

# Physiological evaluation of manual operated weeders and sprayers on farm use

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**Abstract:** Ergonomics is the scientific study of relationship between man and his working environment, which includes ambient conditions, tools and materials, methods of work and organization of work. Two sprayers and weeders namely, knapsack sprayer, foot operated sprayer, wheel hoe and power weeder were evaluated with respect to overall tiredness and body part discomfort experience by the subjects while spraying and weeding in field.

Nine agricultural workers who were free from cardiac and other ailments were selected for operating weeders and sprayers. A polar heart rate monitor was used to measure physiological response of the operators during field operation. During the experiments, the external parameters of ambient temperature and relative humidity and light intensity of the atmosphere were measured with Thermal hygrometer. Each subject was asked to operate the weeders and sprayers in the experimental field for 30 min and heart rate and energy expenditure rate were recorded for every 1 min interval. The oxygen consumption rate was computed by using recorded H.R values. The same procedure was repeated at pre-determined times of a day for all the subjects. The data was analyzed statistically to find the optimum values.

**Keywords:** ergonomics, polar heart rate monitor, thermal hygrometer, dry land welders, sprayers.

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## 1 Introduction

Farming is the backbone of Indian economy. In this agriculture sector there is a lot of field work, such as weeding, reaping, sowing etc. Apart from these operations, spraying is also an important operation to be performed by the farmer to protect the cultivated crops from insects, pests, funguses and diseases for which various insecticides, pesticides, fungicides and nutrients are sprayed on crops for protection. Farming has undergone a great evolution in last 50 years. Out of the various reasons involved for this evolution is control of various diseases on crops.

Weeds are plants, grown in unwanted areas, which impair the quality of farm produce and reduce the crop yields. Weeds compete with crop plants for nutrients and other growth factors and in the absence of an effective control measure, consume 30% to 40% of applied nutrients resulting in significant yield reduction. Manual weeding requires huge labour force and accounts for about 25 % of the total labour requirement (900-1200 man-h/ha) (Nag and Dutt, 1979). In India, about 4.2 billion rupees are spent every year for controlling weeds for production of major crops. At least 40 Mt of major food grains are lost every year due to weeds alone (Singh and Sahay, 2001). Manual weeding accounts for about 25% of total labour requirement during a cultivating season. Often several weedings are necessary to keep the crop weed free. Weeding or hoeing is generally done 15 to 20 days after sowing. Timely weeding is

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essential for a good yield, and can be achieved by using mechanical weeders. Manually operated weeders need human effort to operate. All the agricultural operation involves a certain amount of labour power. The weeding and spraying operations consume 30% of total cost of the cultivation. Moreover, the workers have to be paid sickness benefits and compensation. Occupational stress is becoming an increasingly global phenomenon affecting all countries, all professions and all categories of workers, families and society in general. Ashok Kumaret al. (2013) conducted a study on ergonomical evaluation with different type of wet land weeders and concluded that, the drudgery involved in weeding operation increases stress on the worker, which causing increase in heart rate and oxygen consumption.

The main objective of ergonomics is to achieve an optimal relationship between people and their work environment, where the approach has to be context specific. The working conditions of workers may be hazardous due to various ergonomic risk factors and results in a variety of occupational health problems which include loss of gross efficiency and onset of early fatigue, discomfort, disability of varied degrees and musculoskeletal problems. Ergonomically well designed hand equipments may reduce the discomforts. It also provides comfortable work for the users and gives high product quality to the consumers. As the use of hand equipments may play an important role in the development of disorders and accidents, it is obvious that improvements in the design of hand equipments are essential for promoting professional users' health, particularly where there is intensive exposure.

Ergonomical cost of work consists of the anthropometry, body size, health of the worker, basal metabolic rate, energy expenditure rate, oxygen consumption rate and type of working posture. Many ergonomical studies have been conducted on some selected implements but study on the different combinations of operation like weeding and spraying in dry land farming has not been conducted, also the

ergonomical comparisons' of different operations havenot conducted.

In dry land farming generally, wheel hoe and power weeder are used for uprooting and burying weeds in between standing rows of crop in dry land condition. The knapsack sprayer and foot operated sprayer are most common for spraying operations in the field as well as orchards. Ergonomical evaluation is a tool to evaluate the energy expenditures of workers, their physiological cost and suitability of the method for farm workers and how long they can work continuously without getting fatigue. In view of the above, the ergonomic parameters (heart rate and oxygen consumption rate) of wheel hoe, power weeder, knapsack sprayer and foot operated sprayer were measured for different agricultural labors in dry land condition with the following objectives.

1. To evaluate the dry land weeders (wheel hoe and power weeder) ergonomically with different age group persons at different timings in a day.
2. To evaluate the most commonly used sprayers for dry land farming ergonomically with different age group persons at different timings in a day.
3. To compare the ergonomical results of spraying and weeding operations of different age group persons in different timings.

## 2 Materials and methods

Nine agricultural workers, those who were free from cardiac and other ailments, were selected. Two types of weeders and two types of sprayers as mentioned above were selected and evaluated with different age group persons ( $T_1=25-30$  years,  $T_2=30-35$  years &  $T_3=35-40$  years) at different timings in a day ( $E_1=8.00 - 11.00$  AM,  $E_2=12.00 - 2.00$  PM &  $E_3=4.00 - 6.00$  PM ). The weeders were evaluated by measuring heart rate, and thereafter computing oxygen consumption rate. The physical characteristics of the subjects (Figure 1) involved in the study for spraying and weeding operation with knapsack sprayer, foot sprayer , wheel hoe and power weeder are presented in Table 1. The climatic

factors like relative humidity and temperature were measured with help of thermal hygrometer which is in the

range of  $19\% \pm 3\%$  to  $48\% \pm 3\%$  and  $34^{\circ}\text{C} \pm 3^{\circ}\text{C}$  to  $38^{\circ}\text{C} \pm 3^{\circ}\text{C}$  respectively.



Figure 1 Measurement of physical characteristics of selected subjects

Table 1 Physical characteristics of the selected subjects

Age (years)	Group	Age (Years)	Weight (Kg)	Height (cm)	Hand Length (cm)	Shoulder Length (cm)	Leg Length (cm)
		25	54	166	75	39	96
T <sub>1</sub> -25 to 30		26	90	179	79	40	100
		28	65	179	79	44	106
		30	63	174	73	47	97
T <sub>2</sub> -30 to 35		35	80	170	68	47	92
		33	60	162	64	42	90
		39	53	157	64	42	91
T <sub>3</sub> -35 to 40		40	74	164	69	45	105
		38	66	158	65	42	98

### 3 Manual weeder and sprayers

#### 3.1 Wheel hoe

The wheel hoe is a widely accepted weeding tool for weeding and inter-culture in row crops. It is a long

handled tools operated by push and pull action as shown in Figure 2a. As the name implies, the general construction of wheel hoe comprises of wheel assembly, miniature tool frame, a set of replaceable tools and handle assembly.



Figure 2 Selected wheel hoe (a) and power weeder (b)

### 3.2 Power weeder

This machine consists of a 5 hp diesel engine mounted on the power tiller chassis. It consists of power transmission system, frame, a rotavator assembly and a pair of powered wheels. The power from the engine is transmitted with the help of chain- sprockets arrangement to the rotary unit (or) tilling unit and propelling the machine forward. The selected power weeder during operation is shown in Figure 2b.

### 3.3 Knapsack sprayer

Knapsack sprayer (Figure3a) consists of a pump and air chamber permanently installed in a 9 to 22.5 liters tank. The handle of the pump extending over the shoulder or under the arm of operator makes it possible to pump with one hand and spray with the other. Uniform pressure can be maintained by keeping the pump in continuous operation.

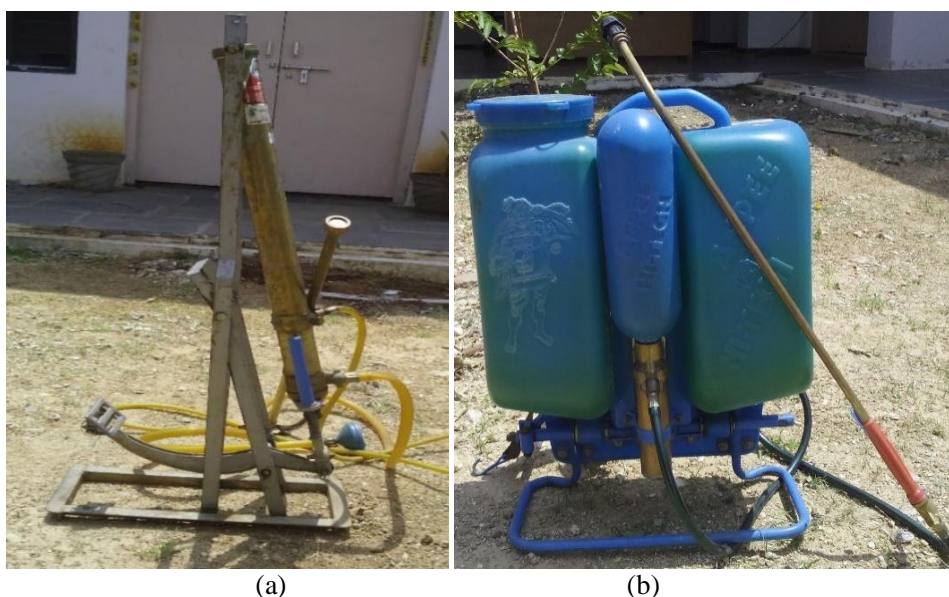


Figure 3 Selected knapsack sprayer (a) and foot operated sprayer (b)

### 3.4 Foot operated sprayer

The foot operated sprayer is one of the ideal and versatile sprayers used for multipurpose spraying jobs. The principle of working is similar to the rocker sprayer. It consists of a pump operated by the foot lever, suction

hose with strainer, delivery hose, spray lance fitted with shut off piston valve, and adjustable nozzles. The foot operated sprayers used for the study is shown in Figure3b.

#### 4 Experimental procedure

A ground nut field of 0.1 ha was selected and subdivided in to three plots for each group for the study at Agricultural research farm, Madakasira in the year 2015. Nine agricultural workers free from cardiac and other ailments were selected for operating the selected weeders and sprayers. The operators were acclimatized with experimental protocol before start of the test. A polar heart rate monitor was used to measure physiological response of the operators during field operation. Speed of travel (km/h) was calculated as per RNAM (1983) test code by using a stop watch for covering a known distance. During the experiment, mean ambient condition (mentioned earlier) was thermally comfortable for the period from January to March, 2015 before actual experiments, each subject operated the weeders for 10 min for warming up, followed by a 5 min rest (Astrand and Rodahl, 1977). Each subject then operated the weeders in the experimental ground nut field in between

the rows for 30 min and then took rest till the heart rate returned to normal. Heart rate was measured at every 1 min during operation and the average reported. The same procedure was repeated at pre-determined times of a day for all the subjects.

The Polar heart rate monitor manufactured by Polar Corporation was used to measure the heart rate of the person. The range of the heart rate monitor was 15 to 240 beats/min. It mainly consists of plastic electrodes which are placed on the reverse side of the belt strip to detect the heart rate during operation and is shown in Figure 4. A Connector which is fitted in front side of belt strip and placed on the chest of the operator to receive heart beat during operation from the electrodes is shown in Figure 5. A receiver which is fitted in watch to mount it on the operators handle to receive the heart rate sensor signal and also to stores the data is shown in Figure 6. It also consists of a separate device which may be called as polar flow link to transfer the data from receiver to the personal computer.

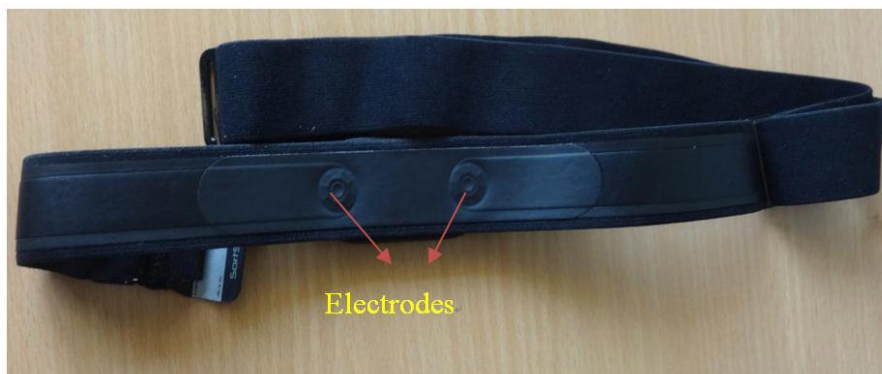


Figure4 Placement of electrodes in belt strip

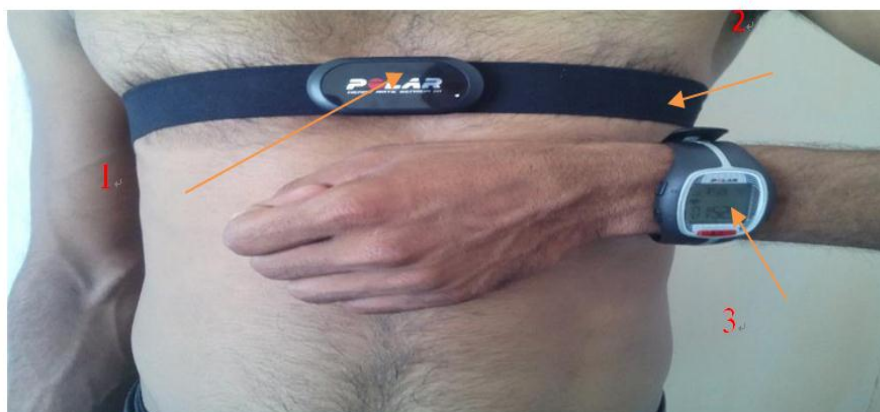


Figure 5 Original view of wearing polar heart rate monitor  
1. Transmitter 2. Electrode strip 3. Monitor



1. Transmitter    2. Electrode strip    3. Monitor    4. Flow link

Figure 6 Components of polar heart rate monitor and data transfer unit

Thermo-Hygrometer (Figure 7) was used for measurement of temperature and moisture content of the atmosphere simultaneously.



Figure 7 Thermo hygrometer

**Computation of oxygen consumption**

It is termed as the amount of oxygen consumed by the whole body per unit time, which is normally expressed as L/min. The oxygen consumption was calculated using the following equation given by Singh et al. (2007).

$$OCR = \frac{EER}{20.88} L / min$$

Where, *EER*= Energy Expenditure Rate

The energy expenditure rate was computed from the heart rate values of the operator and is given by the following equation:

$$EER = \frac{HR - 66.00}{2.4} kJ / min$$

The obtained data was analyzed statistically by 3-factorial RBD design following the analysis of variance (ANOVA) technique. F-test of ANOVA tested the statistical hypothesis of equalities of the treatment means, at 5% level of significance.

**5 Results and discussion**

The experiments were carried out in the research farm of College of Agricultural Engineering, Madakasira. Ergonomical studies were carried out with different weeders and sprayers ( *E*<sub>1</sub>: wheel hoe, *E*<sub>2</sub>: power weeder, *E*<sub>3</sub>: knapsack sprayer and *E*<sub>4</sub>: foot operated sprayer), with different age groups ( *T*<sub>1</sub>: 25 to 30 years, *T*<sub>2</sub>: 30 to 35 years and *T*<sub>3</sub>: 35 to 40 years ) at different timings in a day ( *A*<sub>1</sub>: 8:00 to 10:00 AM, *A*<sub>2</sub>: 12:00 to 2:00 PM and *A*<sub>3</sub>: 4:00 to 6:00 PM) in field during January and march, 2015 as shown in Figure 8.



Figure 8 Measurement of heart rate during weeding and spraying operation

**Heart Rate during weeding and spraying operation**

The heart rate at the beginning is different for the three different age groups and it ranged between 70 to 161 beats/min at 8:00 to 11:00 AM and is increased to 71 to 167 beats/min at 12:00 to 2:00 PM. It is again

decreased to 71 to 162 beats/min at 4:00 to 6:00 PM, which may be due to the variation in the environment. Influence of heart rate on age of operator for different timings in a day during Weeding and spraying operation was presented in Table 2.

**Table 2 Influence of heart rate on age of operator for different timings in a day during Weeding and spraying operation**

Heart rate (beats/min)								
	Wheel Hoe				Power Weeder			
Treatment	25-30 Years	30-35 Years	35-40 Years	Mean	25-30 Years	30-35 Years	35-40 Years	Mean
T1	127.57	115.61	108.34	117.17	117.24	112.7	109.38	113.1067
T2	118.96	115.52	112.02	115.5	118.96	115.52	112.02	115.5
T3	117.02	113.92	105.2	112.04	117.02	113.92	105.2	112.0467
Heart rate (beats/min)								
	Knapsack sprayer				Foot operated sprayer			
Treatment	25-30 Years	30-35 Years	35-40 Years	Mean	25-30 Years	30-35 Years	35-40 Years	Mean
T1	111	106.4	102.96	106.7867	106.8	105.11	101.63	104.5133
T2	114.99	110.09	105.58	110.22	113.47	110.07	104.71	109.4167
T3	109.65	107.12	104.68	107.15	112.21	105.81	102.08	106.7

The average heart rates for different age groups and at different timings using wheel hoe are 127.57 beats/min for 25 to 30 years, 115.61 beats/min for 30 to 35 years and 108.34 beats/min for 35 to 40 years at 8:00 to 11:00 AM. Then it is increased to 132.1 beats/min for 25 to 30 years, 124.31 beats/min for 30 to 35 years and 112.06

beats/min for 35 to 40 years at 12:00 to 2:00 PM and again the heart rate was decreased to 131.17 beats/min for 25 to 30 years, 123.88 beats/min for 30 to 35 years and 108.2 beats/min for 35 to 40 years at 4.00 to 6.00 PM (Figure 9).

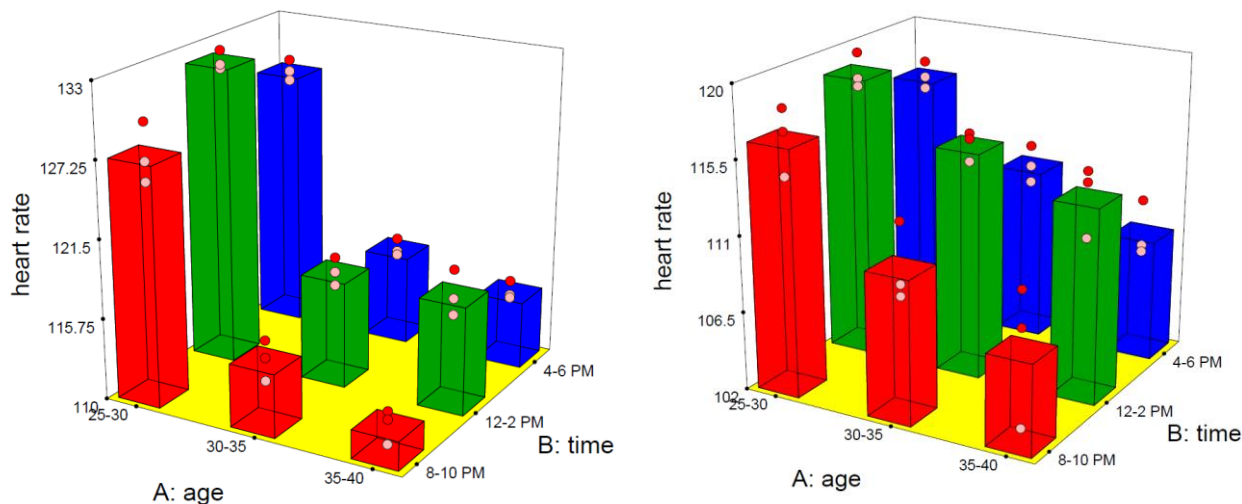


Figure 9 Effect of heart rate on age groups at different timings for weeding operation with wheel hoe and power weeder

The average heart rates for different age groups and at different timings using power weeder are 117.24 beats/min for 25 to 30 years, 112.7 beats/min for 30 to 35 years and 109.38 beats/min for 35 to 40 years at 8:00 to 11:00 AM. Then it is increased to 118.96 beats/min for 25 to 30 years, 115.52 beats/min for 30 to 35 years and 112.02 beats/min for 35 to 40 years at 12:00 to 2:00 PM and again the heart rate was decreased to 117.02 beats/min for 25 to 30 years, 113.92 beats/min for 30 to 35 years and 105.2 beats/min for 35 to 40 years at 4.00 to 6.00 PM. Therefore, the highest heart rate was recorded during 12:00 to 2:00 PM for 25 to 30 years of age group and the lowest heart rate was recorded during 4:00 to 6:00

PM for 30 to 35 years of age group (Figure 9).The average heart rates for different age groups and at different timings using knapsack sprayer are 111 beats/min for 25 to 30 years, 106.4 beats/min for 30 to 35 years and 102.96 beats/min for 35 to 40 years at 8:00 to 11:00 AM. Then it is increased to 114.99 beats/min for 25 to 30 years, 110.09 beats/min for 30 to 35 years and 105.58 beats/min for 35 to 40 years at 12:00 to 2:00 PM and again the heart rate was decreased to 109.65 beats/min for 25 to 30 years, 107.12 beats/min for 30 to 35 years and 104.68 beats/min for 35 to 40 years at 4.00 to 6.00 PM(Figure 10).



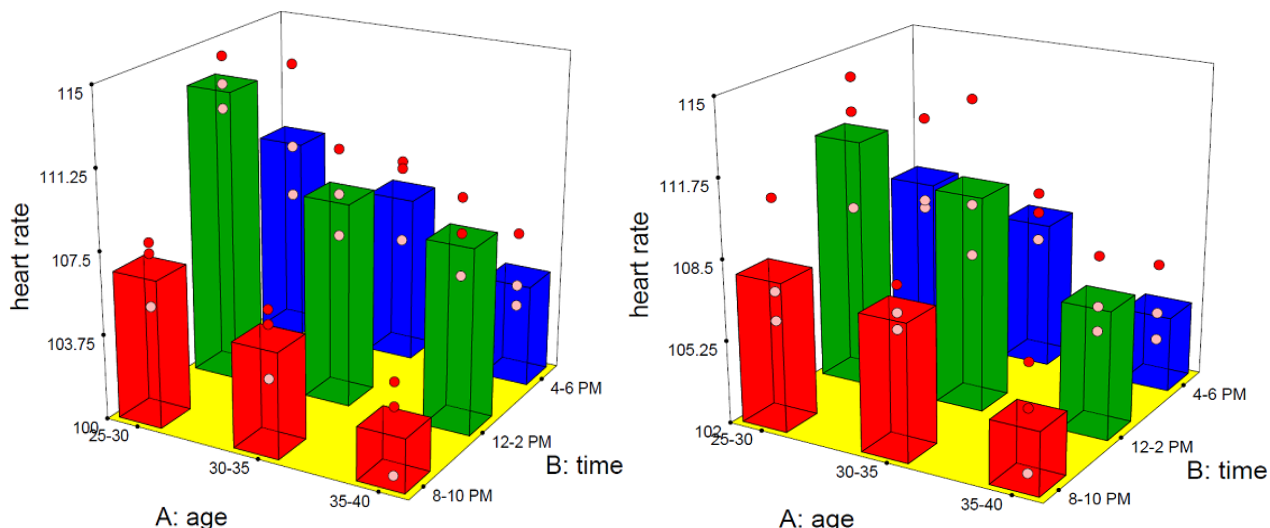


Figure 10 Effect of heart rate on age groups at different timings for spraying operation with Knapsack and foot operated sprayers

The average heart rates for different age groups and at different timings using foot operated sprayer are 106.8 beats/min for 25 to 30 years, 105.11 beats/min for 30 to 35 years and 101.63 beats/min for 35 to 40 years at 8:00 to 11:00 AM. Then it is increased to 113.47 beats/min for 25 to 30 years, 110.07 beats/min for 30 to 35 years and 104.71 beats/min for 35 to 40 years at 12:00 to 2:00 PM and again the heart rate was decreased to 112.21 beats/min for 25 to 30 years, 105.81 beats/min for 30 to 35 years and 102.08 beats/min for 35 to 40 years at 4.00 to 6.00 PM. Therefore, the highest heart rate was

recorded during 12:00 to 2:00 PM for 25 to 30 years of age group and the lowest heart rate was recorded during 4:00 to 6:00 PM for 30 to 35 years of age group (Figure 10).

The effect of energy consumption on age groups at different timings in a day using foot operated sprayer, knapsack sprayer, wheel hoe and power weeder was measured. The average energy consumption for wheel hoe, power weeder, knapsack and foot operated sprayers are 330.57, 305.33, 335.99 and 235.58 cal/min respectively and is shown in Figure 11 and Figure 12.

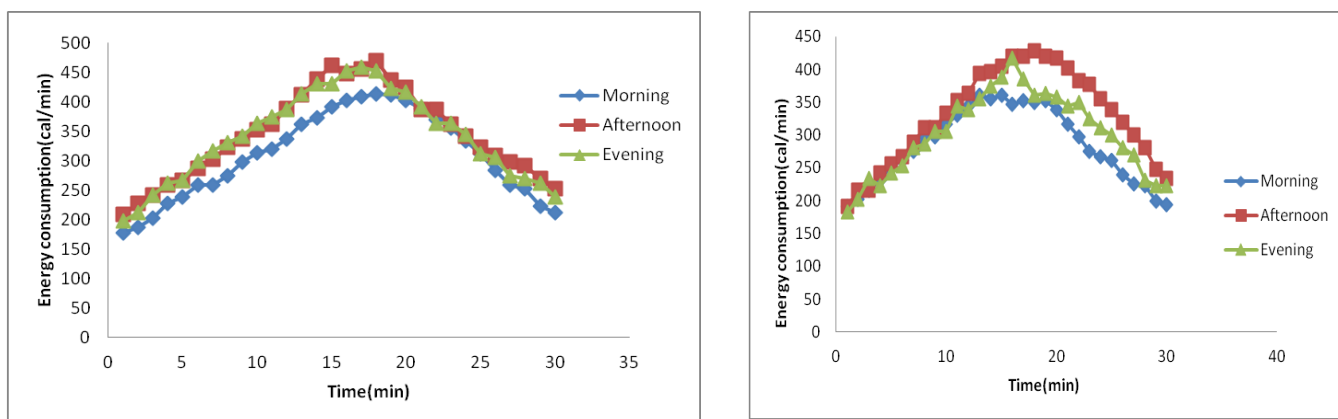


Figure 11 Energy consumption at different timings in a day while operating with knapsack Sprayer and Foot operated sprayer

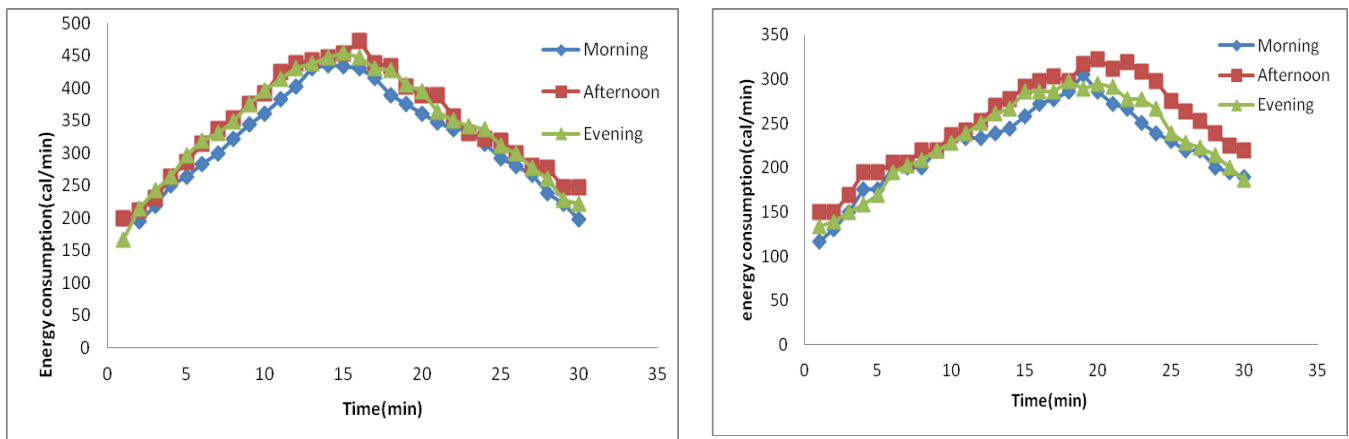


Figure 12 Energy consumption at different timings in a day while operating with wheel hoe and power weeder

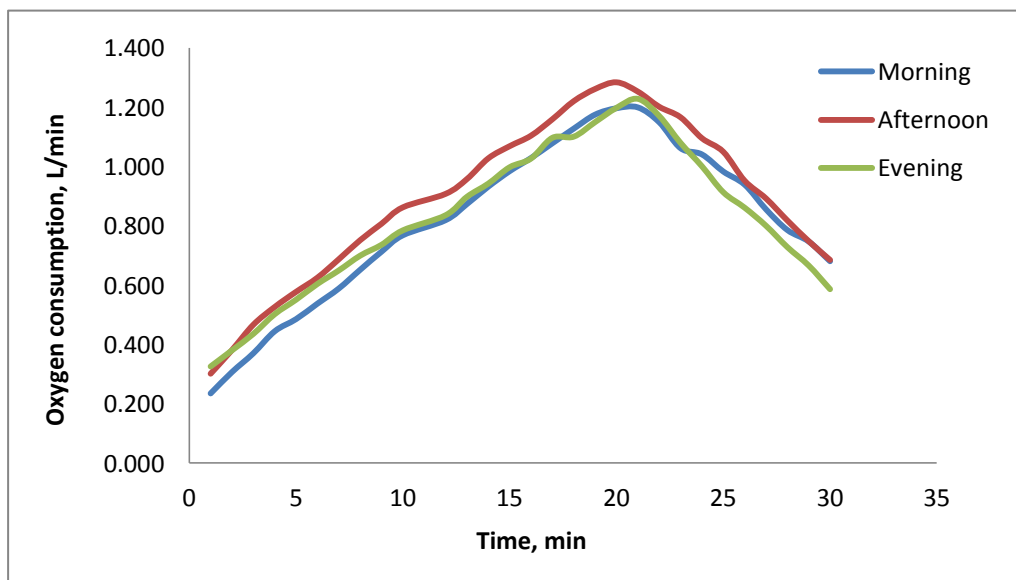


Figure 13 Graph of Oxygen consumption rate with respect to time

The average oxygen consumption rate for 25-30 year person by operating knapsack sprayer in morning, afternoon and evening is founded as 0.901 L/min, 0.977 L/min and 0.8711 L/min respectively. The average oxygen consumption rate for 30-35 year person by operating knapsack sprayer in morning, afternoon and evening is founded as 0.817 L/min, 0.8979 L/min and 0.82073 L/min respectively. The average oxygen consumption rate for 35-40 year person by operating knapsack sprayer in morning, afternoon and evening is founded as 0.744 L/min, 0.789 L/min and 0.7718 L/min respectively and a sample graph of Oxygen consumption rate with respect to time (Hear Rate) is shown in Figure 13.

## 6 Conclusions

The following conclusions are drawn from the study on ergonomical evaluation of manual operated weeders and sprayers.

- (1). Weeding during 12:00 to 2:00 PM developed maximum working heart rate and oxygen consumption rate with the weeders compared to 8:00 to 10:00 AM and 4:00 to 6:00 PM, which might be due to higher temperature.
- (2). Agricultural workers in 25 to 30 years age group developed highest working heart rate and oxygen consumption rate for weeding operation than age groups of 30 to 35 years and 35 to 40 years due to decrease of heart rate with increase of age and decrease of metabolism with age. Oxygen

consumption rate of workers varied from 1.38 to 2.02 L/min for weeding operation with wheel hoe and 1.04 to 1.18 L/min by power weeder in dry land condition.

- (3). Weeding with power weeder between 8:00 and 10:00 AM by workers in 30 to 35 years age group was better than weeding with wheel hoe due to less effort application, minimum heart rate and oxygen consumption rate compared to others.
- (4). Spraying during 12:00 to 2:00 PM developed maximum working heart rate and oxygen consumption rate with the sprayers compared to 8:00 to 10:00 AM and 4:00 to 6:00 PM, which might be due to higher temperature.
- (5). Agricultural workers in 25 to 30 years age group developed highest working heart rate and oxygen consumption rate for spraying operation than age groups of 30 to 35 years and 35 to 40 years due to decrease of heart rate with increase of age and decrease of metabolism with age. Oxygen consumption rate of workers varied from 1.16 to 1.82 L/min for spraying by knapsack sprayer and 1.12 to 1.43 L/min by foot operated sprayer in dry land condition.
- (6). Spraying with foot operated sprayer between 8:00 and 11:00 AM by workers in 30 to 35 years age

group was better than spraying with knapsack sprayer due to more force applied by leg compared to hand, more weight added to the operator while operating knapsack sprayer, less heart rate, low oxygen consumption and easy operation.

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