Indian Journal of Ecology (2022) 49(5): 1808-1813
DOI: https://doi.org/10.55362/IJE/2022/3740

Manuscript Number: 3740
NAAS Rating: 5.79

Development and Evaluation of Adjustable Self-Propelled Rotor Power Weeder for Row Crops

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Abstract: Weed cause serious damage to the crop yield by sharing land, water, soil nutrients, sunlight, etc., which increases cost of cultivation, impairment of quantity and quality. Weed causes reduction in yield, if proper farming practices are not followed. The objective of study is development and evaluation of self-propelled rotor power weeder by considering weeding efficiency, plant damage, field efficiency, performance index, fuel consumption, cost and time of operation. For power weeder an adjustment provision was made to suitable for both 30 and 60 cm spaced crops i.e., groundnut, maize, chilli and cotton. The weeding efficiency and plant damage was evaluated at 30 and 60 days after sowing (DSA). At an optimum moisture content of 13%, the weeding efficiency attained a maximum in all four crops of 30 and 60 DAS. A 3 to 4% of more plant damage was observed at 60 DAS as compared to 30 DAS in all the crops. The highest field efficiency and performance index was found to be 80.07% and 93.09 in maize crop. The average reduction in cost of weeding and time saving by power weeder over manual weeding were 74.84% and 94.51% duly.

Keywords: Rotor power weeder, Weeding efficiency, Plant damage, Field efficiency, Performance index, Cost of operation

Agriculture is most key sectors of Indian economy. India's population is 1.39 billion in 2021. According to National Commission on Population Government of India has estimated that 1.807 billion population by 2050 (Anonymous 2021). To meet the demands of an expanding population, more food must be produced, this can be accomplished by increasing the area under cultivation or by using farming techniques that enhance crop yield. India has about 329 million hectares of land, of which 156 million hectares are cultivated land, 181 M ha of land is under cultivable and the net area sown is about 140 M ha, agricultural statistics at a glance 2015. There is no way to increase the area under cultivation, increasing crop productivity is a viable alternative. A crop yield raised by adopting high-yield variety of seed with good agricultural practises. Weed has a negative impact on crop yield, this includes decreased crop yield, impairment of crop quality, harbouring of plant pests and diseases, which increases like irrigation cost, production cost, lower the quantity and quality of a crop. Weed is responsible for one-third of total yield losses, as well as lowering quality and increases production costs (NRCWS 2007). Due to weeds, the yield reduction in cotton, groundnut, and vegetables like chilli crops ranges from 40-45% (Veerangouda et al 2010), 30-80%, and 30-40% (Rao et al 2014) and sometimes it can be as high as 80-90% which indicate the complete crop failure if adequate management practices are not followed effectively. Weed control is costliest and labour-intensive operations. Weeding operation takes 25% great labour force and 900 to 1200 man-hours per hectare by manually (Weide et al 2008). A study at DWSR suggested that efficient weeding techniques, add extra amount of one crores rupee annually (NRCWS 2007). The developed nations have placed a large emphasis on mechanization of different farming operations, several agriculture machineries were developed and implemented successfully. In India most of the farmers belong to small and marginal, the large heavy machines are high initial investment and it is not affordable to small-scale farmers. The status of landholding in the context of Indian agriculture reveals about 80% of landholdings were below 2-hectare area which comes under small to marginal landholding.

The productivity of farms greatly depends on the availability and use of power in farms. Agricultural implements and machines enable farmers to employ the power for production. Day by day the human power in agricultural operations is diminishing and using of bullock power is also reduced due to its maintenance. Mechanical weeding reduces the drudgery and ensures a comfortable posture during weeding. Weeder is mechanical tool, it uproots partially or completely and burying weeds into soil. Weeding by animal, tractor-drawn, and power operated weeder is carried out when crop is sown in rows. Row crop weeders are simple, cost-effective, and beneficial to small and medium-scale farmers. Weeding operation requires huge manpower and agriculture workers are not easily available in peak seasons. Traditional methods are costly and time-consuming operations, on the other hand, bullock-drawn implements have certain drawbacks like low field capacity, high maintenance cost and limitations of adverse weather conditions, etc., therefore not affordable to the small farmers. Because of growing demand for organically produced foods and concerns about environmental damage, the use of mechanical weeding is increasing in the current context. Mechanical, chemical, and biological weed control methods are available, but mechanical weeding is favoured since the agriculture industry requires non-chemical weed control to assure food safety. Tractor operated weeders can save time 75% and cost by 20% cost over animal drawn, but there are some limiting factors for tractor drawn weeders such as more plant damage, wastage in headlands, more compaction of soil and not suitable for the crops which are having small row to row spacing and the crop height is a limiting factor (Anil et al 2014). Weeding by engine-operated weeders results in one-third cost benefit over manual method (Tajuddin 2006). A power weeder is efficient equipment for weeding operation for line sowing crops (Shekhar et al 2010). The principal aim of designers, scientists of farm machinery are to develop a suitable technology for small to medium-scale farms. However, some of the Indian farmers widely adopted the concept of row cropping and the development of adjustable self-propelled rotor weeder is the need of today's agriculture. In this view, present research is viable option due to its medium cost and small size implying better manoeuvrability in the small landholdings.

MATERIAL AND METHODS

A series of experiments were conducted to develop adjustable self-propelled intercultural equipment and tested its performance for the weeding operation of four different crops. The detailed description of the development and its evaluation is discussed in the following sections.

Experimental site: The research work is carried at college of agricultural engineering, Madakasira, Anantapur district, Andhra Pradesh. The geographical location of the experimental site is 13º 56'58''N and 77º 18'42''E with elevation of 641.6 m mean sea level. A field of 800 m^2 area selected for field evaluation. Field area is split into 4 plots each 200 m^2 of groundnut, maize, chilli, and cotton crops, and each plot has dimensions of 20×10 m^2. is arid place with low precipitation of 532 mm and the maximum temperature is 35 ºC, whereas the minimum temperature of 23 ºC. The average temperature, relative humidity and wind speed is 25.7 ºC, 53% and 10.3 km/h. Soil have proportions of sand, silt, and clay defines the texture of soil (sand 68.0%, silt 14.5%, and clay 17.5%). Sandy loam soils with gravel characterise the Madakasira region for the most part.

Crops: The four major crops are selected for experiment i.e., Groundnut, T_1 (K-9), Maize, T_2 (Priya Gold 4545), Chilli, T_3 (Demon F1), and Cotton, T_4 (Star1, Bollgard-II SCH 234).

Crop morphological parameters: The plant height, plant width, root length, and weed density of four crops were measured with scale by selecting 1 m^2 area at 30 and 60 days after sowing.

Soil moisture content: Soil moisture content was estimated during evaluation of weeder by a digital moisture meter. The probe of moisture meter is inserted into the soil which senses moisture content and directly shows the value of moisture content in the monitor display. The 10, 13, 16, and 19% moisture contents were selected to study the maximum weeding efficiency at optimum moisture content among the four moisture content levels.

Adjustable self-propelled rotor weeder for row crops: The performance of developed adjustable self-propelled rotor weeder was evaluated on maize, chilli, groundnut, and cotton fields to investigate weeding efficiency, plant damage, field efficiency, performance index, fuel consumption, and cost of operation.

Weeding efficiency: Weeding efficiency is ratio of number of weeds before operation to number of weeds after operation, a 1 m × 1 m plot selected to counting number of weeds per square meter area. The weeding efficiency was calculated (Shekhar et al 2010).

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

Where, W_1 = Number of weeds before operation and

W_2 = Number of weeds after operation.

Plant damage: Plant damage (P_d) was estimated by counting number of injured plants after and before the operation in a sample plot. The plant damage was calculated (Yadav and Pund 2007).

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

Where, q = Number of plants in 10 m row length after operation

p = Number of plants in 10 m row length before operation.

Field efficiency: Field efficiency (F_e) is ratio of effective to theoretical field capacity and expressed as a percentage (Nagesh et al 2014).

$$\text{Field efficiency (\%)} = \frac{\text{E.F.C}}{\text{T.F.C}} \times 100 \quad (3)$$

Where, E.F.C = Effective field capacity, ha/h and

T.F.C = Theoretical field capacity, ha/h.

Theoretical field capacity is calculated by (Patange et al 2015).

$$\text{TFC (ha/h)} = \frac{S \times W}{10} \quad (4)$$

Where, S = Forward speed, km/h

W = Width of the implement, m

Effective field capacity is calculated by (Manjunatha et al 2014).

$$\text{EFC (ha/ha)} = \frac{A}{T_p = T_{NP}} \quad (5)$$

Where, A = Area of coverage, ha

T_P = Productive time, h and

T_{NP} = Non-productive time, h.

Performance index: The performance index (PI) of the weeding equipment was calculated (Thorat et al 2014).

$$\text{Performance index} = \frac{\text{FC} \times (100\text{-PD}) \times \text{WE}}{\text{Power (hp)}} \quad (6)$$

Where, FC = Field capacity, (ha/h)

PD = Plant damage, % and

WE = Weeding efficiency, %

Fuel consumption: Top-fill method is used to measure fuel consumption, initially tank is fill to full capacity before testing on levelled surface. After the test, amount of fuel required to fill tank again gives the fuel consumption for given test run and it is expressed in litre per hour. Fuel consumption is calculated (Raghavendra et al 2013).

$$\text{Fuel consumption (l/ha)} = \frac{V}{t} \quad (7)$$

Where, V = Volume of fuel consumed, l

t = Total operating time, h

Cost of operation: The designed and developed machine should be consideration for its cost economics. A developed machine should be considered for cost economics and it perform minimum cost with good performance. The developed adjustable rotor power weeder was determined by straight-line method. Total cost of power weeder was considered by adding both material cost and labour cost for fabrication. Total cost of operation was estimated by fixed and variable costs.

Statistical analysis: The experimental data was analysed by using the SAS 9.3 software.

RESULTS AND DISCUSSION

Developed machine evaluated by considering soil parameters as moisture content, crop parameters like plant width, plant height, weed density, and performance parameters, such as weeding efficiency, plant damage, field efficiency, performance index, fuel consumption, cost of operation and obtained results were discussed in the following sections.

Weeding efficiency: The mean weeding efficiency was77.77 and 72.87% at 30 and 60 days. Among the four crops, the best result was reported as 79.49 and 75.59% at 30 and 60 days in maize crop (Fig. 4).

The weeding efficiency highest and lowest was 79.49% in maize and 76.33% in groundnut at 30 days after sowing, Similarly highest and lowest weeding efficiency at 60 days after sowing were reported as 75.59% in maize and 70.57% in groundnut. The moisture content is increased from 10 to 13%, the weeding efficiency in all the crops varied between

Fig. 1. Developed adjustable rotor weeder

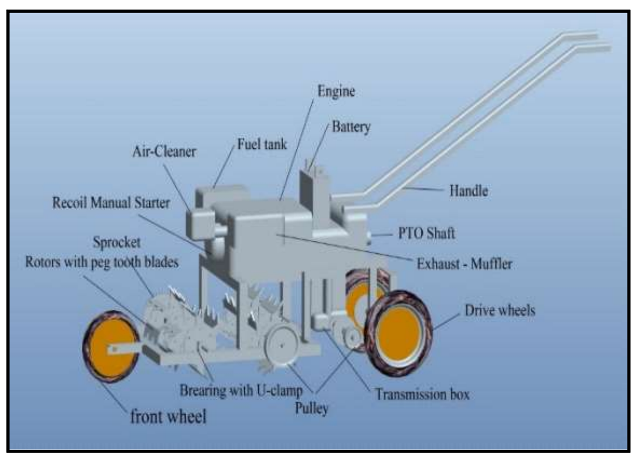

Fig. 2. Isometric view drawn in Pro-e Software

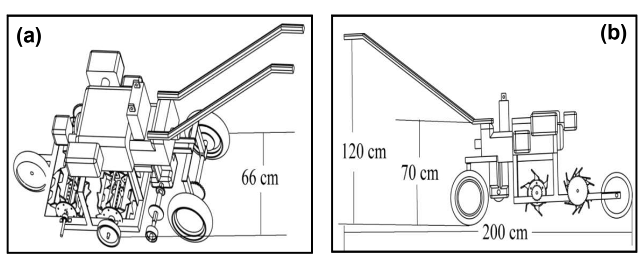

Fig. 3. Line diagram of (a) isometric and (b) side view of rotor weeder

13 and 15%, and then weeding efficiency declined slightly. At an optimum moisture content of 13%, the weeding efficiency attained maximum among all crops. Ojomo et al (2012) observed that moisture contents of 13% recorded maximum weeding efficiency.

Plant damage: Plant damage was estimated using (Eq.2). The mean plant damage was 3.84 and 6.92% at 30 and 60 days. Among four crops, lowest plant damage was observed as 2.91 and 5.59% at 30 and 60 days in maize crop (Table 1).

There were significantly differences among the crops, and plant damage indicated no significant difference among treatments; However, the high and low values of plant damage was 4.65% of 7.14 cm of plant width in groundnut crop and 2.91 of 7.89 cm plant width in maize at 30 days weeding. The high and low values of plant damage at 60 days of weeding were 8.24% of 7.16 cm plant width in chilli crop and 5.59% of 19.06 cm plant width in maize crop. The plant width increased plant damage. Plant width cause 3 to 4% plant damage at 60 days weeding over 30 days of weeding. Aman et al (2014) observed that plant damage at pre-square, square, flowering stages increase with plant width.

Plant height: The plant height of the four crops was measured at 30 and 60 days (Fig. 5) indicated that among four crops maize recorded the highest value of plant height as 69.01 and 47.99 cm at 30 and 60 days and for lowest plant height was recorded in groundnut crop as 10.46 and 14.88 cm at 30 and 60 days.

Weed density: The weed density of the four crops was measured at 30 and 60 DAS (Fig. 6). It indicated that the high and low weed density was 96.5 in maize and 73.75 in groundnut at 30 days weeding (Fig. 6). The high and low weeding at 60 days were 123 and 91.75 in maize and chili.

Effect of depth of cut on weeding efficiency: Depth of cutting is a very important factor in assigning machine efficiency. This greatly influences the weeding efficiency and power requirement. The mean depth of cutting was found to be 4.11 cm. Among the four crops, the best depth of cutting was reported as 4.20 cm in maize crop and was depicted in (Table 2).

The higher depth of cutting as 4.20 cm of 77.54% weeding efficiency in maize crop and lowest was 4 cm of 73.45% in groundnut crop. In chilli crop the depth of cut was 4.07 cm with corresponding weeding efficiency 0f s 74.64% and for cotton, depth was 4.17 cm with corresponding weeding efficiency of 75.73%. The results indicate the depth of cut was increased linearly and the weeding efficiency also increases linearly. Jagvir and Intikhab (2008) reported the same trend on effect of depth of cutting over the weeding efficiency. Field efficiency was estimated using (Eq. 3). The mean-field efficiency was be 79.74% (Fig. 4). Among all crops, the best field efficiency was s 80.07% in maize. Table 2 which indicated that there is no significant difference between treatments of field efficiency. However, the high and low values of field efficiency were 80.07% in maize and 79.39% in chilli. Senthilkumar et al (2014) evaluated 4 hp diesel and 5.5 hp petrol engines and observed that field efficiency of 64.1 and 71.5%.

The performance index gives the overall performance of the weeder (Table 3). The high and low values of performance index were 93.09 in maize and 86.31 in groundnut. The performance index of rotor weeder was 85 in

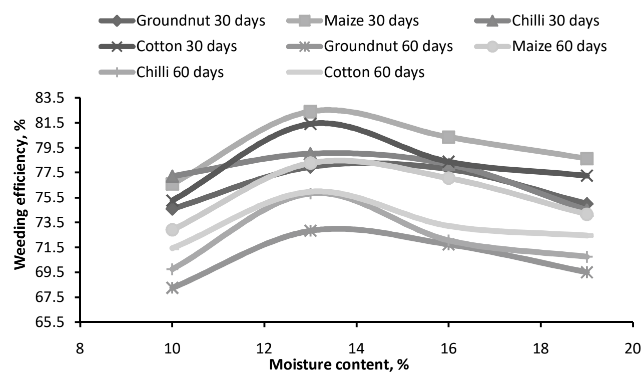

Fig. 4. Effect of moisture content on weeding efficiency

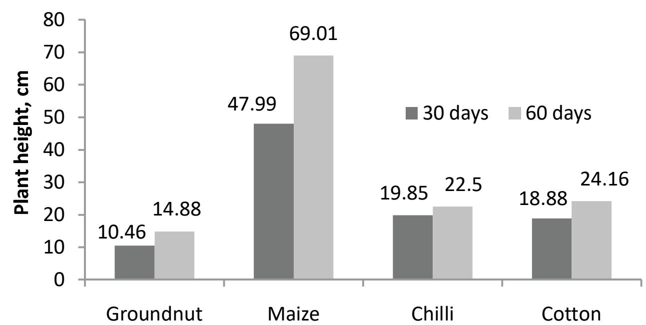

Fig. 5. Plant height at 30 and 60 days

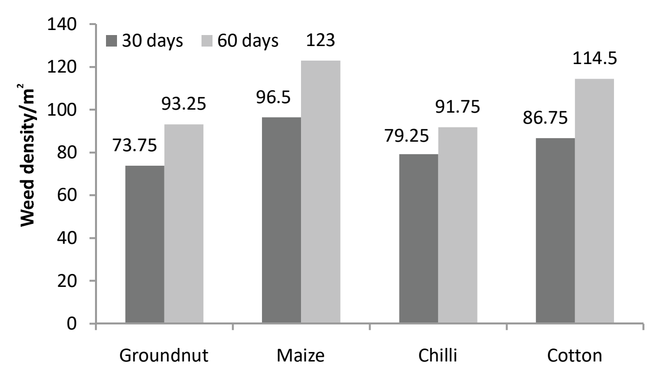

Fig. 6. Weed density at 30 and 60 days

all the four crops, the highest was recorded in maize. The plant damage was more; the performance index was ultimately reduced. Present study the plant damage ranges from 4 to 9%, and plant damage influences the performance index. Fuel consumption was high and low as 0.62 l/h in maize and 0.58 l/h in chilli. The mean fuel consumption was 0.6 l/h. Anil et al (2014) observed power weeder fuel consumption of 5 hp diesel engine as 0.65 l/h, which is nearly equal to developed self-propelled rotor weeder.

The operating cost of weeding was found by using fixed and variable cost of rotor weeder. The weeding operation cost depends on time required for completing the weeding operation. (Table.3) indicated highest and lowest weeding cost were Rs. 1677/ha in chilli crop and Rs. 1662/ha in maize crop. The mean cost of operation was Rs. 1669.25/ha. The cost of operation by manually with khurpi comes as Rs. 6635.36/ha. However, the developed weeder is beneficial to reduce the cost, time, and drudgery of the farmer. The average reduction in cost of weeding by using a self-propelled rotor weeder over the manual weeding was 74.84%. The average saving of time by using a self-propelled rotor weeder over manual weeding was 94.51%.

Table 1. Plant width (cm) and plant damage (%) of row crops

Treatments	Plant width*		Plant damage*	
	30 days	60 days	30 days	60 days
Groundnut	7.14 b	11.27 b	4.65 a	7.07 a
Maize	7.89 b	19.06 a	2.91 a	5.59 a
Chili	6.13 b	7.16 c	4.24 a	8.24 a
Cotton	11.95 a	13.50 b	3.56 a	6.93 a
CD (p=0.05)	1.20	1.86	NS	NS

*There is no significant difference between treatments with similar letters in column

Table 2. Depth of cutting, average weeding efficiency and field efficiency of row crops

Treatments	Depth of cutting (cm)*	Average weeding efficiency (%) of 30 and 60 days*	Average field efficiency (%)
Groundnut	4.00 a	73.45 a	79.63a
Maize	4.20 a	77.54 a	80.07a
Chilli	4.07 a	74.64 a	79.39a
Cotton	4.17 a	75.73 a	79.89a
CD (p=0.5)	NS	NS	NS

Table 3. Performance index, fuel consumption and cost of operation

Treatments	Performance index	Fuel consumption (L/h)	Cost of operation (Rs./ha)
Groundnut	86.31a	0.60a	1672a
Maize	93.09a	0.62a	1662a
Chilli	87.92a	0.58a	1677a
Cotton	89.75a	0.60a	1666a
CD (p=0.05)	NS	NS	NS

CONCLUSION

The optimum moisture content of 13% recorded the maximum weeding efficiency at 30 and 60 DAS in all the crops. A 3 to 4% of more plant damage was at 60 DAS compared to 30 DAS. The depth of cut was increased linearly, the weeding efficiency also increases linearly up to certain limits, beyond the permissible limits, a decreasing trend was observed. The average field efficiency was 79%. Higher performance index was due to less plant damage. The average reduction in cost of weeding and time saving by using developed power weeder over manual weeding were 74.84 and 94.51% respectively.

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Received 17 May, 2022; Accepted 09 September, 2022