Original Research Article

Performance Evaluation of Power Weeder with Different Blade Mechanism in Intra-Row Weeding Operation

ABSTRACT

Aims: Weeding operation is one of the most laborious and time-consuming operation in agriculture. Weeds basically an unwanted plant which competes with crop for light, moisture, and nutrient along with lowering the overall yield. Mechanical weed control methods are preferred among all weeding methods due to many reasons such as timeliness, safety, drudgery and cost effective.

Study Area and Duration: The experiment was conducted in the farmer's field of Abhayapuri, Bongaigaon, Assam in the year 2021 to 2023.

Methodology: In this study a self-propelled engine of 5.76 hp, 4 stroke single cylinder diesel engine was used and three sets of blades including rotary, non-rotary and combining of both having multiple adjustment was developed and fabricated to carry out weeding operation in the vegetable fields of row to row spacing of less than or equal to 75 cm.

Results: Results showed that the field efficiency (90%), fuel consumption (7.7 l/ha), cost of operation (Rs 1217.7 per ha) and plant damage factor (0.01%) was better for rotary blade than non-rotary and combined blade. Whereas effective field capacity (0.07 ha/h), performance index (155.7) and man-hour/ha (14.3) was better for non-rotary blade and the parameters such as depth (4.4 cm) and weeding efficiency (94.2%) was better for combined blade mechanism. From the one-way ANOVA analysis, it showed that blade mechanism showed significant difference on parameters like weeding efficiency, field efficiency, fuel consumption, effective field capacity, cost of operation, man-h/ha and performance index at $p<0.05$ and non-significant for depth and plant damage factor at $P<0.05$.

Conclusion: Study concluded that for intra-row weeding operation, rotary blade along with non-rotary blade was suitable economically whereas combined blade was suitable for weeding performance only besides high cost.

Keywords: Weeding, Intra-Row, Rotary Blade, Non-Rotary Blade, Power Weeder

1. INTRODUCTION

In agriculture practise, weeding is one of the utmost difficult farm duties that accounts major share in the cost of agricultural productivity [22,23,24]. A weed is basically any plant which grows where it is unwanted. A weed can be thought of as any plant growing in the wrong place at the wrong time and doing more harm than good [1,25,26]. Weeds generally competes with crops for moisture, nutrients, and light. Most of the agricultural workers expressed their concern for the effectual weed control measures to control the development and propagation of weeds. Weeds waste excessive proportions of farmers' time, thereby acting as a brake on development [2,27,28]. The reduction in yield due to weeds alone is estimated as 16 to 42% depending on the crop and location [3]. The timeliness rather than frequency of weeding is a major determinant of effective weed control [4.27,29]. Hand weeding is a laborious task along with inefficient (not done on time in most cases), and always not feasible because of adverse soil conditions [5,30,31]. Mechanical weed control is preferred among all weeding methods due to many reasons. A suitable depth and spacing of crop are the key for achieving better yield. The depth of seed placement and the distance from the adjacent row both influence crop performance. Keeping above information and considering future demands to overcome the constraints of power weeding in various dryland crops, a small, lightweight self-propelled multi-purpose weeder is deemed to meet the requirements of the farmer of this region. Introduction of small and cost-effective weeder having multiple provision of blade assembly will help the small and marginal farmers of NER by improving working efficiency and reducing the working time, drudgery and cost of cultivation and increasing crop yields. Current paper deals with the performance evaluation of different blade mechanism of self-propelled power weeder in intra-row mode of operation.

2. REVIEW OF LITERATURE

Weeds accounts for maximum loss in yield which is about 33% than the other losses such as diseases, insects, rodents and other pests [6]. Igbeka [4] reported that proper timing of weeding operation is most significant than the frequency of the operation for rice cultivation. Recommendations have been made for the first weeding to be done 14-21 day after sowing (DAS), followed by a second weeding three weeks later and if necessary, the third one. The percentage yield losses due to weed competition for the first one month, two month and entire crop season were 23.7, 35.4 and 40.8 respectively [7]. Manuwa et al.[8] developed a prototype row crop power weeder and found the field capacity of 0.035ha/h and the field efficiency of 96% having average depth of the cut was 40 mm resulting promising performance.Nkakini et al. [9] conducted the field performance of manually operated petrol engine weeder for the tropical area and obtained the theoretical field capacity as 0.047ha/h and effective field capacity of 0.34 ha/h, which was approximately 20 times more than that of manual weeding and weeding efficiency of 71% for shallow roots. The overall performance index was 1,700 and fuel consumption was 3.2 litres in 8 hours. Similarly, Olaoyeet al. [10] carried out the performance of a rotary power weeder and found field capacity and weeding efficiency of 0.0712 ha/hr and 73% respectively. Also, it reduced drudgery and provide a comfortable posture to the operator during weeding operation and increase productivity. As per study carried out by Karale et al. [11] for self-propelled inter-row cultivator and revealed that the depth of operation was equal for irrespective of soil texture and moisture content. The field efficiency was 80 to 83 % along with actual field capacity 0.21 to 0.27 ha/h.The weeding efficiency was 91 to 97%. The operation cost was found as Rs. 225 to 290 per ha. The overall saving in cost of operation was observed in the range of 25 to 29% over the traditional method

3. MATERIALS AND METHODD

A self-propelled 4-stroke single cylinder diesel engine having power of 5.75 hp and engine speed 1800 was used to perform in intra-row weeding operation. The power weeder was run in three mode of operation such as rotary (RB) and non-rotary blade separately (NRB) and combine blade (CB) mechanism. The blade specifications of rotary blades are-total blade length 40 cm (20 cm each), number of blades 12 (6 in each set), blade width is 4.5 cm, thickness is 0.6 cm, disc diameter is 20 cm, rotor shaft diameter is 2.5 cm and blade angle are 55˚. The dimensions of non-rotary blade are angle of attack is 15˚, approach angle is 50˚, and blade width is 16.8 cm. The effective non-rotary blade width is 60 cm. Each set of non-rotary blade has a provision of vertical adjustment for depth of cut. The attachment of blade assembly in self-propelled power weeder (Fig.1.) and CAD model of power weeder is shown in Fig. 2. The weeding operation was carried out in field crops of spacing greater than or equal to 75 cm (Fig. 3).

3.1 STUDY AREA

The experiment was conducted in the farmer’s field of Abhayapuri, Bongaigaon, Assam. The soil condition of the experimental field was sandy loam having average moisture content of 16%. The plot was divided in three equal parts. The following dependant parameters such as depth of cut, weeding efficiency, effective field capacity field efficiency, fuel consumption and plant damage were calculated after completion of each run.

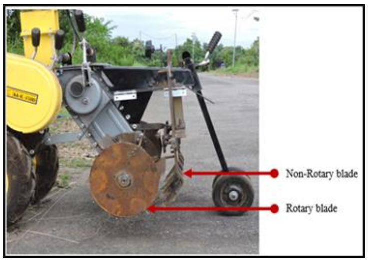

Fig. 1. Self-Propelled Power Weeder with Developed Blade Assembly

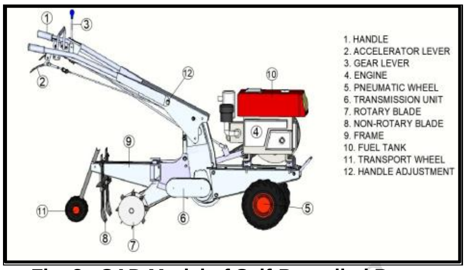

Fig. 2. CAD Model of Self-Propelled Power Weeder with Developed Blade Assembly

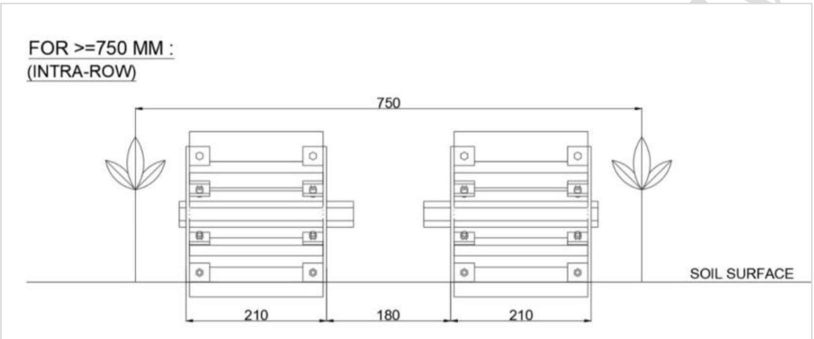

Fig. 3 Method of weeding operation in intra-row weeding

3.2 Field parameteres

3.2.1 Depth of operation

The depth of operation was measured by the vertical distance between the horizontal soil surfaces to the bottom of dugout soil with the help of steel scale. Observations were taken from three randomly selected place after completion of weeding and the average taken.

3.2.2 Width of operation

For determining average width of cut, 3 observations were taken. The measurement of composite width was taken at 3 equidistant places in the direction of travel using steel scale and then averaging it.

3.2.3 Speed

The speed of the weeder will be determined by observing the time required to travel 20 m distance with the help of stopwatch. The average speed of weeder for each treatment plot was recorded separately. The Range of speed will be selected from 0.28 m/s to 0.56 m/s which was ergonomically best suited for walking behind implements [12].

3.2.4 Theoretical Field Capacity (TFC)

Theoretical field capacity of an implement 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.

$$TFC, ha/h = \frac{W \times S}{10}$$

Where, w- width of blade in m, S-speed of operation in km/h

3.2.5 Effective Field Capacity (EFC)

Effective field capacity is an average coverage of the weeder per hour, calculated from the total area weeded in hectares and the total work time which includes time loss in turning at head lands, rests and for any break down or adjustments.

$$EFC, ha/h = \frac{Area\ covered\ by\ weeder}{Total\ time\ taken \times 10000}$$

3.2.6 Field efficiency (FE)

It is the ratio of effective field capacity to the theoretical field capacity expressed as percentage.

$$FE, \% = \frac{EFC}{TFC} \times 100$$

3.2.7 Weeding Efficiency (WE)

It was calculated by considering a random square area from the field and number of weeds including in loop will be counted before and after weeding. There were 3 sets of observations were taken using quadrant method, by randomly selected of spots by a square quadrant of 1 square meter [13], and average value of weeding efficiency was calculated as below.

$$Weeding\ Efficiency(\%) = \frac{N_b - N_a}{N_b} \times 100$$

Where, Nb-number of weeds before weeding, Na-number of weeds after weeding

3.2.8 Fuel consumption (FC)

The fuel consumption has direct effect the economics of the power weeder. Fuel consumption rate is the amount of fuel used per unit time. The fuel consumption rate per tillage operation was determined using refilling (volume) method. A calibrated cylinder was used for refilling the fuel, to quantify the fuel used. The fuel consumption rate was determined using the following relationship [14].

$$Fuel\ consumption, (l/h) = \frac{Q_f}{t}$$

Where, Q_f = Quantity of fuel consumed (l) and t = time taken (h). Area covered within the working duration is converted to fuel consumption per hectare area (ha/l).

3.2.9 Plant damage factor

Plant damage is the measure of damage to crop plants during weeding operation. Plant damage was observed in terms of buried plants by soil mass as well as cutting of plant leaves/tops by rotating action of weeding drums and blade. A number of plants in 10 m row length before and after weeding was observed and the plant damage factor was calculated by using following relation [15].

$$Plant\ Damage\ factor(PDF)(\%) = \frac{Q_2}{Q_1} \times 100$$

Where, Q1 = Number of total plants in 10 m row length before weeding, Q2= Number of plants damaged along 10 m row length after weeding

3.2.10 Performance index

The evaluation of the weeder's effectiveness was conducted using a performance index (PI), as per the formula proposed by Srinivas et al. [16]

$$PI = \frac{FC \times (100 - PDF) \times WE}{Pw}$$

Where, FC = Field capacity in ha/h, PDF = Plant damage factor, %, WE = Weeding efficiency, % and Pw = Power, hp

3.2.11 Cost of operation

The total cost of weeding is gained from machine operation cost and labour cost for weeding. In this study, to cover one hectare land, the amount of fuel consumed by the weeder was calculated by top fill method used by Devojee et al., [17] and hence fuel cost was calculated.

4. RESULTS AND DISCUSION

4.1 Width of operation

From the physical measurement of effective width of operation after completion of each operation, average value was found from three randomly selected place for rotary blade is 38 cm, 58 cm for non-rotary and 59 cm for combined blade. More depth for non-rotary as well as combined blade may be due to non-rotary blade angle [18].

4.2 Speed

The average speed of operation was found as 0.47 m/s, 0.41m/s and 0.4 m/s for rotary blade, non-rotary blade, and combined blade as it is similar findings of Manuwa et al., [8]. Combined blade had more depth of operation resulting more draft generated by the blade which eventually decreases the speed of operation. It was found that the observed speed was within the range suggested by Yadav and Pund [12] for better weeding operation as per ergonomics point of view. Engine speed is significantly impact on Weeding efficiency and it is better to have in the lower side [8].

4.3 Depth

From the Fig. 4. it was observed that the average depth of operation was 3.7 cm for rotary blade, 4.4 cm for non-rotary blade and 4.5 cm for combine blade. Higher depth was in the case of combined blade which may be due to the rotary blade which loosened the soil first up to certain depth followed by non-rotary blade. It helps the non-rotary blade for more penetration. Similar depth of operation was found for power weeder having six rotary blades was 4.6 cm [8, 19]. Better penetration was obtained for furrow like non-rotary blades generating more draft along with more power requirement [20].

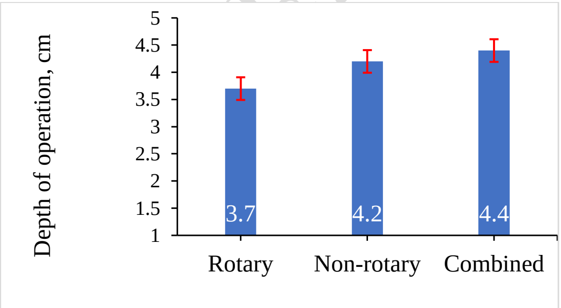

Fig. 4. Bar chart with error bar showing effect of blade performance on Depth of Operation

4.4 Weeding efficiency

Weeding efficiency was found as gradual increasing trend from rotary to combined blade mechanism. From Fig.5., it was observed that the average weeding efficiency of 94.2% for combined blade, which was highest among all, which is a close agreement with Manuwa et al., [8], whereas lowest in the case of rotary blade. This is because of effective blade width is higher in the case of non-rotary blade resulting more coverage of field. But in the case of rotary blade, a strip of width 18 cm is remained untitled for which lower efficiency of 75% was obtained. For rotary blade, lower value may arise due to uneven surface and also while turning the weeder especially for small farmland. Higher value in case of combined blade was due to dual action of blades i.e. rotary blade followed by non-rotary blade.

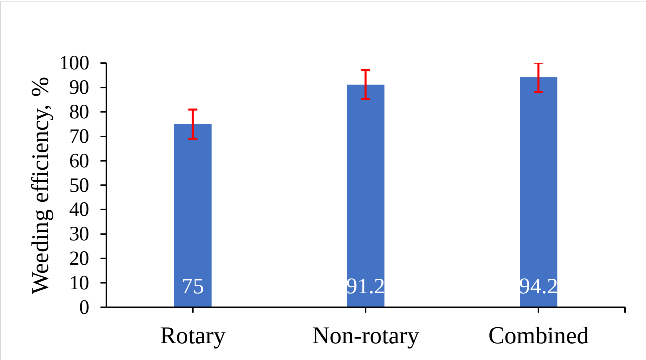

Fig. 5. Bar chart with error bar showing effect of blade performance on Weeding Efficiency

4.5 Effective field capacity (EFC)

It is the average area covered with time. From the Fig. 6, it was seen that EFC was highest in the case of non-rotary blade of about 0.07 ha/h and lowest in the case of rotary blade of about 0.063 ha/h. The non-rotary and combined blade showed similar results with [21]. Since the effective blade width is higher in non-rotary blade resulting more EFC. Whereas the combined effect has slightly lower EFC as because more time is required to cover the area as it lowered the weeder speed.

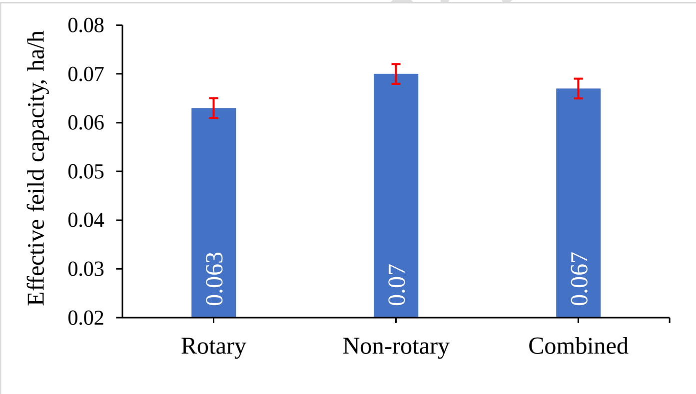

Fig. 6. Bar chart with error bar showing effect of blade performance on Effective Field Capacity

4.6 Field efficiency

Field efficiency is the ratio of effective field capacity to theoretical field capacity. Current study showed that the EFC is higher in the case of rotary weeder (90%), whereas lower in the case of combined blade (77.91%) (Fig.7), this is because of higher theoretical field capacity along with lower effective field capacity. More depth of operation lowers the field efficiency for combined blade mechanism.

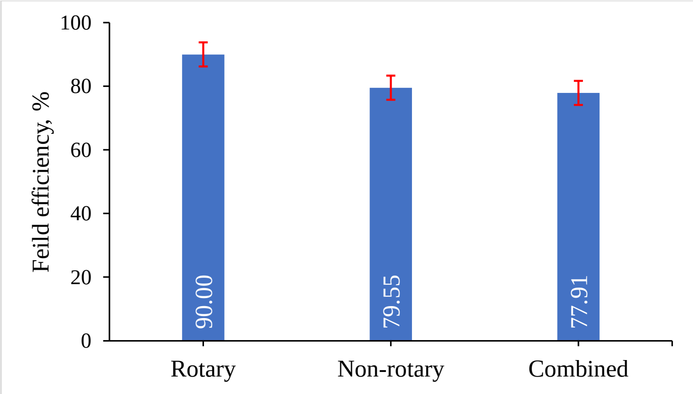

Fig. 7. Bar chart with error bar showing effect of blade performance on Feild Efficiency

4.7 Fuel consumption

From the Fig.8, it was found that more fuel is consumed by the power weeder while operating with combined blade mechanism. This is mainly due higher power consumption is needed to run as combined blade mechanism penetrate more to soil as compared to others. Increasing depth, also increasing the power requirement resulting increasing the fuel consumption [20]. Fuel consumption for combined blade, non-rotary and rotary blades were 8.5 l/ha, 8.2 l/ha and 7.7 respectively. From the economic point of view, rotary blade works better for intra row weeding operation.

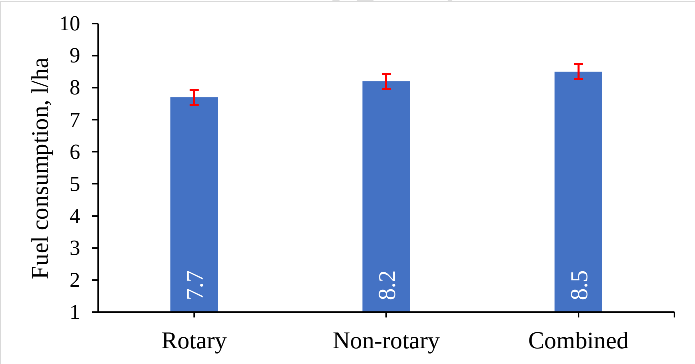

Fig. 8. Bar chart with error bar showing effect of blade performance on fuel cconsumption.

4.8 Plant damage factors

Manual counting of weeds before and after weeding operation were carried out for three randomly selected square quadrant. Fig. 9. showed that plant damage percentage was minimum for rotary blade (0.01%), whereas maximum for non-rotary blade (0.02%). This may be due to more soil inversion takes place near the crop root which results more chances for damaging or uprooting the crops. Though plant damage percentage were minimum for all three cases.

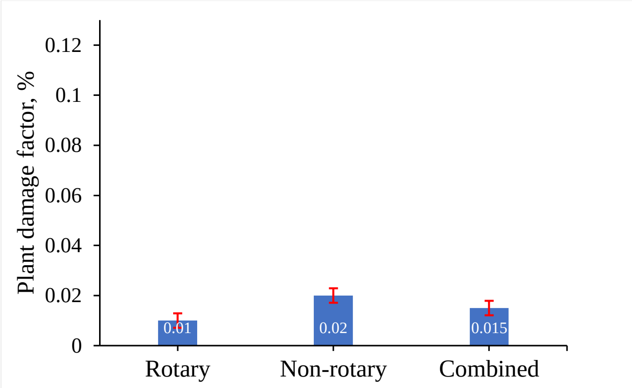

Fig. 9. Bar chart with error bar showing effect of blade performance on Plant Damage Percentage

4.9 Cost of operation and Performance Index

The operational cost of weeding operation was found in the range of Rs 1217.7-1290.1 per hectare (Fig. 10) which was similar agreement with [21] in which maximum was found for combined blade and minimum was found for non-rotary blade. Overall lowest cost of operation was observed in the case of non-rotary blade irrespective of mode of operation. This is due to more width of coverage perused for non-rotary blade corresponding to higher field capacity. Man-hour required for weeding in one hectare land of operation found maximum for combined blade (15.9 man-h/ha) whereas minimum was found for non-rotary blade (14.3 man-h/ha) (Fig. 11) which was similar agreement with Veerangouda et al.,[21]. Performance index was found maximum in the case of non-rotary (155.7) and minimum in the case of rotary blade (115.2) (Fig.12.).

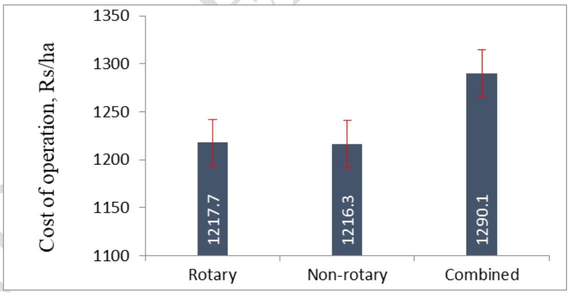

Fig. 10. Bar chart with error bar showing effect of blade performance on cost of operation.

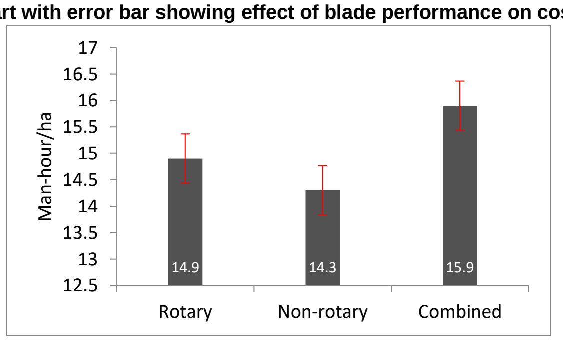

Fig. 11 Bar chart with error bar showing effect of blade performance on man-hour/ha

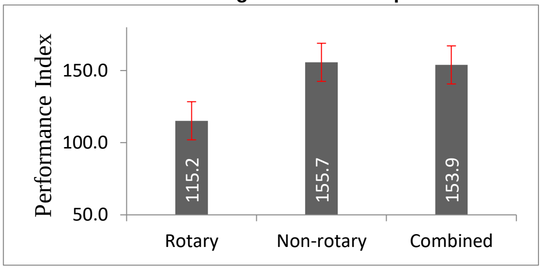

Fig. 12. Bar chart with error bar showing effect of blade performance on performance index.

4.10 STATISTICAL ANANLYSIS

A statistical analysis was carried out to find the significance of varying blade mechanism on various field parameters in intra-row weeding operation (Table 1). One-way ANOVA analysis was performed, and it showed that most of the dependent parameters such as weeding efficiency (F=195.8, p<0.001), field efficiency (F=158.3, p<0.001), fuel consumption (F=19.9, P=0.002), effective field capacity (F=25.32, p=0.001), Cost of operation (F=7002.28, p<0.001), Man-hour/ha (F=5.44, p=0.045) and performance index (F=3205.28, p<0.0001) showed significant difference at a significance level of 0.05. But the parameters such as depth of operation and plant damage factor was not significant in all three modes of operation.

TABLE 1. One Way ANOVA Analysis of Dependent Variables

PARAMETERS		*SS*	*df*	*MS*	*F*	
Depth	Between Groups	1.08	2	0.54	2.88	0.133
	Within Groups	1.12	6	0.19		
	Total	2.2	8			
Weeding efficiency	Between Groups	581.45	2	290.72	195.8	<0.001*
	Within Groups	8.91	6	1.48		
	Total	590.36	8			
Field efficiency	Between Groups	241.27	2	120.63	158.3	<0.001*
	Within Groups	4.57	6	0.76		
	Total	245.84	8			
Fuel consumption	Between Groups	2.63	2	1.31	19.90	0.002*
	Within Groups	0.4	6	0.066		
	Total	3.02	8			
Plant damage	Between Groups	0.00	2	0.00	3.15	0.116
	Within Groups	0.00	6	0.00		
	Total	0.00	8			
Effective field capacity	Between Groups	0.00	2	0.00	25.32	0.001*
	Within Groups	0.00	6	0.00		
	Total	0.00	8			
Cost of operation	Between Groups	10690.16	2	5345.08	7002.28	<0.0001*
	Within Groups	4.580	6	0.763		
	Total	10694.74	8			
Man-h/ha	Between Groups	3.90	2	1.96	5.44	0.045*
	Within Groups	2.160	6	0.36		
	Total	6.08	8			
Performance Index	Between Groups	3141.18	2	1570.59	3205.28	<0.0001*
	Within Groups	2.94	5	0.49		
	Total	3144.12				

* Significant at p<0.05

5. CONCLUSION

The developed power weeder is suitable for small and marginal farmers with different blade arrangement and choice-based operations. The intra-row weeding operation was best suited for field crops having row-to-row spacing more than or equal to 75 cm, otherwise it will work as an inter-row weeding operation. From the performance point of view, combined blade has shown better results whereas, rotary weeder has shown better results from the economic aspects. Also depending on the weed density, either set of blade mechanism can be utilized. This developed weeder blade is not suitable for wetland agriculture crops. The developed blade mechanism has easy and user-friendly attachment or detachment of blade mechanism.

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