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RESEARCH ARTICLE

PERFORMANCE EVALUATION OF SOME MANUALLY OPERATED WEEDERS USED IN JHUM CULTIVATION IN HILL REGIONS OF ARUNACHAL PRADESH

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ABSTRACT

Manual weeding is a labor intensive and time consuming operation in jhum cultivation in hill region of Arunachal Pradesh. However the scarcity of labor during the peak season results in increased of labor wages and delay in weeding operation which ultimately reduced the yield of crop. The present study was undertaken with an objective to evaluate field performance of four different types of manually operated weeders namely wheel hoe with tines, wheel hoe with sweep blade, peg type dry-land weeder and straight blade hand hoe. The trail was conducted in the farmer's cabbage field located at Lakhi village of Papum Pare district of Arunachal Pradesh. The average effective field capacity of 0.0185, 0.022, 0.016, and 0.017 ha/h, respectively were observed for wheel hoe with tine, wheel hoe with sweep type blade, peg type dry-land weeder and straight blade hand hoe at forward speed of 0.285, 0.338, 0.290 and 0.270 m/s respectively. The result revealed that maximum weeding efficiency of 79.72% was recorded for sweep type followed by straight blade (78.19%), tine type (75.71%) and peg type dry-land weeder (72.50%). Wheel hoe with sweep type blade also recorded the lowest labor requirement of 51 man-h per hectare followed by 56 man-h, 66 man-h and 70 man-h per hectare for wheel hoe with tines, straight blade hand hoe and peg type dry-land weeders respectively. Percentage plant damage was highest under straight blade hoe (2.5%) followed by hoe with tine (1.5%), hoe with sweep type blade (1%) and peg type dry-land weeder (0%). Among the weeders, peg type dry-land weeder required minimum power input of 0.071 kW (0.096 hp) followed by straight blade hoe 0.079 kW (0.107 hp), hoe with sweep type blade 0.105 kW (0.142 hp) and wheel hoe with tine weeder 0.112kW (0.152 hp). However the maximum performance index of (1222.75) was observed for wheel hoe sweep type blade followed by straight blade hand hoe (1211.21), peg type dry-land weeder (1208.33) and wheel hoe with tines (976.34).

INTRODUCTION

Weeding is an essential operation in agriculture to prevent undesired species from growing and consuming the key resources (i.e. water, minerals, soil and sunlight) and thereby compromising crop yield. Farmers spend a large amount of time and money managing weeds. They aggressively compete for water, nutrients and sunlight, resulting in reduced crop yield and poor crop quality. Weeds are responsible for significant crop yield losses and for financial losses in agricultural production – in the order of 10% per year worldwide (Oerke, 2006). In India the annual losses due to weeds in food grains is about 82 million tons, pulse 14 million tons, oil seeds 12 million tons and commercial crops about 52 million tons (P. K. Singh, 2013). Weeding is a time consuming and labor intensive operation which accounts for about 25 % of the total labor requirement (900–1200 man-hours/hectare) during a cultivation (Yadav and Pund, 2007). Many research workers have reported that one third of the cost of cultivation is being spent for weeding alone. Delay and negligence in weeding operation affect the crop yield and the loss in crop yields due to weeds in upland crops vary from 40-60 per cent and in many cases cause complete crop failure (Singh, 1988). One of the major laborious and time consuming unit operations involved in Jhum cultivation in Arunachal Pradesh is the weeding operation after clearing land. Jhum cultivation is the main occupation of the farmers in Arunachal Pradesh and it has been practiced since past few decades. Due to hilly, undulating terrain and fragmented land holding in plain and valleys, the farmers conduct most of the crop cultivation and post harvest operations manually using traditional hand tools and implements resulting into yield loss due to delay in conducting various farm operations. Estimates of time and cost for hand weeding are variable and depend on weed flora, weed intensity, cropping season, labor availability and

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efficiency of weeding methods. It is estimated that one-third to one-half of the labor used in rice production is for weed control with an average figures of 30–40 labor-days per hectare and 8-10 man-hour per day (Hobbs and Bellinder, 2004). Intensity of weed problem in Jhum cultivation primarily depends upon the Jhum cycle (Zinke et al. 1978 Kushwaha et al. 1981). High intensity of weeds is always noticed from the second year of cropping. The main practice of control in shifting cultivation is hand weeding 3-4 times during crop growth incurring higher labor cost and reduced net return (Rathore et al. 2012). Because of an inhospitable difficult hilly terrain, wide variations in slopes and altitudes, fragmented and small land holding inhibit mechanization. Power source available from animal and mechanical in the region is very low and most of farm works are depend on human labor.

Till date, traditional tools and indigenous implements dominated over the modern equipments in all agricultural activities. Usually women look after the back breaking work of manual uprooting of weed with bare hands in bending position or using locally made small hand tools such as khurpa (local name: Chenkawn), U-blade weeder (local name: Nerini) etc. and hence, require more time, cost and energy for weeding unit area. Moreover there is an acute labor shortage during the peak time (June - July) which results in increased labor wages and delay in weeding operation which ultimately reduced the yield of crop. To mitigate the problem of weed in Jhum cultivation in Arunachal Pradesh, the state government had recently introduced some improved animal drawn as well as manually operated weeders on trial basis to promote weed mechanization in the hill regions and the equipments are gradually becoming more popular. Keeping in view the importance of use of improved weeders for weed control in Jhum cultivation, this study was carried out to evaluate the performance of some manually operated weeders under dry condition.

MATERIALS AND METHODS

Description of weeder used: The description of the manually operated weeders selected for the trail are explain in the following section and the detail of the specifications are presented in Table 1.

Wheel hoe with sweep type blade: Wheel hoe comprises of wheel assembly, miniature tool frame, sweep type blade and handle assembly (Figure a). The frame has got a provision to accommodated different types of soil working tools (such as straight blade, reversible blade shovel tine etc).The handle assembly has a provision to adjust the height of the handle to suit the operator. The weeder is operated by the action of push and pulls which causes the soil working part to penetrate and cut or uproot the weeds in between the rows.

Wheel hoe with tine: In this wheel hoe five slightly curve tines are attached to the tool frame at regular spacing. The total working width is 200 mm and length of the tine is 80-100 mm (Figure b). The handle height is adjustable to suit the operator.

Peg type dry-land weeder: It consists of a roller, which has two mild steel discs joined by mild steel rods (Figure c). The axle passes through the centre of discs and is mounted on the two arms, which also constitutes the frame. The small diamonds shaped pegs are welded on the rods in a staggered fashion. A V- shaped blade follows the roller assembly and is mounted on the arms. The blade height can be adjusted according to the working depth.

Table 1. Specification of the weeders used in the experimental trial

Wheel hoe with sweep type blade	Five tine wheel hoe	Peg type dry land weeder	Straight blade hand hoe
Tyne material used: medium carbon steel	Tyne material used: medium carbon steel	Roller drum diameter (mm): 250	Raw material used: carbon steel
Wheel diameter: 400 mm	Wheel diameter: 400 mm	Material for roller: mild steel	Handle: wood
Overall length (mm): 1400 -1500	Overall length (mm):1400 -1500	Blade material: medium carbon steel and forged to shape	Blade length (mm): 80
Overall width (mm): 450 - 500	Overall width (mm): 450 - 500	Width of blade(mm): 200	Blade width (mm): 200
Overall height (mm): 800 -1000	Overall height (mm): 800-1000	Overall length(mm): 1780	Blade thickness (mm): 3
Number of sweep: one	Number of tine: five	Overall height(mm): 780	Handle diameter (mm): 32 -38
Width of sweep(mm): 200	Weight(kg): 8	Overall width(mm): 370	Handle length (mm) :1500
Weight(kg): 8		Weight(kg): 10	Weight(kg): 4

The arms are joined to the handle assembly. The handle height can be adjusted according to the operator. For operation the weeder is repeatedly pushed and pulled in between the crop rows in the standing position. The diamond shaped pegs penetrate into the soil and the rolling action pulverizes the soil. The blade in the push mode penetrates into the soil and cuts or uproots the weeds.

Straight blade hand hoe: It consists of a blade, curved arm, ferrule and a long wooden handle. The curved arm joins the blade with the ferrule to which the handle is fixed (Figure d). The blade performs the cutting, uprooting of the weeds, besides stirring the soil. Being a long handled tool, the straight blade hand hoe is operated in the standing posture by pulling action. The pulling action of the blade into the soil cuts or uproots the weeds in between the rows of the crop. The cut or uprooted weeds are buried under the soil and thus creates mulch.

Experimental Procedure: The field experiment was conducted at farmer's field where cabbage was grown. The field is located in Lakhi Village of Papum Pare district of Arunachal Pradesh, India located between Latitude $27^{o}.14^{'}$ and Longitude $93^{o}61^{'}$. The soil was loamy. Row to row distance was 60 cm and plant to plant within the row was 40 cm. The trail was carried out when the crop was 30 days old and the field was infested with grass weeds. And average weed density at the time of weeding was 40 per m^2. The main field was divided into 12 sub plots each of size 20 m x 3 m. Three replications were carried out for each types of weeder. The Figure (e) shows the Farmer's cabbage field where the trail was carried out and Figure (f) shows the field layout of the experimental area.

Type of soil and soil moisture content (db): The test conditions such as soil moisture content, soil type, bulk density of soil, depth of cut (root zone depth of weed), density of

weed, etc. were taken into consideration. Soil samples were collected from representative test plots with the help of soil sampling auger for moisture measurement.

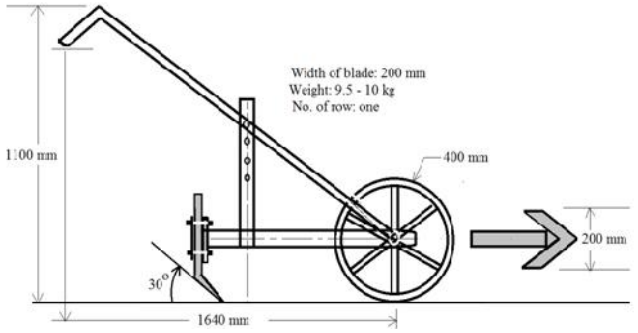

Figure a. Wheel hoe with sweep type blade

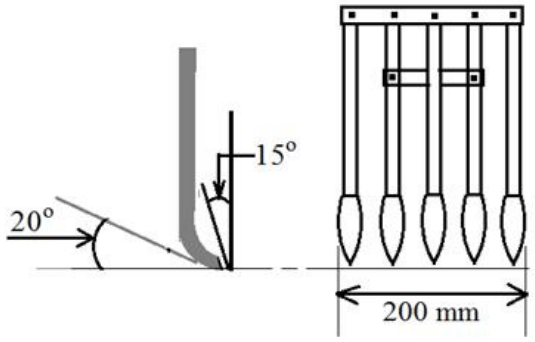

Figure b. Five tines wheel hoe

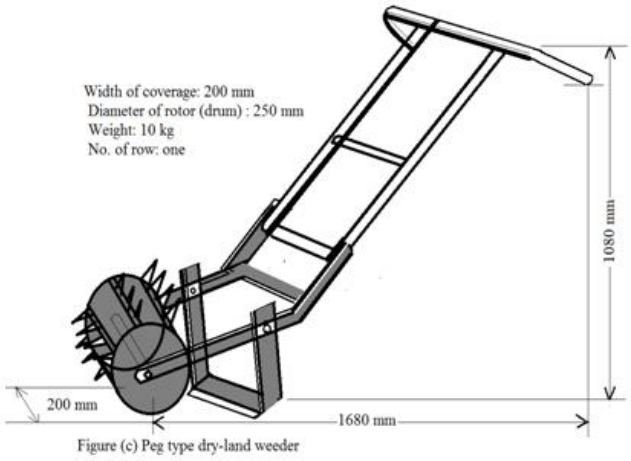

Figure c. Peg type dry-land weeder

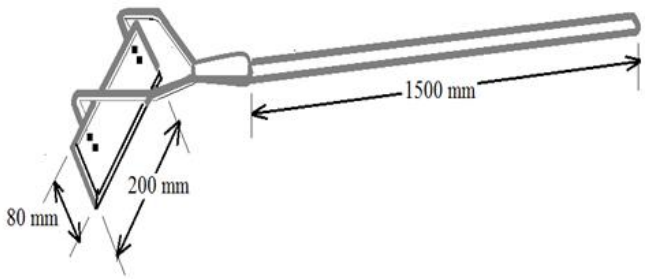

Figure (d) Straight blade hand hoe

Initial weight (W_1) of each sample was taken on digital balance and dried it at 105°C for 8 hours. Dried sample collected from oven and final weight (W_2) was taken. Moisture content (MC) on dry basis has been calculated using the formula:

Soil moisture content (% db) = $(W_1-W_2)100/W_2$ ……..(1)

For measurement of bulk density of soil, cylindrical core samples of soil from each test plots were taken. Then the diameter and length of cylindrical soil sample were measured. The core samples were kept in hot air oven maintained at 105°C for 8 hours. Then the weights of cooled soil samples were noted down. Bulk density was calculated by following formula:

Bulk density of soil sample = M/V ……(2)

Where, M is the mass of oven dried core soil sample (g) and V is the volume of cylindrical core sample (cc).

Cone index

Cone index indication soil hardness and is expressed as force per square centimeter required for a cone to penetrate into soil. Cone index was measured by a digital cone penetrometer.

Weeding efficiency: To determine weeding efficiency in each plot randomly, four patches of 1m × 1m size was taken and the number of weeds were counted before and after weeding operation and the average values were used for calculating the weeding index (efficiency) of the weeder using the following equation (3) (Yadav and Pund, 2007).

$$W_E = \frac{(N_1 - N_2)}{N_2} \times 100 \quad \text{…….(3)}$$

Where, W_E is the weeding efficiency of the weeder (%), N_1 is the number of weeds before weeding operation and N_2 is the number of weeds standing after weeding operation.

Plant damage: The implement may cause damage to the crop during weeding. For determining the percentage of plant damage the number of crops plants in the plot before operation and number of crop plants in the plot after the operation are recorded. The percentage of damaged plants, as a quality of work done, is calculated by following formula

$$D_P = [1- (Q_D/Q_P)] \times 100 \quad \text{…….(4)}$$

Where, D_P is the percentage plant damage, Q_D is the number of plants in the plot after weeding and Q_P is the number of plants in the plot before weeding.

Speed of operation: The operating speed was measured in the test plots for each type of weeder. For determining the operating speed a distance of 10 meter in between the crop rows were marked in all the plots and the weeder was then used in between the straight rows. As the weeder traversed in between the crop rows, time taken to cover 10 meter distance was recorded with the help of stop watch. The speed of operation is calculated from the expression:

$$V = S/T \quad \text{…….(5)}$$

Where V is the working speed (m/s),

S is the distance covered and is taken as 10 meter,
T is the time taken in second (s) to travel the distance S i.e. 10 meters.

A minimum of such four readings were recorded for calculating the average operating speed of each type of weeder in the respective field plots.

Figure e. Cabbage field

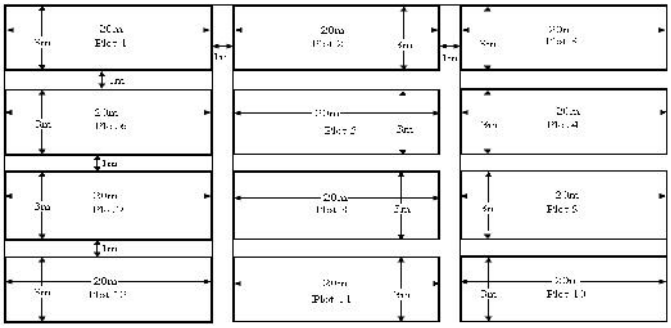

Figure f. Field layout of the experimental area

Productive, delay and total field time: Productive time is the actual (effective) weeding time in the field whereas delay time is the time loss during the operation which includes time consumed in minor adjustments, turning time, rest time etc. Total field time is the time spent in the field to complete a given task and it equal to the sum of productive and delay time. Productive and delay time are recorded separately using two stop watches in each plot. Three replications are carried out for each type of weeder and average workout.

Effective field capacity, Field efficiency: Effective field capacity is the average output per hour, calculated from the total area weeded in hectares and the total work time. Field efficiency (F_E) gives an indication of the time lost in the field and the failure to use the full working width of the implement. Field efficiency, Effective field capacity, and work capacity were calculated by the following equations (Hunt, 1995).

$$F_E = (T_E / T_T) \text{ X } 100 \quad \text{……(6)}$$

$$F_C = V.B.F_E \quad \text{……(7)}$$

$$W_C = 1/ F_C \quad \text{……(8)}$$

Where, F_E is the field efficiency of weeder (%), F_C is the effective field capacity (ha/h), V is the operating speed (km/h), B is the effective width of coverage (m), T_E and T_T are the productive time (effective operating time) and total field time (h) respectively and W_C is the working capacity (h/ha).

Depth and effective width: Depth and width of cut are measured at different spots along the furrow length using a steel scale and average work out. For measuring the depth of cut clean carefully the furrow already cut and measured the vertical distance between the furrow sole and the ground level measured along the furrow wall. The width of cut is measured by taking the horizontal distance between the two walls of furrow.

Draft and power requirement: Draft is the force necessary to push or pull the implement for weeding operation. For manually operated soil working tools the draft should be within the physiological limit of the operator. The draft force of weeder can be calculated by (Yadav and Pund 2007)

$$D = B \text{ x } D_C \text{ x } S_R \quad \text{……(9)}$$

Where, D = Draft force of the weeder (N), D_C is the depth of cut (cm), B is the width of cut (cm) and S_R is the specific soil resistance (N/cm^2). The specific drafts of sandy and silt loams soil ranges from 2 to 5 N/cm^2 (Ajit K. Srivastava, American Society of Agricultural Engineers, 2006 - Technology & Engineering). In this experiment the specific soil resistance of loamy soil is taken as 4 N/cm^2.

Power is calculated from the draft force and forward speed as follows:

$$P (W) = D \text{ x } V \quad \text{……..(10)}$$

Where, P is the power (W), D is the draft (N) and V is the operating speed (m/s).

Performance Index: Performance index of a weeding equipment directly related to field capacity, weeding efficiency and inversely related to power exerted. It indicates the overall performance of the weeder. Field performance of weeding tools was assessed by calculating the performance index as suggested by Gupta (1981).

$$PI = F_C (100 - D_P) W_E /P \quad \text{…….(11)}$$

Where, PI is the performance index, F_C is the effective field capacity (ha/h), D_P is the percentage plant damage (%), W_E is the weeding efficiency (%) and P is the power input (W).

RESULTS AND DISCUSSION

The results of field performance evaluation trails of four types of manually operated weeders namely wheel hoe with tines, wheel hoe with sweep type blade, peg type dry-land weeder and straight blade hand hoe which were carried out in the farmer's cabbage field are presented and discussed in the following paragraph. Field observations like operational speed, width of cut, depth of operation, soil moisture content, bulk density and cone index were recorded. The data collected during field evaluation trails were analyzed to determine the actual field capacity, field efficiency, weeding efficiency, power requirement and performance index. Table 2 shows the field performance of the manually operated weeders.

Field evaluation of wheel hoe with tine: The average soil moisture content, bulk density before and after operation was found to be 15.55 % (db), 1.45 g/cc and 1.3 g/cc respectively. Cone index before and after the weeding operation in the test plot were 1.36 kg/cm^2 and 1.20 kg/cm^2 respectively. The average effective width and depth of operation of the weeder were 18.0 cm and 5.05 cm respectively. The average effective field capacity and weeding efficiency were found to be 0.0185 ha/h and 75.71% respectively. Among the weeders the wheel hoe with tines recorded the lowest performance index of 976.34 and maximum draft of 363.4 N (37.06 kg).

From the experimental trial it was observed that among all the weeders tested, the wheel hoe with sweep type blade recorded the lowest labor requirement of 51 man-h per hectare followed by wheel hoe with tines (56 man-h), straight blade hand hoe (66 man-h) and peg type dry-land weeders (70 man-h per hectare). Sweep type blade also recorded the highest values of average effective field capacity and weeding efficiency of 0.022 ha/h and 79.72% respectively. Among the weeders, peg type dry-land weeder required minimum power input of 0.07 kW (0.096 hp). Minimum power requirement of peg type weeder was due its lower effective width (15.70cm) and lower depth of cut (3.88cm). Lower operating depth may be due to low moisture content (11.8%db) of the field plot. During operation the peg type weeder tends to entangle with weeds which reduces its efficiency. In case of straight blade hand hoe the weed clogged the cutting edge and plant damage (2.5%) was highest compare to other weeders. In case of wheel hoe with five tines, higher effective width (18cm) and higher depth of cut (5.05cm) results to higher draft 363.4N (37.06 kg) requirement. Higher depth of operation may be due to higher moisture content (15.55%db) of the field plot. During the field test it was also observed that some of the weeds escaped in between the tine which reduces the weeding efficiency of the tine weeder.

Table 2. Field performance of manually operated weeders

Sl. No.	Particulars	Units	Wheel hoe with tines	Wheel hoe with sweep type blade	Peg type dry land weeder	Straight blade hand hoe
1	Soil type - loamy soil		loamy soil	loamy soil	loamy soil	loamy soil
2	Soil resistant	N/cm^2(kg/cm^2)	4 (0.407)	4 (0.407)	4 (0.407)	4 (0.407)
3	Moisture content (db)	%	15.55	14.20	11.8	12.20
4	Bulk density before testing	g/cc	1.45	1.34	1.34	1.42
5	Bulk density after testing	g/cc	1.30	1.29	1.30	1.33
6	Cone index before testing	kg/cm^2	1.30	1.34	1.55	1.43
7	Cone index after testing	kg/cm^2	1.20	1.21	1.35	1.24
8	Working width	cm	20	20	20	20
9	Forward speed	m/s	0.285	0.3480	0.290	0.270
10	Effective width	cm	18.00	17.88	15.7	18.00
11	Depth of operation	cm	5.05	4.21	3.88	4.09
12	Theoretical field capacity	ha/h	0.0205	0.0251	0.021	0.019
13	Effective field capacity	ha/h	0.0185	0.022	0.016	0.017
14	Field efficiency	%	90.24	87.85	76.19	89.47
15	Work capacity	h/ha	54.05	45.45	62.5	58.8
16	Labor requirement	man-h/ha	56	51	70	66
17	Draft	N (kg)	363.4(37.06)	301.09(30.69)	243.66(24.84)	294.48(30.02)
18	Power	kW (hp)	0.104(0.14)	0.105(0.143)	0.07(0.096)	0.08(0.108)
19	Weeding efficiency	%	75.71	79.72	72.50	78.19
20	Plant damage	%	1.5	1.0	0.0	2.5
21	Performance index		976.335	1222.747	1208.33	1211.21

Field performance of wheel hoe with sweep type blade: Wheel hoe with sweep type blade recorded a highest average effective field capacity of 0.022 ha/h and lowest labor requirement of 51 man hour per hectare. The average effective width and depth of cut were found to be of 17.88 cm and 4.1cm respectively. The average soil moisture content, bulk density before and after operation was found to be 14.20 % (db), 1.34 g/cc and 1.29 g/cc respectively. Cone index before and after the weeding operation in the test plot were observed to be 1.34 kg/cm^2 and 1.21 kg/cm^2 respectively. It registered the highest weeding efficiency and performance index of 79.72% and 1222.747 respectively.

Field performance of peg type dry-land weeder: In average, peg type dry-land weeder required 70 man hours to complete weeding in one hectare area. Its average effective width, field capacity and weeding efficiency was found to be 15.70 cm, 0.016 ha/h and 72.50 % respectively. The peg type dry-land weeder recorded a minimum power input of 0.07 kW (0.096hp) and zero percentage plant damage.

Field performance of straight blade hand hoe weeder: In case of straight blade hand hoe the average effective operating width, depth of cut and field capacity was observed as 17.80 cm, 4.09 cm and 0.017 ha/h. Weeding efficiency of 78.19 % was recorded with maximum percentage plant damage of 2.5 %. In average the straight blade hand hoe required 66 man hour per ha and the power requirement of 0.08 kW (0.108 hp) and performance index of 1211.21.

Conclusion

Among all the weeder tested, on the whole, the wheel hoe with sweep type blade stands out to be most superior because of its highest average weeding efficiency (79.72%), effective field capacity (0.022 ha/h) and lowest labour requirement (51 man-h per hectare) with minimum plant damage percentage (1%) as compare with other weeders tested. On the other hand the peg type weeder required minimum power input and zero percent of plant damage (0%), however it has the lowest average field capacity (0.016 ha/h), weeding efficiency (72.50%) and field efficiency (76.19 %) and highest work capacity (62.5 h/ha) with labor requirement of 70 man h per hectare when comparison with other types of weeders used in the field trial.

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