

Ergonomical evaluation of manual and power operated weeders in dry land condition

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■ **ABSTRACT** : Weeding operation is an important among field operations, which affects the yield 30 to 60 per cent due to delay and negligence in operation. Drudgery involved in weeding operation increases stress on the worker causing increase in heart rate and oxygen consumption. The main focus of the study was to evaluate ergonomical and mechanical parameters of power weeder and wheel hoe. The estimation of oxygen consumption rate (OCR) by measuring the energy expenditure rate (EER) is a fairly accurate and acceptable method. The heart rate of workers varied from 109.47 to 130.66 beats/min by using power weeder and 130.33 to 147.52 beats/min by using wheel hoe. The oxygen consumption rate of workers from 0.873 to 1.302 L/min with power weeder and 1.389 to 1.738 L/min with wheel hoe. The actual field capacity of 114 and 208 man-h/ha were observed for power weeder and wheel hoe, respectively. The weeding efficiency of power weeder and wheel hoe were observed to be 8 and 75 per cent, respectively. The maximum value of weeding efficiency (8%) was observed in case of power weeder.

■ **KEY WORDS** : Oxygen consumption rate, Energy expenditure rate, Field capacity, Weeding efficiency

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Weeding is one of the most important farm operations in crop production system. Weed growth is a major problem for dry land crops. Weeding consists of removal and disposal of unwanted plants, which grow in a field with the cultivated crop, compete with the crop lands for nutrients and other growth factors. In the absence of an effective control measure, weeds consumes 30-40 per cent of applied nutrients resulting in significant yield reduction. In Indian agriculture, weeding operation is done through manual labour, which consumes more labour and time, results to high cost of operation. An estimate of 400-600 man-h/ hectare (Tajuddin, 2006) is the normal man-hour requirement of hand weeding which amounts to Rs. 2200

per hectare, which also depends upon weed infestation.

The most common methods of weed control are mechanical, chemical, biological and cultural methods. Out of these four methods, mechanical weeding either by hand tools or weeders are most effective in both dry land and wet land conditions. Besides, mechanical weeding keeps the soil surface loose by producing soil mulch. Reduction in yield due to weed alone is estimated to be 16-42 per cent depending on crop and location and involves one third of cost of cultivation (Rangasamy *et al.*, 1993). Weeding and hoeing is generally done 15-20 days after sowing.

Ergonomics is the scientific study of relation between man and his working environment, which

includes ambient conditions, tools and materials, methods of work and organization of work. The performance of a weeder not only depends on the constructional features but also on the workers operating them. The performance of man-implement system may be poor, if ergonomics aspects are not given due attention. Tewari *et al.* (1991) stated that the performance of weeders is interpreted in terms of weeding efficiency and the grade of work relates to rating of workload while worker's comfort is a subjective assessment of operating posture. The physiological cost of work includes the heart rate (HR) and oxygen consumption rate (OCR). Furthermore, severity does not depend on EER; however based on EER severity of work load is classified. Ergonomical evaluation is a tool to evaluate the energy expenditures of workers, their physiological cost and suitability of the method for farm workers and how long they can work continuously without getting fatigue.

Singh (1992) developed a wheel hoe weeder with ergonomic considerations to improve its design and for commercialization through small scale work manufacturers. It required 60-110 man h/ha for weeding in black heavy soil and 25 man-h/ha in light soil. The main objective was to evaluate the mechanical and ergonomical parameters of power weeder and wheel hoe.

■ METHODOLOGY

Power weeder and a wheel hoe were taken to carry out the research in the rows of cotton field with different age group of farmers (20-25, 30-35 and 35-40 years). The weeders were evaluated by measuring heart rate, and thereafter computing oxygen consumption rate.

Power weeder :

Power weeder fitted with an 0.25 hp engine (Mitsubishi, Japan) with an axial through gears care with reduced speed ratio (1:35). A resistance bar is employed to disengage the rotary wheel while in operation condition and also acts like a stand while in resting position. Rotary is providing with wheel of 230 mm diameter, width of 240 mm, depending on necessity. The machine can run on 4, 3, and 2 wheels at different widths 25.4, 20.32 and 5.08 cm, respectively. These wheels fitted on axle have six sharp blades. These blades themselves aid in moving forward while operating in field.

Wheel hoe :

It has light wheel of diameter of six spikes attached to two handles of mild steel to which a working tool is attached. The wheel assists in guiding the implement and in maintaining proper depth.

Details	Power weeder	Wheel hoe
Working width, cm	24	23
Working depth, cm	30-65	35-50
Weight, kg	12	10
Handle type	Adjustable	Fixed
Engine type	Petrol	-
Fuel consumption, lit/h	1.02	-

Experimental procedure :

This experiment was conducted to measure the heart rate with power weeder and wheel hoe during weeding operation in the cotton field. Nine agricultural workers of different age group persons were selected. The physical characteristics of the subjects are presented in Table B. A polar heart rate monitor was used to measure physiological response of the operators during field operation (Fig. C). Speed of travel (km h^{-1}) was calculated as per RNAM (1983) test code by using a stop watch for covering a known distance. During the experiment, mean ambient condition (mentioned earlier) was thermally comfortable. Before actual experiments, each subject operated the weeders for 10 min for warming up, followed by a 5 min rest (Astrand and Rodahl, 1977). Each subject then operated the weeders in the experimental cotton field in between the rows for 30 min, and then took rest till the heart rate returned to normal. Heart rate was measured at every 5 min during operation between 5th and 30th min of operation, and the average reported. The same procedure was repeated at pre-determined times of a day for all the subjects.

Sr. No.	Particular	Participated subjects		
		Group-1	Group-2	Group-3
1.	Age group, years	20-25	30-35	35-40
2.	Age, years	23.6	32.3	37.6
3.	Weight, kg	57.3	59	61.6
4.	Height, cm	169.3	157.3	160.6
5.	Hand length, cm	72.6	71	76
6.	Shoulder length, cm	105.3	114.6	107.3
7.	Leg length	102.6	97	99.3



Fig. A : Schematic diagram of power weeder



Fig. B : Schematic diagram of wheel hoe



Fig. C : Measurement of heart rate during weeding operation with power wheeder and wheel hoe in cotton field

Oxygen consumption rate (OCR) :

It is termed as the amount of oxygen consumed by the whole body per unit time, which is normally expressed as L/min. The oxygen consumption was calculated using the following equation given by Singh *et al.* (2008) :

$$OCR = \frac{EER}{20.88} \text{ L/min}$$

where, EER= Energy Expenditure Rate

Energy expenditure rate (EER) :

The energy expenditure rate was computed from the heart rate values of the operator and is given by the following equation :

$$EER = \frac{HR - 66.00}{2.4} \text{ kJ/min}$$

where, HR = Heart rate

Weeding efficiency :

It is the ratio between the number of weeds removed by a weeder to the number present in a unit area and is expressed as percentage. The weeding efficiency was calculated by the following formula :

$$\text{Weeding efficiency} = \frac{W_1 - W_2}{W_1} \times 100$$

where, W_1 = weeds before weeding in 1 sq. m area of the field

W_2 = weeds after weeding in 1 sq. m area of the field.

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 :

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

where, q = number of plants in a 10 m row length of field after weeding

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

Field capacity :

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{width (m)} \times \text{speed (kmph)}}{10}$$

$$\text{Actual field capacity (ha/h)} = \frac{\text{Area covered (ha)}}{\text{Time taken (h)}}$$

$$\text{Efficiency (\%)} = \frac{\text{Actual field capacity}}{\text{Theoretical field capacity}} \times 100$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Heart rate and oxygen consumption rate :

The heart rate at initially was different for the three different age groups and it ranged between 114 to 171 beats/min at 12:00 to 2:00 PM. It is decreased to 110 to 161 beats/min at 4:00 to 6:00 PM, which may be due to the variation in the environment. The average heart rates for different age groups and at different timings using power weeder and wheel hoe are given in Table 1. The average heart rate of power weeder was 121.14 beats/min for 20 to 25 years, 136.14 beats/min for 30 to 35 years and 128.85 beats/min for 35 to 40 years at 12:00 to 2:00 PM. The heart rate was decreased to 113.00 beats/min for 20 to 25 years, 129.19 beats/min for 30 to 35 years and 123.33 beats/min for 35 to 40 years at 4:00 to 6:00 PM. Therefore, the highest heart rate was recorded during 12:00 to 2:00 PM for 30 to 35 years of age group and the lowest heart rate was recorded during 4:00 to 6:00 PM for 20 to 25 years of age group.

The heart rate was minimum for 20 to 25 years age group and is maximum for 30 to 35 years age group at all the three different timings. This may be due to variations in the environment temperatures and the experience of the subjects. The mean values of the heart rate of the different age groups of operators on different timings in a day (T_1 and T_2) was 128.71 and 121.84 beats/min, respectively, for weeding operation with power weeder.

Average heart rate using wheel hoe was 140.95 beats/min for 20 to 25 years age groups, 152.90 beats/min for 30 to 35 years and 148.76 beats/min for 35 to 40 years during 12:00 to 2:00 PM. The heart rate was in turn decreased to 135.52 beats/min for 20 to 25 years, 143.57 beats/min for 30 to 35 years and 142.09 beats/min for 35 to 40 years at 4:00 to 6:00 PM. The minimum heart rate was recorded by 20 to 25 years of age group at 4:00 to 6:00 PM and the highest rate was observed

for 30 to 35 years of age group at 12:00 to 2:00 PM. The heart rate for 30 to 35 years age group was maximum and minimum heart rate was observed for 20 to 25 years age groups. This may be due to variation in environment temperature and tiredness during the operation. The mean values of the heart rate of the different age groups of operators on different timings in a day (T_1 and T_2) was 147.53 and 140.39 beats/min, respectively, for weeding operation with wheel hoe.

The average oxygen consumption during weeding operation with power weeder was 1.104 L/min for 20 to 25 years, 1.411 L/min for 30 to 35 years and 1.260 L/min for 35 to 40 years during 12:00 to 2:00 PM, and then it was decreased to 0.943, 1.270 and 1.144 L/min during 4:00 to 6:00 PM for different age group of workers, respectively. Fig. 1 shows, the oxygen consumption rate was maximum during 12:00 to 2:00 PM for 30 to 35 years and minimum for 20 to 25 years at 4:00 to 6:00 PM. The decrease in oxygen consumption may be due to environmental cool temperature.

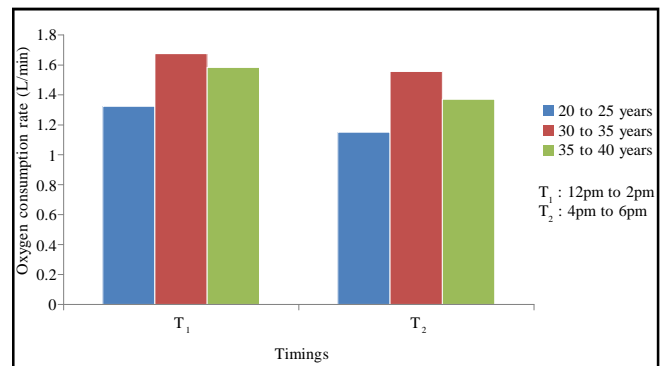


Fig. 1 : Effect of age groups on oxygen consumption rate in different timings for weeding in cotton field with power weeder

The average oxygen consumption during weeding operation with wheel hoe (Fig. 2) was 1.499 L/min for 20 to 25 years, 1.738 L/min for 30 to 35 years and 1.659 L/min for 35 to 40 years during 12:00 to 2:00 PM, and then it decreased to 1.389, 1.552 and 1.520 L/min during 4:00 to 6:00 PM for different age groups of workers,

Table 1 : Effect of age of operator and timings on heart rate in a day during weeding operation in cotton field

	Power weeder				Mean	Wheel hoe				Mean
	A ₁	A ₂	A ₃			A ₁	A ₂	A ₃		
T ₁	121.14	136.14	128.85		128.71	140.95	152.90	148.76		147.53
T ₂	113.00	129.19	123.33		121.84	135.52	143.57	142.09		140.39
Mean	117.07	132.66	126.09		125.27	138.23	148.23	145.42		143.96

respectively. The oxygen consumption was maximum during 12:00 to 2:00 PM for 30 to 35 years and minimum for 20 to 25 years at 4:00 to 6:00 PM. This may be due to the variations in environmental temperature.

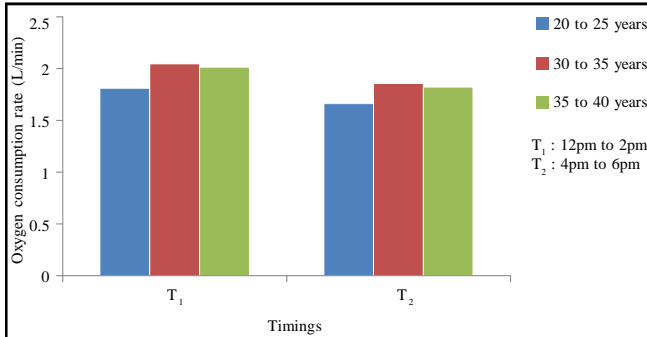


Fig. 2 : Effect of age groups on oxygen consumption rate in different timings for weeding in cotton field with power weeder

Work rest cycle :

Fig. 3 and 4 reveals that after 10 minute start of work, the rate was found to stabilize around the peak heart rate. After 30 min of work the rest was given to the subjects and it was found that rest of 15 min was required by each of the operator to come to the normal position. Thus, the fatigue of the operator can be avoided by giving a rest pause of 15 min.

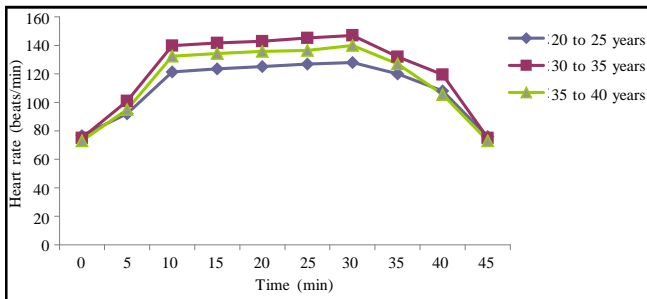


Fig. 3 : Physiological evaluation in terms of heart rate of subjects with power weeder

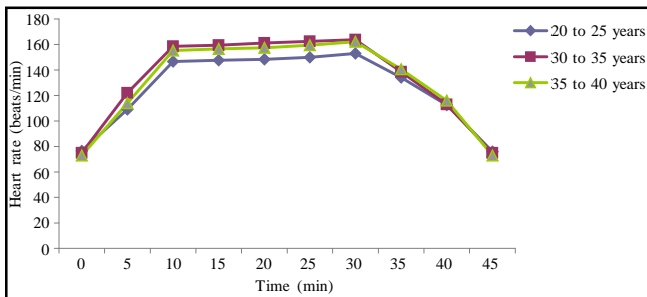


Fig. 4 : Physiological evaluation in terms of heart rate of subjects with wheel hoe

Weeder performance :

The field capacity of the weeders were observed to be 114 and 208 man-h/ha for power weeder and wheel hoe, respectively. The higher man-h required for weeding operation with wheel hoe, where half of the man-h required for power weeder and also the efficiency was higher in case of power weeder (77%) than wheel hoe (72%). The weeding efficiency of the power weeder was 81 per cent and that of wheel hoe was 75 per cent. Hence, in terms of field and weeding efficiency the power weeder was better than wheel hoe. In both the weeders, there was not much plant damage observed during operation in the field.

Conclusion :

Weeding operation done during 12:00 to 2:00 PM developed maximum working heart rate and oxygen consumption with both the weeders compared to 4:00 to 6:00 PM, which might be due to higher temperature. The 30 to 35 years of age groups were observed to be developing developed maximum working heart rate and oxygen consumption higher than the age groups of 20 to 25 years and 35 to 40 years during weeding operation.

The heart rate of the workers varied from 109.47 to 130.66 beats/min for weeding by using power weeder and 130.33 to 147.52 beats/min by using wheel hoe in cotton field. The oxygen consumption rate of the workers varied from 0.873 to 1.302 L/min for weeding by using power weeder and 1.389 to 1.738 L/min by using wheel hoe in cotton field.

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