



Analysis of different paddy transplanting methods in northern India: Ergo - economical study

Pragya Ojha* and Seema Kwatra

Department of Family Resource Management, College of Home Science, G. B. Pant University of Agriculture & Technology, Pantnagar (Uttarakhand), INDIA

*Corresponding author. E-mail: ojha.pragya063@gmail.com

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Abstract: Rice (*Oryza sativa* L.) production constitutes the major economic activity and a key source of employment for the rural population of India. Manual transplanting of paddy in puddle field is a very tedious job and involves lot of fatigue and drudgery. To reduce the labour demand and time consumption, power operated transplanters are also available but the poor socio- economic conditions of Indian farmers restrict them to adopt modern technology. Keeping this in view, the present study was planned to compare the economic cost and the rate of human drudgery among female farm workers, during manual hand transplanting with the power operated eight- row paddy transplanter. For the ergonomical evaluation, twenty female subjects were selected in the age group of 20- 55 years. Physiological parameters like HR, energy expenditure, TCCW and PCW etc. were measured in different transplanting operations. The mean value of working heart rate was assessed to be maximum 138.32 ± 7.67 beats/ min in manual hand transplanting and 110.12 ± 5.79 beats/min in eight- row paddy transplanter. The energy expenditure rate was measured 18.40 ± 0.95 kJ/min in local transplanting method and reduced to 15.17 ± 1.68 kJ/min with paddy transplanter. TCCW was found to be 1965.5 ± 63.66 beats for manual transplanting of paddy and 770.58 ± 39.93 beats by the use of paddy transplanter whereas the PCW was calculated 227.98 ± 22.17 in traditional method and 85.23 ± 2.64 in improved method. The economic cost of mechanized transplanting was 47% less than conventional method.

Keywords: Drudgery assessment, Economical cost, Female agriculture workers, Paddy transplanting, Physiological parameters

INTRODUCTION

Rice is cultivated in 113 countries and it is the staple food of more than 50 percent population of the world. About 90 percent rice area exists in Asia (Das, 2012). India with highest area under the crop is the second largest producer of rice in the world after China but ranks 35th with respect to its productivity (Mohanty *et al.*, 2008). The average rice yield in India is only 2.09 t/ha, as compared to 6.58 t/ha in Japan and world average of 3.91 t/ha (Dinesh and Shivay, 2007). Rice is cultivated in almost all the states of India but most of its cultivation is concentrated in the river valleys, deltas of rivers and coastal plains. The main rice producing states are Tamil Nadu, West Bengal, Andhra Pradesh, Bihar, Punjab, Orissa, Uttar Pradesh, Karnataka, Assam and Maharashtra (Mohanty *et al.*, 2008).

During various rice cultivation operations agriculture workers are suffered with high physical strain and fatigue. In overall paddy cultivation process manual rice transplanting operation is one of the drudgery prone and back- breaking activity. Due to severe weed

problem and grazing in lean season the farmers prefer transplanting than direct sowing of seeds. Generally it is found that the production increases 10-12 percent in transplanting from direct sowing. Manual paddy transplanting is a labour intensive operation which requires 200-250 man-h/ha. During peak season labourers are not available (Das, 2012).

Therefore modern agricultural technologies play a vital role in developing countries. Mechanization increases land productivity by timely completion of farm operations. It increases labour productivity and reduce drudgery of human and animals. It increases production by precision and efficient placement of inputs such as seed, fertilizer, chemicals and irrigation water. Mechanization decreases cost of production by reducing labour needed for particular operation and economy of power and other inputs (Das, 2012).

Though modernization of agriculture is taking place at a rapid pace, but the jobs attended by women remain more or less the same (Kishtwaria *et al.*, 2009). The strength and efficiency of the female agricultural workers is 70 percent of male workers (Astrand and Rodahl, 1986). Manual rice transplantation is a tedious

exercise but women farm workers play a chief role in this activity throughout the world. 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 (Mohanty *et al.*, 2012). Keeping this in view, an attempt was made to compare economic cost and the ergonomic aspects of quantum of drudgery with conventional and mechanized method of paddy transplanting. This research was aimed to know the rate of physiological workload on the female agricultural workers while performing the manual paddy transplanting and reduce their physiological fatigue and human drudgery by introducing an improved technology and ergonomical evaluation both the methods.

MATERIALS AND METHODS

Selection of subject and field: The ergonomical evaluation of paddy transplanting was conducted with female agricultural workers in Tarai agro- climatic zone of Udham Singh Nagar district of Uttarakhand state, India in the month of June- July. Twenty female subjects in the age group of 20- 55 years were selected because they usually attain their highest strength level between 20-45 years (Mc Ardle *et al.*, 2001). The paddy transplanting operation was done for 7:00 A.M.12:30 P.M. and 2:00 P.M. to 5:30 P.M. For the comparison of drudgery and economical cost in mechanized and conventional method, agriculture women performed the paddy transplantation activity with manual transplanting in bending posture and power operated eight row paddy transplanter adopted from Department of Farm Machinery and Power Engineering, College of technology, GBPUA&T, Pantnagar. The detail of specifications of power operated 8 row paddy transplanter is given in Table 1. Field women performed the continuous transplanting operations for 50 minutes and taking 10 minutes break. For the assessment of physical and physiological parameters of female workers heart rate, blood pressure, VO_2 max, body mass index (BMI), age, weight, energy expenditure, total cardiac cost of work (TCCW) physiological cost of work (PCW), rate of perceived exertion and overall discomfort rating were taken into consideration. The physiological parameters were assessed at about 28-32° c temperature and 90-92 percent humidity. Before going to field HR rest, blood pressure, and oxygen consumption rate of the subjects were measured. After 50 minutes of continuous operation HR work, VO_2 , energy expenditure, total cardiac cost of work, physiological cost of work, rate of perceived exertion and overall discomfort rating were measured.

Calibration of subjects: The subjects were calibrated with the Harvard step stool test to determine their physical fitness index by using following formula:
Physical fitness index = Duration of stepping \times 100 / Sum of 1st, 2nd and 3rd minute recovery heart rate

The physical fitness of the respondents was calculated and interpreted by using physical fitness index (PFI) score given by Verghese *et al.* (1994) and the respondents were ranked from poor to excellent. 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 blood pressure of the samples was measured by digital blood pressure monitor and the heart rate was measured by Polar heart rate monitor and recorded as HR=beat/min.

The oxygen consumption rate was calculated by following formula: $VO_2 = 0.023 \times$ Body weight (kg) - $0.034 \times$ Age (years) + 1.65

The body mass index of subjects was calculated by dividing square of height (m^2) to weight (kg).

Assessment of physiological parameters: Following formula was used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW).

Total cardiac cost of work = cardiac cost of work + cardiac cost of recovery.

$TCCW = CCW + CCR$; where

$CCW = AHR \times$ Duration of activity; where

$AHR =$ Avg. working HR- Average resting HR

$CCR = (Avg. recovery HR - Average resting HR) \times$ Duration.

Physiological cost of work = Duration of work/TCCW

Energy Expenditure was calculated using the formula:

$EE (Kj/min) = 0.159 \times HR$ (beats/min) - 8.72

Overall discomfort rating (ODR): ODR was measured on a 10-point visual analogue scale (0- no discomfort, 10-extreme discomfort) that is an adoption of a technique developed by Corlett and Bishop (1976). A scale of 70 cm length was fabricated having 0 to 10 digit marked on it equidistantly. A movable pointer was provided to indicate the rating. At the end of each trial, the subjects were asked to indicate their overall discomfort rating on the scale.

Rate of perceived exertion: The category scale with ratio properties for intermodal and inter individual comparison, constructed by Borg (1980) was used to assess the rate of perceived exertion of female workers after paddy transplanting activity.

Statistical analysis: Two-sample t-test assuming unequal variances was performed among the female rice cultivators to find out whether there is any significant difference in ergonomical parameters of workers for the chosen level of significance ($P < 0.0001$). Statistical analysis was performed using the statistical package IBM SPSS statistics (Version =20).

RESULTS AND DISCUSSION

The mean heart rate of subjects at rest is found in the range 70.25 to 76.50 whereas the mean value was 72.96 and the corresponding oxygen consumption was 0.16 l/min. The maximum VO_2 of female subjects were found to be 1.82 l/min and lies in the range 1.2-2.6.

The mean rate of the oxygen consumption of the 20-40 years age group workers was 1.79 l/min whereas the average range of VO_2 of the female workers of above 40 years was calculated as 1.34 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; Vidhu, 2001).

The mean body mass index (BMI) was 22.05 kg/m² with the range as 19.3 – 24.36 kg/m² that indicated that all the subjects were in normal health as per the classification given by WHO (2000). Mean rate of blood pressure was 117.5mmHg/80 mmHg which is normal in Indian women (Table 2).

Ergonomic evaluation of paddy transplanting: The ergonomic parameters of the female subjects changed according to the type of transplanting procedure from rest value after 50 minutes of work. These values were given in the table 3. Physiological response parameters changed due to work represents the level of fatigue or comfort in a comparative way and according to these how much the workers can work efficiently.

Heart rate: The working heart rate (HR work) of the subjects when the paddy transplanting was performed with conventional method ranged from 123.78 to 156.45 beats/min with a mean value of 138.32 ± 7.67

beats/min. The corresponding values with eight row transplanter were 100.56 to 121.65 and 110.12 ± 5.79 beats/ min, respectively. This showed a significant ($P<0.0001$) decrease of mean HR work by 20.38 %. The mean work pulse (Δ HR) with manual transplanting was observed to be 65.7 ± 0.9 beats/min but reduced to 51.5 ± 1.6 beats/min with mechanized method; a reduction of Δ HR by 21.46 %. Work pulse of 40 beats/ min is the allowable limit for sustained working (Kroemer *et al.*, 1997).

Oxygen consumption rate (OCR): OCR was found to be 1.14 ± 0.43 and 0.68 ± 0.12 l/min, respectively for manual and mechanized method of paddy transplanting. T-test showed a significant decrease (40.35%) in OCR with mechanized method ($P<0.0001$). 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 rests (Mohanty *et al.*, 2008).

Energy expenditure rate (EER): EER with manual transplanting was observed to be 18.40 ± 0.95 kJ/ min whereas with eight row transplanter it decreased to 15.17 ± 1.68 kJ/min (17.55 %). The total cardiac cost of work (TCCW) was found to be 1965.4 and 770.58 in case of manual and mechanical method respectively. With paddy tranplanter, the TCCW reduced by 60.79%. The corresponding physiological cost of work (PCW) was 227.98 and 85.23 in manual and mechanical transplanting, respectively.

Overall discomfort rating (ODR): ODR was 7.95 ± 1.09 and 4.15 ± 0.65 with manual and mechanical method respectively. ODR decreased significantly ($P<0.01$) by 47.80 % with paddy transplanter. The body parts with

Table 1. Specification of power operated eight row paddy transplanter.

Details	Specifications
Type	Single wheel driven using mat type rice nursery
Dimensions(L×W×H)	2410×2130×1300 (mm)
Engine (hp)	4.0, air cooled diesel
Number of rows	8
Row spacing (mm)	238
Hill-to-hill spacing (mm)	100 -200
Working speed (km/h)	1.5-2.0
Speed of travel on road (km/h)	8.24
Field capacity (ha/h)	0.13 -0.20
Weight (kg)	320
Type	Single wheel driven using mat type rice nursery
Dimensions(L×W×H)	2410×2130×1300 (mm)
Engine (hp)	4.0, air cooled diesel
Number of rows	8

Table 2. Physiological parameters of selected subjects (N=20).

Physical characteristics of subjects	Range	Mean± S.D.
Age	(20-55)	39.05±9.03
Height, cm	(145.26-158.89)	151.62±3.60
Weight, kg	(46.36-58.32)	51.11±3.34
BMI, Kg/m ²	(19.3-24.36)	22.05±1.45
HR rest, beats/min	(70.24-76.51)	72.96±1.91
HR max, beats/min	(176-200)	188.2±7.27
VO_2 rest, l/min	(0.12- 0.24)	0.16±0.03
VO_2 Max, l/min	(1.2-2.6)	1.82±0.41
Blood pressure (Sys/Dias), mmHg/mmHg	(110/70-125/90)	117.5/80±10.6/0/14.14
VO_2 max, l/min	(1.2-2.6)	1.82±0.41

Table 3. Comparative ergonomical evaluation of manual transplanting with power operated eight row rice transplanter (N=20).

Ergonomical parameters	Manual rice transplanting		Eight row paddy transplanter		% Decrease	t cal	P value
	Range	Mean±S.D.	Range	Mean± S.D.			
HR work (beats/min)	(123.78-156.45)	138.32±7.67	(100.56-121.65)	110.12±5.79	20.38	13.12**	<0.0001
Work pulse (beats/min)	(59.8-70.8)	65.7±0.9	(45.3-59.5)	51.6±1.6	21.46	34.34**	<0.0001
VO ₂ work (l/min)	(0.69-1.87)	1.14±0.43	(0.54-0.92)	0.68±0.12	40.35	4.60**	<0.0001
EER (kJ/min)	(16.54-20.54)	18.40±0.95	(11.65-17.89)	15.17±1.68	17.55	7.48**	<0.0001
TCCW	-	1965.4±63.66	-	770.58±39.93	60.79	-	-
PCW	-	227.98±22.17	-	85.23±2.64	82.61	-	-
Overall discomfort rating	(6.5-10)	7.95±1.09	(3-5.5)	4.15±0.65	47.80	13.39**	<0.0001
Rate of perceived exertion	(8-10)	9.47±0.59	(0.5-3)	1.22±0.76	87.11	38.34**	<0.0001
Field capacity, ha/h	(0.003-0.015)	0.004±0.002	(0.13-0.20)	0.165±0.02	97.57	35.82**	<0.0001

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.

Rate of perceived exertion (RPE): RPE analysis result showed that the RPE was 9.47 ± 0.59 and 1.22 ± 0.76 with manual and mechanical method respectively. RPE decreased significantly ($P < 0.0001$) by 87.11 % with paddy transplanter.

Economics of transplanting methods: The daily wage of workers was taken to be Rs.200 with ten minutes break after every fifty minutes. Actual working time was observed 7:45 h/man/day. For the conventional method of paddy transplantation, the labour requirement was 243-250 man-h/ha, which means for transplantation of one hectare area, 33.55 man powers is required per day. The cost of manual transplanting was 6710/ha/day. Whereas, the field capacity of 8 row power operated paddy transplanter was 0.13-0.20 ha/h (1.22 ha). The annual fixed cost and variable costs were calculated by depreciation method by taking the purchase cost, annual uses of transplanter and life of machine. Therefore, the economic cost of mechanized transplanting was 47% less than conventional method which is Rs 3557/ha. The transplanter saved 22% labour costs/day as compared to manual transplanting.

Conclusion

On the basis of above findings it was concluded that

the mean heart rate of women workers in the manual method and eight-row rice transplanter was 138.32 and 110.12 beats/min, respectively. The higher values of the work pulse in manual method suggested a need for providing the women workers with adequate breaks for rest. In comparison with traditional practice, eight-row rice transplanter could reduce drudgery by 82.61 and 17.55 percent in terms of physiological cost per hectare and energy expenditure per hectare, respectively. The transplanter enables women to avoid adopting the bending posture in repetitive motion required in the traditional method. The economic cost of mechanized transplanting was Rs 3557/ha, which is 47% less than conventional method. This study also highlighted that due to high level of physiological workload during manual method of paddy transplanting, maximum farm women suffered from the work related disorders and which decreases their performance on the field. In this study it was recommended that for the significant reduction of the physiological workload and human drudgery, there is dire need to create awareness about the use of mechanized method of paddy transplantation, among the farmers of northern India, who are usually involved in conventional and manual method of transplanting.

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