Wet Land Paddy Weeding - A Comprehensive Comparative Study from South India

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ABSTRACT

Evaluation of the performance of wet land weeders is inevitable as weed infestation is one of the limiting factors in the rice cultivation in India. The advent of mechanical rice transplanter to Indian agriculture encouraged farmers to use inter-row weeding tools like Rotary weeder, Cono weeder etc. These instruments are now popularising among farmers instead of tedious and low productive hand weeding. The main objective of this study was to evaluate these weeding tools quantitatively and qualitatively in terms weeding performance, economic aspects, ergonomic effectiveness, subjective judgement of Work Related Body Discomfort (WRBD) and work performance in comparison with hand weeding and the study was conducted in Malappuram district of Kerala State, India. In addition, different weed management practices viz. hand weeding, Rotary weeding + one hand weeding, Cono weeding + one hand weeding, Rotary weeding alone, Cono weeding alone, were conducted in the study area to assess the effect of different weeding methods on crop growth and yield with the help of statistical analysis. Ergonomic results showed that the energy requirements for the male subject group corresponding to rotary weeding, cono weeding and hand weeding were respectively 26.5, 24.0 and 16.0 kJ/ min. For the Female subjects, the corresponding values were 18.0, 15.0 and 9.5 kJ/ min respectively. The Field Performance Analysis in 15 experimental plots at the study area showed the weeding efficiency as 79 % and 72.5 % respectively for Rotary weeder compared to Cono weeder with damage factor of 7.06% and 4.55% respectively. The ANOVA based statistical analysis shown that weeding operation has significant influences on crop growth and yield parameters.

Keywords: Weeder, performance, ergonomics, statistic analysis, crop growth, paddy

1. INTRODUCTION

Rice is the unique major food crop in the world by virtue of its extension and adaptability to broad range of climatic and cultural operations. India is the second largest rice producing country in the world and represents about 10% (225 million) of the total world workforce in agriculture (Nag and Nag, 2004). The ever-growing local and global demand for food grains can only be met by increasing the production through enhancing productivity and intensive cropping. Indian agriculture is of the subsistence type, and therefore not much scope for increasing the area of cultivable land. Hence it is imperative to improve the yield by intensive agriculture which necessitates better inputs and better management. In the same time, it is important to note that the area under rice cultivation is decreasing continuously over the past few decades all over India and particularly in Kerala State. The production and average productivity of rice in the state declined from 5.41 million hectares in 1991-92 to 0.289 million hectares in 2004-05 and the production of rice decreased from 1.067 million tonnes to 0.667 million tonnes during the same period with an average productivity of 2.203 t / ha resulting in an outflow of around Rs. 20000 Million to other states for meeting the annual rice requirement of the state. (John, 2004, Ajithkumar and Anitha, 2006).

Most of the farmers in this area are reluctant to rice cultivation and often convert paddy fields for other cash crops, claiming problems such as low profitability, scarcity of labour and high wages for rice cultivation (Gopikuttan and Kurup, 2004). One of the major laborious and time consuming operations in rice cultivation is weeding**.** The concept of weed control is as old as agriculture itself. The global figure for crop yield loss is accepted as 10% of actual yield (Fletcher, 1983). The yield losses ranges from 10–50% in transplanted rice and 50–90% in upland rice depending on the extend of weed infestation (Pathak et al.,1976). Traditional seedbed-based rice cultivation consumed higher energy for weed management in India (15.3 - 23.7 %), compared to stale seedbed (Chaudhary *et al*., 2006). This is because traditional farmers grant their higher priority to hand weeding in developing countries like India. Estimates of time and cost for hand weeding are variable and depend on weed flora, weed intensity, cropping season, labour availability and efficiency of weeding methods. It is estimated that one-third to one-half of the labour used in rice production is for weed control with an average figures of 30–40 labour-days per hectare and 8-10 man-hour per day (Hobbs and Bellinder, 2004)

Transplanted paddy cultivation is now more popularising in Kerala. To get the full benefit of mechanisation, it is very necessary to use proper weeding implements, which will reduce drudgery and cost of cultivation. Japanese Rotary weeder and IRRI Cono weeder commonly use wet land paddy weeders and are becoming increasingly popular among farmers in India. So it is highly significant to study the comparative performance of these two tools in terms of performance, human energy consumption and fatigue responses. Several researches have been reported on human energy consumption for animal-drawn blade harrow (Gite, 1992), wheeled-type manual weeding tools (Gite *et al*., 1993) and animal-drawn plough (Gite, 1991). So this study was aimed to retrieve relevant information regarding, ergonomic factors and ergonomic aspects of above mentioned weeders. Study to evaluate field performance of five different configurations of weeding blades of a push-pull weeder indicated that the human power requirement to use the weeder was 21.3W and which is sustainable to an average farm worker (Tiwari, et al.,1993). Performance of three commonly using manually operated weeders was evaluated from ergonomics and mechanical considerations by Tiwari et al (1991). In that study three operators included in 5th, 50th and 95th percentiles of the operator population were selected for laboratory and field trials. Their investigation identified ‘khurpi’, an indigenous hand-tool as a very effective and less energy demanded one. Nag et al, 1980 conducted an extensive study on Indian agricultural male workers to assess the occupational work load on the basis of cardio-respiratory responses and individual capacity to perform work. They classified the work intensity of agricultural operations in terms of ‘light’, ‘moderate’, ‘heavy’ and ‘extremely heavy’ which corresponds to energy cost values <9.10 kJ/min, 9.11-18.15 kJ/min, 18.16-27.22 kJ/min and > 27.23kJ/min respectively.

Monitoring heart rate response is considered as one of the accurate means to evaluate the physiological and power demands of work on the worker (Hasalkar et al, 2004). Hasalkar et al, 2004 assessed workload associated with hand weeding activity on women farm labourers. The researchers remarked the hand weeding activity as a light activity due to low heart responses. Though the activity is light, physiological analysis on women workers have shown the activity imposes maximum drudgery because of its monotony in performance, continuous squatting posture and performing it for a longer period of time. Another worth mentioning studies in this field are that of Laguë and Khelifi(2001) and Bagui and Latin (1992). Laguë and Khelifi (2001) determined the energy input time and labour requirements for a number of different weed control strategies in grain corn grown under two different primary tillage modes based on the equipment used. Bagui and Latin (1992) assessed human energy expenditure in manually operated rice transplanters and they classified workload based on critical values. Study was conducted by Umar (2003) to evaluate and compare the inputs of manual energy only and manual-cum-mechanical energy in the production of ground-nuts. Study revealed that weeding had the most energy requirement (45% and 52% of the mean total energy inputs) in ground-nut cultivation. Mari *et al*. (2006) demonstrated an ANOVA based statistical analysis to assess the effect of tillage and machinery traffic on Soil Properties and crop growth characteristics. This study also aimed to perform SYSTAT-based statistical analysis to identify influence of different weeding operations on crop growth characteristics.

Through this study we intend to conduct a holistic evaluation associated with rice weeding activity. So apart from ergonomic and field performance aspects, we also conducted a detailed investigation regarding the performance, economic aspects of weeders and biometric characteristics of the plant in response to weeding operations.

2. MATERIALS AND METHODS

2.1 Study Area and Experimental Conditions

This study was conducted In the Instructional Farm of KCAET Tavanur, Ponnani Taluk, Malappuram District of Kerala State, India. The experimental field belongs to typical wetland region. It is situated at 10^0 53’ 30’’ north latitude and 76^0 east longitude. The field selected had soil with more clay fractions. The test field was divided into fifteen plots of 20 x 10m size. The experimental field was well prepared through two ploughing and levelling. The short duration variety of paddy – Red Triveni was grown in mat nursery. After 17 days, the crop was transplanted to the main field with a row to row spacing of 22.7cm and plant to plant spacing of 12cm using mechanical transplanter. The detail of the farm operations and inputs given to the crop are given in Table 1. There were five treatments as given below and each replicated four times.

H - Hand weeding.
R - Weeding using rotary weeder.
C - Weeding using Cono weeder.
RH- Weeding using Rotary weeder and one hand weeding.
CH-Weeding using Cono weeder and one hand weeding.

Japanese Rotary weeder and IRRI Cono weeder were selected to compare their performance with manual weeding. The specifications of the selected implements are shown in Table 2

Table 1. Details of the farm operations and inputs applied to the field

Operations	Details
Crop	Red Triveni
Type	Short Duration
Crop Duration	109 Days
Nursery Sowing Date	30-06-2003
Transplanting Date	17-07-2003
Basal Application	26-07-2003
First Top Dressing	08-08-2003
Weeding	21-08-2003
Sand:Silt:Clay ratio	63.1:26.3:10.6
Bulk Density(g/cm^3)	1.7
Second Top Dressing	2
Harvesting	17-10-2003
Basal Application (kg/ha)	
Urea	76
Rajphose	
Muriate of Potash	29
First Top Dressing (kg/ha)	
Urea	38
Rajphose	
Muriate of Potash	14.5
Second Top Dressing (kg/ha)	
Urea	38
Rajphose	Nil
Muriate of Potash	14.5

Table 2. Specifications of selected implements

Specifications	Rotary weeder	Cono weeder
Weight (kg)	4.5	6.5
Effective Width (cm)	17	16
Depth of Cut (cm)	6	4
Handle Length (cm)	51.5	42
Handle Circumference (cm)	9	9
Rotor Spacing (cm)	20	25
Float Width (cm)	17	9.5
Float Length (cm)	18	35
Weeder Height (cm)	86	109
Weeder Length (cm)	138	171
Angle of Inclination (Degree)	32	32.5

2.2 Evaluation of Field Performance of Weeders

To evaluate the field performance of weeders, different parameters like weeding efficiency, damage factor, field capacity, performance index, time required for weeding, force required for weeding etc. were measured.

2.2.1 Weeding Efficiency

A square loop (0.25 m^2) was randomly thrown to the experimental plots and the number of weeds included in the loop was counted before and after weeding. Five sets of readings were taken and the average was calculated.
The weeding efficiency or weeding index was calculated using the formula:

$$\text{Weeding Efficiency} = \frac{W_1 - W_2}{W_1} \qquad \dots (1)$$

Where, W_1 - Number of weeds before weeding
W_2 - Number of weeds after weeding

2.2.2 Damage Factor (DF)

DF or quality of work done (Tiwari et al, 1993) is the measure of damage on crop plants, while weeding operation, denoted by the expression given below (Gupta (1981)).

$$DF(\%) = \frac{Q_2}{Q_1} \times 100 \qquad \dots (2)$$

Q_1 - Number of plants in 10 m row length before weeding.
Q_2 - Number of plants damaged along 10 m row length after weeding

2.2.3 Performance Factor (PF)

The performance factor was calculated as (Gupta (1981)):

$$PF = \frac{Field.Capacity(ha/h) \times (100 - DF(\%)) \times WE(\%)}{Power(Hp)} \qquad \dots (3)$$

Where, DF= Damage factor (%)
WE=Weeding Efficiency (%)

2.2.4 Force Analysis

Calibrated proving ring of 100 kgf, with circular ring and dial gauge, connected to the handle of weeder was used for force analysis. The sensitivity of the proving ring was 0.1 kg per division with a least count of 0.002-mm.

2.3 Ergonomic Aspects of weeders

2.3.1 Measurement of Energy Expenditure

The ratio between height and weight of the subjects (H/W) could be extensively used to define and classify physique of the subjects. The physical work capacity is directly correlated with height and inversely with weight of the subjects. Hence in this study, the subjects for the field investigation of performance and ergonomic factors associated with weeding were selected on the basis of their height to weight ratio. The selected subjects were classified to three groups based on their anthropometric observation data viz. 5th percentile, 50th percentile and 95th percentile. However, ergonomic evaluation for weeding operation was conducted only for male and female subjects included in 50th percentile, because that was the major representative group and the measure of central tendency of the whole group of subjects. The anthropometric distribution of the selected subjects for this study was skewed (non-normal), so the 50th percentile can be considered as the reference group which often the correct measure of central tendency than mean value. The anthropometric dimensions of selected 50th percentile subjects were measured and shown in Table 3

The amount of energy spent by the subjects while performing a physical task is closely related to the amount of oxygen consumed. The volume of the oxygen consumed can be thus taken as index of physiological load imposed on the subject. To serve the purpose of estimating energy consumption related to a task, correlation between heart rate and oxygen consumption is established by calibrating the subject. Bicycle Ergonometer was used to calibrate the subject. The general calibration curves for male and female subjects in agriculture for the 5th, 50th and 95th percentile are shown in Figure 1 and Figure 2 (Geetha, 2001). These calibration curves were used to estimate energy expenditure corresponding to different weeding operations. The heart rate responses were recorded using the heart rate monitor attached on the subject and while doing the weeding activity. Five minutes rest was given after 20 minutes of weeding.

Table 3. Anthropometry of the male and female subjects in 50th percentile group

Attribute	Dimensions (Mean Value)	
	Male subjects	Female subjects
Age	29	25
Work Experience	>10 years	6-7 years
Heat beat and Blood Pressure	Normal	Normal
Weight (kg)	61.6	58.2
Height (cm)	164.3	145.2
Eye Height in Standing Position (cm)	158.5	133.2
Shoulder Breadth (cm)	43.5	39.0
Hip Breadth in Standing Position (cm)	33.5	35.5
Chest Depth (cm)	19.1	28.5
Arm Reach (cm)	90.3	71.5
Sitting Height (cm)	80.2	69.5
Seat Length (cm)	44.0	39.5
Forearm Hand (cm)	49.1	39.0
Shoulder Height in Sitting Position (cm)	51.4	48
Foot Length (cm)	24.0	20.5
Foot Breadth (cm)	10.1	9.5
Buttock Knee (cm)	59.1	47.2
Hip Breadth in Sitting Position (cm)	35.2	38.5
Palm Length (cm)	19.5	18.0
Palm Circumference (cm)	24.5	20.5
Wrist Circumference (cm)	16.0	15.0

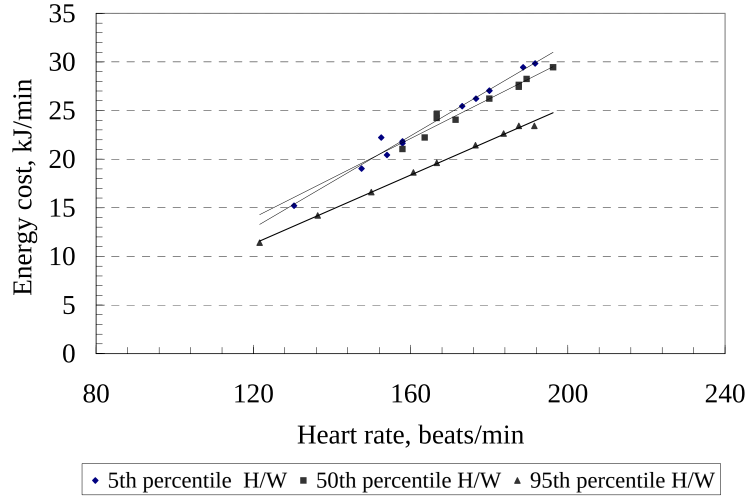

Figure 1. Calibration curve for female subjects

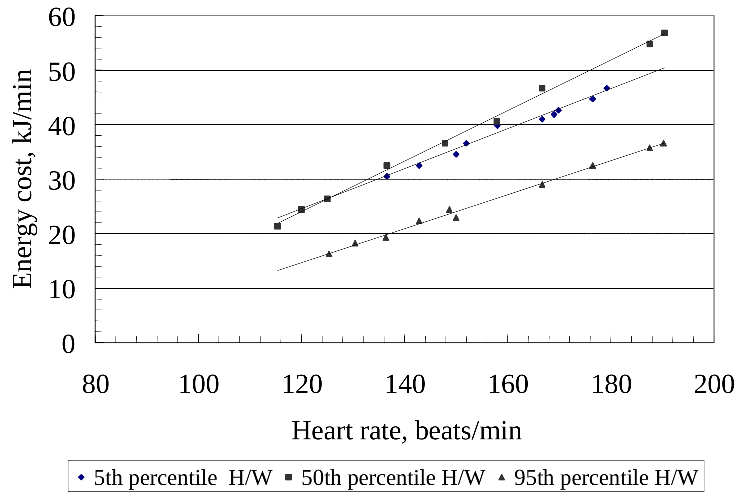

Figure 2. Calibration curve for male subjects

2.3.2 Psychophysical Assessments

Weeding operations performed by subjects were expected to trigger pain or discomfort at different body parts of operator in various intensities. Hence the work-related body discomfort (WRBD) of agricultural labours was to be analysed. The method suggested by Corlett and Bishop (1976) was adopted to assess the WRBD. They introduced the body map discomfort diagram, in which body diagram of the subjects were divided in to several regions numbered for convenient reference and identification. A ten point Rated Perceived Exertion (RPE) scale suggested by Borge (1973) was also used as a means of subjective assessment of the task, which is shown in Table 4.

Table 4. Borges 10 point scale for Ratings of Perceived Exertion

Rating	Intensity of work
0	Nothing at all

0.5	Very very light
1	Very light
2	Light
3	Moderate
4	Some what heavy
5	Heavy
6	Heavy
7	Very heavy
8	Very heavy
9	Very heavy
10	Extremely heavy (maximal)

2.4 Crop Growth Observations

Tillage practices including weeding are important factors influencing growth and yield. To study the effect of different weeding methods on biometric and growth characteristics of crop, different parameters like plant height, grain weight, CGR, RGR, number tillers, length of panicle, number of grains per panicle, crop dry matter, yield etc. were noted.

Two sets of samples were taken during the growth period, i.e. one week before weeding and one week before harvesting. Five plant hills were selected at random from each plot and cut close to the ground level, which were dried separately in hot air oven at 80^0C for 72 hours. Thus the Dry weights of the samples were recorded. In each plot, four quadrants of 0.03m^2 area were selected at random and total tillers were counted and expressed as number per m^2. Another parameter Crop Growth Rate (CGR) was calculated as suggested by Watson (1952) using the formula

$$\mathrm{CGR} = \frac{\mathrm{W}_2 - \mathrm{W}_1}{\mathrm{t}_2 - \mathrm{t}_1} \qquad \text{… (4)}$$

According to Radfords (1967), Where W_1 and W_2 are the shoot dry weights recorded at time t_1 and t_2. CGR is expressed as g^{-1}day^{-1}.

RGR is calculated as per formula given by Williams (1946).

$$RGR(gg^{-1}day^{-1}) = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1} \qquad \text{… (5)}$$

Dry weight of 1000 grains taken from each experimental plot were analysed for effect of different weeding operations. In addition, Total grain yield from different treatment plots were taken separately and the average yield of each treatment were calculated.

2.5 Cost Analysis and Cost Factors

The simple straight line method was used for depreciation and of cost estimation in this study. Salvage value of the weeders was assumed negligible. Taxes, shelter, fuel charges and insurance are not applicable in the case of hand weeders. With these assumptions, the equations for annual cost (AC) can be written as follows:-

$$AC = P(\frac{1}{Y} + 0.5I) + RM + \frac{A}{LC} \qquad \dots (6)$$

Where, P = Purchase price (in Rs.)
I = Rate of interest (assumed as %12 per year)
Y = Estimated life (year)
RM = Repair and maintenance costs (assumed as 5% of purchase price)
C = Field capacity (ha/day)
L = Labour cost (Rs. /day)
A = Total weeding area in an year (ha/year)

3. RESULTS AND DISCUSSION

3.1 Comparative Evaluation of Field Performance

Details of the performance evaluation conducted for Rotary and Cono weeder are shown in the Table 5.

3.1.1 Weeding Efficiency

Weeding efficiency was 79 % and 72.5 % respectively for Rotary weeder compared to Cono weeder. The increased soil contact and soil inversion capacity of Rotary weeder add greater values to its higher weeding efficiency. The Rotary weeder gives better performance even in the later stages of weeding. Cono weeder gives better performance on initial stages of weed growth. If the weeds are matured the Cono weeder just rolls over the weeds with minimum uprooting and inversion.

3.1.2 Damage Factor

The damage factor was, respectively, 7.06% and 4.55% for Rotary and Cono weeder. The higher percentage damage in the case of Rotary weeder compared to Cono weeder was mainly due to the higher effective width of cut of weed rolls. Moreover, greater depth of cut and inversion of Rotary weeder cause the uprooting of crop, which are extending to the row spacing.

Table 5. Performance characteristics of different weeding operations

Characteristics	Rotary Weeding	Cono Weeding	Hand Weeding
Weeding Efficiency (%)	79.0	72.5	-
Damage Factor (%)	7.06	4.55	-
Field Capacity (ha/hr) (Male)	0.021	0.0244	0.003
Field Capacity (ha/hr) (Female)	0.0124	0.0131	0.0025
Performance Index (Male)	302.12	382.62	-
Performance Index (Female)	298.37	381.11	-

Time Required (hr/ha)(Male)	47.7	41.0	333.3
Time Required (hr/ha)(Female)	80.7	76.3	399.8
Force Required (kgf)	4.9	4.5	
Cost of Operation (Rs/ha) (Male)	~1100	~950	~7250
Cost of Operation (Rs/ha) (Female)	~1500	~1400	~7300

3.1.3 Velocity and Field Efficiency of Weeding Operations

Cono weeder had higher velocity of operation than Rotary weeder. For male subjects, the velocity of weeding by Rotary weeder and Cono weeder was 0.38 m/s and 0.44 m/s respectively. And the same for female subjects was 0.29 m/s and 0.32 m/s respectively for Rotary weeder and Cono weeder. The field efficiency for Rotary weeder was 85% with an associated time loss, which is independent of area varying from 5 to 6 h/ha. The time loss for turning was 1.73 h/ha for male subjects and 2.4 h/ha for female subjects. For Cono weeder, the field efficiency was 86.5%. The time loss independent of area, which is required for the operation, was about 4 h/ha. The time loss for turning was 1.83 h/ha for male subjects and 2.51 h/ha for female subjects for the same.

3.1.4 Field Capacity

It was observed that Cono weeder had higher field capacity than the Rotary weeder. The field capacities of Cono weeder were 0.0244 ha/h and 0.013 ha/h and those of Rotary weeder were 0.021 ha/h and 0.0124 ha/h for male and female subjects respectively. In case of hand weeding by male and female labourers, field capacities were obtained as 0.003 ha, and 0.0025 ha respectively. That is, the male and female labourers took an average of 330 and 400 labour hours per hectare respectively. For weeding with Rotary weeder and Cono weeder, it was found that a male subject took an average of 48.78 and 41 h/ha respectively and that by female subject were 80.65 and 76.33 h/ha respectively. This is because the teeth of rotary weeder had more interactions with soil; hence it took more time to operate. Moreover, the higher velocity of operation of Cono weeder adds to its increased field capacity. In case of female subjects the operating speed was less and they took more time for turning the implement.

3.1.5 Performance Index

Performance index of a weeding implement would be directly related to the field capacity, weeding efficiency and (100-damage factor in percentage) inversely related to power exerted. The performance index of Rotary weeder respectively for male and female were 302.12 and 298.37 and that of Cono weeder were 382.62 and 381.11. The performance index of Cono weeder was higher than that of the Rotary weeder; this is because of higher field capacity and minimal damage factor. In weeding operations the energy expenditure and field capacity for female were minimum compared to that of male.

3.1.6 Force Analysis

Force required for pushing the weeder was higher for Rotary weeder. It was noted that force required to push the Rotary weeder was 4.9 kgf and that of Cono weeder was 4.5 kgf. Even though the weight of the Cono weeder was more, soil resistance acting on the rollers was minimum compared to Rotary weeder. So the effort required was more for Rotary weeder.

3.1.7 Time Required for Weeding

The study shows that the time required for hand weeding per hectare was in the range of 300-360 h (average value 333.3 h) for male labours and that for female labours was 375-420 h (average value 399.8 h). For the same area, male labours took an average of 47.7 h and 41.0 h for rotary and cono weeding respectively, while female labours performed the task in 80.7 h and 76.3 h for rotary and cono weeding respectively.

3.1.8 Economic Analysis

The economic aspects of weeding were analysed using the straight-line method. The expenses associated with different weeding operations are depicted in Table 5. The study showed that cost of weeding for female labours could be reduced by 4.85 times and 5.2 times by using Rotary weeder and Cono weeder respectively, compared to hand weeding. While for male labours the weeding cost could be reduced by 6.6 times and 7.6 times by using Rotary weeder and Cono weeder respectively, compared to hand weeding.

3.2 Ergonomic aspects

The main ergonomic aspects related to weeding operation include energy cost and work related body discomfort (WRBD)

3.2.1 Energy Cost Associated with Weeding

Human energy cost is directly related to heart beat response and oxygen consumption. Heart beat responses for male and female under different weeding operations like hand weeding, Rotary weeding and Cono weeding are plotted separately.

3.2.1.1 Energy Cost and Heart Beat Response for Male Subject

For a particular workload the heart beat showed a sudden increase in the first few minutes and then it was stabilised through out the work. After the completion of work the heart beat decreased drastically. The maximum heart beat response for rotary weeding; cono weeding and hand weeding were 129,121,104 heartbeats / min respectively. The increased depth of cut, specially designed blades which cause more interactions with soil and proper coverage of uprooted weeds etc increase the workload for rotary weeding. The weed rolls of Cono weeder will just roll over the obstructions, which cause a reduced workload. From the calibration chart the maximum energy cost corresponding to rotary weeding, cono weeding and hand weeding were respectively 26.5, 24.0 and 16.0 kJ/ min. The indicated values of energy cost assessments have shown slightly higher values compared to earlier studies conducted by Nag et al, 1980. The uprooting of weeds demands a greater physiological cost of the bending posture (16.0 kJ/ min). However the hand weeding is operation falls in the category of "moderate" according to Nag et al, 1980 categorisation of the agricultural work (shown in table 6) whereas the weeding using Rotary and Cono weeder falls in "heavy" category with energy cost of 26.5 and 24 kJ/min respectively.

Table 6. Categorisation of the agricultural work (Nag et al, 1980)

Variables	Light	Moderate	Heavy	Extremely Heavy
VO_2 max(%)	<25%	Up to 50%	Up to 75%	Above 75%
O_2 consumption (l/min)	0-0.435	0.436-0.870	0.871-1.305	>1.306
Energy cost (kJ/min)	<9.10	9.11-18.15	18.16-27.22	>27.23

3.2.1.2 Energy Cost and Heart Beat Response for Female Subject

The heart beat responses of female subject under different weeding operations were observed. The maximum heart beat response for rotary weeding; cono weeding and hand weeding were 136,125,109 heartbeats / min respectively. From the calibration chart the maximum energy cost corresponding to rotary weeding, cono weeding and hand weeding were respectively 18.0, 15.0 and 9.5 kJ / min. From the table 6, we can note that the energy expenditure values falls in "moderate" class of agricultural work categorisation for female workers as the values with in the range 9.11-18.15 kJ/min

The energy cost requirement for male and female subjects under different weeding operations are given in Figure 3

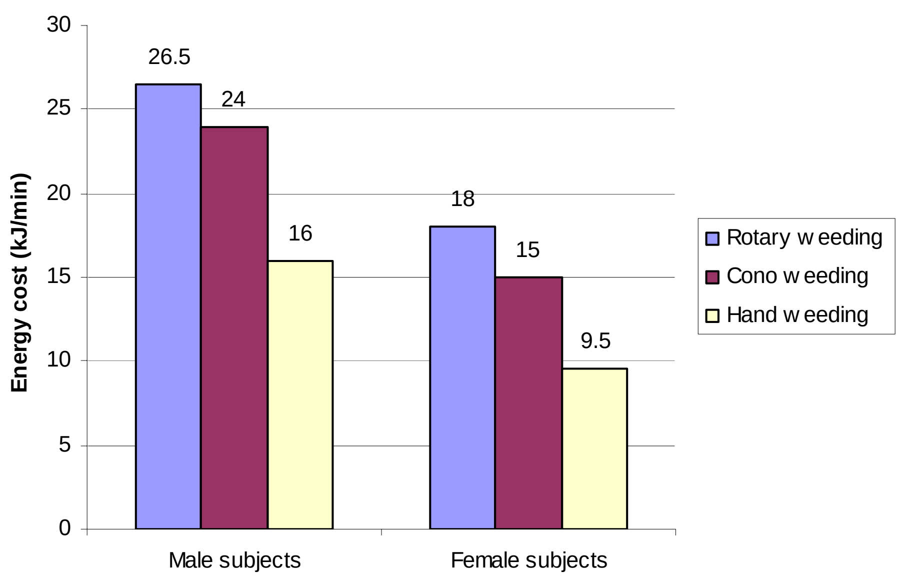

Figure 3. Energy cost associated with different weeding operations for male and female subjects

3.2.2Wok related body discomfort (WRBD)

WRBD is the measure of discomfort related to a particular work. Overall Rated Perceived Exertion (ORPE) was used to express WRBD. ORPE of male and female subjects under different weeding operations like hand weeding, rotary weeding, and cono weeding are shown in the Figure 4, 5, 6, 7, 8, and Figure 9. The figures show that overall discomfort was increasing with time. Discomfort was more for hand weeding, followed by cono weeding and rotary weeding. This is because, while hand weeding the labours are in bending posture. So they experience more discomfort on neck, upper back, mid back, lower back right clavicle and left clavicle. But the other two operations were in standing posture, so the overall discomfort was less than hand weeding.

While rotary and cono weeding, body parts like right thigh, left thigh, left fore arm, right fore arm, right palm, left palm, lower back, left leg, right leg, left shoulder, right shoulder, left arm and right arm experienced discomfort. Cono weeding showed more discomfort rating than rotary weeding on following body parts like right shoulder, left shoulder, right palm, left palm, right fore arm, left fore arm etc. This is because weight of the Cono weeder was more and, length and height of this equipment was not proper for the selected subjects. Due to this, the working posture of hands was improper so they experienced more discomfort. The female subjects experienced greater discomfort than male subjects for the same weeding implement.

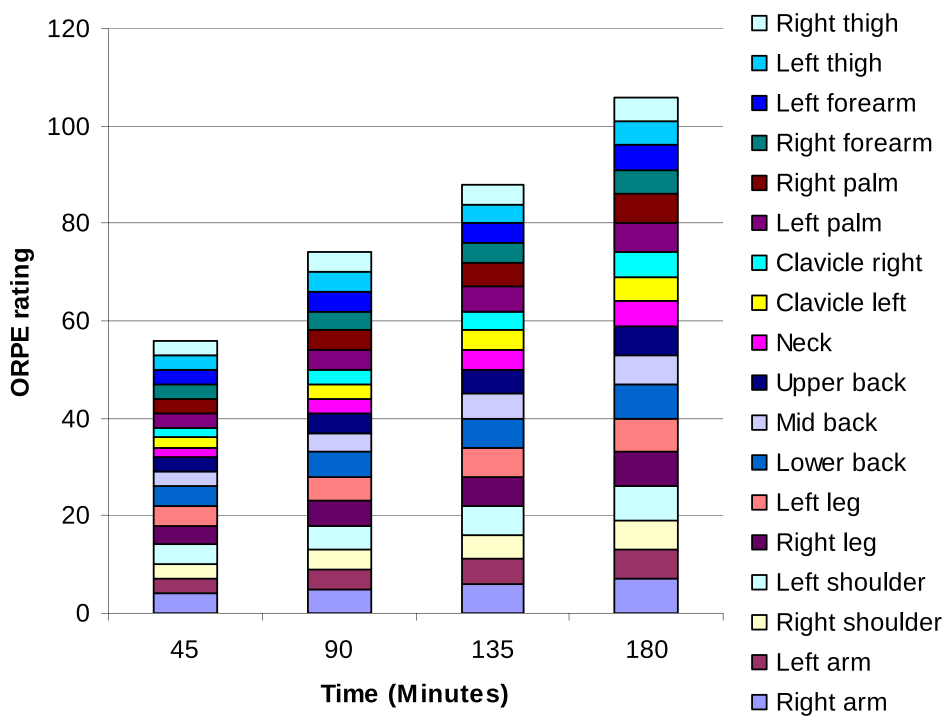

Figure 4. ORPE of male subject while hand weeding

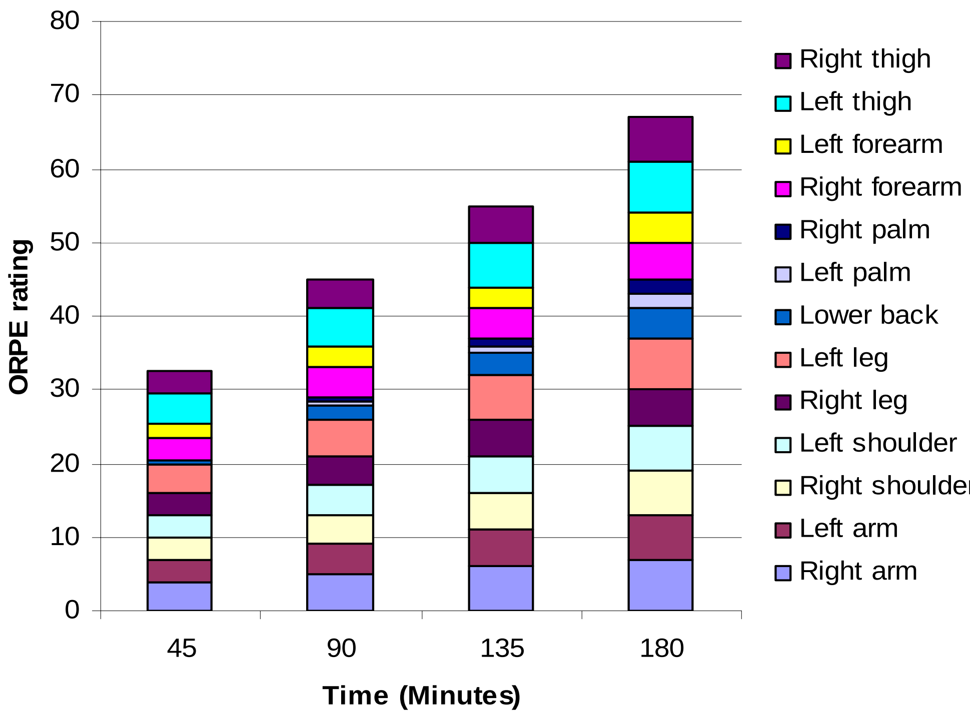

Figure 5. ORPE of male subject while rotary weeding

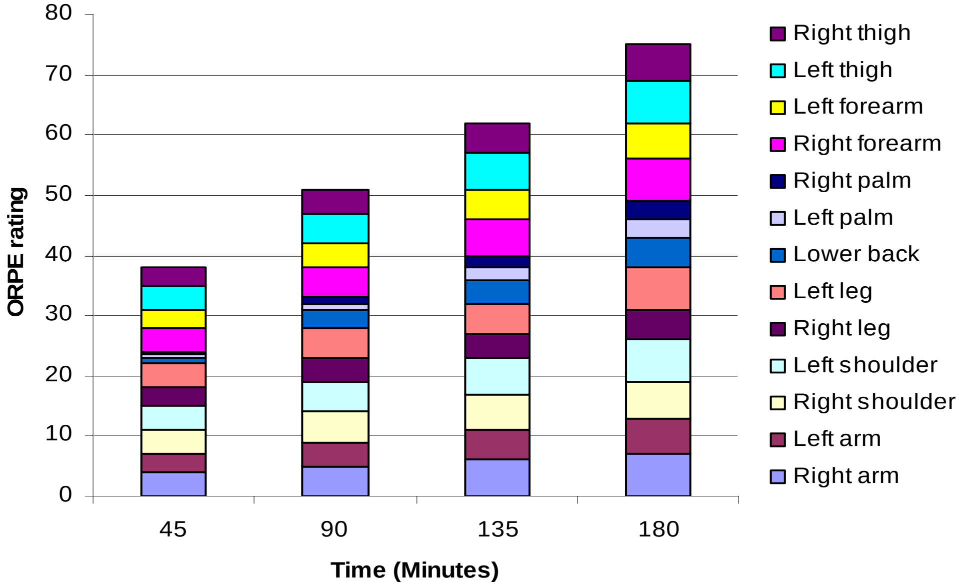

Figure 6. ORPE of male subject while cono weeding

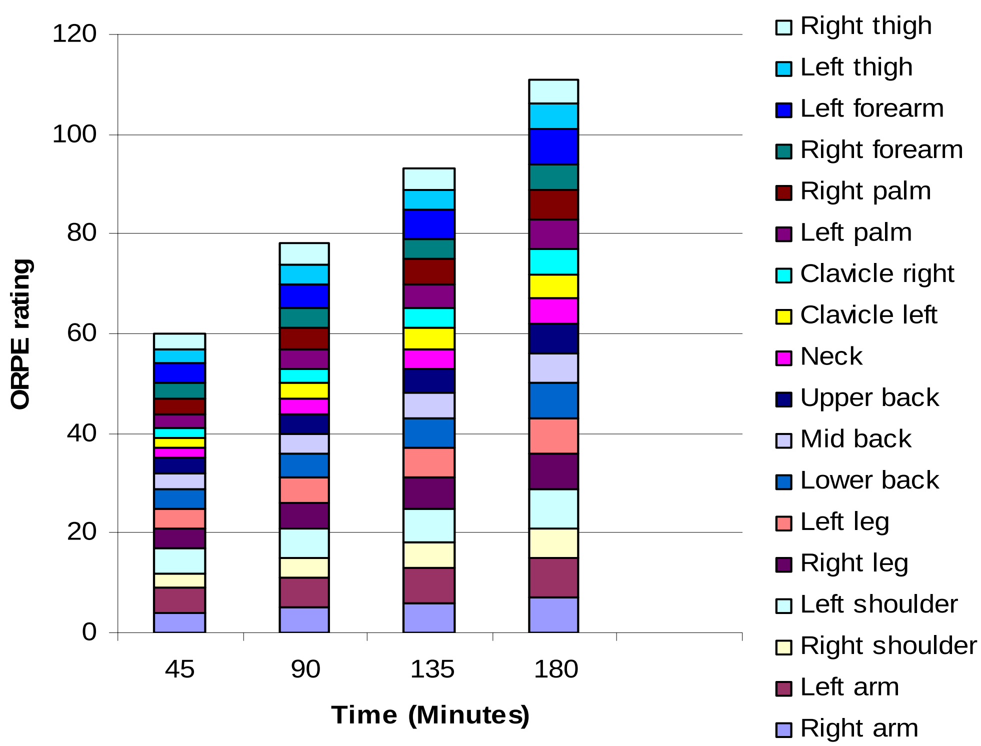

Figure 7. ORPE of female labourer while hand weeding

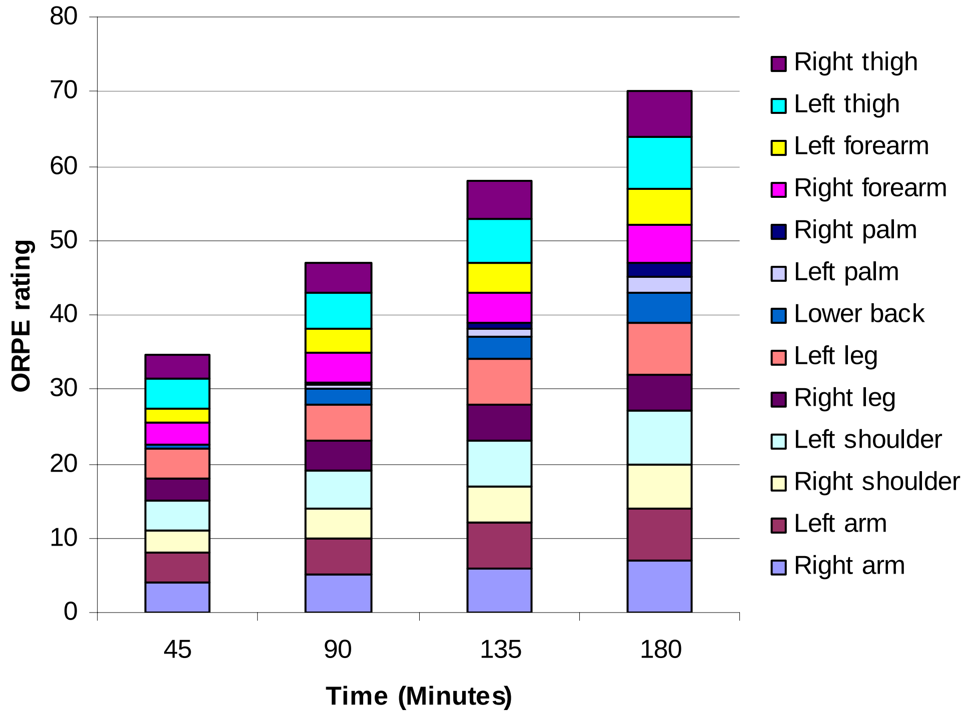

Figure 8. ORPE of female subject while rotary weeding

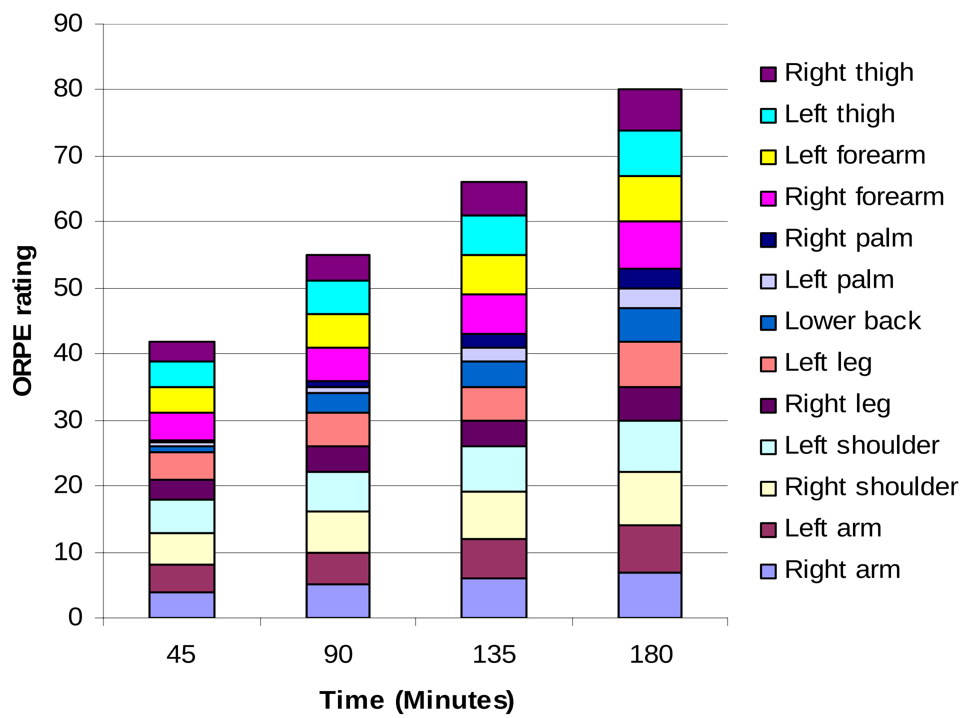

Figure 9. ORPE of the female subject while cono weeding

3.3. Statistical Analysis of Crop Growth Parameters

Data analysis was performed using ANOVA-based on randomised block design and treatment means were compared by Fisher's Least Significant Difference (LSD) procedure at 5% and 10% significance level. There were significant differences in crop growth parameters among the different weeding operations (ANOVA, p< 5% or 10%). Mean yield was highest in H-type and lowest in C-type weeding operation (Table 7). There were also significant differences in different crop growth parameters like grain weight, height of the crop and change in number of tillers among the different weeding practices types. The data was analyzed with ANOVA (Fisher's Least Significant Difference Test) using Systat 8 software and relevant results are showing in Table 6. While statistically analysing for height of crop parameter, the least square difference showed a probability 0.0806 for the difference in means of treatments H and RH which is significant at 10% level of significance. The effect of weeding on grain weight is shown in Fig 10. The statistical analysis for grain weight showed a probability of 0.078 and 0.081 for the difference in means of treatments H and RH, and, H and R respectively which were significant at 10% level of significance. It was also observed that the change in number of tillers was minimal in hand-weeding the maximum was obtained for RH treatment. Thus it revealed the influence of high damage factor of Rotary weeder on crop growth. The CGR and RGR showed less variation with treatments, even though those had higher values for hand weeding which were followed by CH, RH, C and R respectively. It was also revealed from the ANOVA results that the effect of weeding operations on length of panicle, grains per panicle and change in dry weight of crop are statistically insignificant (Data not shown).

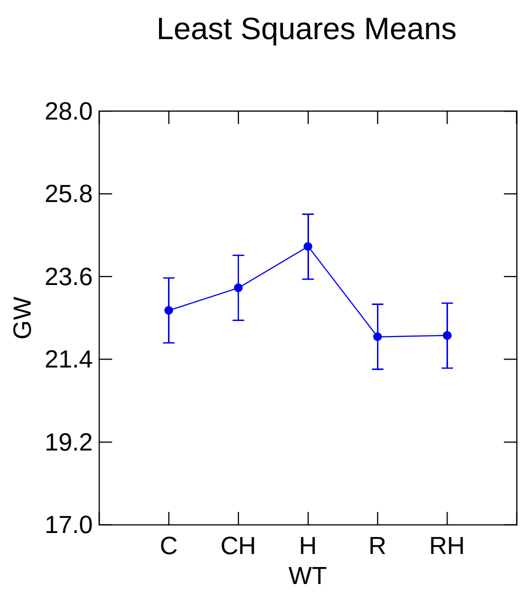

Figure 10. Relation showing 1000 grain weight (gm) under different treatments derived from anova based analysis. (where WT=weeding treatments, GW=grain weight, H=Hand weeding, C= cono weeding, R=rotary weeding, CH=cono+hand Weeding, RH=rotary+hand weeding)

Table 7: Results of data analysis for some crop growth parameters using ANOVA based on randomised block design and treatment means were compared by Fisher's least significant difference (LSD) procedure

			Height of the Crop		
	C	CH	H	R	RH
C	1.000				
CH	0.280	1.000			
H	0.106	0.540	1.000		
R	1.000	0.280	0.106	1.000	
RH	0.9	0.23	0.086**	0.901	1.000
			1000 Grain Weight		
	C	CH	H	R	RH
C	1.000				
CH	0.634	1.000			
H	0.194	0.389	1.000		
R	0.579	0.312	0.078**	1.000	
RH	0.597	0.324	0.081**	0.979	1.000
			Change in Number of Tillers		
	C	CH	H	R	RH
C	1.000				
CH	0.083**	1.000			
H	0.428	0.020*	1.000		
R	0.297	0.428	0.083**	1.000	
RH	0.052**	0.789	0.013*	0.297	1.000
			CGR		
	C	CH	H	R	RH
C	1.000				
CH	0.706	1.000			
H	0.627	0.911	1.000		
R	0.876	0.596	0.523	1.000	
RH	0.859	0.841	0.756	0.739	1.000
			RGR		
	C	CH	H	R	RH
C	1.000				
CH	0.761	1.000			
H	0.675	0.881	1.000		
R	0. 761	0.596	0.523	1.000	
RH	0. 593	0.640	0. 569	0. 398	1.000
			Yield		
	C	CH	H	R	RH
C	1.000				
CH	0.024*	1.000			
H	0.030*	0.007*	1.000		
R	0.045*	0.731	0.004*	1.000	
RH	0.010	0.608	0.017*	0.398	1.000

* Means significant at the 5% probability level

** Means Significant at 10% probability level

4. CONCLUSIONS

The study revealed that both the weeders selected for the study has its own strengths and limitations. Rotary weeder can be recommended in the later stages of weed growth as the better weeding efficiency, more turning of the soil and uprooting of weeds overrules the higher cost of operation. Cono weeder performed the task with comparatively higher field capacity, better performance index in the early stages of weed infestation. The field performance analysis have shown that Weeding efficiency as 79 % and 72.5 % respectively for Rotary weeder compared to Cono weeder with damage factor of 7.06% and 4.55% respectively. It was found that a male subject took an average of 48.78 and 41 h/ha respectively for weeding operation with rotary and cono weeders; where as the female subject took 80.65 and 76.33 h/ha respectively. The study also emphasised the variation of energy expenditure and overall discomfort associated with different weeding practices. Work Related Body Discomfort (WRBD) of farmers, associated with traditional hand weeding could be reduced to a considerable extent by switching over to these weeders. The energy cost analysis shown that weeding with these two tools viz. Cono weeder and Rotary weeder falls in “heavy” class of agricultural labour classification and hand weeding falls in “moderate” class for male labourers where as for female labourers these three weeding operations are in “moderate” class. However, the rural farming group including male and female subjects selected for the ergonomic study was relatively small, so possible changes are expected within the state and across the country. It is envisaged that mechanising the manual weeding operation could displace labour force and which could be used in other productive activities that could lead to increased productivity and can solve labourer scarcity to a large extend. The hand weeding was a superior weeding system for crop growth parameters than any other system employed in this study. The rotary weeding system also showed consistently greater results which were comparable to hand weeding. The performance analysis results demonstrated that weeding tools can produce large reductions in the weeding costs and significant reductions in labour time, whereas hand weeding reached the best efficiency in weed control. The study could conclusively identify weeding operation, as one of the major factors which can pose a great influence on crop yield and growth related parameters.

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