Oryza Vol. 55 No. 2, 2018 (317-323)
DOI 10.5958/2249-5266.2018.00039.5

Development and evaluation of power operated weeder in rice

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Received : 10 July 2017 Accepted : 08 June 2018 Published : 27 June 2018

ABSTRACT

A power operated single row dry land weeder for inter row weeding was developed and evaluated in rice crop and compared with traditional methods of manual weeding. The power weeder consisted of engine, blades assembly and transmission system. Vertical J shape blades were developed and mounted on a circular rotating element on its horizontal side; the motion was transferred to blades units by amended transmission system. The rotating blades cut the weeds and also give forward motion to the machine. Three different row to row spacing 20 cm, 25 cm and 30 cm and four different type of blade having width 12 cm, 14 cm, 16 cm and 18 cm has been used in the study. The effect of blade width on forward speeds, depth of operation, field capacity, plant damage, and weeding efficiency, were studied. Cost of operation and energy required per unit area were studied in comparison to the traditional methods. It was found that plant damage and weeding efficiency increased with increase of blade width. For row to row spacing of 20 cm, 25 cm and 30 cm, blade width of 14 cm, 16 cm and 18 cm, respectively, was recommended because of less plant damage and high weeding efficiency. The developed power weeder helps in reduction of drudgery involved in weeding operation and it also reduces the cost involved in the operation.

Key words: *Cutting blade, economics, energy, unterrow weeder, weeder design*

INTRODUCTION

Rice contributes more than 60% and 25% to the cereals production of Asia and of the world, respectively, and it formulates nearly 30% of all the food being consumed in Asia (Timmer, 2010). For rice crop among all agricultural field operations starting from field preparation to harvesting, weeding operation consumes more labour and time. Heavy weed infestation has been proved to be the major constraint for the success of rice production, especially direct seeded rice given that weed prevalence is higher than in the conventional method of growing rice in flooded conditions (Farooq et al, 2011b; Kumar et al., 2016; Roy et al., 2011). In direct seeded rice systems, yield losses due to weeds are reported to be 70-80% (Hussain et al., 2008; Mahajan et al., 2009; Singh et al., 2007). Further, rice yield in DSR has been reported to be improved by 27-30% through implementation of suitable weed control methods (Hussain et al., 2008; Mishra and Singh, 2012). Weed control is important to conserve input for crop, as weeds compete for water, nutrients, space and light resulting in low yields but at the same time it is most laborious jobs in agriculture that accounts for a considerable share of cost involved in agricultural production (Guru et al., 2018).Majority of the farmers are using traditional tools and equipment for weed control involving drudgery, high cost of operation, wastage of agricultural inputs and damage to crop produce (Shrivastava, 2000). The use of chemical for weed removing from paddy crop was most common practice among farmers. Chemical weeding significantly reduces the yield in comparison to mechanical weeding and also two times chemical is required to control the weeds in DSR.

Mechanical control is among the most important classical weed management methods. Although it is one of the ancient weed control methods, recent advances have helped to shape it as an innovative weed control technique. Mechanical weeding having some advantage over chemical weeding i.e. slow growth of weeds and no adverse effect on plant growth (Kwangwaropas, 1999). Manually operated rotary tillers can be used for controlling weeds in aerobic rice systems, but these require a lot time, energy, and labour to accomplish weed control operation (Patel et al., 2018). The development of advanced motorized rotary tillers has rendered it an effective and economically viable weed control technique. Also, motorized rotary tillers will reduce the time and energy needed to accomplish the process. Development of power weeder is beneficial to reduce the time involved in weeding operation, reducing drudgery occurred due to continuous changing in posture of farm workers and also reducing the cost of operation. With the use of power weeder 10 man-hr are required to cover one-hectare area as compared to 167 man-hr for weeding manually for maize crop (Dixit and syed, 2008). The power weeder has higher field capacity as compare to hand khurpi, peg type dry land weeder, animal drawn blade hoe (Veerangouda et al., 2010). The manual weeder has limitation of working width and required more time to cover area between crops. Tractor drawn cultivator was evaluated for weeding operation and found successful for weeding in large row spaced crops (Verma and Guru, 2015). Most of the research conducted on rice weeding machines was either on wet land weeders or manual operated dry land weeders. To mechanize the weeding operation for dry DSR, light weight power operated weeder was developedat ICAR-National Rice Research Institute, Cuttack with the following objectives:

Design and development of power operated weeder for dry DSR.

Design of different width of cutting blade suitable for 20, 25, and 30 cm row to row spacing of rice.

Evaluation of developed weeder with different width of cutting blade for field capacity, weed control efficiency and compared with traditional methods of weeding .

MATERIAL AND METHODS

Development of power weeder

Power weeder capable to uproot, cut and bury weeds under dry land conditions was developed. A conceptual drawing was prepared before development of power weeder (Fig. 1). The major components of the power weeder were engine, engine mounting frame, main frame, transmission system, jaw type clutch assembly, clutch control lever, handle, two transport wheels, rotary tine assembly, support wheel and rubber flap (Plate 1). The weeder moves due to the thrust provided by the soil engaged on vertical blades. The design was kept as simple as possible so that operator can easily operate the machine.

Calculation of power requirement of dry land weeder

Power requirement: The power requirement was calculated using the following equations:

$$P_D = \frac{S_R \text{ x d x w x v}}{75} \text{ (H.P.)}$$

Where,

S_R = soil resistance, Kgf/cm^2

d = depth of cut, cm;

w = effective width of cut, cm;

v = Linear velocity of the tyne at the point of contact with soil (m/s)

Hence Power requirement for one row weeder is estimated as;

S_R=1.05, d = 5 cm, w = effective width = 6 cm, v = 1

$$P_D = \frac{10.5 \text{ x } 5 \text{ x } 6 \text{ x } 1}{75}$$

The total power is estimated as

Pt = Pd = 0.42 = 0.525 h.p.

n=0.8

Where Pd = Power required to dig the soil

n = Transmission efficiency

Power source

Based on the power requirement calculation for power weeder a 4 stroke, 3600 rpm, 1.03 kW, petrol-start kerosene run engine with 1.5 litre fuel tankcapacity was used to give power to cutting blades of designed weeder. The main components of engine were recoil starter, fuel tank, fuel filler cap, air cleaner, muffler, and output shaft. For better stability of the machine engine was fitted above the supporting wheels and in centre to

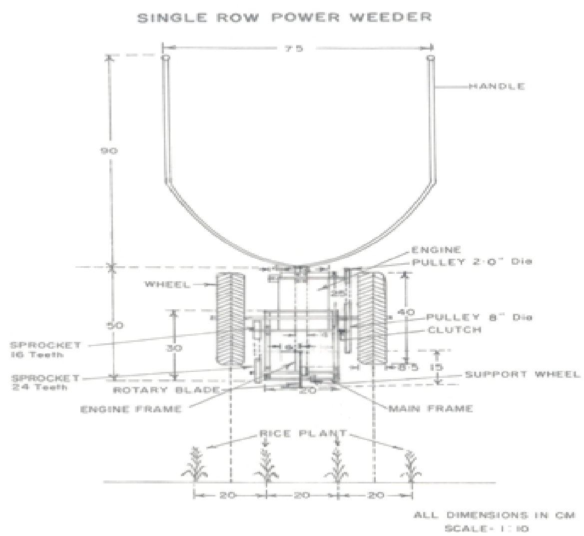

Fig. 1. Design of power operated dry land weeder.

distribute the weight evenly between both the wheels.

Transmission system

To make the weeder light in weight no gearbox was used for speed reduction. In order to get optimum forward speed pulley and chain sprocket were used as speed reduction unit. Engine speed of 3600 rpm was reduced to 470 rpm at rotary blade. Power can be made on and off to the rotary unit by turning the clutch control lever. A clutch lever was provided near the operating handle so that operator can easily engage or disengage the power from cutting blade.

Cutting blades

Four size of cutting blades having width 12 cm, 14 cm, 16 cm and 18 cm were designed to evaluate the performance of weeder. J shape blades were designed for the weeding operation because its better performance over C and L shape blades in terms of mixing quality (Bhamota et al., 2014). Six blades were mounted on rotor shaft of weeder. Blades were designed with dimension15 cm length and 0.5 cm thickness with cutting width of 6 cm, 7 cm, 8 cm and 9 cm. Each blade was fixed in opposite to next blade. This alternate opposite direction arrangement of blades gives coverage of double the width *i.e.,* 12 cm, 14 cm, 16 cm and 18 cm. The blade cut the soil and gives forward motion to the power weeder. Two supporting wheels were provided to adjust the depth of cut and a rear wheel was provided to control the direction of weeder.

Plate 1. View of power weeder.

Frame, handle and supporting wheels

Two supporting wheels of diameter 45 cm on both sides of weeder were provided to adjust the depth of cut and to provide stability during operation. The wheels also support weeder during transportation. Wheel spacing was made adjustable to work in different row to row spacing of crops. Light weight frame was designed to hold on the engine and transmit the load on supporting wheels.Handle height was made adjustable and can be adjusted by the operator as per comfort. Clutch in centre and accelerator on right were fixed on the handle.

Depth control wheel

A roller type depth control wheel with adjustable height was fitted in the front of machine to get uniform depth of intercultural operation. The diameter of the depth control wheel was 20 cm.

Safety covers

Safety covers designed for chain drive to avoid accidents. GI sheet shield above cutting blade and rubber flap behind cutting blade were provided to stop the soil thrown by cutting blades.

Evaluation procedure

Site characterization and experimental set up

Field experiment was conducted in *Rabi* 2015 and *Rabi* 2016 at National Rice Research Institute, Cuttack, India. Soil was characterized as silt loam with sand 22 %, silt 50 %, clay 27 % having bulk density 1.43 Mg

Table 1. Specification of developed power weeder and comparison with manual finger weeder.

Particulars	Developed power weeder	Manual finger weeder
Overall dimensions (LxWxH)	1800x600x 1100 mm	1530x85x 120 mm
Power source	1.03 KW engine	manual
Number of rows	1	1
Weeding mechanism	Rotary blade	Push pull action
Number of blades/ fingers	6	4
Wheel rim diameter	40 cm	-
Wheel base	40 cm (adjustable)	-
Width of cut	12, 16 & 18 cm	15 cm
Weight of the unit	38.4 kg	3 kg
Soil cutting depth	40-50 mm	40 mm

m^{-3}. Five treatments involved 4 width of blades along-with control involving manual finger weeding and subsequently by hand weeding was replicated in RBD. Size of each plot was 12 x 6 m^2. Field was prepared by using one operation of tractor drawn M B plough followed by TD cultivator and than puddling using TD rotavator. Manual line sowing of pre germinated rice (Pooja variety) seeds at row spacing of 20, 25 and 30 cm was done to evaluate the performance of developed weeder with different width of cutting blades. Row spacing of 20 cm was used to evaluate the performance of traditional methods of weeding in rice. Grassy weeds were more dominant in the experimental field.

Traditional weeding methods

Developed weeder was evaluated in comparison to popular methods of weeding in eastern India involving manual finger weeder and hand weeding after 20 DAS. Finger weeder operated by one person. Operator has to moves the handle forward and backward so that the weeds get uprooted by both actions. The weeder consists of a M.S plate to which 4 curved M.S rod were welded and a handle was attached. The two outside fingers were larger than the inside fingers. The fingers were so shaped and welded that they all touch the ground at a time. The fingers have been suitably spaced so that there was no clogging. The brief specification of developed weeder and finger weeder was given in Table 1.

Machine parameters

Trained operator was selected to operate the developed weeder effectively in field. Weeding operation was performed 20 days after sowing of the crop. The effect of width of the blade, operational speeds, and depth of operation on field capacity, plant damage, and weed control efficiency were studied as per given equations.

Weeding efficiency: Weight of weeds per unit area was counted before and after the experiment and the weed control efficiency was calculated as

Weeding Efficiency (%)= (Number of weeds per unit area before operation)/(Number of weeds per unit area after operation)

Field capacity and field efficiency: It was calculated as [Kepner et al, 2005; BIS 1981)

Theoretical field capacity (ha/h)= (Speed (km/h)×Width of implement (m)/10

Actual field capacity (ha/h)= (Total area covered (ha)/(Total time taken (h)

Field efficiency (%)= (Actual field capacity)/(Theoretical field capacity)×100

Plant damage: It is mechanical damage to the plants by the implement during operation due to abrasion, cut, etc. It was calculated as -

Plant damage (%)= (Number of damaged plants per unit area)/(Total number of plants per unit area)×100

Operational Speed and Fuel Consumption: It was calculated as given formula below:

Fuel Consuption (l/h)=(Fuel cosumed per plot in litre)/(Time consumed in hour)

Operational speed (km/h)=(Distance covered in km)/(Time consumed in hour)

Economics and energy calculations

Fixed cost includes depreciation, rate of interest, interest cost, tax , insurance, housing and variable cost includes repair and maintenance cost, fuel cost, lubrication cost, and labour cost. On the basis of these parameters total

Table 2. Energy input equivalents for the components of power weeder.

Energy input source	Input energy
Man (adult)	1.96 MJ/h
Petrol	48.23 MJ/l
Kerosene	41.30 MJ/l
Self propelled machines	68.4 MJ/kg

Table 3. Field performance of single row dry land weeder.

Parameters	Row to row spacing (cm)											
	20				25				30			
Blade width (cm)	12	14	16	18	12	14	16	18	12	14	16	18
Speed, km/h	1.28	1.45	1.27	1.27	1.35	1.45	1.20	0.98	1.30	1.63	1.23	1.19
Actual Field capacity, ha/h	0.025	0.029	0.022	0.025	0.033	0.030	0.029	0.031	0.039	0.049	0.035	0.036
Plant damage,%	Nil	Nil	14.0	25.6	Nil	Nil	1.57	13.1	Nil	Nil	Nil	Nil
Weeding efficiency,%	61.5	71.3	84.6	88.3	51.4	62	68.0	73.7	41.6	51.0	56.0	61.3

cost was calculated. Energy required for operation of developed weeder and traditional methods were calculated on the basis of energy input equivalents (Table 2)(Panesar and Bhatnagar, 1987).

RESULT AND DISCUSSION

The power weeder was tested in the laboratory for its proper functioning. At engine speed of 3600 rpm, the rotary blade was moving with 470 rpm. Wheel spacing was kept 40 cm, 50 cm and 60 cm for crop row spacing of 20 cm, 25cm and 30 cm respectively. Average weed intensity in the field observed was 6.04 t/ha. Machine was tested with depth of operation of 1 to 5 cm. Thrust action of rotating blades at 1 and 2 cm depth setting was observed poor which caused slow movement of weeder. At 5cm depth setting machine stopped due to heavy load on the engine. It worked satisfactorily at depth of 3 and 4cm.Weeder was evaluated in field at 4 cm depth (Table 3). The operation view of weeder was given in Plate 2.

Plate 2. Power operated dry land weeder in operation.

Effect of width of cutting blade on plant damage

Width of blade was selected as 12 cm, 14 cm, 16 cm and 18 cm for three different row to row spacing of rice crop 20 cm, 25 cm and 30 cm. For all three selected row to row spacing, there was no plant damage was found for 12 cm and 14 cm width of blade. As the width of blade increased from 16 cm to 18 cm plant damage was also increased for 20 cm and 25 cm row to row crop spacing. While for 30 cm spacing all four width of blade performed better and gave no plant damage. Plant damage was increased by 25.6 % by increasing the cutting blade width from 14 cm to 18 cm in crop grown 20 cm apart. Similarly, plant damage was increased by 13.1 % when cutting blade width was increased from 14 cm to 18 cm for 25 cm spacing of crop.

Effect of width of cutting blade on weed control efficiency

Weed control efficiency was increased with the blade width of weeder. Weed control efficiency of 61.5%

Table 4. Comparative evaluation of developed weeder with traditional method of weeding.

Parameters	Developed weeder	Finger weeder	Manual weeding
Field capacity (ha/h)	0.0257	0.0027	0.004
Total man power required for weeding (Man-h/ha)	38.91	149.25	250.0
Plant damage (%)	Nil	Nil	Nil
Weeding efficiency (%)	61.53	76.3	100
Total cost of weeding(US $/ha)	45.9	71.75	120.19
Energy required for weeding(MJ/ha)	1732.00	777.78	1493.75

Table 5. Economics of weedingperformed with developed power weeder.

	Developed weeder	Finger weeder	Manual weeding
Total fixed cost, Rs/h	8.8		
Total variable cost, Rs/h	68.5		
Cutting blade width, cm	12	16	18
Field capacity of machine (ha/h)	0.0257	0.029	0.036
Cost of using the weeder (US $/ha)	45.9	40.7	32.8

and 71.3 % was recorded in 12 cm and 14 cm blade width of weeder under 20 cm spacing without any plant damage. Under 25 and 30 cm row spacing weed control efficiency was found higher (73.7% and 61.3%) with 18 cm width of cutting blade. Plant damage was very less (1.57%) with 16 cm blade width of weeder. For 30 cm row spacing 18 cm blade width weeder was recommended as it provided highest weeding efficiency of 61.3%.

Recommendation of width of cutting blade

Cutting blade width 12 cm and 14 cm were not given any plant damage during operation. Blade width of 14 cm performed better in terms of weed control efficiency over 12 cm width of blade. Cutting blade width of 14 cm was recommended for 20, 25 and 30 cm row to row spacing because it did not damage the crop and achieved weed control efficiency 71.3 % and 62 % for 20 cm and 25 cm row spacing of crop (Fig. 2). Blade

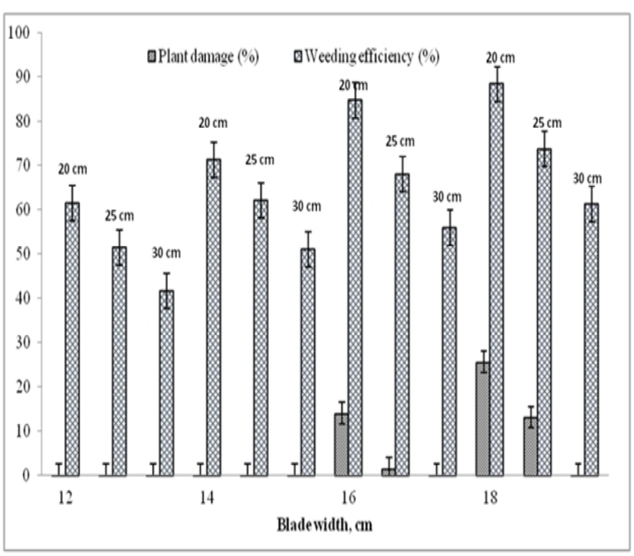

Fig. 2. Plant damage and weed control efficiency of power weeder with different blades in rice (20, 25, & 30 cm row to row spacings).

width 16 cm can be used for 25 cm and 30 cm row spacing because it gave very less plant damage i.e., < 2% and no plant damage under 25 and 30 cm row spacing respectively. Blade width of 18 cm was recommended only for 30 cm spacing because weed control efficiency obtained was 61.3 % without any damage to the crop. As per the performance considering minimum damage to the plants and highest weed control efficiency 14 cm, 16 cm, and 18 cm cutting blade width was recommended for 20 cm, 25 cm, and 30 cm row to row spacing, respectively.

Comparative evaluation of developed weeder with traditional method of weeding

Developed power weeder was compared with finger weeder and manual weeding under 20 cm row spacing of rice (Table 4). Develop power weeder reduced the human efforts involved in weeding operation and also pulverized the upper layer of soil which benefitted the root growth of plant. In manual weeding weeds were removed from fields and thrown away but with power operated weeder weeds were cut down and mixed with the upper layer of soil which gives extra benefits over manual weeding in terms of soil nutrition. Apart from that hand weeding was tedious job and power weeder took very less time as compared to finger weeder and manual weeding. Field capacity of developed weeder was around 4 times higher as compared to finger weeder. By using power weeder man power requirement was reduced by 73.9 % and 84.4 % over finger weeder and manual weeding, respectively. Cost of weeding was also less with power weeder and saving of $25.85/ha and $74.29/ha was realized over finger weeder and manual weeding, respectively (Table 5). Energy requirement of developed weeder was higher as that of other weeding methods. Cost of weeding with 18 cm width of cutting blade was minimum ($32.8/ ha) because of higher field capacity of weeder. The cost of weeding increases by 24 % and 40 % with the use of 16 cm and 12 cm width of blade, respectively.

CONCLUSION

Traditional methods of weed control require more labour and cost as compared to developed power weeder. Power weeder eliminated drudgery involved in weeding operation. As per the performance of weeder, plant damage and weed control efficiency increased with increase in blade width. As per recommendation plant damage should be very less therefore for 20 cm, 25 cm, and 30 cm row to row spacing 14 cm, 16 cm, and 18 cm blade width was recommended for its better weeding performance in the field. The cost of operation of single row power weeder was found \$45.9/ha, \$40.7/ha, and \$32.8/ha for 20 cm, 25 cm and 30 cm row to row spacing, respectively, which was much less than traditional method of weeding. Power weeder cannot perform very close to the plants and between the plants, so manual weeding was required to cover those areas.

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