of weeds, shape of blades, moisture content of the soil at testing site and cutting depth of the weeder blades.

Draft is an important parameter in the development of weeder and it must be within the physical limits of the operator. The average draft required for weeding was found to be 39.15 kg. However, maximum pushing force for Indian agricultural work ranges from 25 to 30 kg. Though, the draft for developed weeder is higher but it was comfortable in operation because the operators selected for the study were tall and strong enough. However, it was observed that the draft depends on the type of soil, effective cutting width and depth of cut. In manually operated weeders, the tool works in a shallow depth so the soil resistance has a little impact on the draft requirement of the tool.

The average power requirement for the weeder was estimated to be 0.17 hp, which is higher by 50% because of the higher width of cut. Further, it was concluded that if one want to reduce the power requirement, reduction in effective width of cut is needed which subsequently reduces the field capacity of the weeder.

3.2 Field Parameters of the Test Plot

Field performance test of the manually operated paddy weeder was conducted at the Instructional Farm of BCKV. For proper weed management in the field and to remove the problems in the operation of wet paddy weeder, an existing manually operated rotary weeder was tested in the field and it was observed that the performance of the weeder was satisfactory. The manually operated weeder has been tested in the wet field for evaluation for its effective performance in terms effective field capacity, field efficiency, weeding efficiency, cost of operation etc.

3.2.1 Speed of travel

It is an important parameter of the weeder performance evaluation. The test was conducted by selecting certain fixed distance say 10 m and the time was noted to travel this distance. Five readings of travel speed were taken and average travel speed was calculated and listed in the Table 1.

Table. 1 Effect of Difference Time and Speed

Sr. No.	Distance Covered (m)	Time taken (s)	Travelling speed (m/s)	Average (m/s)
1	10	9.2	1.08	0.99 $\pm$ 0.088
2	10	10.5	0.95	
3	10	10.4	0.96	
4	10	9.21	1.08	

5	10	11.3	0.88	

3.2.2 Field capacity

The field capacity of developed weeder was calculated by selecting a respective three plots of size 10 × 10 m. The weeder was operated in these plots and the different observations were recorded. The observations are presented in Table.2.

Table. 2 Effect of Difference Time and Field Capacity

Plot No.	Area of plot (m^2)	Time to cover this area (min)	Field capacity (ha/h)	Average (ha/h)
1	100	17.52	0.034	0.035
2	100	16.20	0.037	
3	100	17.23	0.034	

3.2.3 Weeding efficiency

The weeding efficiency test was performed on selected plots and the respective readings were noted and reported in Table 3. And Table 4.

Table. 3 Effect of Different Treatments of Weeding on Field Efficiency in Plot 01

Sr. No	Area (m^2)	Before weeding	After weeding	Weeding Efficiency (%)	Avg. (%)
1	0.5	55	15	72	74.2
2	0.5	85	19	77	
3	0.5	69	14	79	
4	0.5	91	23	74	
5	0.5	88	27	69	

Table. 4 Effect of Different Treatments of Weeding on Field Efficiency in Plot 02

Sr. No.	Area (m^2)	Before weeding	After weeding	Weeding Efficiency	Avg. (%)
1	0.5	42	21	50	65.6
2	0.5	71	17	76	
3	0.5	55	19	65	
4	0.5	61	22	63	
5	0.5	68	18	74	

3.2.4 Theoretical Field Capacity

Width of operation, (w) = 0.13 m

Average working speed, (s) = 3.384 km/h

So,

$$\text{Theoretical field capacity} = \frac{w \times s}{10} \qquad \ldots \qquad (18)$$

$$= \frac{0.13 \times 3.384}{10}$$

$$= 0.043 \text{ ha/h}$$

2.2.5 Field Efficiency

$$\text{Field Efficiency} = \frac{\textit{Actual field capacity}}{\textit{Theoretical field capacity}} \times 100 \qquad \ldots \qquad (19)$$

$$= \frac{0.035}{0.043} \times 100$$

$$= 81.3\ \%$$

3.2.6 Weeding efficiency under different implements

The maximum weeding efficiency was observed with 'Khurpi' (95.05 per cent) followed by push type rotary weeder (65.6 to 74.2%) and power weeder (89.5 per cent). The maximum weeding efficiency with 'Khurpi' was observed because of the capability of this hand tools to work between plant to plant spaces in a row. However, push type rotary weeder and power weeder cannot be used for closer plants. This may be the reason for low weeding efficiency.

3.2.7 Field efficiency under different implements

The average field capacity was found maximum for khurpi (91.5 per cent) followed by push type cycle weeder (85.4) and power weeder (71.25 per cent). The difference in field capacity of different tools/implements is because of the width of soil cutting parts and forward speed. The power weeder due to its faster movement and its width it can cover larger field so that it has highest field efficiency compared to other weeder which are slow in speed. Inter culturing operation with 'Khurpi' is usually done by the operator in sitting posture and the forward speed is quite less, which accounts the minimum field capacity of 'Khurpi' during weeding operation.

2.2.8 Cost of operation under different weeding tool

The cost of operation of khurpi was found maximum (Rs 1750/ha) followed by power weeder (Rs 1300/ha) and push type rotary weeder ((Rs 8000/ha). As weeding is a labour consuming process and because of minimum field capacity of 'khurpi' the cost of operation of 'khurpi' for weeding was maximum. The cost of operation of power weeder was found more than both wheel hoe and grubber which might be due to higher purchase cost of this implement and lower annual use which were responsible for increasing the fixed cost of power weeder in spite of having higher width of operation and speed of operation resulting in higher field capacity of this machine.

3.3. Cost Analysis

3.3.1 Cost of manually operated rotary weeder

Material used for fabrication of weeder and their quantity with their price for determining the cost of weeder. Initial cost of weeder was calculated Rs. 8000 /-. Labour charges also added to determine the cost of weeder. The materials were purchased from market, so as per current market values cost of weeder was determined.

3.3.2 Cost of operation

Cost of operation determined by considering the cost of weeder. Cost of operation was calculated Rs.4.82/ha by fixed cost and Rs.511.25/ha variable cost of weeder, Cost of operation was then compared with other method of weeding, which used during experiments. Parameters evaluated after cost analysis is given in Table 5.

Table. 5 Cost analysis of Weeder

Total Fixed Cost/ha. (Rs)	Total Variable Cost/ha. (Rs)	Operating Cost/ Annum (Rs)
4.82	511.25	516.07

4. CONCLUSION

The significance of new developed manually operated rotary weeder is-

I. To save the cost of operation by saving the time and labour requirement.

II. Work well in paddy field without much damaging the plants.

III. Have long life and cost of operation will also less.

IV. Local women would be able to use this weeder due to its light weight and easy operation.

V. The manually type weeder could be easily fabricated by local artisans.

For full fill this requirement of weeding a work was conducted to design, development and evaluation of manually operated paddy weeder. Additionally, therefore, manually type of weeder would be economically efficient.

i. Average travelling speed of power weeder was 2.0 km/h. This was not much fluctuating with different depth of operation and speed of blade.

ii. Width of cut of power weeder was found 13 cm, which was mainly depending on the depth of cut because disturbance of soil varies with depth of operation.

iii. Field efficiency was found to be 65.15 to 75.07 %.

iv. Weeding efficiency was found as 65.46 to 73.25 %.

v. Two skilled operators were required to operate the weeder continuously.

vi. Plant damage was not much in power weeder because working width of weeder was only 13 cm in each row.

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