

Full Length Research Paper

Ergonomical evaluation of manually operated weeder under wet land condition

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Drudgery involved in weeding operation increases stress on the worker causing increase in heart rate and oxygen consumption. Ergonomic evaluation of weeding operations by different age group of workers at different working hours showed that the heart rates corresponding to cono- weeder and Mandava weeder were 154.54 beats/min and 140.17 beats/min, respectively. Oxygen consumption rate was 1.76 l.min⁻¹ and 1.47 l.min⁻¹, respectively. Working during 12:00 to 2:00 PM with both weeders developed maximum heart rate and oxygen consumption rate as compared to 8:00 to 11:00 AM and 4:00 to 6:00 PM. Agricultural workers of 25 to 30 years age group developed maximum working heart rate and oxygen consumption rate during weeding operations, which were higher than the age groups of 30 to 35 years and 35 to 40 years. The ANOVA based statistical analysis showed that weeding operation had significant influences on age group of workers, timings in a day and type of weeder.

Key words: Agricultural worker, weeding, drudgery, heart rate, oxygen consumption.

INTRODUCTION

Ergonomics is the scientific study of the relationship 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.

Weeds compete with crop plants for nutrients and other growth factors and in the absence of an effective control measure, consume 30 to 40% of applied nutrients resulting in significant yield reduction (Dryden and Krishnamurthy, 1977). In India, about 4.2 billion rupees are spent every year for controlling weeds for production of major crops. At least 40 Mt of major food grains are lost every year due to weeds alone (Singh and Sahay, 2001). Manual weeding accounts for about 25% of total labour requirement during a cultivating season (Nag and

Dutt, 1979). Often several weedings are necessary to keep the crop weed free. Weeding or hoeing is generally done 15 to 20 days after sowing. Timely weeding is essential for a good yield, and can be achieved by using mechanical weeders. Manually operated weeders need human effort to operate. Weeds should be controlled and eliminated at their early stage.

Rice and groundnut are very sensitive to weed competition in the early stage of growth, and failure to control weeds in the first three weeks after seeding reduces the yield by 50% (Gunasena and Arceo, 1981; Singh, 1988; Rangaswamy et al., 1993; Yadav and Pund, 2007). Kathirvel et al. (2004) ergonomically evaluated cono-weeder with farm women for assessing its suitability to farm women labourers, and reported that mean heart rate was 149.59 beats/min and corresponding oxygen consumption rate was 0.690 l.min⁻¹. Energy expenditure for cono-weeding was 13.42 kJ.min⁻¹ and the work was classified as "heavy". 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

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Figure 1. Schematic diagram of cono weeder.



Figure 2. Schematic diagram of mandava weeder.

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. Cono-weeder and Mandava weeder are used for uprooting and burying weeds in between standing rows of rice crop in wetland condition. 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. Ease of performing an operation affects the output of the worker. When weeding in wetland crop (paddy), the body is in discomfort posture and while walking in puddled field the worker experiences higher oxygen consumption rate to overcome more resistance. In view of above, the ergonomic parameters (heart rate and oxygen consumption rate) of cono-weeder and Mandava weeder were evaluated in wet land condition.

MATERIALS AND METHODS

Two types of manual weeder widely used for weeding under shallow water conditions were selected and evaluated with different age group of workers (25 to 30, 30 to 35, and 35 to 40 years) at different day timings ($T_1 = 8.00$ to 11.00 AM, $T_2 = 12.00$ to 2.00 PM, and $T_3 = 4.00$ to 6.00 PM). The weeders were evaluated by measuring heart rate, and thereafter computing oxygen consumption rate. The atmospheric temperature varied between 25 to 30°C , 35 to 40°C , and 27 to 32°C at 8.00 to 11.00 AM, 12.00 to 2.00 PM, and 4.00 to 6.00 PM, respectively, and $48 \pm 3.4\%$ of relative humidity R.H during the period of study.

Manual weeder

Cono weeder

It consists of two truncated rollers one behind the other, and is fitted at the bottom of a long handle (Figure 1). The conical rollers have serrated blades on the periphery. A float provided in the front portion prevents the unit from sinking into puddled soil. The cono-weeder is used for trampling green manure crop in wetland in addition to weeding operation, and it distributes the top soil causing increase in aeration. One person can operate the weeder.

Mandava weeder

It consists of a single drum with serrated edges (Figure 2). It was developed by a farmer in Mandava village in Raichur. A mechanism removes soil from the drum plates. The weeder is less heavy than cono-weeder due to simplicity in design, has better handle arrangement and of low cost. It is most suitable for weeding in paddy crop with inter-row spacing. One person can operate the weeder. The specifications of the weeders are given in Table 1.

Experimental procedure

A paddy field of 0.4 ha was selected and subdivided in to three plots for each group for the study at Agricultural college farm, Bapatla in the year 2009. Paddy seedlings were planted with a rice transplanter in rows with row spacing of 300 mm and hill-to-hill spacing of 180 mm. Weeding was done in between the rows. Nine agricultural workers free from cardiac and other ailments were selected for operating the weeders. The physical characteristics of the subjects are presented in Table 2. The operators were acclimatized with experimental protocol before start of the test. A polar heart rate monitor was used to measure physiological response of the operators during field operation (Figure 3 and 4). 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 for the period from January to March, 2009. 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 paddy field in between the rows for 30 min and the length of each run is about 160 m, and then took rest till the heart rate returned to normal. Heart rate was measured at every 3 min during operation between 3^{rd} and 30^{th} min of operation, and the average reported. The same procedure was repeated at pre-determined times of a day for all the subjects.

Oxygen consumption rate (OCR)

The oxygen consumption rate (amount of oxygen consumed by the

Table 1. Specifications of weeders.

Details	Cono weeder	Mandava weeder
Working Width, cm	18	12
Weight, kg	8.5	7.5
Height of handle from ground level, cm	100	125
Over all dimensions, cm	110 × 18 × 100	110 × 12 × 125

Table 2. Average of basic body dimensions of weeder operators (N= 9).

S/No.	Particular	Participated subjects		
		Group-1	Group-2	Group-3
1.	Age, range (years)	25-30	30-35	35 - 40
2.	Age (years)	28.3 ± 1.5	31.3 ± 2.5	37.5 ± 1.7
2.	Weight (kg)	49.8 ± 9.3	46.0 ± 7.1	45.4 ± 8.3
3.	Stature (cm)	157.3	156.5	158.7
4.	Hand length (cm)	84.5	82.5	86.5
5.	Functional leg length (cm)	96.4	95.5	97.5
6.	Palm length (cm)	9.5	9.1	9.7
7.	Grip diameter (inside,(cm)	4.6	4.8	4.7
8.	Shoulder Length (cm)	107.5	109.5	108.4

**Figure 3.** Measurement of heart rate during weeding operation with cono weeder.

whole body per unit time) was computed from the heart rate values of the operator and is given by the following equation (Singh et al., 2008).

Oxygen consumption rate (L/min) = $0.0114 \times \text{HR} - 0.68$

The oxygen consumption (L/min) was converted in kJ (1 L O₂ = 20.93 kJ)

Energy expenditure rate (EER)

The energy expenditure rate was computed by using the following

equation given by Nag et al. (1979) and Philip (2002).

$$EER = OCR \times 20.86 \text{ kJ/mi}$$

Where EER= Energy expenditure rate.

Weeding efficiency

The weeding efficiency (the ratio between the numbers of weeds removed by a weeder to the number of weeds present in a unit area and is expressed as percentage) was calculated by the following formula (Anonymous, 1985):



Figure 4. Polar heart rate monitor.

$$\text{Weeding Efficiency (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100$$

Where, W_1 = Weeds before weeding in 1 m² area of the field, and
 W_2 = Weeds after weeding in 1 m² area of the field.

Plant damage

The plant damage (the ratio of the number of plants damaged in a row to the number of plants present in that row) was calculated by the following formula (Anonymous, 1985; Yadav and Pund, 2007):

$$\text{Plant Damage, } R(\%) = \left(1 - \frac{q}{p}\right) \times 100$$

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

The field capacity of the weeder (ha/h) was calculated by fixing the area of 300 m² (150 × 2). The draft required by the weeder was calculated by using the equation (1). The power input required for weeding operation was calculated by considering draft and traveling speed with Equation 2. The performance of the weeder was assessed through performance index with the help of Equation 3, suggested by Gupta (1981).

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

Where, D – Draft of a weeder (kg)
 W – Width of cut (cm)
 d_w – Depth of cut (cm)
 R_s – Soil resistance (kg/cm²)

$$\text{Power (hp)} = (D \times S) / 75 \quad (2)$$

Where, D = Draft (kg)
 S = Travelling speed (m/s)

$$P.I. = (A \times E \times R) / P \quad (3)$$

Where, PI = Performance Index

A = Field Capacity of weeder (ha/h)

E = Weeding efficiency (per cent)

R = Plant damage (per cent)

P = Power input (HP)

Statistical analysis

The data obtained was analyzed statistically by 3-factorial RBD design by considering as Factor 1: Weeders (2), Factor 2: Different age groups and Factor 3: Different timings in a day. The experimental data obtained were analyzed statistically using analysis of variance (ANOVA) technique at 5% level of significance (Table 4).

RESULTS AND DISCUSSION

Heart rate

Initial heart rate was different for three different age groups, ranging between 74 and 92 beats.min⁻¹ at 8:00 to 11:00 AM, which increased from 81 to 98 beats.min⁻¹ between 12:00 and 2:00 PM. It decreased to 71 to 92 beats.min⁻¹ between 4:00 and 6:00 PM. The decrease might be due to variation in the work environment. The average operating speed was found to be 15 m/min. Average heart rates of different age groups at different time of work using both weeders are given in Table 3. Average heart rate of the cono-weeder was 156.16 beats.min⁻¹ for 25 to 30 years, 146.03 beats.min⁻¹ for 30 to 35 years and 145.05 beats.min⁻¹ for 35 to 40 years at 8:00 to 11:00 AM. It increased to 163.44 beats.min⁻¹ for 25 to 30 years, 158.57 beats.min⁻¹ for 30 to 35 years and 161.87 beats.min⁻¹ for 35 to 40 years between 12:00 and 2:00 PM. Heart rate decreased to 157.97 beats.min⁻¹ for

Table 3. Influence of heart rate on age of operator for different timings in a day during weeding operation.

Treatment	Heart rate (beats/min)							
	Cono weeder (E ₁)				Mandava weeder (E ₂)			
	25-30 Years	30-35 Years	35-40 Years	Mean	25-30 Years	30-35 Years	35-40 Years	Mean
T ₁	156.15	146.03	149.04	150.41	142.50	131.57	134.45	136.17
T ₂	163.44	158.57	161.86	161.29	148.88	144.12	147.43	146.81
T ₃	157.97	145.76	152.09	151.94	143.85	131.21	137.53	137.53
Mean	159.18	150.12	154.12	154.54	145.08	135.63	135.63	140.17

Table 4. Statistical hypothesis of equalities of the treatment means, at 5% level of significance.

Factors	Standard errors	Critical difference
F ₁	0.5287	1.0363
F ₂	0.6476	1.2692
F ₃	0.6476	1.2692
F ₁ *F ₂	0.9158	1.7950
F ₁ *F ₃	0.9158	1.7950
F ₂ *F ₃	1.2160	2.1984
F ₁ *F ₂ *F ₃	1.5862	3.1090

25 to 30 years, 145.76 beats.min⁻¹ for 30 to 35 years and 152.09 beats.min⁻¹ for 35 to 40 years between 4.00 and 6.00 PM. Heart rate was lowest for subjects in 30 to 35 years age group and highest for 25 to 30 years age group at all work timings. This might be due to variations in the environment temperatures also due to decrease of heart rate with increase of age (Kathirvel et al., 2004). The mean value of the heart rate of the different age group of operators on different timings in a day (T₁, T₂ and T₃) was 150.41, 161.29 and 154.54 beats.min⁻¹, respectively, for weeding operation with cono-weeder.

Average heart rate using Mandava weeder was 142.51 beats.min⁻¹ for subjects of 25 to 30 years, 131.57 beats.min⁻¹ for 30 to 35 years and 134.46 beats.min⁻¹ for 35 to 40 years between 8.00 and 11.00 AM, which increased to 148.89, 144.12 and 147.43 beats.min⁻¹ between 12:00 and 2:00 PM. It subsequently decreased to 143.89 beats.min⁻¹ for 25 to 30 years, 131.21 beats.min⁻¹ for 30 to 35 years and 137.54 beats.min⁻¹ for 35 to 40 years between 4:00 and 6:00 PM. Subjects in age group of 30 to 35 years had minimum heart rate between 4:00 and 6:00 PM, while the subjects between 25 and 30 years had highest rate between 12:00 to 2:00 PM. Heart rate of subjects in 25 to 30 year age group was highest, while it was lowest for 30 to 35 year age group. The mean value of the heart rate of the different age group of operators on different timings in a day (T₁, T₂ and T₃) was 136.17, 146.81 and 137.53 beats.min⁻¹, respectively, for weeding operation with Mandava weeder.

In the Table 4, the first factor, weeders E₂ (Mandava weeder) is significantly the best as low heart rate and oxygen consumption of the operators were recorded, compared to E₁ (Cono weeder) due to its less weight and easy to operate nature. In the second factor, age groups also showed significantly on heart rate and oxygen consumption of the operator. The age group A₂, between 30 to 35 years has low heart rate and oxygen consumption as compared with A₁, between 25 to 30 years and A₃, between 35 to 40 years. The third factor, the timings are also showing significant effect on heart rate and oxygen consumption of the operator. The timing T₁ (8:00 to 11:00 AM) is highly significant with low heart rate and oxygen consumption followed by T₃ (4:00 to 6:00 PM) and T₂ (12:00 to 2:00 PM) due to the change in the environmental conditions. In the interaction effects the factor F₂ × F₃ are also significant i.e. workers aged between 30 to 35 years weeding at 8:00 to 11:00 AM and at 4:00 to 6:00 PM are having significantly low heart rate and oxygen consumption followed by workers aged between 35 to 40 years while weeding at 8:00 to 11:00 AM. But the workers of age groups 25 to 30 years and 35 to 40 years recorded the highest heart rate and oxygen consumption at 12:00 to 2:00 PM. In the interaction effects the factors F₁ × F₃ are also significant i.e. a worker with weeder E₂ at 8:00 to 11:00 AM has significantly low heart rate and oxygen consumption followed by a worker using weeder E₂ at 4:00 to 6:00 PM. In the interaction effects the factors F₁ × F₂ are also significant i.e. a worker aged between 35 to 40 years and using mandava weeder are having significantly low heart rate and oxygen consumption. But the highest heart rate and oxygen consumption was recorded by using the cono weeder. Where as in the interaction effects the factor F₁ × F₂ × F₃ i.e. the interaction between age groups, timings and weeders are non-significant. Average oxygen consumption rate for operating cono-weeder was 1.80 l min⁻¹ for subjects of 25 to 30 years, 1.60 l min⁻¹ for 30 to 35 years and 1.66 l.min⁻¹ for 35 to 40 years during 8:00 to 11:00 AM. It increased to 1.94, 1.85 and 1.91 l.min⁻¹, respectively, during 12:00 to 2:00 PM and decreased to 1.84, 1.59 and 1.72 l.min⁻¹, respectively, during 4:00 to 6:00 PM for the age groups of workers. Average oxygen consumption for operating Mandava weeder was 1.527

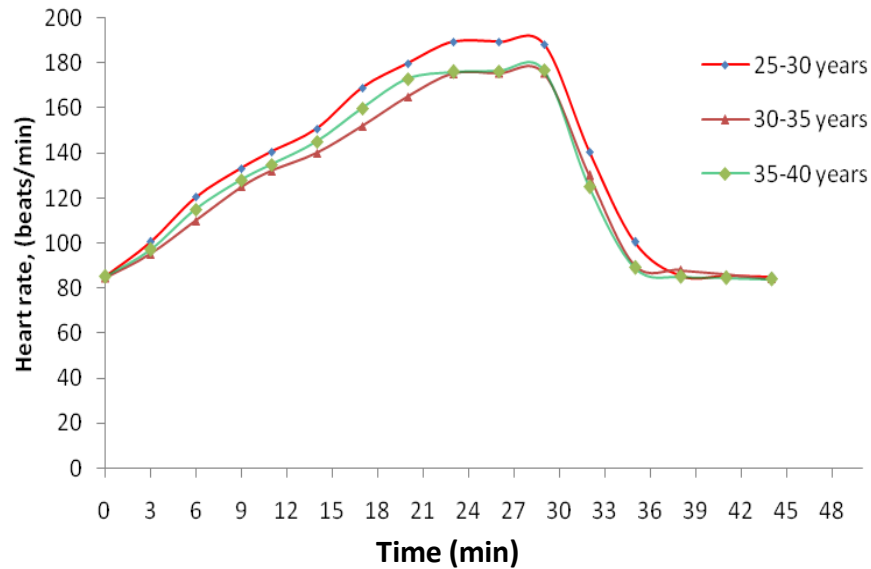


Figure 5. Physiological evaluation in terms of heart rate of subjects with cono weeder.

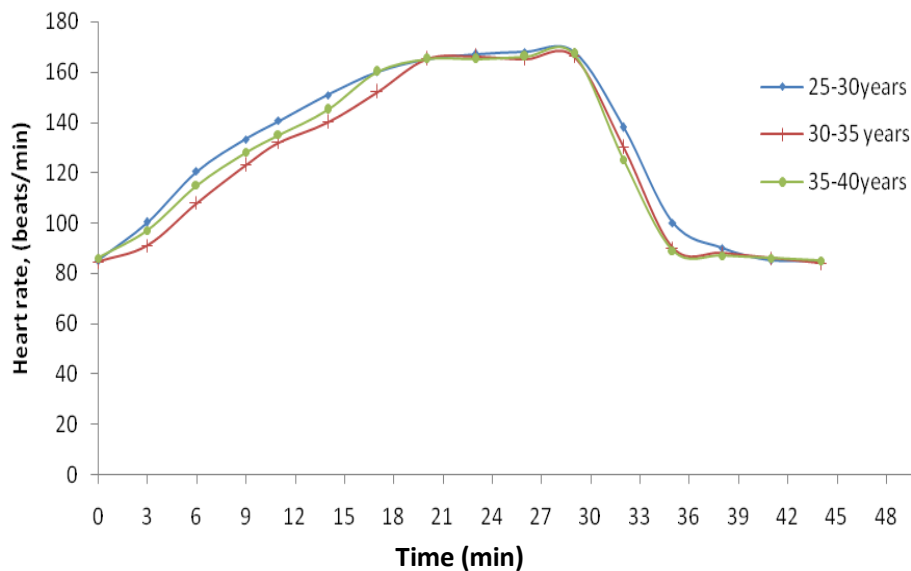


Figure 6. Physiological evaluation in terms of heart rate of subjects with mandava weeder.

$\text{l} \cdot \text{min}^{-1}$ by subjects of 25 to 30 years, $1.308 \text{ l} \cdot \text{min}^{-1}$ for 30 to 35 years and $1.366 \text{ l} \cdot \text{min}^{-1}$ for 35 to 40 years during 8:00 to 11:00 AM (Figure 6). It increased to 1.654 , 1.559 and $1.625 \text{ l} \cdot \text{min}^{-1}$, respectively, during 12:00 to 2:00 PM and decreased to 1.554 , 1.301 and $1.428 \text{ l} \cdot \text{min}^{-1}$ during 4:00 to 6:00 PM for different age groups of workers.

Work rest cycle

Figures 5 and 6 indicated that after 24 min of start of work, heart rate stabilized to around the peak heart rate.

After 30 min of work, rest was given to the subjects. It was observed that rest of 15 min was required by each of the operator to return to normal heart rate. Thus, fatigue of operator can be avoided by giving a rest of 15 min, similar results were observed by Yadav and Pund (2007).

Weeder performance

The field capacity of the conoweeder and mandawa weeder was nearly closer and found out to be 0.0225 ha/h and 0.0196 ha/h . The weeding efficiency of the cono

weeder was 77.14% and that of Mandava weeder was 72.00%. Hence, in terms of weeding efficiency and field capacity cono-weeder was better than the Mandava weeder. Plant damage caused by cono-weeder and Mandava weeder were 0.83 and 0.81%, respectively. Plant damage was lower with use of Mandava weeder than cono-weeder. It was observed that the weeding efficiency depends on the root zone depth of weeds, shape of blades, and moisture content of the soil at testing site and cutting depth of the weeder blades.

Draft is an important parameter in the selection of weeder and it must be within the physical limits of the operator. The average draft required for both the weeder was nearer about 17.25 kg. However, maximum pushing force for Indian agricultural work ranges from 20 to 30 kg (Gite and Yadav, 1985). 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 traveling speed was found to be 15 m/min. The average power requirement for both the weeder was estimated to be 0.0575 hp. The performance index of the cono weeder and mandava weeder was found to be 25.05 and 19.88. Hence a cono weeder is more suggested for wet land weeding operation.

Conclusions

1. Weeding during 12:00 to 2:00 PM developed maximum working heart rate and oxygen consumption with both cono and Mandava weeders compared to 8:00 to 11:00 AM and 4:00 to 6:00 PM, which might be due to higher temperature.
2. Agricultural workers in 25 to 30 years age group developed highest working heart rate and oxygen consumption rate for manual weeding operation than age groups of 30 to 35 years and 35 to 40 years due to decrease of heart rate with increase of age.
3. Oxygen consumption rate of workers varied from 1.60 to 1.94 l.min⁻¹ for weeding by cono-weeder and 1.30 to 1.65 l.min⁻¹ by Mandava weeder in wet land condition.
4. Weeding with cono weeder between 8:00 and 11:00 AM by workers in 30 to 35 years age group was better than weeding with cono weeder due to its less weight, less heart rate, low oxygen consumption and easy operation mechanism.

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