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Development and Ergonomic Evaluation of a Three row Power Paddy Weeder for Wet land Paddy Cultivation

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Abstract:- 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. Weeding by mechanical devices reduces the cost of labour and also saves time. At present power paddy weeders available in the market were designed to work in two rows at a time. In this study modification was done to attach a cono weeder in line with the float of the power paddy weeder so as to cover the weeding in three rows at a time and ergonomically evaluated. Psychophysical measurement technique was used to quantify the overall discomfort as well as body part discomfort. The physiological cost involved in operation of the three row power paddy weeder was found out and the average working heart rate of the subject was 110 beats min^{-1}. The predicted oxygen consumption rate was 0.971 l min^{-1} that is 47% of their aerobic capacity (VO_2 max) which was above the acceptable limit of 35% of VO_2 max. The weeding index was found to be 88%. Area covered by the power paddy weeder was 40 cent/hour while planting 30 cm row spacing. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 4.0 and scaled as "More than light discomfort". If only one worker is engaged for the weeding operation with this equipment, 9 min rest could be provided after 30 min of operation.
Keywords:- power paddy weeder; heart rate; aerobic capacity; weeding index; discomfort

I. INTRODUCTION

Rice is the staple food of Keralites and its cultivation had been the main occupation for generations. Though agriculture is the oldest industry of the world and also the largest labour absorbing profession, it has now become an uneconomical exercise in Kerala, particularly in the case of rice cultivation. The rice of Kerala thus costs about double of that from other states. The drudgery involved in cultivating rice is too intense and it calls for a decent compensation. In rice cultivation, weeding is an important but equally labour intensive operation. Weeding requires a lot of labour force in compared to other operations. Manual weeding requires a huge labour force and accounts for about 25% of the total labour requirement [10]. Mechanical weeding is generally the most economical method of weed control.

Farm implements and machinery hitherto have not been ergonomically designed and developed. Ergonomic interventions are needed to design user friendly equipment and tools without affecting health and safety of the worker. Hence there is an urgent need to study the ergonomic aspects in detail to qualify the drudgery involved in the agricultural equipment and tools. This would greatly help the researchers to appropriately design simple and labour effective gadgets considering ergonomic requirements. In this study, the existing power paddy weeder was modified to work in three rows at a time and evaluated ergonomically to assess its suitability.

II. MATERIALS AND METHODS

A. Subjects

Three healthy male operators based on age and medical fitness were selected for the study. The strength or power is expected to be maximum in the age group of 25 to 35 years [4]. Hence three subjects were chosen from the age group of 25 to 35 years. The physiological characteristics of selected subjects are given in Table 1.

Table 1: Physiological characteristics of participants

Sl.No:	Variable	Subjects		
		1	II	III
1	Age, years	29	26	33
2	Body weight, kg	65	52	70
3	Height, m	1.65	1.63	1.83
4	Resting heart rate, beats min^{-1}	60.00	69.00	69.00
5	ECG	Normal	Normal	Normal
6	Blood pressure, mm of Hg	120/80	120/80	120/80

B. Establishing relationship between Oxygen uptake and Heart Rate

On a separate day and before performing activities, the relationship between heart rate and oxygen uptake for each subject was determined. Both heart rate and oxygen uptake have to be measured simultaneously in the laboratory at a number of different sub maximal workloads [6]. Since the relationship between the two variables is linear during a typical sub maximal workload, a subject's heart rate measured in the field can be converted into an estimate of oxygen uptake by referring to the laboratory data. The selected three subjects were calibrated in the laboratory by measuring oxygen consumption and heart rate simultaneously while running on the treadmill to arrive at the relationship between heart rate and oxygen consumption. The oxygen consumption was measured using Benedict-Roth Spirometer and the heart beat rate was recorded using Polar heart rate monitor.

C. Modifications of power paddy weeder

Power paddy weeder is a manually operated implement powered by 1.75 Hp petrol engine and designed to work in two rows of 20 to 30 cm spacing in wet lands. It works by the rotary motion of blades and the weeds were uprooted and buried in the field itself. A float provided in the front portion prevents the unit from sinking into the puddled soil. At present power paddy weeder works in two rows and modification was done to attach a cono weeder in line with the float of the power paddy weeder so as to cover the weeding in three rows at a time (Fig.1). The float from power weeder as well as float and cone from cono weeder was removed initially. The length of float of conoweeder was increased by attaching a separate MS sheet (4mm) below the float and the unit bolted to the power weeder. A clamp in MS sheet (20x6 mm) was made for fixing the cone unit and assembling the unit to the paddy power weeder. The depth of cone and float was modified and handle height was adjusted.

Fig.1: Photographic view of modified power paddy weeder

D. Field layout experiments

The experiment was conducted in farmers feld in Chadayamangalam Block of Kollam District, Kerala, India. The modified power paddy weeder was put in proper test condition before conducting the tests. All the three subjects were equally trained in the operation of the power paddy weeder. They were asked to report at the work site at 7.30 am and have a rest for 30 minutes before starting the trial. To minimize the effects of variation, the treatments were given in randomized order. All the subjects used similar type of clothing. The subjects were given information about the experimental requirements so as to enlist their full cooperation.The heart rate was measured and recorded using computerized heart rate monitor for the entire work period. Each trial started with taking five minutes data for physiological responses of the subjects while resting on a stool under shade. They were then asked to operate the power paddy weeder (already started by another person) for duration of 15 minutes and same procedure was repeated to replicate the trials for all the selected subjects.

E. Data analysis

The recorded heart rate values from the computerized heart rate monitor were transferred to the computer and the values of heart rate at resting level and from 6^{th} to 15^{th} minute of operation were taken for calculating the physiological responses of the subjects. The stabilized values of heart rate for each subject from 6^{th} to 15^{th} minute of operation were used to calculate the mean value for power paddy weeder. From the mean

values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate (VO_2) of the subjects were predicted from the calibration curves of the subjects. The energy costs of the operations were computed by multiplying the value of oxygen consumption (mean of the values of three subjects) by the calorific value of oxygen as 20.88 kJ lit-1 [8]. 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 Table 2 ([14] and [13]).

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

Grading	Physiological response		
	Heart rate (beats min^{-1})	Oxygen uptake, lit min^{-1}	Energy expenditure, kcal min^{-1}
Very light	<75	< 0.35	<1.75
Light	75-100	0.35 - 0.70	1.75-3.5
Moderately heavy	100-125	0.70 - 1.05	3.5-5.25
Heavy	125-150	1.05 - 1.40	5.25-7.00
Very heavy	150-175	1.40- 1.75	7.00-8.75
Extremely heavy	>175	> 1.75	>8.75

F. 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 8.00 AM and have a rest for 30 minutes before starting the trial. After 30 minutes of resting, the subject was asked to operate the modified power paddy weeder for duration of two hours. Sufficient rest period was given for each subject between the two trials on the same day with the same subject.

1) 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 [3] 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.

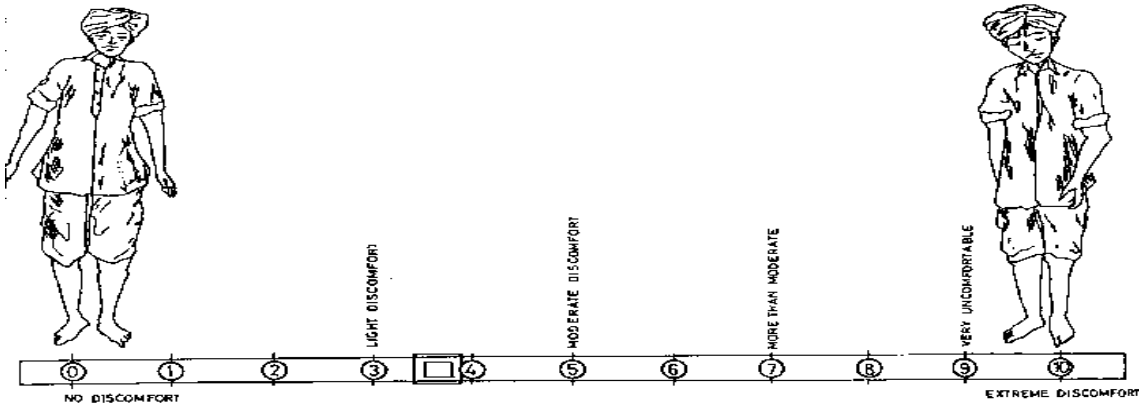

Fig.1: Visual analogue discomfort scale for assessment of overall body discomfort

At the ends of each trial subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the three subjects were added and averaged to get the mean rating.

2) Body part discomfort score (BPDS)

To measure localized discomfort, [3] technique was used. In this technique the subject's body is divided into 27 regions as shown in Fig.2. A body mapping similar to that of Fig.2 was made to have a real and meaningful rating of the perceived exertion of the subject. 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 total body part score for a subject was the sum of all individual scores of the body parts assigned by the subject. The body discomfort score of all the subjects was added and averaged to get a mean score.

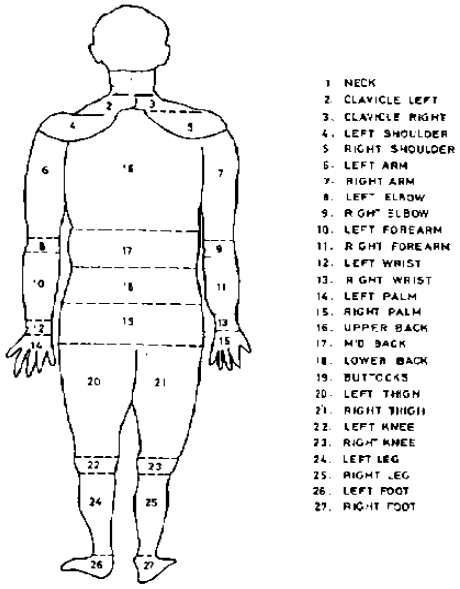

Fig.2: Regions for evaluating body part discomfort score

Weeding index was calculated by using the following formula [1].

$$e = [(W_1 - W_2)/W_1] \times 100 \quad \ldots\ldots\ldots\ldots (1)$$

Where,
e = weeding Index, per cent
W_1 = number of weeds/m^2 before weeding
W_2 = number of weeds/m^2 after weeding

Higher the value (e) means the weeder is more efficient to remove the weeds.

III. RESULTS AND DISCUSSION

A. Calibration process

By using the data on heart rate and oxygen consumption rate, calibration chart was prepared with heart rate as the abscissa and the oxygen uptake as the ordinate for the selected three subjects.

It is observed that the relationship between the heart rate and oxygen consumption of the subjects was found to be linear for all the subjects. This linear relationship defers from one individual to another due to physiological differences of individuals [5]. The relationship between the two parameters oxygen consumption (Y) and heart rate (X) was expressed by the following linear equations.

For subject I, $Y = 0.0152 X - 0.8824$ ($R^2 = 0.9628$) --- (1)
For subject II, $Y = 0.0199 X - 1.2505$ ($R^2 = 0.9849$) --- (2)
For subject III, $Y = 0.0156 X - 0.7415$ ($R^2 = 0.9575$) --- (3)

Where,
Y = Oxygen consumption, l min^{-1}
X = Heart rate, beats min^{-1}

It is observed that R^2 value (coefficient of determination) was very high for all the subjects which indicated that a good fit was arrived between oxygen consumption and heart rate.

B. Energy cost of operation

The average working heart rate of the operator was 110 beats min^{-1} and the corresponding value of oxygen consumption rate predicted from the calibration chart was 0.971 l min^{-1}. The corresponding energy expenditure was 20.27 kJ min^{-1}. Based on the mean energy expenditure, the operation was graded as "Moderately Heavy". The weeding index was found to be 88%. Area covered by the three power paddy weeder was 40 cent/hour for a 30 cm row spacing planting while two row power paddy weeder cover only 30 cent/hour. The paddy weeder improves soil aeration and root growth. The disadvantages are starting torque is less and row to row distance should be correct.

C. 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. [12] 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 [8] and [9]. The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity (VO_2 max).

Each subject's maximum heart rate was estimated by the following relationship [2].

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

The mean oxygen uptake in terms of maximum aerobic capacity was calculated and it was 47% and the value was above the acceptable limit of 35% of VO_2 max indicating that the modified power paddy weeder is could not be operated continuously for 8 hours without frequent rest-pauses.

D. Overall discomfort rating (ODR)

Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10- extreme discomfort) was 4.0 and scaled as " More than Light discomfort" during weeding.

E. 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 paddy weeder was 27.25.

F. Limit of continuous performance (LCP)

The work pulse (Δ HR) was 39 beats min^{-1} and it was within the limit of continuous performance of 40 beats min^{-1}.

G. Work rest cycle

For every strenuous work in any field requires adequate rest to have an optimum work out put. Better performance results can be expected from both the operator and the worker only when proper attention is given for the work rest schedule for different operations.

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 three row power paddy weeder.

The rest pause to the subject was calculated using the following formula as given by [11]:

$$R = \frac{T\,(E-A)}{E-B}$$

Where.

R = Resting time (min)

T = Total working time/day (min)

E = Energy expenditure during working task (kcal/min)

A = Average level of energy expenditure considered acceptable (kcal/min)

B = Energy expenditure during rest (kcal/min)

Average level of energy expenditure considered acceptable was 4 kcal min^{-1}[7].

Rest pause was calculated using the above formula as all the subjects operated continuously for the 30 min period and it was found that 9 min 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.

IV. CONCLUSION

The existing two row power paddy weeder was modified to a three row power paddy weeder and was ergonomically evaluated at Farming Systems Research Station, Sadanandapuram, Kottarakkara, Kerala for weeding paddy in wet land cultivation. The physiological cost was found out and the mean working heart rate of operator was 110 beats min^{-1}. The operation was graded as " Moderately Heavy". The work pulse of the power paddy weeder is within the limit of continuous performance of 40 beats min^{-1}. The oxygen uptake in terms of VO_2 max was above the acceptable limit of 35% of VO_2 max indicating that the three row power paddy weeder was could not be operated continuously for 8 hours without frequent rest-pauses. It is suggested that two operators may be engaged in shift for a day long work with three row power paddy weeder. The weeding index was found to be 88%. Area covered by the three row power paddy weeder was 40 cent/hour while planting 30 cm row

spacing. Mean overall discomfort rating on a 10 point visual analogue discomfort scale (0- no discomfort, 10-extreme discomfort) was 4.0 and scaled as "More than Light discomfort".

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