

Original Research Article

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## Ergonomic Evaluation of Manually Operated Two Row Paper Pot Onion Transplanter

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### ABSTRACT

#### Keywords

Paper pot transplanter, Ergonomics, Labour, Dimension of human body, Heart rate, drudgery, Energy expenditure rate

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The world production of vegetables, India is the second largest producer next to china. In India, there is no mechanization available for onion transplanting. The transplanting of onion seedlings mainly depends on farm workers. So, manually operated two row paper pot onion transplanter was developed. In agricultural mechanization, the major role of ergonomics is to increase the efficiency of the operation. The study was conducted to evaluate the manually operated two row paper pot onion transplanter and compared with conventional method of transplanting. It was found that the maximum heart rate, energy expenditure rate, oxygen consumption rate and work pulse value of farm workers were 118 beat  $\text{min}^{-1}$ , 9.8 KJ  $\text{min}^{-1}$ , 0.66 L/min and 32 beats  $\text{min}^{-1}$  with the workload of moderate in two row paper pot onion transplanter and the maximum heart rate, oxygen consumption rate and energy expenditure rate of farm workers were 135 beats  $\text{min}^{-1}$ , 12.6 KJ  $\text{min}^{-1}$ , 0.859 L/min and 50.5 beats  $\text{min}^{-1}$  with the work load of heavy in conventional method. The overall discomfort rate and musculo-skeletal problem is less in transplanter compared with conventional methods.

### Introduction

Onion (*Allium cepa* L.) is an important vegetable that is used daily in a variety of ways. Onion demand is high worldwide. The total onion production in the world is 93.2226 million tonnes under an area of 4.96 million ha. India produces 19.2 million tonnes of onion from a cultivation area of 1.2 million ha, which is 19.9 % of global production. Tamil Nadu produces 10.62 million tonnes of

onion from a cultivation area of 28.36 thousand ha (Horticultural Statistics at a Glance, 2018).

Onion crop is raised by various methods such as direct seed sowing, planting bulbs in the field and raising nursery seedlings with subsequent transplanting in the field. In India, the most common method is transplanting because of high yield and better quality produce. However, transplanting of onion

seedlings is done manually in all onion growing regions in India because of the non-availability of suitable machines. But manual transplanting is more time consuming and labor-intensive than mechanical transplanting as the women workers have to work in bending posture. Labor shortage during peak season causes delays in transplanting, leading to a drastic reduction in yields (Chaudhari *et al.*, 2001). As the demand for mechanization of onion production has increased in India due to the shortage of labor, an attempt has been made to develop a manually operated two-row paper pot onion transplanter that is structurally simple, functionally accurate, and economically feasible.

Ergonomics is the study of human abilities and characteristics which affect the design of equipment, system, and jobs. The suitability of equipment for farm women can better be judged using ergonomic studies, which cover all aspects that deal with anthropometry, assessment of workload, working environment, safety features, and mechanisms to optimize human-machine environment systems. This helps in increasing working efficiency with reduced drudgery by fitting to the capabilities and limits of human operators. The overall performance of a transplanter mainly depends on both constructional features and operation (Gite *et al.*, 1997).

Many manually operated equipment like weeder, seeder, transplanter etc. Which are similar to developed transplanter were ergonomically evaluated by various researchers.

Tiwari and Gite (1998) estimated the heart rate, oxygen consumption rate and energy expenditure rate during weeding operation by using a power tiller. Singh S P, (2010) carried out a study on ergonomic evaluation of manually operated cono weeder with farm and the heart rate, work pulse rate and oxygen consumption rate was observed. Vyavahare *et*

*al.*, (2012) reported the review based on to produce the anthropometric and strength data of agricultural farm workers for designing farm equipment and to evaluate the ergonomics aspects of farm equipment. The main reason to evaluate the ergonomic and optimizations of farm equipment are to reduce the musculoskeletal disorder and to prevent injuries to farm workers while using farm equipment. Tripathi *et al.*, (2016) conducted a study on ergonomic evaluation of vegetable production by hand operated salping transplanter and traditional method of transplanting. They measured heart rate, energy expenditure rate, musculo-skeletal problem and posture discomfort rate and also compared with traditional method. Pradhan *et al.*, (2014) conducted an experiment to calculate the heart rate, oxygen consumption and relative cost of workload in different paddy transplanting operations. To calculate the heart rate, energy expenditure and oxygen consumption rate, Yadav *et al.*, (2007) investigated the ergonomic evaluation of a six row paddy transplanter which is manually operated. Vinay kumar *et al.*, (2018) conducted an experiment on ergonomic evaluation of manually operated single row vegetable transplanter for different crops like brinjal, chilli, and tomato in different sites to work out heart rate and energy expenditure rate and compared with traditional method of transplanting. Amita Gautam *et al.*, (2020) conducted an experiment on ergonomic evaluation of farm women for ambika paddy weeder and hand weeding, harvesting by serrated sickle and traditional sickle and threshing by paddy thresher and hand beating and also for winnowing operation to work out the heart rate, oxygen consumption rate and energy expenditure rate.

## **Materials and Methods**

The study was done in agricultural engineering college and research institute. Based on the extensive review of several

research papers, the ergonomic parameters selected. The selected ergonomic parameters are energy expenditure rate, work pulse rate, workload, overall discomfort rate and musculoskeletal problems.

The study was conducted to estimate the heart rate, energy expenditure rate, oxygen consumption rate, work pulse rate, work load, overall discomfort rate and musculo-skeletal problems in two row paper pot onion transplanter and compared with conventional method of onion transplanting.

### **Selection of workers**

The 10 nos. of farm workers with good health and age between 25 - 35 years were selected. At an age group of 25 – 35 years humans have maximum strength (Grandjean, 1982., Gite and Singh, 1997). Therefore, farm workers between the age group of 25 – 35 years were selected. The Physiological characteristics of selected workers is given in Table 1.

### **Growing of seedlings**

Seedlings were grown in a paper pot and also raised under a shade net. Commercially available mediums were used such as soil and soil + vermicompost + FYM (1:1:1). Water was sprinkled every day. 15 cm height and 0.8 cm neck diameter are suitable for onion transplanting. It is achieved in 6 – 10 weeks depending on soil condition. Conventionally, the farmers were selected for the 30 days old plug seedlings for transplanting practices.

### **Field preparation**

As per agronomic requirement the field was prepared for paper pot transplanting. By using cultivator and rotavator the field was prepared until soil tith fine. The plot size was 20×10 m.

### **Transplanting of onion seedlings**

The onion transplanter was designed with simple construction parts, low cost and more efficient in transplanting the onions. The CAD diagram is shown in fig 1. The main functions of two row paper pot onion transplanter includes,

To open the furrow,  
To convey the seedling due to gravity force and  
Cover the seedling by using furrow closer.

The functional components are handle, tray, tray holder, paper pot conveyor body, furrow opener, ramp, furrow closer and friction wheel. The handle was designed based on ergonomically. The 5<sup>th</sup> percentile value of elbow height for farm workers was 896 mm and the 95<sup>th</sup> percentile value of elbow height for male workers was 1098 mm considered to design a handle. Handle height of the developed transplanter should be adjustable between 0.90-1.10 m. Onion seedlings were transplanted by manually operated two row paper pot onion transplanter and also conventional method. Table 2 shows the specification of the developed transplanter.

### **Ergonomic evaluation**

The transplanter was loaded with seedling trays and kept ready for the operation. The farm workers were asked to take sufficient rest before the start of operation. Ergonomic evaluation was conducted using both a developed transplanter and conventional method of onion seedlings shown in figure 2 and 3.

### **Heart rate (beats min<sup>-1</sup>)**

The subject's heart rate was measured before and during operation using a polar heart rate wrist watch. The farm workers were asked to

take sufficient rest before operation and after 30 minutes of work by transplanter and conventional method of transplanting, the heart rate was recorded.

### **Energy expenditure rate (KJ min<sup>-1</sup>)**

The Energy expenditure rate was calculated from heart rate, the Varghese (1994) proposed an equation. It is given below:

$$\text{EER (KJ min}^{-1}\text{)} = 0.159 \times \text{HR (beats min}^{-1}\text{)} - 8.72 \quad (1)$$

### **Oxygen consumption rate (OCR)**

OCR was determined by utilizing the formula derived by Singh *et al.*, 2008. It is denoted by L min<sup>-1</sup>.

$$\text{OCR (L/min)} = 0.0114 \times \text{HR} - 0.68 \quad (2)$$

### **Work pulse value**

Work pulse value was calculated by subtracting the mean heart rate during work with the mean heart rate during rest (Singh S.P, 2012). The calculated values of work pulse were compared with acceptable work pulse value of 40 beats min<sup>-1</sup> as the limit of continuous performance (Brundke, 1984).

### **Work load**

The workload was classified on the basis of average heart rate and average energy expenditure rate during transplanting operation. The workload was categorized as per the following classification of workload (Table 3) in different occupations proposed by Varghese *et al.*, (1994).

### **Musculo-skeletal problem (MSP)**

Musculoskeletal problems and posture were taken by asking the farm labours as to where they felt pain in their body after transplanting

with onion transplanter and conventional method.

### **Overall discomfort rate (ODR)**

ODR was measured by using visual analogue scale. It was divided into 10 equal parts (0 - no discomfort, 10 – extreme discomfort). This scale was developed by Corlet and Bishop (1976). The length of scale is 70 cm (Fig. 4.). The overall discomfort rate was indicated by using movable pointers. After transplanting of seedlings by every farm labourers were called to mention their ODR on the scale.

## **Results and Discussion**

### **Ergonomics evaluation of developed transplanter**

#### **Energy expenditure rate**

Energy expenditure rate was calculated on the basis of maximum heart rate by using the Varghese (1994) equation. The physiological parameters of the farm workers for the transplanter and convention methods were shown in table 4. In conventional methods of transplanting the maximum heart rate recorded was 135 beats min<sup>-1</sup> and in the case of developed transplanter the maximum heart rate was 118 beats min<sup>-1</sup>. Based on the maximum heart rate the energy expenditure rate was calculated the value of conventional method is 12.6 KJ min<sup>-1</sup> and developed transplanter is 9.8 KJ min<sup>-1</sup>. Energy expenditure rate was lower in developed transplanter compared with conventional method of transplanting as shown in figure 5.

#### **Oxygen Consumption Rate (OCR)**

The oxygen consumption rate was calculated based on maximum heart rate. The value of conventional method and developed transplanter were 0.859 L/min and 0.66 L/min. Oxygen consumption rate was lower

in developed transplanter as compared with conventional method of transplanting.

**Work pulse value**

The work pulse value of farm workers were 30 beats min<sup>-1</sup> and 50.5 beats min<sup>-1</sup> under developed transplanter and conventional method of transplanting. In developed transplanter operation, the work pulse value was less as compared to acceptable workload (30<AWL). The conventional method of transplanting, the work pulse rate was high as

compared to acceptable workload (50.5 > AWL).

**Work load**

The workload was classified as moderate using tow row paper pot onion transplanter and heavy with conventional method of transplanting. Farmers were comfortable while working with the developed transplanter as they were relieved from back pain.

**Table.1** Physiological characteristics of farm workers

Sl.No	Particulars	Average values
1	Age, years	29.4 ± 3.09
2	Weight, kg	62.5 ± 6.46
3	Heart rate at resting posture, beats min <sup>-1</sup>	85

**Table.2** Specification of manually operated two row paper pot onion transplanter

Sl.No	Details	Specification
1	Type	Manually operated two row paper pot transplanter
2	Dimension (L×W×H), cm	157×60×90
3	Weight, kg	30
4	Planting mechanism	By the gravity force
5	No. of rows	2
6	Effective width, cm	60
7	Power source	One person
8	Seedling tray dimension (L×W×H), cm	60
9	Number of person needed for transplanting	Two (alternate operation and brings seedlings)

**Table.3** Classification of workload

Physical workload	Physiological variables	
	Energy Expenditure (KJ/Mi)	Heart beats (Beats/Mi)
Very light	Up to 5.0	Up to 90
Light	5.0-7.5	91-105
Moderate	7.6-10.0	106-120
Heavy	10.0-12.5	121-135
Very heavy	12.6-15.0	136-150
Extremely heavy	>15.0	Above 150

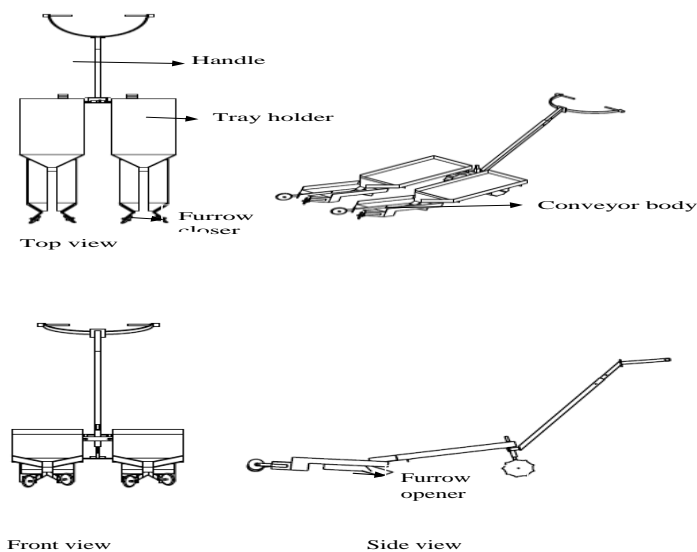
**Table.4** Basic anthropometric and physiological parameters of the farm workers- Average values

SI.No	Particulars	Transplanter	Conventional meth
1	Resting heart rate, beats min <sup>-1</sup>	85	85
2	Maximum heart rate, beats min <sup>-1</sup>	118	135
3	Energy expenditure, (KJ min <sup>-1</sup> )	9.8	12.6
4	Oxygen consumption rate (L/min)	0.66	0.859
5	Work pulse value, beats min <sup>-1</sup>	32	50.5
6	Work load	Moderate	High

**Table.5** Overall discomfort rating (ODR), Responses on musculo-skeletal problems and perceived exertion experienced by respondents (RPE)

Transplanting methods	ODR	MSP	RPE
Transplanter	5	Moderate to light pain in hands, shoulder and legs	Moderate
Conventional method	8	Heavier pain in upper and lower back, hands, legs and fingers	Heavy

**Fig.1** Isometric view of manually operated two row paper pot onion transplanter



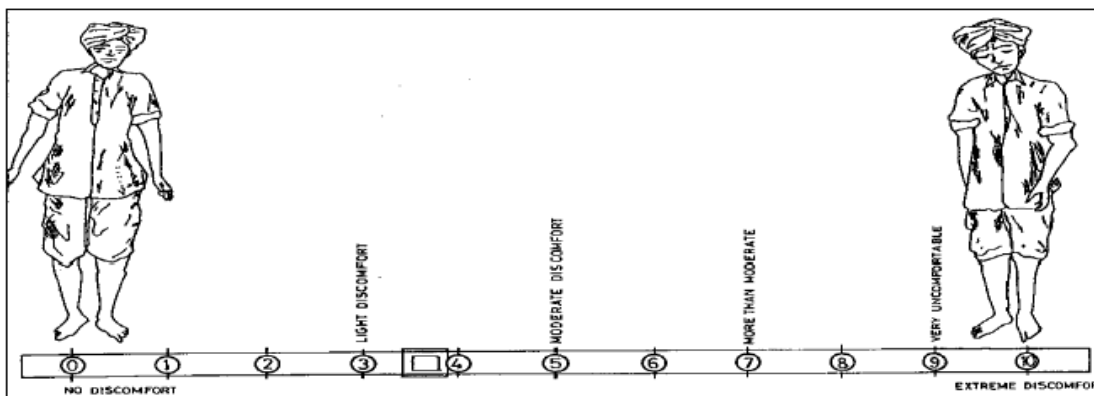
**Fig.2** Operation of developed transplanter in actual field operation



**Fig.3** Manual transplanting of onion seedlings

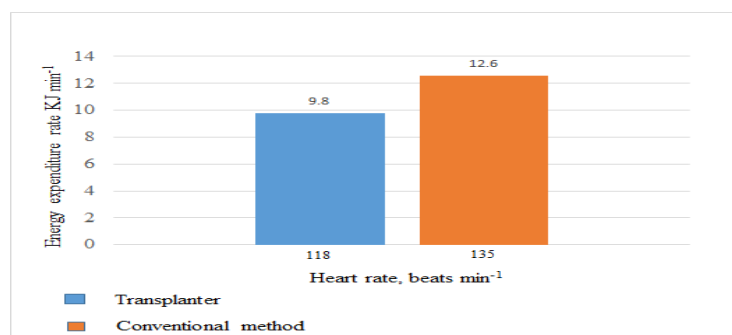


**Fig.4** Visual analogue discomfort scale for assessment of overall body discomfort



(Corlett and Bishop, 1976)

**Fig.5** Comparison of developed transplanter and conventional method of onion transplanting based on heart rate and energy expenditure rate



### Musculo-skeletal problems (MSP)

Musculo-skeletal problems and posture were evaluated by asking farm workers as to where they felt pain in their body after transplanting seedlings with a developed transplanter and conventional method. Table 4 indicates that

the transplanting with conventional methods makes heavier pain in the upper and lower back, hands, legs and fingers. In the case of two row paper pot transplanter made moderate discomfort and slight pain in hands, shoulder and legs. In transplanter sitting posture was eliminated and also rating of

perceived exertion as moderate compared with conventional method of transplanting.

### **Overall discomfort rate**

Musculoskeletal problems are very prominent for transplanting operations because they take more time and are continuous. The conventional methods performed continuous sitting posture which resulted in heavy workload, energy expenditure and in case of two row paper pot transplanter was used in standing posture and thus result in moderate musculo-skeletal problem, energy expenditure rate and workload (Table 5).

In conclusion the manually operated two row paper pot onion transplanter with the selected 10 farm workers were ergonomically evaluated and compared with conventional method of transplanting. The conventional method of transplanting maximum heart rate, oxygen consumption rate, energy expenditure rate, work pulse value and workload was 135 beats  $\text{min}^{-1}$ , 0.859 L/min, 12.6 KJ  $\text{min}^{-1}$ , 32 beats  $\text{min}^{-1}$  and heavy respectively. The corresponding values for the developed transplanter were 118 beats  $\text{min}^{-1}$ , 0.66 L/min, 12.6 KJ  $\text{min}^{-1}$ , 50.5 beats  $\text{min}^{-1}$  and moderate respectively. The overall discomfort rate was moderate as in developed transplanter and compared with conventional methods of transplanting.

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