

# Development and Ergonomic Evaluation of Manual Weeder

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## ABSTRACT

To increase the productivity per unit area of small land holdings and considering the economic condition of Indian farmers, it is quite necessary to have suitable agricultural implements which farmers can use and also allow them to use for custom hiring. Weeding is an important agricultural unit operation. Delay and negligence in weeding operation affect the crop yield up to 30 to 60 per cent. With regard this, a manually operated weeder was developed and tested ergonomically. Various parameters such as speed of travel, time of operation, field capacity, weeding efficiency and horse power requirement were considered during the testing. The ground wheel of weeder (390 mm  $\Phi$ ) was fabricated from mild steel flat of 52 x 3 mm. The weeding blades were made from steel flat to impart enough strength to sustain the prevailing forces acting on it. V-shape support made of mild steel was directly welded to the handle to join the ground wheel with the main frame. The arrangement was also made to adjust the height and angle of the handle as per the need and posture of the operator. The weeding efficiency of the developed weeder was satisfactory and it was easy to operate. The developed weeder could work up to 30 mm depth with field capacity of 0.048 ha/hr and higher weeding efficiency was obtained up to 92.5 %. During weeding operation, the peak heart rate of the subjects was found to range from 142 to 150 beats per min. In case of heavy work and dense grass infested field, the rest pause of 14 min was required by the subjects to come to the normal heart rate. The overall performance of the weeder was promising.

**Keywords:** Weeder, ergonomic, weeding efficiency, heart rate, performance, India.

## 1. INTRODUCTION

Weeding is an important but equally labour intensive agricultural unit operation. Kharif crops are most affected due to weeds. Weeding accounts for about 25 % of the total labour requirement (900–1200 man-hours/hectare) during a cultivation season (Nag and Dutta, 1979). Delay and negligence in weeding operation affect the crop yield up to 30 to 60 per cent (Singh, 1988). In India about 4.2 billion rupees are spent every year for controlling weeds in the production of major crops. At least 40 million tones of major food grains are lost every year due to weeds alone (Singh and Sahay, 2001). Dutta (1981) reported that the reduction of yield due to weed was 11.8 % of the total yield in Asia. Many research workers have reported a reduction of 5 to 60 per cent of crop yields. Obnoxious weeds like *Carthamus oxycantha*, *Cyperus rotundus*, *Saccharum spontaneum*, *Cynodon dactylon*, *Avena fatua*, *Phalaris minor*, *Parthenium hysterophorus*, etc. have infested large areas in various states of India (Biswas *et al.*, 1999). It reveals that one third of the cost of cultivation is being spent for weeding alone (Rangaswamy *et al.*, 1993).

In India, the weeding operation is carried out with indigenous hand tools like '*Khurapi*' and spade. Recently many improved hand tools have been introduced for weeding. Straight blade

hoes and triangular blade hoes made by black smiths and village artisans are traditionally used. Use of rotary tools e.g. discs and rotating rods is limited. A triangular blade hoe was developed and introduced by Agricultural Training & Research Centre (ATRC), Bardoli (Gujarat) for secondary tillage and weeding operations. These tools vary in design from place to place. In Gujarat, the use of bullock drawn implements is very less for weeding purpose. In spite of tools available, the farmers are still practicing the manual uprooting of weeds, which is labour intensive and costly. Manually operated weeders available in India are not very common in Gujarat and farmers are not using them either they are not suitable for them or requires modifications.

Various types of cutting blades are used for manually operated weeder. Where weeders are continuously pushed, V-shape sweep is preferred and tool geometry of these cutting blades is based on soil-tool-plant interactions (Bernacki *et al.*, 1972). Due to fragmented land holding the use of mechanized weeders are very limited. Though many manually operated weeders are available they are not popular because farmers feel it to be heavy as compared to conventional hoes (Kumar, 1983). For mechanical control of weeds, mostly human and animal powers are utilized. Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity. Manual weeding can give a clean weeding, but it is a slow process (Biswas, 1990).

Singh (1992) developed a wheel hoe weeder with ergonomic considerations to improve its design and for commercialization through small-scale manufacturers. It required 60-110 man-h/ha for weeding in black heavy soil and 25 man-h/ha in light soil. Kumar *et al.*, (2000) evaluated hand weeder operation on ergonomic basis using simulated actuary motion. Subjects with distinct anthropometric characteristics were evaluated ergonomically on the simulator with loading of 20 to 120 N increased in steps of 20 N. The subjects' responses were also studied while operating the weeders in the field. The results indicated that the push-pull actuation of manual weeders contributed the maximum continuous load application of 60 N with least fatigue. The simulation studies on actuary motion were able to assess the man-machine interaction accurately.

All these studies revealed that there is no versatile design of weeder. However, it is a region specific technology, the design of which differs from region to region to meet the requirements of soil type, crops grown, cropping pattern and availability of local resources. Therefore, the effort has been made to develop a weeder to meet the demand of farmers in Gujarat (India) and it was tested in the field through ergonomic point of view for its efficiency.

## 2. MATERIALS AND METHODS

The ground wheel of the weeder was made from mild steel flat of 52 x 3 mm. The diameter of the wheel was 390 mm and it has a hub (16 mm  $\Phi$ ) made from mild steel flat of 52 x 3 mm. The spokes were provided for attaching the hub in the center of the wheel. The ground wheel shaft, 115 mm in length having threads on its either ends, was made from mild steel bar of 9 mm diameter. The weeding blades were made from 25 x 150 mm mild steel flats because it is strong enough to sustain the prevailing forces as well as to carry the load of the implement. The blades were sharpened at the lower end so that it can penetrate into the soil at proper angle and desired depth during weeding. The prongs were made of mild steel square bar having dimensions 175 x 10 x 10 mm. The blade was fixed at one end of the prong and at the other end threads were provided to fix it with the headpiece. The headpiece was made from galvanized iron pipe of 30 mm in diameter and 350 mm in length. The

grooves were made on it at the required spacing for the adjustment of spacing between tynes (blades). U-shape support was made from the mild steel flat (280 x 25 x 6 mm) and shaft of round wheel was fixed to it with the help of nut and bolts. V-shape support was made from the mild steel flat (330 x 40 x 6 mm) and was directly welded to the handle to join the ground wheel with the main frame. Handle was fabricated from two mild steel pipe of 320 mm in length and 20 mm diameter having an angle of  $160^{\circ}$  to each other. The height of handle at an angle of  $37^{\circ}$  with horizontal was 955 mm. The height and angle can be adjusted as per the need of the operator to suit his posture. Depth control wheel was made from mild steel strip of 25 x 3 mm. The diameter of ground wheel was 120 mm (Figure 1).

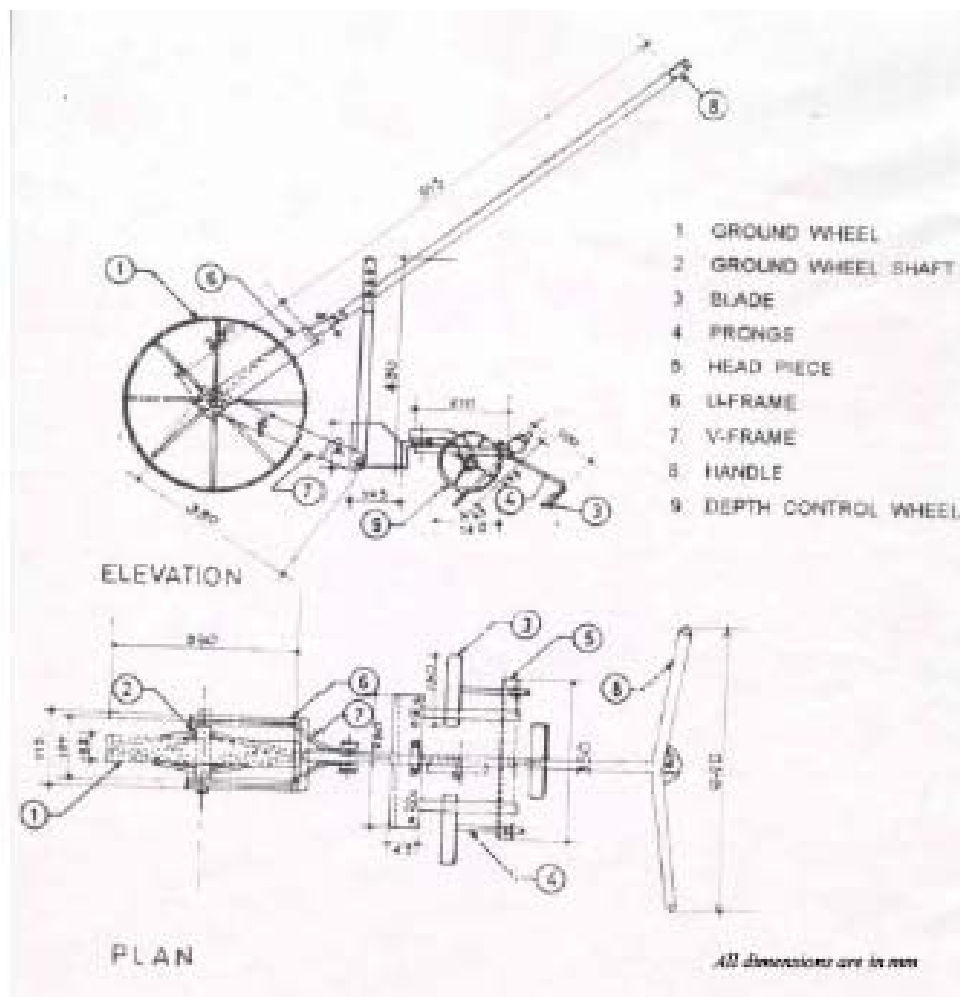


Fig. 1. Developed manual weeder for groundnut crop

### 3. EXPERIMENTAL PROCEDURE

The performance of the developed weeder was evaluated in the field of groundnut crop (Figure 2 a & b). The test was carried out in three series of short run tests. Selection of land was done according to RNAM (1983) test code. The test conditions such as soil moisture content, soil type, bulk density of soil, root zone depth of weed, density of weed, etc. were taken into consideration. Speed of travel in km/h was calculated as per RNAM (1983) test

code by using a stop watch. The field capacity of the weeder (ha/h) was calculated by fixing the area of  $300 \text{ m}^2$  ( $150 \times 2 \text{ m}$ ). The draft required by the weeder was calculated by using the equation (1). Weeding efficiency was worked out by using equation (2). The power input required for weeding operation was calculated by considering draft and traveling speed with equation (3). The percentage plant damage during field operation was calculated from equation (4). The performance of the weeder was assessed through performance index with the help of equation (5), suggested by Gupta (1981).



Fig. 2 (a) Developed Manual Weeder



Fig. 2 (b). The weeding operation by developed weeder for groundnut crop

$$D = W \times d_w \times R_s \quad \dots \dots \dots (1)$$

Where, D – Draft of a weeder, (kg)

W- Width of cut, (cm)

$d_w$  – Depth of cut, (cm)

$R_s$  – Soil resistance, (kg/cm<sup>2</sup>)

$$e = \{ (W_1 - W_2) / W_1 \} \times 100 \quad \dots \dots \dots (2)$$

Where, e = Weeding efficiency, %

$W_1$  = Count of weeds between two rows before weeding.

$W_2$  = Count of weeds between two rows after weeding

$$\text{Power (hp)} = (D \times S) / 75 \quad \dots \dots \dots (3)$$

Where, D = Draft, kg

S = Travelling speed, m/sec

$$\% \text{ Plant Damage} = \{ 1 - (q / p) \} \times 100 \quad \dots \dots \dots (4)$$

Where, q = Number of plants in a 10 m row length after weeding

p = Number of plants in a 10 m row length before weeding

$$\text{P.I.} = (A \times E \times R) / P \quad \dots \dots \dots (5)$$

Where, PI = Performance Index

A = Field Capacity of weeder, ha/hr

E = Weeding efficiency, per cent

R = Plant damage, per cent

P = Power input, HP

To evaluate the weeder through ergonomic point of view, 20 subjects in the age group of 20 to 55 years were selected at random. The basic body dimensions were measured and average was worked out (Table 1). The operators were acclimatized with the experimental protocol before the start of the test. Heart rate was measured to know the physiological response of the operators. The subject each representing 5<sup>th</sup>, 50<sup>th</sup> and 95<sup>th</sup> percentile value was selected for the test. Initially heart rate was measured in normal rest position and then in working field conditions at an interval of two minute for 18 minute working period and then rest was given to the operator till it returns to the normal.

Table 1. Average of basic body dimensions of weeder operators (N=20)

Sr. No.	Parameter	Mean	S. D.	(Age Group : 20 – 55yrs)	
				5 <sup>th</sup> percentile	95 <sup>th</sup> percentile
1	Age, years	38.34	9.74	22.32	54.36
2	Weight, kg	55.25	9.73	39.24	71.26
3	Stature, cm	163.12	6.49	152.44	173.79
4	Eye height, cm	152.88	6.55	142.10	163.66
5	Acromial height, cm	137.75	5.81	128.20	147.31
6	Elbow height, cm	102.84	6.54	92.09	113.59
7	Olecranon height, cm	100.80	5.67	91.48	110.12

8	Iliocrystale height, cm	98.42	5.25	89.79	107.05
9	Trochanteric height, cm	83.79	5.01	75.54	92.04
10	Arm reach from the wall, cm	83.32	4.44	76.02	90.62
11	Elbow rest height, cm	19.61	2.09	16.18	23.05
12	Functional leg length, cm	93.02	3.61	87.08	98.96
13	Elbow grip length, cm	35.66	2.43	31.66	39.65
14	Hand length, cm	17.68	1.28	15.58	19.78
15	Hand breadth at metacarpal-III, cm	8.26	0.45	7.52	9.00
16	Hand thickness at metacarpal-III, cm	2.25	0.31	1.74	2.77
17	Palm length, cm	9.76	2.14	6.25	13.28
18	Grip diameter (inside), cm	5.07	0.51	4.24	5.91
19	Instep length, cm	17.99	1.17	16.07	19.91

#### 4. RESULTS AND DISCUSSION

The weeding test was performed on the farm of Junagadh Agricultural University, Junagadh for GJ – 11 variety of groundnut crop. The test started 30 days after the previous weeding operation was finished. The groundnut crop was about 67 days old at the time of tests having row-to-row spacing of 600 mm. The average moisture content of the soil was 8.2 % at the time of testing. The average plant population per square meter area was 24 and average height of plant was 30 cm. It was observed that root zone depth differs for different types of weeds. Minimum root zone depth of 2 cm for *Jungli Gobi* and maximum depth of 10 cm for *Burmuda Grass* was observed.

Five readings of travel speed were taken and average travel speed was calculated and used in the study. The average traveling speed was found to be 20 m/min. During testing it was observed that the traveling speed also depends on the parameters such as weight of the operator, height of the operator and physical condition of the operator. Therefore, to avoid the error in result analysis the subjects of more or less equal weight and anthropometry were selected for the study. The developed weeder was found easy to operate at the speed of 20 m/min.

The field capacity of the developed weeder was calculated by selecting the representative three sample plots of size 150 x 2 m. The field capacity of the developed weeder was found out to be 0.048 ha/h, which was higher than the already available weeders. The probable reason behind this may be the 45 cm width of weeder, which was not previously tried. It was also observed that if the effective cutting width is reduced, the field capacity is also reduced. The field capacity of this developed weeder was also superior as compared to the available local weeders.

The average weeding efficiency for the developed weeder was found to be 92.5 %, which shows that the weeder is efficient. It was observed that the weeding efficiency depends on the root zone depth of weeds, shape of blades, moisture content of the soil at testing site and cutting depth of the weeder blades.

Draft is an important parameter in the development of weeder and it must be within the physical limits of the operator. The average draft required for weeding was found to be 39.15 kg. However, maximum pushing force for Indian agricultural work ranges from 25 to 30 kg

(Gite and Yadav, 1985). Though, the draft for developed weeder is higher but it was comfortable in operation because the operators selected for the study were tall and strong enough. However, it was observed that the draft depends on the type of soil, effective cutting width and depth of cut. In manually operated weeders the tool works in a shallow depth so the soil resistance has a little impact on the draft requirement of the tool.

The average power requirement for the weeder was estimated to be 0.17 hp, which is higher by 50 % because of the higher width of cut. Further, it was concluded that if one want to reduce the power requirement, reduction in effective width of cut is needed which subsequently reduces the field capacity of the weeder.

The performance index for the developed weeder was found out to be 2611.7 (Table 2). It was observed that the developed weeder was not only suitable for groundnut crop but it could also be used for other crops as row spacing could be adjusted. The angle of penetration of blades can be changed as per the requirement.

Table 2. Field Performance of the developed Weeder

S. No.	Description	Particular
1	Effective width of cut	45 cm
2.	Number of runs required in between rows	1
3	Depth of weeding	3.0 cm
4	Draft requirement	39.15 kg
5	Plant damage	Nil
6	Power input	0.17 hp
7	Performance index	2611.7

The average weight and stature of the operators was found to be 55.25 kg and 163.12 cm respectively. The inside grip diameter and instep length was found to be 5.07 and 17.99 cm respectively. The peak heart rate was found to be 143, 142 and 150 beats/min for subjects  $S_1$ ,  $S_2$  and  $S_3$  respectively. Figure 3 reveals that after 8 min of start of work, the rate was found to stabilize around the peak heart rate. After 18 min of work the rest was given to the subjects, and it was found that rest of 14 min was required by each of the operator to come to the normal position. Thus, the fatigue of the operator is avoided by giving the rest pause of 14 min. After 8 min of work, the heart rate of the subject stabilizes in the range of 125 – 150 beats/min, the work can be rated as heavy type of work (Christiansen, 1953).

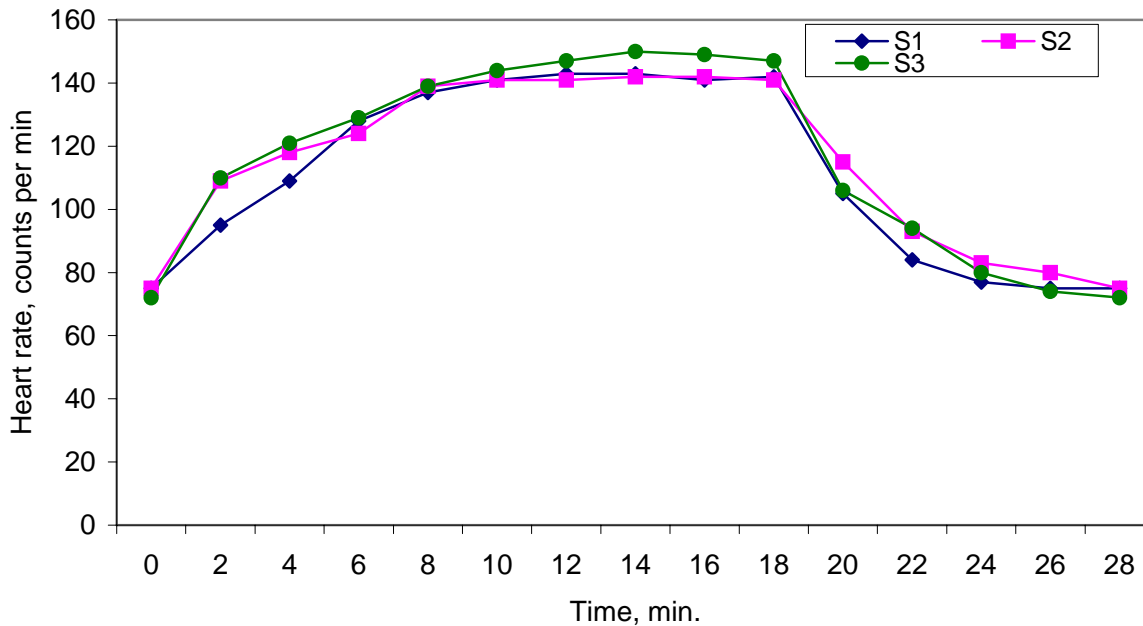


Figure 3 Physiological evaluation in terms of heart rate of subjects S1, S2 & S3.

## 5. CONCLUSIONS

The weeding efficiency of the developed weeder was found satisfactory and it is easy to operate. The developed weeder could work upto 3.00 cm depth with field efficiency of 0.048 ha/hr and higher weeding efficiency was obtained upto 92.5 %. The rest pause of 14 min was required by the subjects during the heavy work to come to normal position. The peak heart rate was found to range from 142 to 150 beats per min. The overall performance of the weeder was satisfactory.

## ACKNOWLEDGEMENTS

The authors are thankful to College of Agril. Engg. & Tech., Junagadh Agricultural University, Junagadh for providing facilities to carry out this work. Thanks also to Mr Thanki and Mr Vadaliala for extending help during the course of investigation.



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