

Ergonomical Evaluation of Manually Operated Paddy Transplanters for Female Agricultural Workers in the State of Odisha

S. K. Mohanty¹ and M. K. Ghosal²

Abstract: A four-row manually operated paddy transplanter developed by CRRI; Cuttack has been ergonomically evaluated during 2013-14 with the twelve numbers of female agricultural workers in the age group of 18-45 years in the state of Odisha. Based on the ergonomical study of operating the four row manual paddy transplanter, a two-row paddy transplanter suitable for female workers of the state of Odisha has been developed at College of Agricultural Engineering and Technology, OUAT, Bhubaneswar with a view to popularize it among them. Both the transplanters have been evaluated and compared ergonomically among the same selected female agricultural workers. The mean value of age, weight, height, VO_2 (max) and body surface area (BSA) were measured to be 31.1 years, 51.7 kg 152.3cm, 1.71 l/min and 1.52m² respectively. It was observed that the mean value of working heart rate and increased heart rate (" HR) was 137.5 and 67.5 beats/min in case of four row paddy transplanter as against 127.7 and 47.1 beats/min in two-row paddy transplanter. The oxygen consumption rate (OCR) and relative cost of work load (RCWL) of these workers were also recorded to be 1.06 l min⁻¹ and 62.3 percent in four row transplanter and 0.99 l min⁻¹ and 53.5 percent in two-row paddy transplanter. The force required to operate the transplanter and field capacity were observed to be 121.6 N, and 0.11 ha/hr for four-row transplanter and 101.8 N and 0.05 ha/hr for 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 and discomfort of the body parts during working.

Key Words: Farm mechanization, Manual paddy transplanters, Ergonomics, Female agricultural workers.

INTRODUCTION

A number of manually operated farm tools has been designed and developed by different organizations in the country (Singh *et al.* 2007). These are mainly designed for the male agricultural workers keeping their physical and physiological parameters into consideration (Singh and Bockhop, 1985). Women play a major role mostly in the rice cultivation throughout the country starting from planting to harvesting and post-harvest operations (Karunanithi and Tajuddin, 2003). In Odisha, rice is one of the most important crops and staple food of the people (Patra and Nayak, 2001). The total area

cultivated for rice crop is around 4.2 million hectares out of 5.7 million hectares (Satpathy and Mohanty 2005). Transplanting of paddy is generally preferred over direct sowing of seeds due to severe problem of weeds (Obulamma and Reddy, 2002). Almost 70 percent of the transplanting and its associated activities are performed by the farm women. Transplanting of seedlings in puddled soil is the widely accepted practice in rice cultivation (Goel and Verma, 2000). With this practice, the yield increases by about 10%. It causes uniform crop stand with higher yield than direct seeded crop. But transplanting of rice seedlings is a very labour

¹ Research Engineer, AICRP on ESA, Dept. of Farm Machinery and Power, Orissa University of Agriculture and Technology (OUAT) Bhubaneswar, Odisha

² Professor, Dept. of Farm Machinery and Power, CAET, Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha

Corresponding E mail: mkgghosal1@rediffmail.com

consuming process. During the transplanting season, there occurs an acute shortage of labour. Optimum plant density and timely operation in the rice cultivation has been considered essential for maximizing the yield of rice (Khan and Gunkel, 1988; Syedul *et al.* 2000; Manjunatha *et al.* 2009; Chaudhary and Varshney 2003). Hence mechanical transplanting has been observed to be most promising option as it saves labour, minimizes stress and drudgery, ensure timely transplanting and attains optimum plant density contributing to higher productivity (Tripathi *et al.* 2004). The power operated transplanter is also available but the socio-economic condition of the farmers in the state does not permit them to purchase the same due to its high cost. To make the transplanting operation easy, four-row paddy transplanters have been developed by different research centers, but these are designed looking into the average working capability of only male agricultural workers. Ergonomically suitable and low cost drudgery reducing agricultural implements need to be designed and evaluated predominantly for women workers with a view to divert their male members to other profitable business for raising the income of the family. Hence attempt in this paper has been made to study the suitability of operating the four row manual rice transplanter for the female workers of the state of Odisha and to compare it with a 2-row manual rice transplanter with a view to get them involved in the activity of mechanical rice transplanting by using the most comfortable one. Ergonomical evaluation of the above rice transplanters (manually four row and two row rice transplanters) has therefore been studied for female workers in order to popularize them among them in the state of Odisha.

MATERIALS AND METHODS

A commercially available 4-row manual transplanter used for the study is shown in Fig.2. Twelve subjects who were exposed and trained with the traditional transplanting operation were selected for the study and were in the age group 18-45. The anthropometric data of the selected subjects have been mentioned in Table 1. All the subjects were involved in the operation of rice transplanting both by manual method (Fig. 1) and by manually

operated mechanical rice transplanters. The experiments were conducted in the Central Farm of OUAT, Bhubaneswar during the year 2013-14. The strength of the worker is generally attained the highest value between the age of 20-45 years (Astrand and Rodahl, 1977). The body surface area (BSA), body mass index (BMI), ponderal index, heart rate, OCR, BP was recorded for each subject. The instruments like polar heart rate monitor (S-810) and meta max-II were used to measure the HR (heart rate) & OCR (oxygen consumption rate) of the workers before the experiment and during the operation. Their maximum aerobic power (VO_2 max) was also calibrated in the laboratory. In field operation the average data of WHR (working heart rate) and OCR were measured from the average value of 6th min to 15th min of continuous operation for all treatments. The experiments were conducted from 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 6th to 20th minutes of work of each subject was considered for calculating the HR and OCR as the WHR and OCR of the subjects generally stabilize after 3-6 minute (Baqui and Latin, 1982).

A. 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 (Astrand and Rodahl, 1977) and were chosen in such a way that the physical characteristics lie between the 5th and 95th percentile values of the female operators of eastern India (Nag 1981). The details of the physical measurements of these subjects are mentioned in Table 2. All the subjects were right handed.

B. 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_{2max}). The resting heart rate (HR_{rest}), oxygen consumption rate at rest (VO_{2rest}) and the blood pressure were measured at rest and 15 minute prior to any experiment. The HR_{work} and the OCR (VO_{2work}) were measured between 6th to 20th minute

Table 1
Anthropometric data of the female workers (N=12)

Sl No.	Body dimension	Female subjects under study		
		5 th	Mean	95 th
1	Height, cm	140	152	165
2	Weight, kg	35	52	56
3	Elbow height, cm	90	97	103
4	Olecranon height, cm	89	95	106
5	Illiocrystale height, cm	79	91	103
6	Iliosspinal height, cm	77	85	97
7	Knee height, cm	39	45	51
8	Arm reach from wall, cm	70	78	87



Figure 1: Paddy transplanting in bending posture (local practice)

of work of each subject as it is considered that the heart rate gets stable after 3-5th minute of the work [2]. The average HR and OCR were taken as representative value for each subject during the working period. 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 value for heart rate. The OCR was measured by Metamax-II having volume transducer, oxygen and CO₂ analyzer, temperature and pressure sensors. The accuracy of the oxygen analyzer is 0.1% by volume. Twenty observations were taken between 6-20th minutes and the average was taken as the representative OCR.

RESULTS AND DISCUSSION

(A) 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 (Karunanithi and Tajuddin, 2003). The mean blood pressure of the subjects was 111 mm Hg / 79 mm Hg which is normal for the Indian women. The mean body mass index (BMI) was 22.32 kg/m² with the range of 20.5 - 23.25 kg/m² indicating all the subjects in normal health (Singh *et al.* 2007).

(B) Ergonomical Evaluation of Paddy Transplanters

The specifications of two-row and four-row manual transplanters have been mentioned in Tables 3 and 4 respectively. The ergonomical parameters of female agricultural workers in 20 minutes of operations of the above paddy transplanters along with the local method have been presented in Table 5. 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 in physiological responses depends on how much the subjects' efforts are put in the process of doing a work.

Fig. 1 shows the drudgery involved in doing the work of manual transplanting in bending posture. The working heart rate (HR_{work}) of the women operators were recorded to be in the range of 106.2-118.3 beats/min with a mean value of 113.4 \pm 3.8 beats/min in the local practice of transplanting. The mean HR_{work} increased to 127.7 \pm 3.71 beats/min while operating with the two row paddy transplanter (Fig. 3). The mean HR_{work} further increased to 137.4 \pm 3.4 beats/min while operating with the four row paddy transplanter (Fig 2). The

Table 2
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	1.71	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, <u>mM/l</u> of blood	0.9-1.3	1.2	0.08



Figure 2: Paddy transplanting with 4-row paddy transplanter



Figure 3: Paddy transplanting with 2-row paddy transplanter

Table 3
Technical specification and working of two row manual paddy transplanter

1. Name	OUAT two row rice transplanter
2. Type	Manual using mat type seedlings
3. Overall dimension L x W x H (mm)	
4. Weight (kg)	
5. Row spacing (cm)	24
6. Seedlings age (days)	20-25 with 4-5 leaf stage
7. Planting depth (cm)	3-4
8. Number of hills per square meter	30-35
9. Number of seedlings per hill	2-5
10. Cost of machine	Rs. 5000/-
11. Field capacity (ha/hr) (man-hours/ha)	0.008 (120)
12. Field efficiency	50-60%

Table 4
Technical specification and working of four row manual paddy transplanter

1. Name	CRRRI 4 row rice transplanter
2. Type	Manual using mat type seedlings
3. Overall dimension L x W x H (mm)	910 x 565 x 655
4. Weight (kg)	24
5. Row spacing (cm)	24
6. Seedlings age (days)	20-25 with 4-5 leaf stage
7. Planting depth (cm)	3-4
8. Number of hills per square meter	30-35
9. Number of seedlings per hill	2-5
10. Cost of machine	Rs. 9000/-
11. Field capacity (ha/hr) (man-hours/ha)	0.02 (50)
12. Field efficiency	50-60 %

Table 5
Ergonomical parameters of female agricultural workers (N=12)

Ergonomical parameters	Local Practices	2-row paddy transplanter	4-row paddy transplanter
HR _{rest}	70.33	70.27	70.7
HR _{work}	113.43	127.7	137.49
Work pulse,	43.09	64.67	67.
VO _{2rest}	0.19	0.20	0.20
VO _{2work}	0.57	0.99	1.06
RCWL (%)	33.47	58.46	62.3.
Area coverage, ha /day	0.03	0.05	0.11
Man days /ha	33	20	9

work pulse rate (Δ HR) ranged between 37.2-48.2, 59.3-69.3 and 63.2-72.1 beats/min in local practice, 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.

The oxygen consumption rates were recorded to be in the range of 0.50-0.62 l/min in random transplanting (broadcasting) 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 to 1.10 l/min with the mean value of 0.99 ± 0.06 l/min. In case of four-row paddy transplanter higher oxygen consumption rates (OCR) were recorded in the range of 0.89-1.17 l/min and mean value of 1.06 ± 0.08 l/min. The relative cost of work load (RCWL) which is the percentage of VO₂max of each subject was recorded to be 33.47 ± 2.11 , 58.46 ± 5.45 and 62.3 ± 4.37 % for random transplanting, two-row and four-row paddy transplanter respectively. It was reported that an OCR of 0.63 l/min and HR of 105 beats/min were considered acceptable for women workers for sustained work of 6 hours with intermittent rest. The body parts discomfort score has been presented in Table 6. 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 with two-row paddy transplanter indicating a decrease of 11.19%.

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

Table 6
Body parts discomfort of operators using 10 point ODR scale.

Sl 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

(6.50) and in case of two-row paddy transplanter, maximum discomfort of 8.20 was observed in elbow followed by both chest (7.75), shoulder (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 i.e. walking, pulling and pushing the seedlings simultaneously.

CONCLUSIONS

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} , ΔHR , OCR and relative cost of workload (% of VO_{2max}), EER (Energy expenditure rate) reduced from 137.49 to 127.7 beats/min, 67.49 to 64.67 beats/min, 1.06 to 0.99 l/min, 62.3 to 53.46% and 22.16 to 20.76 kJ/min respectively. The overall body parts discomfort reduced by 11.19% in case of two row transplanter. The force requirements in pulling the transplanter in forward direction by female subjects were 121.6 N and 101.8 N for four row and two row paddy transplanters respectively.

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