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Ergonomical studies on single row power weeder for rice crop

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ABSTRACT

Weed infestation was identified as one of the major constraints of rice cultivation and different weed control methods had significant effect on crop growth and yield parameters. The single row power weeder would serve the purpose of minimum damages done to rice plants, cost effectiveness, low weight and easy to operate .Tests were carried out to assess the ergonomical performance of the single row power weeder on the basis of number of weeding operation done by male and female workers. The performance of male workers was more efficient than female worker. The actual field capacity of power weeder operated by male worker found as 0.045 ha h^{-1} with weeding efficiency of 80.95 per cent and operated by female workers was 0.038 ha/h and 80.5% ,respectively. The physiological response of male and female workers during operation was recorded and it was found that the mean working heart rate of male workers was 108.9 beat min^{-1} and female workers was 114.2 beat min^{-1}. The oxygen uptake in terms of VO_2 max was above the acceptable limit of 35% of VO_2 max and it was found that the power weeder could be operated continuously 21 min by male workers and 18 min by female workers for frequent working. The energy expenditure rate of male and female workers was found 12.73 and 13.32 kJ min^{-1}, respectively. The operation was graded as "light" work for male and "moderate" work for female workers according to ICMR report it means that single row power weeder is operated frequently by both male and female workers.

***Keywords*:** Body part discomfort, energy expenditure, overall discomfort, oxygen consumption and weeding efficiency

Weed control is one of the most difficult tasks in agriculture that accounts for a considerable share of the cost involved in agriculture production. More than 33 per cent of the cost incurred in cultivation is diverted to weeding operations there by reducing the profit share of farmers. Adoption of single row power weeder use in SRI plays a significant role in improving the growth, yield and economics of rice. Today the agricultural sector requires non-chemical weed control that ensures food safety. Weeding is one of the most important field operations and consumes 15 per cent of total energy spent in crop production.

Ergonomics (or human factors) is an applied science for adjusting work to man in the light of his anatomy, physical and psychology. Ergonomical studies in the field of agriculture are used to Design of tools, equipments, machines, processes and procedures for occupational safety and also to Control and modification of workload, work rate and thermal environment for optimum comfort and productivity. Ergonomical tools used for evaluate the energy expenditures of workers, their physiological cost and suitability of the method for farm workers.

MATERIALS AND METHODS

For ergonomic evaluation of power weeders, six subjects were selected from agricultural workers in and around IGKV, Raipur. Each subject was asked to operate the power weeders in a SRI rice field having a row-to-row spacing of 25 cm at IGKV, Raipur. Regardless of activity level, a minimum level of energy is required to sustain the body's everyday functions. Resting metabolism, the amount of calories needed to supply the body with the minimum level of energy, differs between individuals depending on variables such as age, weight, body composition and energy expenditure. The physiological characteristics of selected subjects are given in the table1. Body age is based on resting metabolism. Body age is calculated by using weight and body fat percentage to produce a guide to judge whether the body age is above or below the average for actual age. Body age varies according to Body composition and resting metabolism, even if height and weight is the same.

Field layout experiments

All the six subjects were equally trained in the operation of the power rice weeder. They were asked to report at the work site at 9:00 am and have rest for 30 minutes before starting the trial. To minimize the effects of variation, the treatments were given in randomized order. The heart rate was measured and recorded using stethoscope for the entire work period. Each trial started with taking five minutes data for physiological responses of the subjects while resting on a chair under shade. They were then operating the single row power weeder only for duration of periods till they were feeling no fatigue and same procedure was repeated to replicate the trials for all the selected subjects.

Heart rate

The stethoscope was used to measure the average heart rate during the rest and working condition (beats min^{-1}).

ÄHR=average working HR"average HR during rest ….. (1)

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Oxygen consumption rate (l min^{-1})

The oxygen consumption rate (amount of oxygen consumed by the 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^{-1}) =0.0114×HR-0.68 ..... (2)

Oxygen consumption rate (kJ) = Oxygen consumption rate × 0.93(1 LO_2=20.93kJ) .....(3)

The physiological responses like heart rate and oxygen consumption rate (OCR) were measured. The Work load in term of OCR (OCR as % of VO_2 max) was determined.

The energy expenditure rate (EER) (kJ min^{-1})

The energy expenditure rate (EER) was determined by multiplying the OCR Work with the calorific value of oxygen 20.93 kJ l^{-1} (Nag and Dutt, 1980). The physiological response of workers was studied during the testing of the weeder.

Blood pressure (mm of hg)

The digital B.P. apparatus was used to record systolic and diastolic blood pressure and pulse rate. The energy cost of the subjects thus obtained was graded as per the tentative classification of strains in different types of jobs given in ICMR report as shown in the table 2.

Table 1: Physiological characteristics of participants

Variable	M1	M2	M3	F1	F2	F3
Weight, kg	54.9	49.6	40.5	74.90	37.6	45.0
Age, year	38.0	21.0	23.0	45.00	40.0	20.0
Height ,cm	157.0	160	160.0	145.00	157.0	163.0
Fat, %	18.4	20.8	13.7	37.04	20.6	17.0
RM, kcal	1366.0	1284	1154.0	1467.00	946.0	1085.0
BMI	22.1	19.3	15.8	29.30	15.5	16.7
Body Age, year	34.0	18.0	18.0	37.00	18.0	18.0

Table 2: Tentative classification of strains (ICMR) in different types of jobs

	Physiological response		
Grading	Heart rate (bpm)	Oxygen uptake, l min^{-1}	Energy expenditure, kJ min^{-1}
Very light	<75	<0.35	<1.75
Light	75-100	0.35-0.70	1.75-3.2
Moderately heavy	100-125	0.70-1.05	3.2-5.25
Heavy	125-150	1.05-1.40	5.25-7.00
Very heavy	150-175	1.40-1.75	7.00-8.75

Assessment of postural discomfort

Assessment of postural discomfort included overall discomfort rating (ODR) and body part discomfort score (BPDS). The subjects were asked to report at the work site at 9:00 AM and have a rest for 30 minutes before starting the trial. After 30 minutes of resting, the subject was asked to operate the power rice weeder for duration of two hours. Sufficient rest period was given for each subject and the second trial should be started after the lunch.

Overall discomfort rating (ODR)

For the assessment of ODR, a 10 - point psychophysical rating scale (0 – no discomfort, 10 - extreme discomfort) was used which is an adoption of technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly (Fig.1). A movable pointer was provided on the scale to indicate the rating. The overall discomfort ratings given by each of the six subjects were added and averaged to get the mean rating.

Body part discomfort score (BPDS)

To measure localized discomfort, technique was used. The subject was asked to mention all body parts with discomfort, starting with the worst and the second worst and so on until all parts have been mentioned. The subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on. The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The subjects were asked to locate the body parts with respect to degree of discomfort in the order as extremely heavy, very heavy, moderately heavy, heavy, light and very light. The body part discomfort was determined by the following formula (Corlett and Bishop, 1976):

BPDS = S Xi x S .... (4)

Where,

BPDS = Body parts discomfort score

Xi = Number of body parts

S = Discomfort score (6 to 1)

Work rest cycle

The actual rest time taken for each subject was found from the heart rate response curves of respective operations. The rest time was measured from the cease of the operation till the heart rate of the subject reaches resting level. The rest time taken was averaged to arrive at the mean value for single row power rice weeder. The rest pause to the subject was calculated using the following formula as given by:-

$$R = \frac{T(E - A)}{E - B} \quad \ldots. (5)$$

Where,

R = Resting time (min)

T = Total working time day^{-1} (min)

E = Energy expenditure during working task (kcal min^{-1})

A = Average level of energy expenditure considered acceptable (kcal min^{-1})

B = Energy expenditure during rest(kcal/min)

Description of machine

An engine operated rice power weeder have power source of 2 hp, 6000 rpm, two-stroke petrol engine which is capable of providing the required power for weeding operation. The accompanying views and photographs show the general features of the machine. The technical specifications of the engine are shown in the table 3.

Table 3: Technical specifications of the machine

S.No.	Specification	Value
1.	Number of cylinder	1
2.	Engine maximum power at 6000 rpm	2 hp
3.	Weeding width	140 mm to 250 mm
4.	No. of Blades	4 as per field condition
5.	Rotor speed	176 rpm
6.	Weeding depth	3 - 8 cm
7.	Power transmission	Light weight aluminum gear box
8.	Fuel tank capacity	1.1 Litre
9.	Fuel	Petrol mixed with lub.oil(1lts of petrol with 40 ml of oil)
10.	Material of blade	Mild steel-L type blade
11.	Overall dimension (LxWxH)	1345.8 x 573 x 1020 mm
12.	Total weight	14.5 kg

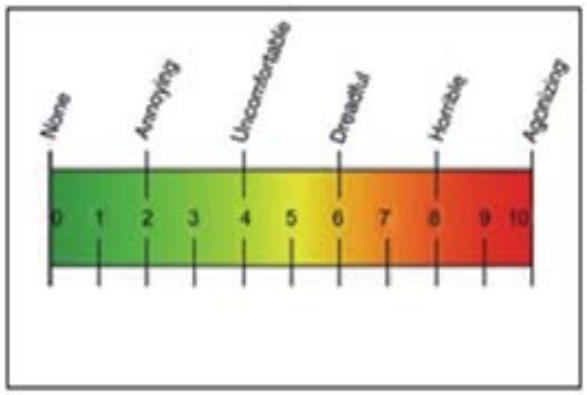

Fig. 1: Overall discomfort rating (ODR) scale

Fig. 2: power weeder

Machine performance parameters

Weeding efficiency

It is the ratio between the numbers of weeds removed by power weeder to the number of weeds present in a unit area and is expressed as a percentage. The samplings were done by quadrant method, by randomly selection of spots by a square quadrant of 1 square meter (Tajuddin, 2006).

$$\text{Weeding efficiency \%} = \frac{W_1 - W_2}{W_1} \quad \text{.....(6)}$$

Where,

W1 = Number of weeds counted per unit area before weeding operation

W2 = Number of weeds counted in same unit area after weeding operation

Effective field capacity

Effective field capacity is the actual average rate of coverage by the machine, based upon the total field time. It is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of the travel and the amount of field time lost during the operation. Effective field capacity is usually expressed as hectare per hour (Kepner *et al.,* 1978).

$$\text{EFC} = \frac{A}{T_p + T_i} \quad \text{.....(7)}$$

Where,

EFC = Effective field capacity, ha/h

A = Actual area covered, ha

Field efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity, expressed as percentage. It includes the effect of time lost in the field and of failure to utilize the full width of the machine.

$$\eta e = \frac{\text{EFC}}{\text{TFC}} \text{x} 100 \quad \text{..... (8)}$$

Where,

e = Field efficiency, %

EFC = Effective field capacity, ha hr^{-1}

TFC = Theoretical field capacity, ha hr^{-1}

RESULTS AND DISCUSSION

The body dimensions of the subjects indicating the mean, standard deviation and minimum and maximum values for relevant anthropometric parameters of male and female agriculture workers, respectively. In general the male subjects were heavier and taller than female subjects. The mean lean body mass of male subject was also higher than female subjects.

Physical and physiological response

Heart rate

Initially heart rate was different for each person ranging between 64 to 74 beats/min. For a particular workload the heart rate increases suddenly and then established throughout the work. After the completion of the work, heart rate decreases drastically. Average heart rate of different Person (male or female) after the commencement of weeding operation was found as 110,103.5, 113.2, 112.4, 115.7 and 114.5 beats /min. There was significant difference in heart rate of male and female worker after completing of the work.

Oxygen consumption rate

Average oxygen consumption rate of different subject before and after weeding operation was observed. The minimum oxygen consumption rate was obtained after weeding operation found to be 0.49 l/min for M2 subject (male worker) and maximum oxygen consumption rate was found to be 0.64 l/min for F2 subject (Female worker). Statistical analysis of oxygen consumption rate was found to be significant at 5% level of significance it means that there was difference in OCR of different subject.

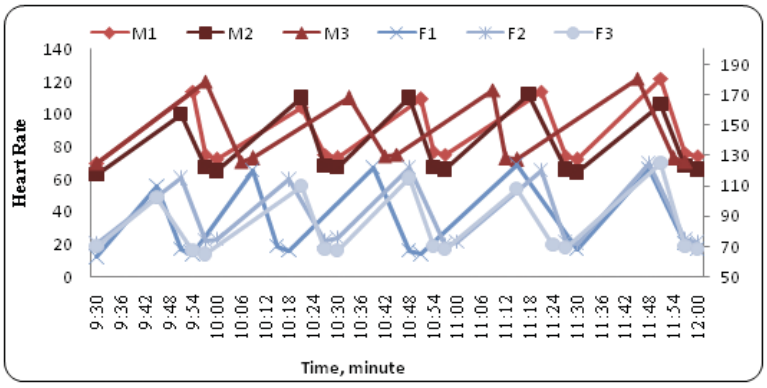

Fig. 3: Variation in heart rate of male and female worker during weeding operation before 12PM

Table 4: Physical response of subject with power weeder

Subject	Before				After		
	time, min	heart rate	OCR, l/min	EER	heart rate	OCR, l/min	EER
S_{M1}	20.6	73.2	0.15	3.22	110	0.57	12.54
S_{M2}	18.1	65.2	0.06	1.32	103.5	0.49	10.43
S_{M3}	23.2	72.5	0.15	3.05	113.2	0.61	12.73
S_{F1}	19.2	64.8	0.06	1.22	112.4	0.6	12.54
S_{F2}	18.5	71.6	0.14	2.84	115.7	0.64	13.33
S_{F3}	18.5	67.8	0.09	1.94	114.5	0.62	13.04
SEm ±	**0.389**	**3.030**	**0.005**	**0.096**	**4.910**	**0.026**	**0.544**
CD	**1.228**	**9.56**	**0.015**	**0.305**	**15.49**	**0.082**	**1.715**
CV	**3.430**	**7.59**	**7.47**	**7.39**	**7.63**	**7.6**	**7.58**

Energy expenditure rate

The energy expenditure rate responses of male and female subjects under weeding operations were observed. It was found that the minimum energy expenditure rate after weeding operation was obtained in the subject M2 (10.43 kJ min^{-1}) and maximum EER after weeding operation was found in F2 (13.33 kJ min^{-1}). From the statistical analysis it was observed that there was significant effect in EER at 5% level of significance i.e. there was difference in EER of male and female workers.

Energy cost of operation

Based on the mean energy expenditure, the operation was graded as "light" for male worker and "Moderate" for female worker. In single row power rice weeder, the subjects can do the weeding in a standing posture. It means that power rice weeder operate more comfortably.

Acceptable workload (AWL)

To ascertain whether the operations selected for the trails were within the acceptable workload (AWL), the oxygen uptake in terms of VO_2 max (%) was computed. Saha *et al*. (1979) reported that 35% of maximum oxygen uptake (also called maximum aerobic capacity or VO_2 max) can be taken as the acceptable work load (AWL) for Indian workers which is endorsed by Nag *et al*., 1979 and Nag and Chatterjee, 1981. Each subject's maximum heart rate was estimated by the following relationship (Bridger, 1995).

Maximum heart rate (beats min^{-1}) = 200 - 0.65 × Age in years. ….. (9)

The mean oxygen uptake in terms of maximum aerobic capacity was calculated and it was 45% and the value was above the acceptable limit of 35% of VO_2 max indicating that the power rice weeder is could not be operated continuously for 8 hours without frequent rest-pauses.

Overall discomfort rating (ODR)

Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 3.0 and scaled as "Light discomfort" during weeding. (Rameshan *et al*., 1987)

Body part discomfort score (BPDS)

The majority of discomfort was experienced in the left shoulder, right shoulder, left wrist, right wrist, left thigh and right thigh region for all the subjects during weeding and the body part discomfort score of subjects during weeding with power rice weeder was 24.64.

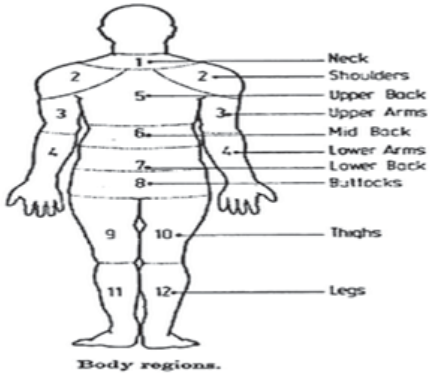

Fig. 4: Regions for evaluating body part discomfort score

Work rest cycle

Rest pause was calculated, as all the subjects operated continuously for different time period and it was found that rest could be provided to operator who was engaged in operating the equipment. The rest period calculated was also in agreement to the recovery heart rate of operator. If two operators are engaged with a machine in shift, it could be operated for day-long work. The work rest cycle graph was between heart rate and recovery time.

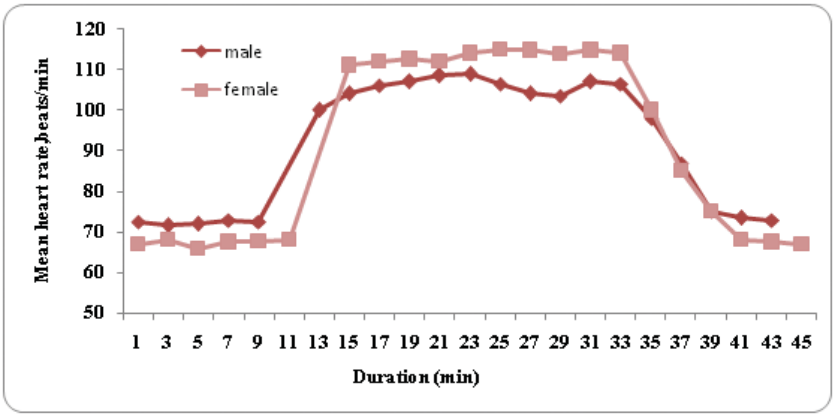

Fig. 5: Mean heart rate and recovery time during weeding operation

Conclusion

- The physiological response of male and female workers during operation was recorded and it was found that the mean working heart rate of male workers was 108.9 beat/min and female workers was 114.2 beat/min.
- The oxygen uptake in terms of VO_2 max was above the acceptable limit of 35% of VO_2 max and it was found that the power weeder could be operated continuously 21 min by male workers and 18 min by female workers for frequent working.
- The average resting time of male and female worker after weeding operation was 8 and 10 minutes respectively. i.e. person takes 10 min rest between weeding operation when they feel tired and then again they do their work frequently and this process repeated for whole day.

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