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RESEARCH ARTICLE

Performance and economical evaluation of two row self-propelled narrow crop rotary weeder for managing weeds in mustard crop

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ABSTRACT

The conventional manual weed management is one of the labour intensive and expensive operation in crop production as it involves low efficiency, time consuming, human drudgery and higher cost of operation. The use of self-propelled rotary weeder for mechanical weeding reduces the drudgery and ensures a comfortable posture of operator or farmer during weeding operation. Hence, a self-propelled narrow crop rotary weeder was developed by department of Farm Machinery & Power Engineering, COAE&T, CCS HAU, Hisar during the winter *(Rabi)* season of 2016 and was evaluated for its performance in mustard crop having row to row spacing of 45 cm. Three forward speeds (1.6, 1.8 and 2 km/h), two blade lengths (180 and 195 mm) and three speeds of rotor (330, 360 and 390 rpm) were selected for its evaluation and results were compared with manual hand weeding using Kasola (tool smaller than spadi in size). The effective field capacity of 0.09 ha/h, field efficiency of 67.98%, weeding efficiency of 80.12% and plant damage of 2.9% were observed at the best combination of operational variables *i.e.* rotor speed of 360 rpm, blade length of 180 mm and forward speed of 1.6 km/h. The labour requirement with rotary weeder was reduced to 11.11 man-h/ha when compared to 160 man-h/ha for manual hand weeding. Thus, rotary weeder saved 93% of labour and 75.45% of cost of operation in comparison to manual hand weeding using Kasola in mustard crop.

Keywords: Economical weeding, Mechanical weeding, Mustard, Plant damage, Rotary weeder, Weed management, Weeding efficiency

INTRODUCTION

There are several constraints in agriculture like climate change, insects, pests *etc*. but, weeds are the major reason for declined yield per unit agricultural area in India (Rao and Chauhan 2015). Weeds reduced crop yield by about 65%, depending on the crop, the degree of weed infestation, the plant species, and management measures (Devojee *et al.* 2018). Weeds compete with associated crops for nutrients and other growth factors and if any effective control measure is not performed; they utilize 30 to 40% of soil applied nutrients causing significant crop yield loss (Goel *et al.* 2008) and reduced produce quality. Weed management in crops is one of the labour intensive and expensive operation in crop production. Total actual economic loss of about USD 11 billion was estimated due to weeds alone in 10 major crops of India (Gharde *et al.* 2018). Thus, timely management of weeds is essential to achieve increased agricultural production (Rao and Nagamani 2010). The most common methods for weed control are mechanical, chemical, biological and other methods such as field preparation, crop rotation, growing of intercrops, mulching, solarisation and maintaining optimum plant population (Borbale *et al.* 2021). Herbicide usage is becoming more popular among farmers but problems of environmental contamination, residual toxicity and herbicide resistance development amongst weeds, if not used properly, are major concerns of herbicide use. Manual weeding requires large labour force and accounts for nearly 25% of the total labour requirement (900–1200 man-h/ha) during a cultivation season (Nagesh *et al.* 2014). The problem of labour shortage and high labour charges for agricultural operations is increased with time. The introduction of new agricultural machinery has reduced drudgeries of manual operations with the passage of time and became more popular as a source of power among the farmers (Kunnathadi *et al.* 2016). Mechanical weeding is generally performed by tillage, cutting and pulling weeds. This method of

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weed control is very effective as it manages the weeds and also keeps the soil surface loose ensuring soil aeration and increased water intake capacity. Mechanical weeding using improved hand tools or power operated machines appear to be most practical and efficient method.

Mustard [*Brassica juncea (*L.*)* Czern.] is one of the most important winter oilseeds crops in India and it accounts for nearly 20-22% of total oilseeds produced in the country (Samar *et al.* 2017). India is the third largest producer of rapeseed-mustard in the world after China and Canada with total world's production area of 19.29% and production of 11.12% (Anonymous 2014, Meena and Sharma 2019). In India, mustard seed is mainly grown in North West parts of India. Haryana, Rajasthan and Uttar Pradesh are the major mustard producing states in the country (Meena 2018). It is well known that weeds interfere with crop plants causing serious impacts either in the competition for water, light and nutrients. Weed competition in mustard is more serious in early stage because crop growth during winter (*Rabi*) season remains slow during first 4 to 6 weeks after sowing. However, during latter stage it grows vigorously and it has suppressing effect on weeds. Among the factors responsible for the low productivity of the mustard weeds are major constraints as they cause yield loss up to 76.3% (Kumar *et al*. 2012) in Indian mustard.

The use of power weeder is the need of the time because they reduce the cost of weeding, maintain timeliness, meet-up scarcity of agricultural labour, and environment friendly as compared to use of weedicide and also pulverize the soil (Kumar *et al.* 2014, 2018). Chemical weed management methods come with several drawbacks, including a negative impact on desired plant growth and the accumulation of chemical residues, which can harm consumers (Borbale *et al.* 2021). The farmer's interest on the use of mechanical weeders has increased due to disadvantages involved in manual and chemical weed control and growing demand for organically produced food. Non-chemical weed control ensures food safety. The precise inter- and intra-row weeders could contribute significantly to safe food production. Though there are various rotary power weeders available for wide row spacing crop 60 cm but, the problem exists with narrow spaced crops 30 cm and ideal row spacing was 45 cm (Shekhawat *et al.* 2012). Hence, a two row self-propelled rotary power weeder was developed for narrow spaced crops to tackle the existing issue of mechanical weed control in narrow spaced crops and to save the environment degradation. This study was conducted with an objective to evaluate the performance of rotary weeder and compare it with manual hand hoe *i.e. Kasola* in farmer's mustard crop field.

MATERIALS AND METHODS

The two rows self-propelled narrow crop rotary weeder was developed by department of Farm Machinery & Power Engineering, COAE&T, CCS HAU, Hisar. It consists of 5 hp diesel engine for transmitting power to rotary units and driving wheels of the weeder. The rotary units consisted of four flanges (two in each unit) and four J types blades having 180- and 195-mm length that are mounted on each flange. Ground clearance is a major factor that affects the plant damage by the weeder during field operation. Hence, keeping in view plant height of crop at the time of weeding the tyre size of 2.75-18 inches with V-shape lugs was selected for the weeder that maintains high ground clearance and provides good traction (**Figure 1**). The technical specification of two row self-propelled narrow crop rotary weeder is depicted in **Table 1**.

Table 1. Specification of two rows self-propelled rotary narrow crop rotary weeder

Particular	Detail
Fuel	Diesel
Engine hp	5
Starting system	Recoil
Cooling system	Air cooled
Type of clutch	Dog clutch
Overall dimensions of machine (L×W×H), mm	1900 × 950 × 1070
Size of tyre, inch	2.75-18
Width of cut each rotary unit, cm	22
Rotary unit wt, kg	52
Overall weight of weeder, kg	178

The performance of two row self-propelled narrow crop rotary weeder and manual hand hoe *i.e.* Kasola were evaluated on farmer's mustard crop field at village Neoli district Hisar, Haryana. The weeding operation was carried out after 40 days of sowing mustard crops at a depth of 5 to 5.5 cm. The weeding operation was carried out at 30,45 and 60 days after sowing (DAS) at different speeds of weeder in sugarcane crop (Mohan et al. 2020). The weeding operation was carried out at 3 to 5 cm (Devojee *et al.* 2019) and 4 to 5 cm (Guru *et al.* 2018) depth of operation. Three factorial randomized block design of experiment was used with two length of blades 180 and 195 mm, three speeds of rotor 330, 360 and 390 rpm and three forward speeds of 1.6, 1.8 and 2 km/h. The performance of a manual-operated single-row

Figure 1. Two rows self-propelled narrow crop rotary weeder

Figure 2. The two rows self-propelled narrow crop rotary weeder during field operation weeding efficiency

weeder used for groundnut crop with a blade length of 200 mm was evaluated. Experiments were conducted in clay soil using prototype rotary blades and a C-shaped blade at rotational speeds of 150, 218, 278 and 348 rpm (Niyamapa and Chertkiattipol 2010). Three replications were maintained for each of the treatment. The weeding efficiency, field efficiency, plant damage and cost of operation were the performance parameters measured for this comparative study. In order to see the significance of variables on dependent parameters the data was analyzed with the help of analysis of variance technique programme given by O.P. Sheoran (www.hau.ac.in) and SPSS version 19.0. Critical differences were also analyzed at 5% level of significance. The results of the performance of weeder on best combination of variables were compared with performance of manual hand hoe *i.e. Kasola*. The field performance parameters studied include:

Weeding efficiency, (%)

Weeding efficiency of weeder was calculated by using equation given below (Goel 2009):

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

Where,

W_1 = Weed density (no./m^2) before operation

W_2 = Weed density (no./m^2) after operation.

Field efficiency (E_f), (%)

It is the ratio of actual field capacity to theoretical field capacity, usually expressed in percentage. It was calculated as follows,

$$\text{Field efficiency } (E_f), \% = \frac{AFC}{TFC} \times 100$$

Where,

E_f = Field efficiency, %

TFC = Theoretical field capacity, ha/h

AFC = Actual field capacity, ha/h

Crop plant damage, (%)

The percentage of crop plant damage was calculated by counting the number of damaged crop plants after weeding in sample plot and the total number of plants in sample plot before weeding. The following expression was used for calculation (Yadav and Pund 2007):

$$\text{Plant damage, (\%)} = \{1 - \frac{q}{p}\} \times 100$$

Where,

q = Number of crop plants damaged in 25 m row length after weeding, and

p = Total number of crop plants in 25 m row length before weeding.

Economics

Cost of operation, labour requirement and payback period were the economic parameters considered for this study. Cost of operation in rupees per hectare was calculated by considering depreciation, interest, insurance, housing, tax, repair and maintenance, fuel cost and operator wages for the power weeder where as for the manual hand hoe *i.e.* Kasola only the operator wages were taken into consideration. The initial price (total cost of manufacturing) of two rows self-propelled narrow crop rotary weeder was ₹ 63700 and annual use was considered as 500 hours per year for calculation of other economic parameters. The initial price (total manufacturing cost) of developed weeder was ₹ 150000 (Mohan *et al.* 2020).

RESULTS AND DISCUSION

The experiments were conducted for weeding in mustard crop after one month of crop sowing during the *rabi* season of year 2016. The area of experimental plot was one acre with average moisture content of 12.07% (wb) at the time of weeding. Three levels of soil moisture content 7.73, 12.28 and 16.18% was taken at the time of weeding operation in maize crop (Hegazy *et al.* 2014), The type of soil was sandy loam with bulk density of 1.59 g/cm^3. The soil resistance of sandy loam soil was 0.3 kg/cm^2 (Basavaraj *et al.* 2016). The average height of crop at the time of weeding was 22.8 cm and average weed density (number of weeds per square meter) was 97.6. A view of narrow crop rotary power weeder during field operation is shown in **Figure 2**.

The statistical analysis of data on the influence of study variables on weeding efficiency indicated that the weeding efficiency was highly influenced by the blade length, rotor speed and forward speed at 5% level of significance with CD value 0.62, 0.759 and 0.759, respectively. The ANOVA of weeding efficiency is given in **Table 2**. The interactions of the variables were non-significant except for blade length and rotor speed of rotary unit with CD value 1.073.

The blade length, rotor speed and forward speed had significant effect on weeding efficiency of the rotary weeder (**Figure 3**). The maximum weeding efficiency 80.12% was found at rotor speed 360 rpm, forward speed 1.6 km/h and blade length 180 mm. As the blade length decreased from 195 mm to 180 mm, the weeding efficiency increased from 78.34% to 80.12%, because higher blade length of 195 mm got stuck in ground during operation and weeder goes out of row and weeds were intact in these places. The blade length of 195 mm goes deeper in the soil as compared to blade length of 180 mm and creates problem in balancing the two row self-propelled narrow crop rotary weeder. The increased forward speed from 1.6 to 2 km/h, the weeding efficiency decreased due to the difficulty to balance the weeder in between the rows of crop at high forward speed. The increased rotor speed from 360 rpm to 390 rpm creates negative draft and increases the forward speed of weeder that reduces the weeding efficiency as mentioned above. At 390 rpm two row self-propelled narrow crop rotary weeder creates negative draft and also more weeding efficiency, less plant damage found at rotor speed of 360 rpm. Hence, based on the observations made, the rotor speed of 360 rpm, forward speed of 1.6 km/h, blade length of 180 mm and depth of operation was 5 to 5.5 cm was selected for maximum weeding efficiency. The weeding efficiency of power weeder in sugarcane crop is in the range of 98.74 to 91.22, 96.80 to 84.93 and 94.67 to 73.72 at 0.584, 1.35 and 4.153 km/h, respectively (Mohan *et al.* 2020).

Field efficiency

The field efficiency was influenced by the blade length, rotor speed and forward speed at 5 per cent level of significance with CD value 0.112, 0.137 and 0.137, respectively (**Table 3**). The interactions of variables were also significant.

The blade length, rotary speed and forward speed had significant effect on field efficiency

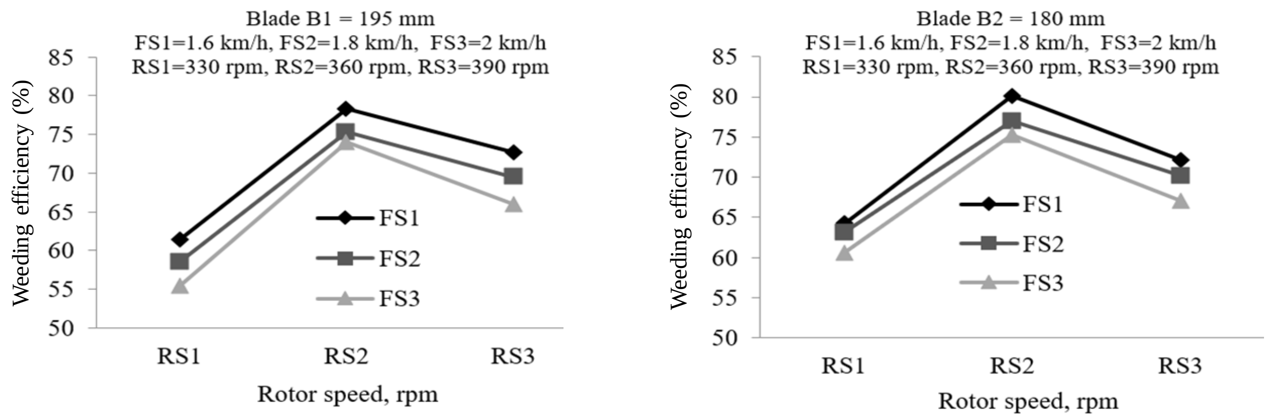

Figure 3. Influence of blade length, rotary speed and forward speed on weeding efficiency of two rows self-propelled narrow crop rotary weeder

Table 2. Effect of study variables on weeding efficiency of two rows self-propelled narrow crop rotary weeder (ANOVA)

Source of variation	DF	Sum of squares	Mean squares	F-calculated	Significance
Replication	2	0.531			
Blade length	1	55.446	55.446	44.196	0.00000
Rotor speed	2	2344.930	1172.465	934.563	0.00000
Blade length x rotor speed	2	33.055	16.528	13.174	0.00006
Forward speed	2	235.147	117.573	93.713	0.00000
Blade length x forward speed	2	3.388	1.694	1.350	0.27273
Rotor speed x forward speed	4	6.505	1.626	1.296	0.29102
Blade length x rotor speed x forward speed	4	3.465	0.866	0.6910	0.60359
Error	34	42.655	1.250		
Total	53	2725.122			

(**Figure 3**). As the rotor speed increased from 330 rpm to 390 rpm the field efficiency increased from 66.69 % to 69.29% as the rotary unit creates negative draft and give a pushing action to rotary weeder. The generated negative draft also reduces the wheel slippage and increases the field efficiency because, generated negative draft gives pushing action to two row self-propelled narrow crop rotary weeder. As weeding efficiency is more important parameter for weeding operation and highest weeding efficiency was obtained at rotor speed of 360 rpm and it was selected for weeding operation. As the blade length decreased from 195 mm to 180 mm, the field efficiency increased from 67.93% to 68.10% as blade length of 195 mm goes deep and gets stuck in ground causing time wastage at those places. The increase in forward speed from1.6 to 2.0 km/h the field efficiency increased from 67.79% to 68.30%, but it was difficult to operate the rotary weeder at high speed in between the crop rows and hence the operating speed of 1.6 km/h was considered optimum for machine field operation.

Crop plant damage

The plant damage was influenced by the blade length, rotor speed and forward speed at 5% level of significance with CD value 1.313, 1.608 and 1.608, respectively (**Table 4**). The crop plant damage varied from 1.19% to 12.93% and 1.20% to 9.96% for blade length of 195 mm and 180 mm respectively. As the blade length decreased from 195 mm to 180 mm, the marginal mean of crop plant damage decreased from 6.13% to 4.13% as control of weeder is difficult for operator with blade length of 195 mm resulting in blade going out of row into the crop which results in crop plant damage. Srinivas *et al*. (2010) reported plant damage for blade length 150 mm (C type blade) and 160 mm (L type blade) was 3.4% and 5.1%, respectively. The crop plant damage of ridge profile power weeder was 2.66% for ridge planted crops (Thorat *et al*. 2014).

As the rotor speed increased from 330 rpm to 390 rpm the marginal mean of plant damage increased from 2.27 % to 8.59% as at high rotary speed rotary weeder creates negative draft and creates problem of weeder control. Similarly, as the forward speed increased from 1.6 to 2.0 km/h the marginal mean of plant damage increased from 3.61% to 4.89% (**Figure 4**). The minimum plant damage (2.90%) occurred at optimized machine variables.

On the basis of field performance of weeder at different levels of study variables, *viz*. blade length, rotor speed and forward speed the maximum weeding efficiency, field efficiency and minimum plant damage were observed at blade length of 180 mm, rotor speed of 360 rpm and forward speed of 1.6 km/h. Hence, weeder performance was evaluated at these levels of study variables and compared with manual hand hoe *i.e*. Kasola. (**Table 5**).

Economical analysis

The estimated economical parameters for the two rows self-propelled rotary narrow crop rotary

Table 3. Effect of study variables on field efficiency of two rows self-propelled narrow crop rotary weeder (ANOVA)

Source of variation	DF	Sum of squares	Mean squares	F-calculated	Significance	LSD (p=0.05)
Replication	2	0.178				
Blade length	1	1.338	1.338	32.802	0.00000	0.112
Rotor speed	2	59.257	29.628	726.407	0.00000	0.137
Blade length x rotor speed	2	0.790	0.395	9.683	0.00047	0.194
Forward speed	2	1.449	0.725	17.764	0.00001	0.137
Blade length x forward speed	2	0.769	0.384	9.425	0.00055	0.194
Rotor speed x forward speed	4	1.205	0.301	7.389	0.00021	0.237
Blade length x rotor speed x forward speed	4	1.637	0.409	10.032	0.00002	0.335
Error	34	1.387	0.041			
Total	53	68.009				

Table 4. Effect of study variables on crop plant damage during the operation of two rows self-propelled narrow crop rotary weeder (ANOVA)

Source of variation	DF	Sum of squares	Mean squares	F-Calculated	Significance
Replication	2	4.049			
Blade length	1	147.246	147.246	6.156	0.00001
Rotor speed	2	504.259	25.129	44.787	0.00000
Blade length x rotor speed	2	14.435	7.217	1.282	0.29054
Forward speed	2	97.786	48.893	8.685	0.00090
Blade length x forward speed	2	0.319	0.159	0.028	0.97212
Rotor speed x forward speed	4	26.120	6.530	1.160	0.54564
Blade length x rotor speed x forward speed	4	7.502	1.875	0.333	0.85371
Error	34	191.404	5.630		
Total	53	993.118			

weeder and manual hand hoe *i.e.* Kasola (**Table 6**), revealed that labour requirement for weeding operation in mustard crop by manual hand hoe was 160 man-h/ha whereas it was only 11.11 man-h/ha with narrow crop rotary power weeder. Speed of operation, field capacity, width of cut, field efficiency, depth of operation, weeding efficiency, and plant damage was 1.6 km/h, 0.09 ha/h, 900 mm, 67.98%, 50 to 55 mm, 80.12% and 2.9% for and two row self -propelled narrow crop rotary weeder and for manual hand hoe (*Kasola)* was 1.0 km/h, 0.05 ha/h, 250 mm, 74.43%, 40 mm, 94.6% and 2.4%, respectively. The speed of operation, width of cut,

Table 5. Comparative performance of two rows self-propelled narrow crop rotary weeder (narrow crop weeder) and manual hand hoe *i.e. Kasola*

Particular	Two row self - propelled narrow crop rotary weeder	Manual hand Hoe (Kasola)
Speed of operation, km/h	1.6	1
Field capacity, ha/h	0.09	0.05
Width of cut, mm	900 (Two row)	250 (Single row)
Field efficiency, %	67.98	74.43
Depth of operation, mm	50 – 55	40
Weeding efficiency, %	80.12	94.6
Plant damage, %	2.9	2.4
Fuel consumption, l/h	1.6	-

depth of operation, field capacity and weeding efficiency was 1.2 km/h, 450 mm, 30 mm, 0.048 ha/h and 92.5%, respectively of developed power weeder in groundnut crops. The crop plant damage was 2.5% with hand operated hoe (Singh 2017). The developed weeder was higher field efficiency 74.43 as compared to cono-weeder 72.89% (Shakya et al. 2016). Thus, the narrow crop rotary power weeder saves 93% labour over manual method of weeding using Kasola. The cost of operation for manual and rotary power weeder was found ₹ 7060 per ha and ₹ 1733/ha, respectively. The rotary weeder saves ₹ 5327/hectare as compared to manual method. The payback period for developed rotary weeder was found to be 1.45 years when annual working hours are assumed as 500 (**Table 6**).

Conclusion

The best performance of the two row narrow crop rotary weeder was observed with blade length of 180 mm, rotor speed of 360 rpm and forward speed of 1.6 km/h. At the best combination of study variables, the weeder gave effective field capacity of 0.09 ha/h, field efficiency of 67.98%, weeding efficiency of 80.12% and plant damage of 2.9%. The rotary weeder saves 75.45% of cost and 93% of labour as compared to manual method of weeding in mustard crop. In order to avoid the drudgery, labour and greater cost of

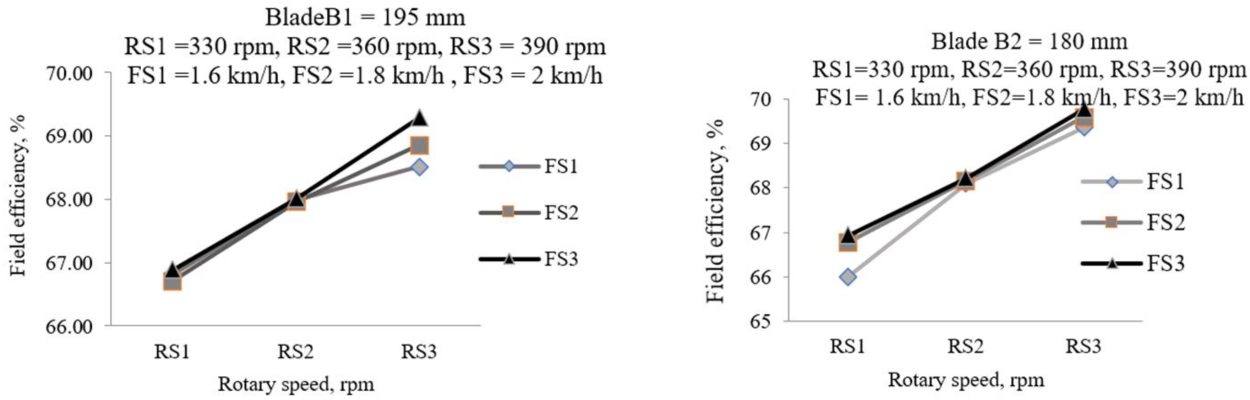

Figure 4. Influence of blade length, rotary speed and forward speed on field efficiency of two rows self-propelled narrow crop rotary weeder

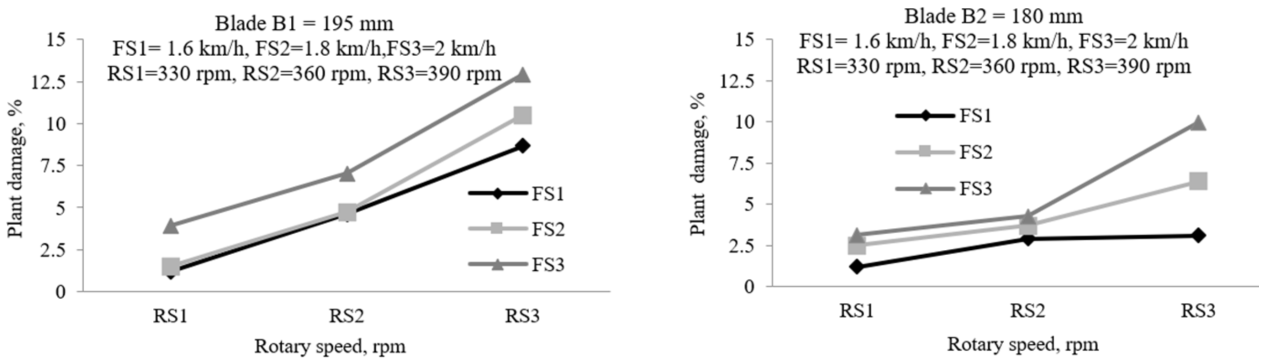

Figure 5. Influence of blade length, rotor speed and forward speed on crop plant damage during the operation of two rows self-propelled narrow crop rotary weeder

Table 6. Comparative economics of the usage of two rows self-propelled narrow crop rotary weeder (narrow crop weeder) weeder and manual hand hoe *i.e.* Kasola

Particular	Rotary power weeder	Manual hand hoe (*Kasola*)
Cost of operation, `/h	156	44.125
Cost of operation, `/ha	1733	7060
Saving in cost of operation over manual, `/ha	5327	-
Saving in cost of operation over manual, %	75.45	-
Payback period, yr	1.45	-
Break Even Point, h/yr	112.44	-
Labour requirement man-h/ha	11.11	160.0
Saving in labour requirement, %	93	-

operation involved in manual weeding, the narrow crop rotary power weeder could be advantageously used for weed management in mustard crop.

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