RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 5 | Issue 2 | October, 2012 | 153 –157

Ergonomical evaluation of paddy transplanting operations in Odisha

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Received : 19.04.2012; Revised : 10.07.2012; Accepted : 25.08.2012

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ABSTRACT : Transplanting of paddy is a very tedious job mostly done by female agricultural workers during the peak season. Most of the agricultural implements are generally designed for the male workers keeping in view of their physiological and physical capabilities. Manual transplanting of nursery in puddled field is time consuming and involves lot of fatigue and drudgery. Now power operated transplanters are also available but the socio-economic condition does not allow them to adopt the modern technology. To ease the transplanting operation, four-row paddy transplanter has been developed by different research centers which were evaluated with 12 female agricultural workers in the age group of 18-45 years. A two-row paddy transplanter was developed at College of Agricultural Engineering and Technology, OUAT, Bhubaneswar as per the anthropometric and strength data to suit the female workers of Odisha. The mean value of age, weight, height, VO_2 max and body surface area was 31.1 years, 51.7 kg 152.3cm, 1.71 l/ min and 1.52m^2. Physiological parameters like heart rate, Oxygen consumption rate(OCR) and relative cost of work load (RCWL) etc were measured in different transplanting operations. It was recorded that the mean value of working heart rate and increased heart rate (Δ HR) was 137.5 and 67.5 beats / min in case of four row paddy transplanter against 127.7 and 47.1 beats/ min in two-row paddy transplanter. The oxygen consumption rate (OCR) and RCWL of these workers were also recorded to be 1.06 l min^{-1} and 62.4 per cent in four row transplanter and 0.91 l min^{-1} and 53.5 per cent in two-row paddy transplanter. The force required to operate the transplanter and field capacity was recorded to be 121.6 Nm, 111.3 Nm and 0.11 ha / hr, 0.05 ha / hr for four –row and two-row paddy transplanter, respectively. The two row paddy transplanter was observed to be suitable for female workers against four row paddy transplanter considering the physiological parameters into consideration.

KEY WORDS : Ergonomics, Manual transplanters, Heart rate, Oxygen consumption rate, relative cost of Work load, Field capacity

HOW TO CITE THIS PAPER : Mohanty, S.K., Mishra, J.N. and Ghosal, M.K. (2012). Ergonomical evaluation of paddy transplanting operations in Odisha. *Internat. J. Agric. Engg.*, **5**(2) : 153-157.

A number of manually operated farm tools been designed and developed by different organizations in the country. These are mainly designed for the male workers keeping their physical and physiological parameter into consideration. Women play a major role in the rice farming throughout the world right from sowing, transplantation and to post harvest processing and that rice farming is a back breaking exercise. Transplanting and associated activities shared 22.3 per cent of total time spent by farmers family women and 45.6 per cent of women wage earners. The overall participation of farm women in transplanting and related activities was 36.5 per cent, Arya (2004). Rice is shown either by direct seeding, known as broadcasting or by transplanting, while studying it is observed that 10 to 12 per cent higher yield was observed from transplanted rice than direct seeded rice. The transplanting operation is generally done by farm women. The 4-row manual paddy transplanting required skill so that the plant to plant and row to row spacing can be obtained. To case the transplanting in bending posture for through out a day, a 4-row transplanter available in the market has been ergonomically evaluated. However, the study was mostly done for female workers in the age group of 18-45 years to evaluate the equipment for its suitability for farm women and to modify it to their requirement if necessary. Physiological cost of work is influenced by the health of the operator, nutrition, basal metabolic rate (BMR) and energy expended while working. These measurements are also important from the safety point of view because whenever physical capacity of a person in exceeded, it is bound to cause considerable fatigue and decrease in the degree of alertness

of the subject, making the operation unsafe. Thus, studies on human energy measurements in agricultural operations can provide a rational basis for recommending methods and equipment for performing the agricultural operations more effectively and safely. Heart rate bears a linear relationship with the intensity of physical exercise and oxygen consumption especially if the steady state is reached.

Nag and Dutt (1980) concluded that, the transplanting of rice by hand demanded higher energy. Walking in a puddled field itself required 22 per cent more oxygen uptake and the heart rate was higher by 11 beats min^{-1}. As the transplanting operation needs to be done in a puddled field, the workers have to immerse their feet in mud (mid calf to knee depth) during their activities and it takes about 240 man-hours to plant one-hectare area. Baqui and Latin (1982) studies human energy expenditure in rice transplanting using IRRI manual rice transplanter in comparison with traditional hand transplanting by indirect calorimetry. The maximum energy expenditure in machine and hand transplanting were 3.79 and 3.09 kcal min^{-1}, respectively. Ergonomical evaluation of paddy transplanter was carried out and they observed that the mean heart rate and energy expenditure of the male subjects were 136.03 beats min^{-1} and 24.45 kJ min^{-1}. The corresponding oxygen consumption for this heart rate was 1.171 l min^{-1} and the operation of paddy transplanter was graded as 'heavy' Anonymous (2002). Karunanithi and Tajuddin (2003) studied the energy expenditure of male workers varied from 2.4 to 4.9 kcal min^{-1} whereas that of female workers varied from 2.3 to 3.5 kcal min^{-1}. Male workers consumed 2 to 10 per cent more energy than female workers for performing the same task

METHODOLOGY

Commercially available 4-row manually transplanter as shown in Fig. A was used for the study. Fifteen subjects in the age group 18-45 were selected for the study because they usually attain their highest strength level between 20 – 45 (Mc Ardle *et al.*, 2001). All the subjects were taken for the study, who were exposed and trained with the transplanter.

Fig. A : Operation of manually operated four row paddy transplanter

The experiment was conducted in the central farm of OUAT during the year 2007-08. Their heights, weight, body surface area, body mass index, ponderal index heart rate, OCR, BP were recorded. Polar heart rate monitor (S-810) and meta max-II were used to measure the HR and OCR before test and during operation. Their maximum aerobic power (VO_2 max) was also calibrated in the laboratory. In field operation the average data of WHR and OCR were measured from the average value of 6^{th} min to 15^{th} min of continuous operation for all treatments. The experiments were conducted for 10.00 am to 1.30 PM and 2.30 PM to 5.00 PM every day. The total duration of trial for each subject was kept as 25 minutes with 10 min rest before and after the work. The heart rate and OCR data from 6^{th} to 20^{th} minutes of work of each subject was considered for calculating the HR and OCR as the subjects WHR, OCR stabilized after 3-6 minute (Astrand and Rodahl, 1997).

Selection of subjects:

The subjects selected were in the age group of 18-45 years because they usually attain their highest strength level between 20-45 years (Mc Ardle *et al.*, 2001) and were chosen in such a way that the physical characteristics lie between the

Table A : Anthropometric data of the female workers (n=12)

Sr. No.	Body dimension	Female subjects of West Bengal (Tewari *et al.*, 2007)			Female subjects of Odisha (Satapathy and Mohanty, 2005)			Female subjects under study		
		5^{th}	Mean	95^{th}	5^{th}	Mean	95^{th}	5^{th}	Mean	95^{th}
1.	Height, cm	141	150	159	142	152	161	140	152	165
2.	Weight, kg	34	43	55	34	44	54	35	52	56
3.	Elbow height, cm	90	96	103	88	96	104	90	97	103
4.	Olecranon height, cm	85	91	98	86	94	101	89	95	106
5.	Illiocrystale height, cm	83	89	97	80	88	96	79	91	103
6.	Illiospinal height, cm	79	87	94	75	83	90	77	85	97
7.	Knee height, cm	38	42	46	37	44	50	39	45	51
8.	Arm reach from wall, cm	-	-	-	68	77	85	70	78	87

5th and 95th percentile values of the female operators of eastern India. The details of the physical measurements of these subjects are placed in Table 1. All the subjects were right handed.

Calibration of the subjects:

The subjects were calibrated in the laboratory with a treadmill to determine their maximum sustainable heart rate (HR_{max}) and oxygen consumption rate ($VO_{2\,max}$). The resting heart rate (HR_{rest}), oxygen consumption rate at rest ($VO_{2\,rest}$) and the blood pressure were measured at rest and 15 minute prior to any experiment. The HR_{work} and the OCR ($VO_{2\,work}$) was measured between 6th to 20th minute of work of each subject as it is considered that the heart rate gets stable after 3-5th minute of the work (Astrand and Rodahl, 1977). The average HR and OCR were taken as representative value for each subject for the working duration. The HR was measured by polar heart rate monitor (Model S-810) of Polar make with an accuracy of ± 1 beat/min. The polar transmitter detects the HR and transmits it to the wrist receiver. Twenty observations were taken between 6-20th minutes and the average was taken as the representative HR. The OCR was measured by Metamax – II having volume transducer, oxygen and CO_2 analyzer, temperature and pressure sensors. The accuracy of the oxygen analyzer is 0.1 per cent by volume. Twenty observations were taken between 6-20th minutes and the average was taken as the representative OCR.

■ RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Physical and physiological characteristics of female subjects:

The mean resting heart rate of the subjects was found to be 70.3 beats/min with a range of 65 - 75 beats/min and the corresponding mean OCR was 0.19 l/min. The maximum heart rate was in the range of 176 – 200 beats/min with a mean value of 188.2 beats/min. The mean $VO_{2\,max}$ was observed to be 1.70 l/min. In general, it was observed that the $VO_{2\,max}$ of female decreased with increase in age. Similar results of $VO_{2\,max}$ of Indian female subjects were also reported earlier (Nag *et al.*, 1988; Gite, 1996; Vidu, 2001). The mean blood pressure of the subjects was 111 mm Hg / 79 mm Hg which is normal in Indian women. The mean body mass index (BMI) was 22.32 kg/m^2 with the range as 20.5 – 23.25 kg/m^2 that indicated that all the subjects were in normal health as per the classification given by Garrow (1987).

Ergonomical evaluation of paddy transplanters:

Physiological responses parameters show the distress symptoms. Any departure from the equilibrium of the physiological responses quantifies the distress level for any work. The change is physiological responses depends on how much the subjects efforts in the process of doing a work.

The working heart rate (HR_{work}) of the women operators ranged from 106.2-118.3 beats/min with a mean value of 113.4 ± 3.8 beats/min in case of manual threshing in bending posture. The mean HR_{work} increased to 134.9 ± 3.71 beats/min while operating the two row paddy transplanter. The mean HR_{work} further increased to 137.4 ± 3.4 beats/min while operating the four row paddy transplanter. The work pulse (Ä HR) ranged between 37.2-48.2, 59.3-69.3 and 63.2-72.1 beats/min in manual , two row and four row paddy transplanter, respectively with corresponding mean value of 43.0 ± 3.3, 64.6 ±3.3 and 67.5 ± 2.5 beats/min in manual, two row and four row paddy transplanter, respectively.

The oxygen consumption rate (OCR) ranged from 0.50-0.62 l/min in random transplanting with a mean value 0.57 ± 0.04 l/min with female workers. While operating with two-row paddy transplanter the oxygen consumption rate (OCR) was observed to vary in the range of 0.80 – 1.10 l/min with the mean value of 0.99 ± 0.0b l/min. In case of four-row paddy transplanter higher oxygen consumption rate (OCR) in the

Table 1 : Physical and physiological characteristics of the subjects (n=12)

Physical and physiological characteristics	Range	Mean	Std. deviation
Age (Years)	18 - 44	31.1	8.06
Weight (kg)	45 - 59	51.7	4.91
Height (cm)	142.1 – 162.9	152.3	7.61
HR_{rest}, (beats/min)	65 - 76	70.3	3.17
HR_{max}, (beats/ min)	176 - 200	188.2	7.27
$VO_{2\,rest}$, (l/min)	0.16 – 0.24	0.19	0.02
$VO_{2\,max}$, (l/min)	1.56 – 1.81	1.7	0.08
Blood pressure (Sys/Dias), mmHg/mmHg	100/72-122/86	111 / 79	6.88 / 3.28
BSA (m^2)	1.37 – 1.69	1.52	0.12
BMI (kg/m^2)	20.5 – 23.25	22.32	0.82
Blood lactate accumulation (mM/l of blood)	0.9-1.3	1.2	0.08

Table 2 : Body parts discomfort of operators using 10 point scale

Sr. No.	Body parts	Body parts discomfort			
		Four-row transplanter		Two-row transplanter	
		Mean	Sd	Mean	Sd
1.	Foot	6.20	0.63	5.00	0.45
2.	Leg	6.50	0.58	5.54	0.65
3.	Knee	7.00	0.66	5.85	0.57
4.	Thigh	7.35	0.49	6.00	0.64
5.	Lower back	7.15	0.53	6.25	0.62
6.	Waist	8.60	0.74	6.85	0.49
7.	Chest	8.75	0.64	7.75	0.50
8.	Back	6.58	0.54	5.43	0.53
9.	Elbow	8.56	0.46	8.20	0.48
10.	Wrist	5.60	0.60	5.45	0.45
11.	Hand	7.25	0.65	4.65	0.57
12.	Shoulder	7.85	0.53	7.53	0.62
13.	Neck	6.65	0.45	5.35	0.70
14.	Face	5.85	0.65	4.50	0.43
Total body parts		6.70	0.63	5.95	0.59

range of 0.89-1.17 l/min and mean value of 1.06 ± 0.08 l/min was recorded. The relative cost of work load(RCWL) which is the per cent of VO_2max of each subject was recorded to be 33.4 ± 2.11, 58.46 ± 5.45 and 62.4 ± 4.37 per cent for random, two-row and four-row paddy transplanter, respectively. However, it was above the allowable limit in case of modified thresher. Gite and Singh (1997) reported that an OCR of 0.63 l/min and HR of 105 beats/min for women were considered acceptable for sustained work of 8 hours with intermittent rest.

The body parts discomfort score has been presented in Table 2. The overall body parts discomfort score was 6.7 ± 0.63 in case of four-row paddy transplanter and reduced to 5.95 ± 0.59 when operated by two-row paddy transplanter, which was a decrease of 11.19 per cent. Maximum discomfort of 8.75 was reported by the operators in chest working in four row paddy transplanter followed by waist (8.60), elbow (8.56), hand (7.25), shoulder (7.85), lower back (7.15), leg (6.50), in case of two-row paddy transplanter maximum discomfort of 8.20 was observed in elbow followed by both chest and shoulder (7.75, 7.53), waist (6.85). The body parts feeling discomfort in chest, waist and elbow may be due to the reason that the transplanters are operated in awkward posture ie walking, pulling and pushing the seedlings simultaneously.

Conclusion :

The ergonomic evaluation of two and four row paddy transplanter revealed that the physiological responses reduced in two row paddy transplanter from that of the four row paddy transplanter. The HR_{work}, ÄHR, OCR and relative cost of workload (% of $VO_{2\ max}$), ERR reduced from 137.49 to 134.94 beats/min, 67.49 to 64.67 beats/min, 1.06 to 0.99 l/min, 62.4 to 58.46 per cent, 22.16 to 20.76 kJ/min, respectively. The overall body parts discomfort was reduced by 11.19 per cent. More force in pulling the transplanter in forward direction by female subjects was obtained which were 121.6 N and 101.8 N for four row and two row paddy transplanters, respectively.

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