



Ergonomics of Manual Transplanting Operations with Female Workers in Eastern India

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ABSTRACT

Rice is the most important cereal food crop of India. The total production of rice is estimated at record 116.42 million tones and has area of 43.79 million hectares under rice cultivation. Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. Manual hand transplanting consumes a lot of energy and time and full of fatigue, but the poor socio-economic condition of the farmers does not allow them to adopt power operated transplanter. Transplanting operation by different research centers have been developed as two-row and three-row paddy transplanter. Keeping this in view fifteen female subjects were selected in the age group 18-45 years. The HR work, HR rest, Oxygen Consumption Rate (OCR), Relative Cost of Work Load (RCWL) and Energy Expenditure Rate (EER) were reduced from 130.8 beats/min to 127.7 beats/min, 70.6 beats/min to 70.2 beats/min, 1.02 l/min to 0.9 l/min, 59.6 percent to 57.8 percent and 21.3 to 20.7 from three-row transplanter to two-row transplanter. All these planters have their own limitations and restrictions. Hence, the present study was undertaken to evaluate the transplanters which will be helpful for the farmers to select the suitable transplanter. The transplanters were evaluated in terms of planting parameters like missing hills, floating hills and buried hills. The field capacity, planting efficiency and field efficiency were also measured to recommend a suitable machine. Three-row manual rice transplanter was found to be better in performance on the basis of total unproductive hills (6.9%), planting efficiency (93%), and field efficiency (72%). The draft requirement for two-row and three-row manual rice transplanter was found to be 7.2 kg and 8.2 kg respectively. The cost of operation for two-row and three-row manual rice transplanter was found to be Rs 7300/ha and Rs 9250/ha respectively.

Keywords: Transplanter; Working heart rate; Oxygen consumption rate; Missing hill; Buried hill

INTRODUCTION

Rice is the basic food crop and being a tropical plant, it flourishes comfortably in hot and humid climate. Rice is mainly grown in rain fed areas that receive heavy annual rainfall. That is why it is fundamentally a Kharif crop. It demands temperature of around 25 degree Celsius and above and rainfall of more than 100 cm. Rice is the staple food of eastern and southern parts of India. For the year 2018-2019 area under rice cultivation in eastern India is about 19.88 million hectares with 45.43 million tons of production (Source: Directorate of Economics and Statistics 2018-19). Rice is a semi-aquatic plant which grows in a variety of soils provided water is available. Mainly, there are two

methods of planting rice viz. direct seeding and transplanting. In direct seeding, the seeds are sown (either by row seeding or broadcasting of germinated or ungerminated seeds) in the field under dry or wet condition at the beginning of rainy season [1]. This method of seeding requires minimum labor and well suited for upland farms. However, it suffers from few limitations i.e., the rate of germination of all seeds is not uniform, heavy rain extricate the seeds from the soil, seeds are vulnerable to birds. Due to these inherent demerits of direct seeding, transplanting method is preferred. In transplanting process, seedlings are raised in nursery at least a month before planting. These seedlings are then planted manually or mechanically in the puddled soil [2]. Puddling is achieved by repeated intensive

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tillage under ponded-water conditions, which helps in reducing water losses through percolation and controlling weeds by water stagnation in rice fields. The mechanical transplanters are available in the market which uses mat type of nursery for transplanting, but for raising mat type of nursery it requires a lot of skill and management in comparison to the traditional root wash type of nursery. In paddy cultivation transplanting is very drudgeries operation in overall paddy cultivation processes and 22.3% of total time is spent in this operation [3]. Generally, it is found that the production increases 10%-12% in transplanting from direct sowing. Therefore, the study is conducted to compare the ergonomically field evaluation of different manual transplanters i.e., two-row manual rice transplanter (root wash type) (Figures 1 and 2) and three-row manual rice transplanter (mat type) (Figure 3) with traditional hand transplanting [4].



Figure 3: Three-row manual rice transplanter.

METHODOLOGY

Selection of subjects

For this ergonomical evaluation 15 subjects were selected those have experience of transplanting. The selected fifteen subjects were in the age group of 18-45 years as at this age maximum strength can be utilized, they cover the 5th to 95th physical characteristics of total female population shown in Table 1 [5].



Figure 1: Traditional method of rice transplanting.



Figure 2: Two-row manual rice transplanter (root wash type).

Physical and physiological parameters	Range	Mean	Std. Deviation
Age, years	15-45	31.1	8.06
Weight, kg	45-59	51.7	4.91
Height, cm	142.1-163	152.3	7.61
HR beats/min	rest, 65-76	70.3	3.17
HR beats/min	max, 176-200	188.2	7.27
VO2 l/min	rest, 0.16-0.24	0.19	0.02
VO2 l/min	max, 1.56-1.81	1.71	0.08
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
Experience, years	3-25	-	-

Table 1: Physiological parameters of selected subjects (N=15).

Calibration of subjects

The selected subjects are calibrated in laboratory before conducting the test. To get the maximum heart rate, maximum oxygen consumption, heart rate at rest the subjects were undergone treadmill test. The average value of fifteen subjects was taken as representing value for working duration. The heart rate was measured by Polar heart rate monitor and oxygen uptake was measured by K4b2. The Energy Expenditure was calculated by the formula [6]:

$$EER (kJ/min) = OCR (l/min) \times 20.88$$

The detail of specifications of two-row manual rice transplanter (root wash type) and three-row manual rice transplanter (mat type) are placed in Table 2.

SL. No.	Parameter	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)
1	Type of machine	Manual	Manual
2	Type of nursery used	Root washed	Mat type
3	Type of steering	Manual	Manual
4	Overall dimensions L × W × H (cm)	164 × 50 × 94	600 × 600 × 940
5	Planting mechanism	Four bar mechanism	Fixed fork
6	Row spacing (cm)	25	24
7	Hill to hill distance (cm)	25	Adjustable

Table 2: Technical specifications of different transplanters.

Statistical analysis

One way ANOVA test assuming unequal variances was performed among the female rice cultivators to find out whether there is any significant difference in ergonomical parameters of female workers shown in Table 4 for the chosen level of significance (P<0.001). Statistical analysis was performed using the statistical package IBM-SPSS statistics (Version=20) [7].

RESULTS AND DISCUSSION

Comparative ergonomical evaluation of traditional method of transplanting, two-row manual rice

transplanting (root wash type) and three-row manual transplanting (mat type)

The ergonomical parameters of the female subjects changed according to the type of transplanting procedure from rest value after 30 minutes of work. These values were given in the Table 3.

SL. No	Parameter	Traditional method of transplanting	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)
1	HR _{rest} (beats/min)	70.3	70.2	70.6
2	HR _{work} (beats/min)	113.4	127.7	130.8
3	Work pulse (beats/min)	43.0	57.5	60.2
4	VO _{2 rest} (l/min)	0.19	0.20	0.20
5	VO _{2 work} (l/min)	0.75	0.9	1.02
6	EER, kJ/min	15.3	20.7	21.3
7	RCWL (% of VO _{2 max})	33.4	57.8	59.6
8	Area coverage, ha/day	0.054	0.096	0.108
9	Man days/ha	17	16.6	11.3
10	Continuous operating time, min	12	24	27

Table 3: Variation of ergonomical parameters.

Heart rate

The working heart rate (HR_{work}) of the subjects when the paddy transplanting was performed with conventional method ranged from 110.5 to 122.6 beats/min with a mean value of 116.3 ± 3.61 beats/min. The corresponding values with two-row and three-row transplanter were 123.78 to 156.45 and 136.37 ± 10.88 beats/min and 126.42 to 163.3 and 142.4 ± 10.56 respectively. This showed a significant (P<0.001) increase of mean HR_{work} by 17.1% and 22.3% for two and three-row rice transplanters. The mean work pulse (HR) with manual transplanting was observed to be 63.93 ± 3.16 beats/min but reduced to 54.16 ± 5.74 and 54.8 ± 4.89 beats/min with two-row

and three-row mechanized method. Work pulse of 40 beats/min is the allowable limit for sustained working [9].

Oxygen Consumption Rate (OCR)

OCR was found to be 0.42 ± 0.13 , 0.6 ± 0.12 and 1.28 ± 0.35 l/min, respectively for manual, two-row and three-row mechanized method of paddy transplanting. ANOVA test showed a significant decrease (42.8%) in OCR with two-row root wash type transplanting compare to manual transplanting ($P < 0.001$). In the 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 rests [10].

Energy Expenditure Rate (EER)

EER with manual transplanting was observed to be 17.8 ± 1.59 kJ/min whereas with two-row and three-row transplanter it slightly increased to 18.68 ± 1.72 and 20.15 ± 1.96 kJ/min.

Overall Discomfort Rating (ODR)

ODR was 8.4 ± 1.43 , 4.62 ± 1.46 and 4 ± 1.11 with manual, two-row and three-row mechanical method respectively. ODR decreased significantly ($P < 0.001$) with paddy transplanter (Table 4). The body parts with maximum discomfort as expressed by the operators were right upper leg, lower back, right lower leg, right foot, right upper arm and right in the descending order. The body parts discomfort was mainly due to the effort to maintain a static and bending posture while manual transplanting [11].

Parameter	Traditional method of transplanting		Two-row manual rice transplanter (root wash type)		Three-row manual rice transplanter (mat type)		F-value	P-value
	Rang	Mean \pm S.D.	Rang	Mean \pm S.D.	Rang	Mean \pm S.D.		
HR work (beats/min)	110.5-122.6	116.3 \pm 3.61	123.7-156.4	136.3 \pm 10.88	126.4-163.3	142.4 \pm 10.56	34.35	<0.001
Work pulse (beats/min)	59.8-70.8	63.93 \pm 3.16	46.3-64.6	54.16 \pm 5.74	48.3-63.4	54.8 \pm 4.89	19.93	<0.001
VO2 work (l/min)	0.69-1.1	0.42 \pm 0.13	0.45-0.9	0.6 \pm 0.12	0.85-2.01	1.28 \pm 0.35	27.06	<0.001
EER, kJ/min	15.3-20.54	17.8 \pm 1.6	16.4-21.3	18.68 \pm 1.72	17.2-22.7	20.15 \pm 1.96	6.49	0.003

Parameter	Traditional method of transplanting	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)	F-value	P-value			
ODR	6.5-10.4	8.4 \pm 1.43	3-6.6	4.62 \pm 1.4	2.5-5.4	4 \pm 1.11	15.62	<0.001
Field Capacity (ha/day)	0.003-0.009	0.007 \pm 0.002	0.013-0.016	0.015 \pm 0.013	0.015-0.018	0.016 \pm 0.013	36.38	<0.001
Man days/ha	17-19	17.8 \pm 0.8	15.5-18	16.7 \pm 0.9	11.3-14.2	12.2 \pm 1.2	45.90	<0.001

Table 4. Comparison of different parameters with different transplanting methods.

Self-reported pain/Discomfort

Workers were asked few questions about perceived pain/discomfort, which lasted, for at least 24 hours. Majority of the respondents were feeling pain and discomfort in different body parts (Figure 4) (Tables 5 and 6).

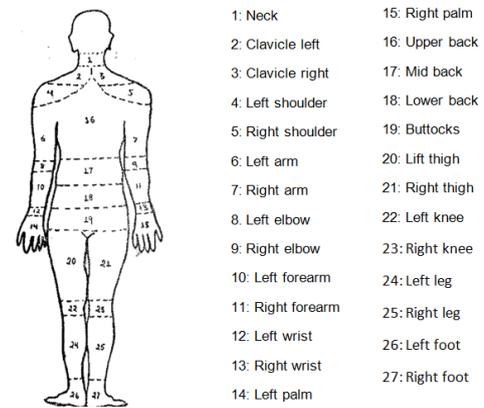


Figure 4: Body parts discomfort score chart.

S. No.	Body parts	Traditional method of transplanting	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)
1	Neck	11(68)	32(20)	2(15)
2	Right shoulder	6(36)	12(80)	7(45)
3	Right wrist	8(52)	12(80)	8(50)
4	Lower back	12(76)	7(45)	4(25)
5	Buttocks	4(24)	6(40)	11(72)
6	Upper arm	5(28)	8(50)	8(50)
7	Thighs	7(44)	7(45)	7(45)
8	Hips	7(44)	9(60)	6(40)
9	Feet	7(48)	8(50)	9(60)

Table 5: Discomfort in different body parts of the subjects during different transplanting methods.

Traditional method of transplanting	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)
Mid back	Left knee	Buttocks
Lower back	Right knee	Lift thigh
Buttocks	Mid back	Right thigh
Lift thigh	Lower back	Clavicle left
Right thigh	Neck	Clavicle right
Right wrist	Clavicle left	Left shoulder
Left wrist	Clavicle right	Right shoulder
Left palm	Left shoulder	Left forearm
Right palm	Right shoulder	Right forearm
Right shoulder	Left arm	Left wrist
	Left elbow	Right wrist
	Left forearm	Left palm
	Left wrist	Right palm
	Left palm.	

Table 6: Body parts feeling discomfort during different transplanting methods.

68 percent female who were involved in manual transplanting had pain and discomfort in neck. 45 per cent female respondents who were involved in manual uprooting were suffering from neck pain.

In shoulders cent per cent respondents reported discomfort during manual transplanting and uprooting [12].

Total three-fourth of the total respondents reported pain in elbows during manual transplanting and majority (85 per cent) respondents were suffering from elbow pain.

About majority of workers feeling pain and discomfort in buttocks, right wrist, hip and feet in two-row manual rice transplanter (root wash type) and three-row manual rice transplanter (mat type), it is due to continuous movement of right palm for cranking operation and due to backward movement while operating the machines [13]. Body parts discomfort score chart is shown in Figure 4 and measurement of different bending position angles shown in Figure 5 and results obtained are shown in Table 7.

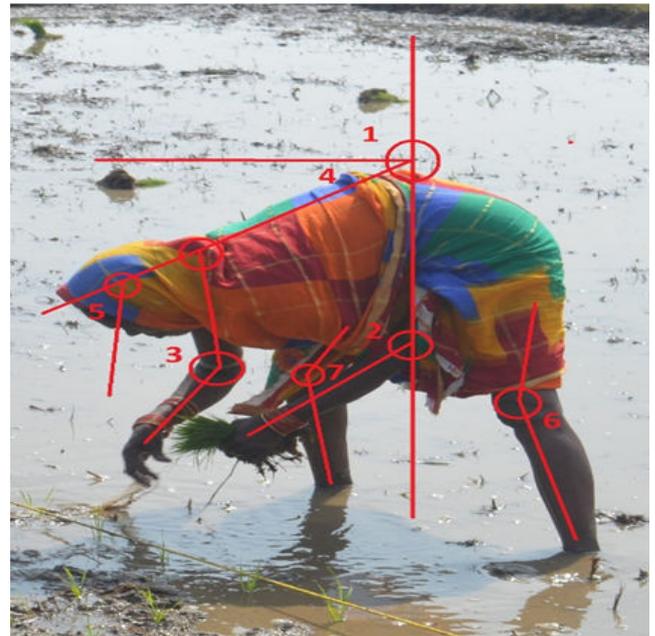


Figure 5. Measurement of different bending position angles.

Angle in degrees	Subject 1	Subject 2	Subject 3
Waist angle with vertical line (1)	110	105	115
Left elbow (2)	105	100	103
Right elbow (3)	170	172	175
Waist angle with horizontal line (4)	20	15	25
Eye (5)	60	55	57
Left knee (6)	120	118	115
Right knee (7)	120	115	116

Table 7: Different bending position angles (in degrees) during traditional rice transplanting.

Comparative field evaluation of different transplanters

The results obtained from the present study have been summarized in Table 8.

SL. No.	Parameter	Traditional method of transplanting	Two-row manual rice transplanter (root wash type)	Three-row manual rice transplanter (mat type)
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1	Number of seedlings/hill	2-3	2-3	2-4
2	Hill to hill distance, mm	Adjustable	25	Adjustable
3	Number of hills/m ²	26-28	24	30-35
4	Missing hills, %	-	2.08	4.58
5	Floating hills, %	-	1.47	1.54
6	Buried hills, %	-	1.53	0.89
7	Total unproductive hills, %	-	5.08	6.89
8	Planting efficiency, %	-	91.96	93
9	Draft, kg	-	7.3	8.2
10	Field capacity, ha/h	0.009	0.016	0.018
11	Field efficiency, %	-	75	72
12	Cost of operation (Rs/ha)	15000	7300	9250

Table 8: Comparative field evaluation of different transplanters.

CONCLUSION

The ergonomical analysis of different paddy transplanting methods revealed that the physiological response reduced in two-row paddy transplanter from that of three-row and manual paddy transplanter. The HR work, HR rest, OCR, RCWL and EER were reduced from 130.8 beats/min to 127.7 beats/min, 70.6 beats/min to 70.2 beats/min, 1.02 l/min to 0.9 l/min, 59.6% to 57.8% and 21.3 to 20.7 from three-row transplanter to two-row transplanter. Missing hills may be primarily due to the entanglement of roots, non-uniformity of seedling in the mat and buckling of mats. Maximum missing hills permissible is 8%. It was found minimum for two-row manual transplanter (2.08%) followed by three-row manual transplanter (4.58%). Floating hills may have occurred due to poor anchorage of seedlings in

the soil. Maximum floating hills permissible is 3%. It was found to be minimum in case of two-row manual transplanter (1.47%) followed by three-row transplanter (1.54%). Buried hill occurred due to the flow of the soil along with the transplanter due to higher float sinkage. Buried hills was found minimum in case of three-row manual transplanter (0.89%) and maximum in case of two-row transplanter (1.53%). Planting efficiency was 91.96% and 93% for two-row and three-row manual transplanter respectively. The draft requirement for two-row and three-row manual transplanter was found to be 7.2 kg and 8.2 kg respectively. The cost of operation for two-row and three-row manual transplanter was found to be Rs 7300/ha and Rs 9250/ha. The field capacity and field efficiency were found to be as follows for two-row manual transplanter (0.45 ha/h, 75%) and for three-row manual transplanter (0.016 ha/h, 72%) respectively. It can be concluded that manual uprooting and transplanting is more physically demanding activity as compared to mechanical transplanting activity. Most of the times workers adopted standing, bending and sitting posture for performing manual rice transplanting. Thus, it can be concluded that through mechanization, the level of MSDs can be reduced or minimized.

REFERENCES

1. Das FC. Status and Prospect of Agricultural Mechanization in Cambodia. *J Agriculture*. 2014.
2. Das FC. Rice Knowledge Management Portal. DKC. 2011.
3. Gite LP. Ergo-economical analysis of different paddy transplanting operations in Eastern India. *J Agriculture*. 2013; 6(6):23-27.
4. Goel, A.K, Swain, S Debaraj, B. Effect of seedling age on performance of rice transplanter. *J agricultural Mech*. 2008; 40 (3):41-46.
5. Goel AC, Verma KS. Comparative study of directly seeding and transplanted rice. *Indian J Agril Res*. 2000; 34(3):194-196.
6. Nag PK, Dutt P. Circulo-respiratory efficiency in some agricultural work. *Appl Ergonomics*. 1980; 11:81-84.
7. Ojha P, Seema K. An Ergonomic study on human drudgery and musculoskeletal disorders by rice transplanting. *Stud Home Com Sci*. 2012; 6(1):15-20.
8. Pradhan S, Mohanty SK. Ergo-economic analysis of different paddy transplanting operations in eastern India. *J Agril Veterinary Sci*. 2014; 6 (6):23-27.
9. Pragya O, Seema K. Analysis of different paddy transplanting methods in northern India: Ergo-economical study. *J Applied Natural Sci* 2014; 6 (2):654-658.
10. Singh G, Sharma TR, Bockhop CW. Field performance evaluation of a manual rice transplanter. *Journal of Agril Engg Research*. 1985; 32(3):259-268.
11. Satapathy GC, Mohanty SK. Collection and compilation of anthropometric and strength data of male and female agricultural workers of Odisha. *Ergon Safety Agril*. 2005; 53:1-10.
12. Singh S, Vatsa DK. Performance evaluation of PAU manual paddy transplanter in hills of Himachal Pradesh. *Agril Engg*. Today 30 (3): 19-25.
13. Dash T. Development and evaluation of root wash type two-row manual rice transplanter. M.Tech (Agril. Engg) thesis Odisha University of Agriculture and Technology, Bhubaneswar, India. 2020.