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Research Paper :

Economic evaluation of direct paddy seeder

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ABSTRACT

Direct paddy seeder is becoming popular for wet seeding because of its less initial investment, easy operation, low repair and maintenance cost. Here, we analyze the human energy expenditure during operation of a direct seeder for assessing the suitability to rural women. A comparison was also made between mechanized and manual operations. Nine female subjects were selected for the investigation. The parameters used for the ergonomical evaluation of the direct paddy seeders include heart rate and oxygen consumption rate, energy cost of operation and acceptable workload. The selected nine subjects were calibrated in the laboratory by indirect assessment of oxygen uptake. The maximum aerobic capacity of the selected nine subjects varied from 1.21 to 1.51 1 min^{-1}. The average energy expenditure before 9 am was 15.87 kJ min^{-1} while after 11 am it was increased to 17. 05 kJ min^{-1} during seeder operation. The subjects expended more energy during sowing in lines than paddy seeder operation to the tune of 36% before 9 am and 44% after 11 am. Based on the mean energy expenditure, the operation was graded as "moderately heavy" for direct seeder while it was "heavy" for manual sowing. The oxygen uptake in terms of VO_2 max was above the acceptable workload for both operations.

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Key words : Direct paddy seeder, Human energy expenditure, Acceptable workload

Rice is the staple food for most people in Asia. It is not only a major cereal crop in Asia but also a way of life for thousands of millions of people all over the world. Human energy is predominantly used in most of the rice farming operations starting from land preparation to threshing. It is estimated that nearly 145 man-days are required per hectare of rice (Veerabadran and Pandian, 1999). Exclusive dependence on human labour will become counter-productive since it is scarce and costly in rice growing regions. Very often mechanization is equated with tractorization or automation of farm operations. Mechanization to fully substitute human labour may change social dissension. However, mechanization as a tool to reduce drudgery and to increase labour efficiency should be the criteria where large percentage of population depends on agriculture as a means of livelihood.

The application of ergonomics can help in increasing the efficiency and thereby productivity of the workers without jeopardizing their health and safety. The performance of any machine especially manually operated ones could be considerably improved if ergonomic aspects are given due consideration (Gite, 1993). The farmers have been continuously using the tools and equipments which have been developed by trial and error methods and which are inefficient with respect to drudgery removal, safety aspects and ease of operation. Hence, there is an urgent need to study the ergonomic aspects in detail to quantify the drudgery involved in agricultural operations.

Most technologies developed for small-scale farmers are geared to men with no concern for their appropriateness for women, who possess different physiques and energy capabilities in comparison to men. There is an urgent need to design and develop farm tools specifically for female operators in order to improve overall ease of use, safety, and effective integration of women in farming system innovations (Kaul and Ali, 1992). Systematic efforts to evaluate the energy expenditure of female labourers are generally non-existent. Hence, the energy measurements for different operations performed in rice farming under different environmental conditions are essential. Here, we analyze the human energy expenditure during operation of a direct seeder for effective use of women labourers available for rice cultivation.

METHODOLOGY

Selection of subjects:

A preliminary survey was conducted among women agricultural labourers engaged in rice cultivation in southern districts of Kerala. Nine subjects were selected having anthropometric dimensions conforming to statistical requirements from the available anthropometric data base of the study region. The medical and bio-clinical investigations were also conducted to assess the medical fitness of selected subjects which included Electro Cardio Graph (ECG), blood pressure and bio-clinical analysis.

Calibration of subjects:

To evaluate physiological workload using heart rate, the relationship between heart rate and oxygen uptake for each subject must be determined. Both variables have to be measured simultaneously in the laboratory at a number of different submaximal workloads. This process is known as calibrating the heart rate-VO_2 relationship for a subject. Since the relationship between the two variables is linear, a subject's heart rate when it is subsequently measured in the field can be converted into an estimate of oxygen uptake by reference to the laboratory data. The selected nine subjects were calibrated in the laboratory by measuring oxygen consumption while pedalling a standard bicycle ergometer and the corresponding heart rate 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 computerized heart rate monitor (Polar make).

Field layout experiments:

The experiment was conducted during 2008-2009. Direct seeding is a labour saving technology in rice crop establishment and is being rapidly adopted by farmers. Broadcasting of pre-germinated paddy in a puddle field results non-uniformity in plant stand and difficulty in adopting the improved intercultural tools for weeding. Direct paddy seeder is a manually pulling implement covers 8 rows of 20 cm row to row spacing at a time. The specification of the selected Paddy drum seeder is furnished in Table 1.

Table 1 : Specifications of paddy drum seeder

Sr. No.	Description	Specification
1.	Power source	One labour
2.	Row to row spacing, mm	200
3.	Shape of the drum	Hyperboloid
4.	Number of rows	8
5.	Diameter of the drum, mm	200
6.	Type of metering mechanism	Orifice type on the periphery of the rotating drum
7.	Diameter of the seed metering hole, mm	9
8.	Number of seed metering holes	9
9.	Weight of the unit, kg	10
10.	Type of ground wheel	Lugged wheel
11.	Diameter of ground wheel, mm	600
12.	Operating speed, km h^{-1}	1.0
13.	Level of filling the seed drum	Half volume
14.	Type of handle	Swinging type

The drum seeder was put in proper test condition before conducting the tests, i.e. in full working order with the drum filled to 2/3rd of its capacity. All the nine subjects were equally trained in the operation of the paddy seeder. The trials were conducted two times a day, at different time intervals *i.e.*, before 9 am and after 11 am in order to find out the changes in energy expended and heart rate due to environmental condition. 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 subject was allowed to operate the seeder in the field at a speed of 0.70 kph (Vidhu, 2001). 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. Each trial was carried out for 15 minutes of duration and same procedure was repeated to replicate the trials for all the selected subjects.

The physiological response of the subjects while sowing the seeds in lines by manually was also assessed to compare the energy expenditure in manual and mechanized operation.

Data collection and analysis:

The recorded heart rate values from the computerized heart rate monitor were transferred to the computer through the interface provided in all the above cases. From the down loaded data, the values of heart rate at resting level and 6th to 15th minute of operation were taken for calculating the physiological responses of the subjects (Tiwari and Gite, 1998). The heart beat rate increases rapidly in the beginning of an exercise and reaches a steady state by the end of sixth minute (Davies *et al*. 1964). The stabilized values of heart rate for each subject from 6th to 15th minute of operation were used to calculate the mean value for all the selected implements.

From the values of heart rate (HR) observed during the trials, the corresponding values of oxygen consumption rate ($V0_2$) of the subjects were predicted from the calibration chart of the subjects. The energy costs of operation of the selected implements were computed by multiplying the oxygen consumed by the subject during the trial period with the calorific value of oxygen as 20.88 kJ lit^{-1} (Nag *et al*. 1980) for all the subjects. 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 (Vidhu, 2001).

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

Acceptable workload (AWL):

Work load can be expressed as percentage of the individual's maximal aerobic power *i.e.* how much of the individual's maximal aerobic power has to be taxed in order to accomplish the work in question. 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.* (1980) and Nag and Chatterjee (1981). 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.

RESULTS AND DISCUSSION

The results obtained from the present investigation are summarized below :

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 nine subjects (Fig.1). 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, which is in close agreement with the results reported by Kroemer and Grandjean (2000) and Vidhu (2001). This linear relationship defers from one individual to another due to physiological differences of individuals. The relationship between the two parameters oxygen consumption (Y) and heart rate (X) was expressed by the following linear equations.

For subject I, Y = 0.0115 X - 0.6121 (R^2 = 0.9137) — (1)

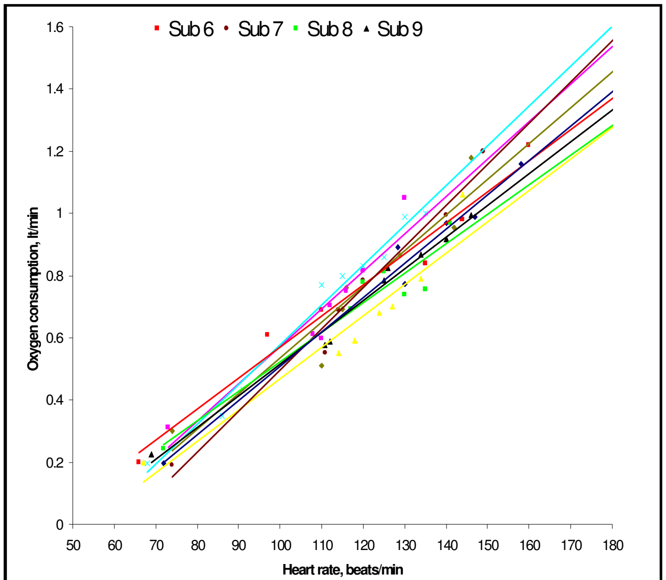

Fig. 1 : Calibration chart of subjects

For subject II, Y = 0.011X – 0.5963 (R^2 = 0.98) — (2)
For subject III, Y = 0.012 X - 0.0.6307 (R^2 = 0.9011) — (3)
For subject IV, Y =0.0101 X – 0.5407 (R^2 = 0.9121) — (4)
For subject V, Y = 0.0128 X – 0.7049 (R^2 = 0.9824) — (5)
For subject VI, Y = 0.01 X – 0.4281 (R^2 = 0.9734) — (6)
For subject VII, Y = 0.0132 X -0.8279 (R^2 = 0.9767) —(7)
For subject VIII, Y =0.0095 X – 0.425 (R^2 = 0.9153) —(8)
For subject IX, Y =0.0102 X – 0.5073 (R^2 = 0.9824) —(9)

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. The variation in oxygen consumption was accounted by 91.37 per cent by the heart rate for subject I, 98 per cent for subject II, 90.11 per cent for subject III, 91.21 per cent for subject IV, 98.24 per cent for subject V, 97.34 per cent for subject

VI, 97.67 per cent for subject VII, 91.53 per cent for subject VIII and 98.24 per cent for subject XI, respectively. The examination of subject characteristic equation showed that the lower the value of slope the higher the capacity to work and strength of the subject.

Each subject's maximum heart rate was estimated by the following relationship (Bridger, 1995).

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

The oxygen uptake corresponding to the computed maximum heart rate in the calibration chart gives the maximum aerobic capacity (VO_2 max) (Fig.1).

Energy cost of operation:

The physiological response of the subjects during operation of paddy drum seeder and grading of the work are furnished in Table 3. It is observed that there existed a significant difference in the energy expenditure among the subjects for doing the same operation under similar conditions. This might be due to the variation in linear relationship between the heart rate and oxygen consumption among the subjects and physiological differences of individuals.

It is further noticed that the average energy expenditure before 9 am was 15.87 kJ min^{-1} while after 11 am it was increased to 17. 05 kJ min^{-1} . The variation may be attributed to the effect of environment on the subject since the heart rate integrates the total stress on the body and responds more quickly to changes in work demand and indicates more readily the quick changes in body function due to changes in work environment. Based on the mean energy expenditure, the operation was graded as "moderately heavy" before 9 am and "heavy" after 11 am.

Table 4 shows the energy expenditure of the subjects while sowing the seeds in lines manually. It is observed that the energy expended by the subjects was 21.52 kJ min^{-1} before 9 am while it was 24. 54 kJ min^{-1} after 11 am. The subjects expended more energy during sowing in lines than paddy seeder operation to the tune of 36% before 9 am and 44% after 11 am. While sowing in lines, the women labourers takes a tedious bending posture. In the distorted posture, the muscles have to contract unnecessarily for holding the body erect. Such postures may also affect the pulmonary ventilation rate and increase the respiration frequencies to expel out the extra carbon dioxide produced in the tissues by increased metabolic rate. Based on the mean energy expenditure, the operation was graded as " heavy" before 9 am and " very heavy" after 11 am.

Acceptable workload (AWL):

The VO_2 max for the subjects was computed from the calibration chart and the values are furnished in Table

Table 3 : Energy cost of paddy drum seeder

Time	Subjects	Average heart rate (beats min^{-1})	VO_2 (l min^{-1})	Energy cost (kJ min^{-1})	Grading of work
Before 9 am	I	116	0.7219	15.073	
	II	125	0.7787	16.259	
	III	124	0.8573	17.900	
	IV	122	0.6915	14.438	
	V	118	0.8055	16.819	Moderately heavy
	VI	119	0.7619	15.908	
	VII	117	0.7165	14.961	
	VIII	126	0.772	16.119	
	IX	122	0.7371	15.391	
	Mean	121	0.7603	15.874	
After 11 am	I	124	0.8139	16.994	
	II	129	0.8227	17.178	
	III	132	0.9533	19.905	
	IV	127	0.742	15.493	
	V	120	0.8311	17.353	
	VI	126	0.8319	17.370	Heavy
	VII	125	0.8221	17.165	
	VIII	123	0.7435	15.524	
	IX	127	0.7881	16.456	
	Mean	126	0.8165	17.049	

Table 4 : Energy cost of sowing in lines by hand

Time	Subjects	Average heart rate (beats min^{-1})	VO_2 ($l\ min^{-1}$)	Energy cost ($kJ\ min^{-1}$)	Grading of work
Before 9 am	I	135	0.9404	19.636	
	II	139	0.9327	19.474	
	III	144	1.0973	22.912	
	IV	159	1.0652	22.241	
	V	150	1.2151	25.371	
	VI	148	1.0519	21.964	Heavy
	VII	145	1.0861	22.678	
	VIII	140	0.905	18.896	
	IX	146	0.9819	20.502	
	Mean	145	1.031	21.519	
After 11 am	I	150	1.1129	23.237	
	II	164	1.2077	25.217	
	III	159	1.2773	26.670	
	IV	145	0.9238	19.289	
	V	169	1.4583	30.449	
	VI	158	1.1519	24.052	
	VII	155	1.2181	25.434	Very heavy
	VIII	165	1.1425	23.855	
	IX	156	1.0839	22.632	
	Mean	158	1.1752	24.537	

5. The maximum aerobic capacity of the selected nine subjects varied from 1.21 to 1.51 min^{-1}. Individual differences in the value of the maximum VO_2 max is due to the differences in the ability to supply oxygen to the muscles and also due to genetic factors (Nag and Chatterjee, 1981; Bridger, 1995) whereas Noakes (1988) suggested that failure of muscle power might be the reason for the variation of the VO_2 max among the subjects.

Table 5 : VO_2 max for selected subjects

Subjects	Maximum heart rate (beats min^{-1})	Maximum aerobic capacity (VO_2 max), $l\ min^{-1}$
I	174	1.39
II	173	1.31
III	168	1.39
IV	173	1.21
V	173	1.51
VI	168	1.25
VII	170	1.42
VIII	174	1.23
XI	179	1.32
Mean	172	1.33

The mean oxygen uptake in terms of maximum aerobic capacity of selected operations was calculated and the values are depicted in Table 6. For field operations with direct paddy seeder the oxygen uptake in terms of VO_2 max was varied from 57.57 % to 61.39 % while these values varied from 77.52% to 88.36% for sowing in lines manually. All values were much higher than that of the AWL limits of 35 per cent indicating that the selected operations could not be operated continuously for 8 hours without frequent rest-pauses.

Conclusion:

There existed a significant difference in the energy expenditure among the subjects for doing the same operation under similar conditions. The subjects expended more energy during sowing in lines than paddy seeder

Table 6 : Oxygen uptake in terms of VO_2 max for selected operations

Selected operation	Mean VO_2		VO_2max (%)		AWL (35 % of VO_2 max)
	Before 9 am	After 11 am	Before 9 am	After 11 am	
Sowing with paddy drum seeder	0.7603	0.8165	57.57	61.39	> AWL
Sowing in lines manually	1.031	1.1752	77.52	88.36	> AWL

operation to the tune of 36% before 9 am and 44% after 11 am. Direct seeder operation was graded as "moderately heavy" while it was "heavy" for manual sowing. The oxygen uptake in terms of VO_2 max was above the acceptable workload for both operations. The present investigation concluded that the use of direct seeder for sowing paddy seeds reduced the workload/ drudgery of women labourers in rice farming operations and enhancing their opportunities for remunerative employment and income using women friendly equipment.

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