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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 labour intensive and time consuming operation in Jhum cultivation system in hill region of Arunachal Pradesh. However the scarcity of labour during the peak season results in increased of labour 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 push pull weeder with five tines, push pull weeder 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 five tine, wheel hoe with sweep 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 weerder (72.50%). Push pull weeder with sweep type blade also recorded the lowest labour requirement of 51 man-h per hectare followed by 56 man-h, 66 man-h and 70 man-h per hectare for push pull five tines weeder, straight blade hand hoe and peg type dry-land weeders respectively. Percentage plant damage was highest under straight blade hoe (2.5%) followed by push pull with five tine (1.5%), push pull with sweep 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), push pull with sweep blade 0.105 kW (0.142 hp) and push pull with five tine weeder 0.112kW (0.152 hp). However the maximum performance index of (1222.75) was observed for push pull weeder with sweep blade followed by straight blade hand hoe (1211.21), peg type dry-land weeder (1208.33) and push pull weeder with five tines (976.34).

1. 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 sun) 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 labour intensive operation which accounts for about 25 % of the total labour requirement (900–1200 man-hours/hectare) during a cultivation (Yadav and Pund, 2007).

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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, labour availability and efficiency of weeding methods. It is estimated that one-third to one-half of the labour used in rice production is for weed control with an average figures of 30–40 labour-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 labour 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 labour. 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 labour shortage during the peak time (June - July) which results in increased labour 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.

2. Materials and Methods

2.1 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 accommodate 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.

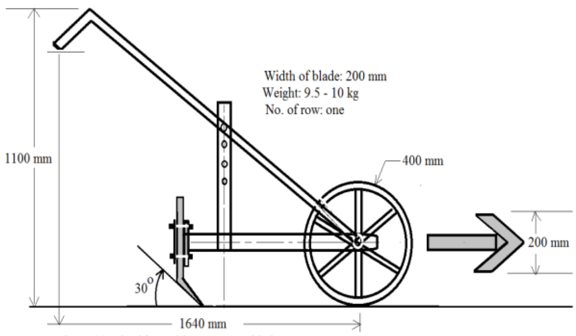

Figure (a) Wheel hoe with sweep tpye blade

2.2 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 8 - 100 mm (Figure b). The handle height is adjustable to suit the operator.

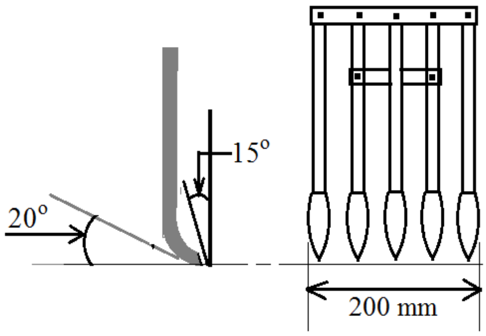

Figure (b) Five tine wheel hoe

2.3 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. 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.

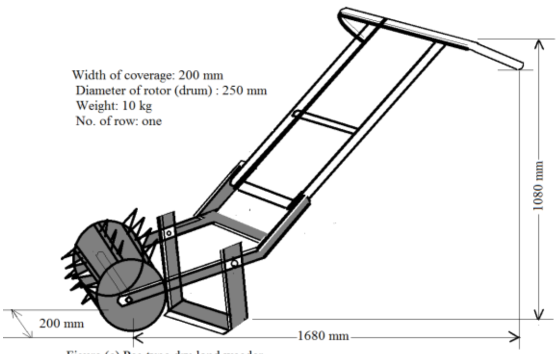

Figure (c) Peg type dry-land weeder

2.4 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.

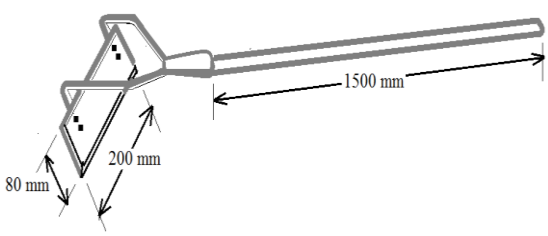

Figure (d) Straight blade hand hoe

2.5 Experimental Procedure

The field experiment was conducted at farmer's field where cabbage was grown. The field was located in Lakhi Village of Papumpare district of Arunachal Pradesh. 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. The experiment was laid out in complete randomized design and three replications of each types of weeder. The Figure (e) shows the Farmer's cabbage field where the trail was carried out.

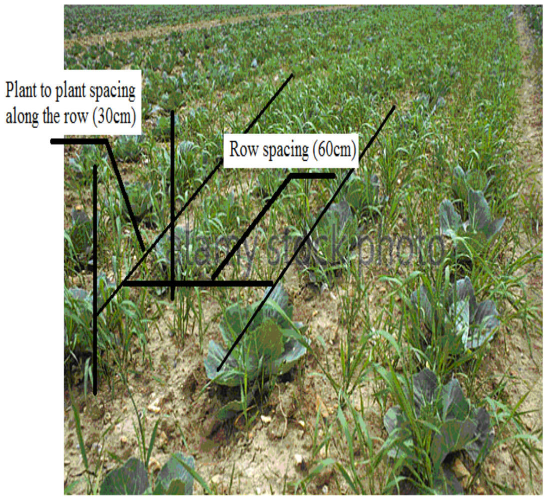

Figure (e) Cabbage field

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. A minimum of such five readings were recorded for calculating the average operating speed of each type of weeder in the respective field plots. The number of crops plants in the row, number of damaged plants, number of weeds (weed density) before and after the operation as well as the total field time and actual time for weeding with different types of weeder were noted to evaluate the performance parameters of the weeders.

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

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. 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) =

$$\frac{(W_1 - W_2)}{W_2} \times 100 \quad (1)$$

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 = V/M (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 centimetre 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).

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

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 after weeding operation.

Effective field capacity

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. Effective field capacity (F_C), field efficiency (F_E) and work capacity (W_C) were calculated by the following equations (Hunt, 1995).

$$F_C = V.B.\,F_E \quad (4)$$

$$F_E = (T_E / T_T) \times 100 \quad (5)$$

$$W_C = 1/ F_C \quad (6)$$

Where, F_C is the effective field capacity (ha/h), V is the operating speed (km/h), B is the effective width of coverage per run (m), F_E is the field efficiency of weeder (%), T_E and T_T are the effective operating time (productive time) and total working time (h) respectively and W_C is the working capacity (h/ha). Total working time includes effective time, time lost for turning, and minor adjustment, rest time.

Plant damage

The implement may cause damage to the crop during weeding. The percentage of damaged plants, as a quality of work done, is calculated by following formula:

$D_P = [1- (Q_D/Q_P)] \times 100$ (7)

Where, D_P is the percentage plant damage, Q_D is the number of plants in 10 meter row length after weeding and Q_P is the number of plants in 10 m row length before weeding.

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)

$D = B \times D_C \times S_R$ (8)

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

P (kW) = draft force (N/1000) x speed (m/s) (9)

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 (PI), as suggested by Gupta (1981)

$PI = F_C (100 - D_P) W_E /P$ (10)

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

3. Results and Discussion

The results of field performance evaluation trails of four types of manually operated weeders namely Wheel hoe with sweep type blade, wheel hoe with tines, 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, input power 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 all the weeders the maximum draft of 367.64 N (37.48 kg) was recorded in the case of weeding operation using wheel hoe with tine.

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 labour 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 0.079 kW (0.107hp) and zero percentage plant damage.

Table 2. Field performance of manually operated weeders

Sl. no	Particulars	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	Labour requirement, man-h/ha	56	51	70	66
17	Draft, N (kg)	367.64(37.48)	316.48(32.26)	245.83(25.06)	288.22(29.38)
18	Power , kW (hp)	0.112(0.152)	0.105 (0.142)	0.071(0.096)	0.079(0.107)
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	1222.74	1208.33	1211.21

Field performance of straight blade hand hoe weeder

In case of straight blade hand hoe the average effective operating width, depth of cut operation and field capacity was observed as 17.80 cm, 4.09 cm and 0.017 ha/h. Weeding efficiency of 78.19 % was recoded 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 0.079 kW (0.107 hp) and performance index of 1211.21. From the experimental trial it was observed that among all the weeders tested, the wheel hoe with sweep type blade recorded the lowest labour 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 0.071 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 367.64N (37.48 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.

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 labour requirement of 70 man h per hectare when comparison with other types of weeders used in the field trial.

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