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Development and Performance Evaluation of Manually Operated Finger Weeder

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Abstract: ***A push-type manually operated finger weeder with an adjustable long handle, was developed and tested; manually operated finger weeder for dry land crops was evaluated to find its performance. It was compared with traditional method of weeding. Groundnut and black gram were the crop plants chosen for the field trial. The bulk density and moisture content of the soil were 1.64 and 1.65 g/cm3 and 17.15 and 20 percent, respectively in groundnut and blackgram field. The developed weeder impacts the speed, effective field capacity, draft, power needed, field efficiency, and weeding efficiency. It was found that, these were considerably higher at 0.55 km/h, 0.038 ha/h, 11.8 kg, 0.022 hp and 95.74 %, and 82.22 %, in field respectively in operators having BMI of 22.77 kg/m2. According to an economic analysis, the cost of weeding per hectare was found to be Rs.1109.11/- and Rs. 1147.8/- in groundnut and blackgram field.***

Keywords: Finger weeder, performance evaluation, weeding efficiency, weeding, manual weeder, ergonomics

1. Introduction

The mechanization raises agricultural productivity, increase profitability and also improves quality of life of farming community. There are several constraints in agriculture like climate change, insect and pests but weeds are one of the major reasons for declined yield per unit agricultural area in India. Weeding is an important and necessary intercultural operation in a crop production system. In the same way, it is labour intensive agricultural operation. In terms of labour requirement, weeding takes up to 25 % of the labour requirement during a cultivation season (Yadav and Pund, 2007). Major investment in crop production goes toward weed control in the case of major crops. About 4.2 billion rupees were spent every year for controlling weeds in the country. Because of weeds alone, around 40 million tons of major food grains were lost every year (Dixit and Syed, 2008).

The objectives of the study carried out were:

1) To develop a manually operated finger weeder
2) To evaluate the performance of developed finger weeder.

2. Review of Literature

Rao and Chauhan (2015) reported that in India, the widely diverse agriculture and fanning systems are plagued by several forms of weed problems. Weeds reduce crop yields by 10 to 80 percent, as well as lowering product quality and posing a health and environmental risk. Agriculture, forestry, and the aquatic environment are all hampered by invasive alien weeds. Weed control in India has always relied heavily on human weeding. However, rising labour prices and scarcity are prompting farmers to use labor-saving methods.

Malavia *et al.* (1998) indicated that weed was the main cause of yield loss in Gujarat. Aside from that, weeds deplete a significant quantity of plant nutrients and degrade soil quality.

Milberg and Hallgren (2004) undertook field trials testing pesticides in Sweden to investigate a large-scale pattern in cereal yield loss owing to weeds. They weighed the relative importance of variations in areas, crops, soils, and years. Weed biomass explained 31% of the variation in yield loss owing to weeds in a negative hyperbolic function.

Gite and Yadav (2007) studied an optimum handle height for push-pull type manually operated dry land weeder. He compared four handle heights i.e., 0.6, 0.7, 0.8 and 0.9 of shoulder height (SH) for operating the weeder. Based on physiological responses, working at 0.7 SH was found to be least strenuous while working at 0.9 SH was found to be most strenuous leading to tiredness in the subjects. Handle height of 0.6 SH proved too low for the subjects resulting in increased fatigue as compared to 0.7 SH and 0.8 SH. Based on the results, 100 cm handle height is recommended for a push-pull type manually operated dry land weeder. The weeding efficiency of wheel hoe was found to be 70 %.

Yadav *et al.* (2007) stated that the handle at an angle of 37^0 with horizontal and height of the handle was 955 mm. The height and length can be adjusted as per the need of the operator to suit his posture.

Swarna *et al.* (2018) studied the three tyne wheel hoe to find out the efficacy of weeder in reducing drudgery among women engaged in weeding activity. The workload during activity was determined based on energy expenditure. Three tyne wheel hoe was found useful in terms of saving time, human effort, increasing work capacity and productivity. It was found to be compatible, easy to handle and applicable in field situations as well as most efficient for weeding vegetable fields. The study proved that weeders were ergonomically sound, women-friendly, drudgery reducing and improved workers efficiency.

Gite and Yadav (1985) stated that the muscles of the operator provided adequate power to operate the tool for pulling/pushing or swinging action. They also stated that the strength of female workers is approximately 50-67 % of male strength. Males can exert up to 500 N and females

about 250 N. This is mainly due to females having smaller grip sizes and muscles.

Sam and Regeena (2015) studied on development and ergonomic evaluation of long handle weeders for uplands. In this study two long handle, weeders were designed and developed. It was observed that the mean heart rate of an operator was 136 beats/min and 125 beats/min.

Yadav *et al.* (2018) carried out an anthropometric survey for female agricultural workers of Gujarat State. A group of 382 female agricultural workers were selected and 38 body dimensions were precisely measured and recorded from each subject. The data measured were statically analyzed for mean, standard deviation, 5^{th} and 95^{th} percentile values which are used in design. The mean weight and stature of female agricultural workers were found to be 48 kg and 1522 mm, respectively.

3. Material and Methods

The manually operated finger weeder was developed based on the principle of weeds failure due to soil shearing, impact and abrasion. The material selection was considered in terms of cost, availability, durability, overall weight and affordability. The design parameters considered were the ease of operation, average walking speed of the operator and energy requirement of the weeder.

The push-type manually operated finger weeder is shown in isometric view, top view, side view and front view as in Figures 1, 2, 3 and 4 respectively.

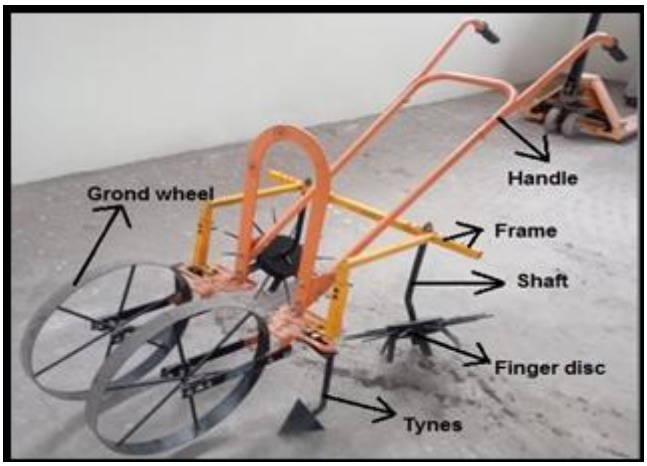

Figure 1: Isometric view of developed finger weeder

Figure 2: Top view of developed finger weeder

Figure 3: Side view of developed finger weeder

Figure 4: Front view of developed finger weeder

The main components of the machine and their functions are as follows:

1) Handle

This was fabricated with MS pipes of lengths 1200 mm making a total length of 1400 mm. The handle enables the operator to push and direct the machine during operation within the crop rows. The handle is made adjustable to create comfort to the operator irrespective of the operator's height. The essence of the long handle is to enable an upright posture while on weeding operation.

2) Frame

The component like tines and finger disc assembly is required to attach with a frame and looking to lower the cost of construction of finger weeder. The purpose of the frame is to support all the components required for the smooth operation of the developed finger weeder (handle, finger disc, tines, wheels, etc). The frame was fabricated from galvanized iron pipes with rectangular cross sections of 25×3 mm, 20×3 mm and a thickness of 2 mm, such that the overall dimensions of the frame are 700×350 mm.

3) Finger disc

A finger disc was fixed on the mainframe which was fitted with a shaft by nut and bolt. The function of the finger disc is to dig up the layer of the soil and remove the weeds. The finger disc was made up of cast iron material. The concept of finger disc was considered, finger weeder is operated by push action and it allows moving of the finger disc by

ground driven. The overall diameter of the finger disc and length of the finger is 381 mm and 114.3 mm. The diameter and thickness of the bottom disc are 282 mm and 3 mm.

4) Tines

The tines were fabricated from MS flat having a height of 250 mm, a width of coverage 120 mm and 3 mm thickness. A tines were fixed on the main frame which fitted by the nut and bolt. The function of the tines is to penetrate or lift off the soil and uproot the weeds. The tines have a 20-30 mm depth of cut.

5) Ground wheel

The ground wheel was fabricated from MS flat. The weeder consists of two wheels. The overall diameter and width of ground wheels are 380 mm and 40 mm and thickness of 3 mm.

4. Experimental Procedure

1) Speed of operation

Operational speed of weeders was calculated by fixing two poles, 10 m apart in the test plot. The time required to travel the 10 m distance was recorded to calculate the average value of time. From this time the effective field capacity has been estimated.

2) Theoretical field capacity

Theoretical field capacity is the rate of coverage of an implement based on 100 percent of the time at rated speed and covering 100 percent of its rated breadth. It was calculated with the help of the following formula (Kepner *et al.*, 1982).

$$\text{Theoretical field capacity}\left(\frac{\text{ha}}{\text{h}}\right) = \frac{\text{Width of coverage(m)} \times \text{speed}\left(\frac{\text{km}}{\text{h}}\right)}{10}$$

3) Effective field capacity

The effective field capacity of the weeder is calculated by fixing the area of which had the fixed length and fixed width. This is the actual area covered by the weeder. The field capacity of the weeder was determined in terms of ha/h. It was calculated using the following formula.

$$\text{Effective field capacity}\left(\frac{\text{ha}}{\text{h}}\right) = \frac{\text{width of coverage(m)} \times \text{length of strip(m)}}{\text{time taken(hr)} \times 10000}$$

4) Field efficiency

Field efficiency is the ratio between actual field capacity and theoretical field capacity. This is calculated by using the following equation.

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

5) Weeding efficiency

Weeding efficiency was calculated by using the following formula:

$$\text{Weeding efficiency (\%)} = \frac{X - Y}{X} \times 100$$

Where,
X = No. of weeds before operation
Y = No. of weeds after operation

6) Plant damage

It is the ratio of the number of plants damaged in a row to the number of plants present in that row. It is expressed in percentage. The Plant damage was calculated by the following formula:

$$\text{Plant damage percentage (percentage)} = \frac{q}{p} \times 100$$

Where,
q = Number of damaged plants in sample plot
p = Total number of plants in sample plot

7) Draft requirement

The draft requirement for the manually operated finger weeder device can be calculated based on the maximum push developed by humans. The horizontal component of push in the line of motion is considered a draft. The draft of the developed weeder was measured with the help of a load indicator arrangement fitted at the handle beam of the weeder.

8) Power

The amount of power required to operate the weeder was calculated with the help of the following formula.

$$\text{HP} = \frac{\text{Draft (kg)} \times \text{speed (m/s)}}{75}$$

9) Energy consumption

The finger weeder was operated manually in the field. The human energy utilized in the weeding operation in the field for weeder was evaluated using the following formula. (Chaudhary *et al.*, 2006)

$$E_m = 1.96\, N_m\, T_m$$

Where,
N_m = Number of labours spent on farm activity
T_m= Useful time spent by labour on a farm activity (h/ha),
E_m= Manual energy expended (MJ/ha)

10) Cost of operation

Cost of operation was calculated by considering depreciation, interest, housing, repair and maintenance and operator wages, for the finger weeder and traditional local tool only the operator wages are taken into consideration.

5. Results and Discussion

The field performance of finger weeders for groundnut and blackgram crop at levels of soil moisture content of 17.15 % and 20 %.

1) Speed of operation of finger weeder

Speeds of operation of finger weeder were calculated by noting down the time required to cover 10 m of weeding

length. Speed was calculated by calculating the average of three trails with different operators as shown in Table 1.

Table 1: Speed of operation of finger weeder

Parameters	Speed (km/h)	
	Groundnut	Blackgram
O_1	0.55	0.55
O_2	0.50	0.50
O_3	0.40	0.40
Average	0.48	0.48

2) Theoretical and Effective field capacity

The theoretical field capacity of the developed finger weeder was evaluated. The values of theoretical field capacity with respect to different operators were calculated. During the operation, the theoretical field capacity were observed for different operators and it was found to be 0.047 ha/h, 0.043 ha/h and 0.034 ha/h for O_1, O_2 and O_3 respectively in case groundnut field as well as blackgram field. The higher theoretical field capacity of the implement resulted in highest speed. The effective field capacity of the weeder was calculated on the basis of the actual area covered by the weeder. During the operation, the effective field capacity were observed for different operators and it was found to be 0.038 ha/h, 0.036 ha/h and 0.033 ha/h for O_1, O_2 and O_3 respectively in case groundnut field and 0.037 ha/h, 0.035 ha/h and 0.031 ha/h in blackgram field.

3) Field efficiency

The ratio of effective field capacity and theoretical field capacity expressed in percentage is known as field efficiency. During the operation, the field efficiency were observed for different operators and it was found to be 81.25 %, 85.71, 95.74for O_1, O_2 and O_3 respectively in case groundnut field and 79.26 %, 82.75 % and 91.83 % in blackgram field.

4) Weeding efficiency

Weeds uprooted by the weeding operation before and after weeding were counted to obtain weeding efficiency. The weeding efficiency was calculated. Mean values of weeding efficiency with respect to different operators are shown in Table 2.

Table 2: Mean Value of Weeding Efficiency in Groundnut and Blackgram Field

Parameters	Weeding efficiency (%)	
	Groundnut	Blackgram
O_1	82.22	70.58
O_2	76.92	72.83
O_3	81.25	78.66
Average	80.13	74.02

5) Plant damage

The number of plants damaged was recorded on the basis of plant population in a unit area before and after the weeding operation. Plant damage is expressed as a percentage. During the operation, the plant damage was observed for different operators and it was found to be 0.00 %, 11.11, 12.50 for O_1, O_2 and O_3 respectively in case groundnut field and 8.00 %, 5.00 % and 13.60 % in blackgram field.

6) Draft of implement

During the operation, the draft values were observed for different operators and it was found to be 10.2 kg,10.5 kg and 11.2 kg for O_1, O_2 and O_3 respectively in case groundnut field and 10.8 kg, 11.5 kg and 11.8 kg in case of blackgram field. The higher moisture content of soil resulted in a higher draft. It is based on the fact that an increase in soil moisture increases cohesion forces which further increase the requirement of force. The developed weeder draft was calculated by measuring draft with the help of a load indication system mounted on the handle beam. The maximum pushing force for Indian agricultural work ranges from 25 to 30 kg (Gite and Yadav, 1985).

7) Power requirement

The power required to operate the weeder was calculated by taking into consideration draft and the speed of the operation. During the operation, the power requirement were observed for different operators and it was found to be 0.020 hp, 0.019 hp and 0.016 hp for O_1, O_2 and O_3 respectively in case groundnut field and 0.022 hp, 0.021 hp and 0.17 hp in blackgram field. The higher power of the implement resulted in lowest draft and highest speed.

8) Energy Consumption

The value of energy consumption of finger weeder was determined using operational time, the number of labours required for operation and the coefficient of human energy consumption. Similarly, values of energy consumption of hand weeding were determined considering operational time, number of labours required for operation and coefficient of human energy consumption. During the operation, the energy consumptionwere observed and it was found to be 49.74 MJ/ha in groundnut field and 51.66 MJ/ha in blackgram field by the finger weeder. The energy consumption by hand weeding were observed and it was found to be 839.664 MJ/ha in groundnut field and 671.96 MJ/ha in blackgram field.

9) Cost of Operation

The value of the cost of operation of the finger weeder was determined using fixed cost, the variable cost of operation and effective field capacity. Similarly, the value of the cost of operation of hand weeding was also determined. The values of the cost of operation of finger weeder and hand weeding are given in Table 3.

Table 3: Values of cost of operation of finger weeder and hand weeding

Parameter	Finger weeder		Hand weeding	
Cost of operation (Rs/ha)	Groundnut	Black-gram	Groundnut	Black-gram
	1109.11	1147.8	2678.57	2142.85

6. Conclusions

Conclusion was found during observations after the development and testing of the manually operated finger weeder that the overall benefits accruing and associated with the use of the equipment include

1) Finger weeder work faster than the traditional method of removing weed.

2) The developed unit performed the functional requirement satisfactorily. It can be easily attached or detached.
3) The draft requirement in operation is within the limit.
4) The damage to the plants is negligible.
5) The field capacity of operation is quite satisfactory.
6) The device proved quite useful to reduce the cost of production of crops by way of partial mechanized weeding operation. Improvement could be brought in their postures, thereby facilitating them to walk comfortably along the rows while weeding with this finger weeder.
7) It is easy to operate and the weeding efficiency is also satisfactory.
8) It required less labour and it is more economical than hand weeding.
9) Its not required any fuel and power, Hence maintenance cost is very less.

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