ERGONOMIC EVALUATION OF WOMEN FARM WORKERS USING DIFFERENT MANUAL WEEDING TOOLS IN MAIZE CROP OF UDAIPUR DISTRICT

ABSTRACT

Women play a major and crucial role in doing the agricultural operations. The women workers in Udaipur district mostly uses sickle and khudali for doing weeding operations. This study was conducted in 2019-20 at instructional Farm, CTAE, Udaipur with women farm workers during the manual weeding operation by using different traditional tools like hand hoe (khudali) along with technically and ergonomically designed wheel hoe. The main objective of the study was to investigate the most drudgery prone tool and to recommend the proper tool for doing weeding operations in maize crop. Use of proper tools not only reduce the drudgery but also improves the operating efficiency along with the comfort, besides improving the productivity of the women farm workers in doing the operation. In view of this, an effort has been made to assess the physical and physiological parameters of women farm workers who are using traditional farm tools along with the improved tools for doing weeding operation in maize crop. The whole study was conducted on ten female farm workers identified from the population of workers in the age group of 18 to 45 years. During the experiment, physiological workload i.e., heart rate, oxygen consumption rate, energy expenditure rate and physical workload i.e., overall discomfort rate, rate of perceived exertion and Musculo-skeletal problems were measured. The Pratap wheel hand hoe saves nearly 36% of the cardiac cost of the worker per unit of output and wheel hand hoe saves nearly 38% of the cardiac cost of the worker per unit of output which is nothing but reduction in drudgery by 36% and 38% by both the weeding tools over khudali. Area covered with Pratap wheel hand hoe and wheel hoe were 1.70 and 1.69 times more over khudali.

Key words: *Agricultural activities, women farm workers, weeding, Ergonomic assessment.*

Introduction

Agriculture, with its allied sectors, is the largest source of livelihoods in India. Seventy percent of its rural households still depend totally on agriculture for their livelihood, with 82 percent of farmers being small and marginal (Anonymous, 2021). The share of agriculture in GDP increased to 19.9 per cent in 2020-21 from 17.8 per cent in 2019-20. The last time the contribution of the agriculture sector in GDP was at 20 per cent was in 2003-04 (Shagun Kapil, 2021). India is on; to be looking towards tremendous growth.

Agriculture is generally considered as the most drudgery prone industry which displays high physical workload. It is also noticed that there is very little history of application of ergonomics in design of agricultural equipment. Hence, there is a need for exploiting the

available resources and technologies at appropriate and maximum level with changing agricultural scenario and global competition to boost the productivity by introducing best Ergonomical practices in agricultural region. It is reported that the foundation reasons of many product complaints and failure are often related back to an ergonomic mismatch. A descent understanding of ergonomics and human interaction may be a necessity for the merchandise to become successful within the market. The purpose of ergonomics is to enable a tool/implement to function better by improving the interactions between the human and the tool/implement.

Inter-cultivation practices in agriculture provides maximum possibility for the crop to ascertain and grow strongly up to time of maturity. Weeding operation is the fore most important factors in production of maize. If weeding operation is not properly done then it results in yield losses worldwide with an average of 12.8% despite weed control applications and 29.2% in the case of no weed control (Oerke and Steiner, 1996). Therefore, controlling of weeds is a crucial management practice for production of maize and that ought to be carried out properly for achieving maximum yield of the grain.

In Udaipur, most of the female farm workers having mostly small land holdings use the traditional manual tools for the weeding operation. The commonly used tools are sickle and hand hoe (khudali). Majority of the farm women performs this operation by bending and squatting postures for longer times. Though, this method is very demanding of labour and full of drudgery. It is very clear that the poor posture due to design of the tool can increase the discomfort for both the healthy workers as well as less fit individuals. It requires large amount of human power to perform the weeding operation.

It is also been observed from the survey that there is more amount of human power with least amount of ergonomics that was involved in the design of tools/implements and also in the environment in which they work. Ergonomically designed tools and working environment provides promising and encouraging results by enhancing the operating efficiency by reducing the drudgery , besides providing working comforts and thereby improving the productivity of workers with better safety and health. Hence, there is an urgent need to consider these issues in improving the relationship between the female farm farmers and their working environment. Therefore, the study was conducted to assess the ergonomic relation between the tool and the female farm workers during weeding operation in maize crop by using the traditional manual tools along with the ergonomically improved tool. The percentage reduction of drudgery over the traditional manual tools can also be identified.

Materials and Methods

Physiological and physical workload was calculated during the weeding operation of maize crop which was performed in the month of July, 2020 at CTAE Instructional farm, Udaipur. The study was conducted on ten female farm workers selected from the representative population of workers between 5^{th} and 95^{th} percentile of the anthropometric criteria. During the study period all the operations were performed by these ten female farm workers only. Selected subjects had agriculture as their main source of livelihood. All the subjects selected did not have the habits of chewing tobacco and taking any type of liquor. Subjects were between 18-45 years of age. Subjects were free from any chronological disease, physical disorder and were medically fit. In morning, the uniform time of 6h for weeding operation was given in between 10 AM to 1 PM and in evening from 2 PM to 5 PM. All the female farm workers were allowed to take rest for 15 minutes before performing the task and asked to perform the weeding operation by using the *Kudali* continuously for 30 minutes and then allowed to take rest for 15 minutes. The same procedure was followed for other two tools (Pratap wheel hand hoe and wheel hand hoe) by following proper work-rest cycle.

For assessment of effect of physiological and physical work load on the performance of female farm workers, three different tools namely *kudali*, Pratap wheel hand hoe and wheel hand hoe in maize crop during weeding operation were taken as independent parameters. Six dependent parameters including three physiological workloads namely heart rate (HR), oxygen consumption rate (OCR) and energy expenditure rate (EER) and three physical workloads namely, Overall discomfort rate (ODR), Rate of perceived exertion and Musculo-skeletal disorders were selected for this study.

Instrumentation

During the experiment, the measuring tape and weighing scale were used to measure the physical characteristics like height and weight. Stopwatch was used for recording the time. Instrumentation used to conduct the experiments for measurement of physiological and physical workload is described below.

a. Physiological workload

Computerized ambulatory metabolic measurement system

The computerized ambulatory metabolic measurement system measures the oxygen consumption at every breath that's why it is known for breath by breath measurement and is more accurate than mixing chamber measurement. Heart rate (resting HR, working HR) and oxygen consumption rate were measured by using $K4b^2$ make by Cosmed (Italy). Based on the

oxygen consumption rate, the energy expenditure rate (EER) was calculated by using the following formula given by (Nag and Dutt, 1980).

1. Energy expenditure rate (EER) (kJ/s) = 20.88 (kJ/l) x OCR (l/min)

2. Increase in Heat rate, ΔHR (beats/min) = Average working heart rate – average resting heart rate

3. Output (m^2/h) = area covered x duration / average time

4. Cardiac cost of worker per unit of output (beats/ m^2 area covered) = ΔHR x duration / output.

b. Physical workload

1. Overall Discomfort Rating (ODR)

Corlett and Bishop created the overall discomfort rating (ODR) in 1976 for the evaluation of discomfort by using a 10-point psycho-physical rating scale. A scale of 70 cm length was fabricated having 0 to 10 digits marks on it equidistantly as shown below in figure 1. A movable pointer was provided to indicate the rating. The subject was asked to report her discomfort level on the scale before start of work. she was again asked to report the discomfort level at the end of work. The difference in the score of before and after the work was the real discomfort score.

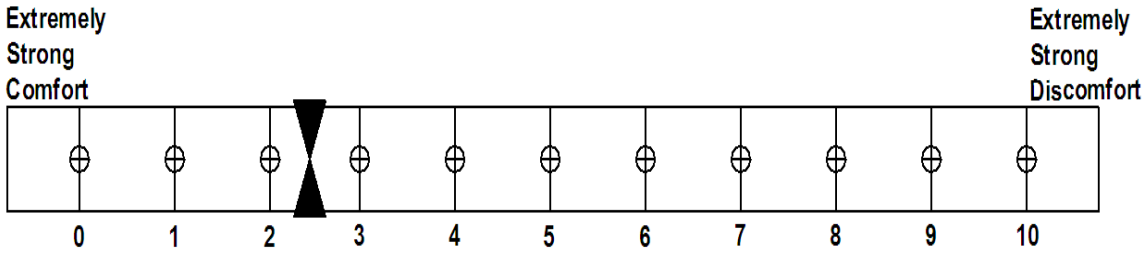

Figure 1 ODR 10-Point Scale

2. Rating of perceived exertion

Rating of Perceived Exertion was measured at 5-point scale developed by Varghese *et al.* (1994)

very light –1,light-2, moderately heavy-3, heavy-4,very heavy-5

3. Musculo-skeletal problems

Incidences of Musculo-skeletal problems during the activity were identified with the help of body map (Corlett and Bishop, 1976) as shown in figure 2, which indicates different body parts (Figure) viz; upper body parts (eye, neck, shoulder joint, upper arm, elbows, wrist/hands) and lower body parts (lower arm, low back, upper leg/ thigh, knees, calf muscles, ankles, feet). The scorecard showing the value from 0-6.

0-no pain, 1-very mild, 2-mild, 3-moderate, 4- moderately heavy, 5- severe, 6- very severe was used to quantify the stress on the muscles.

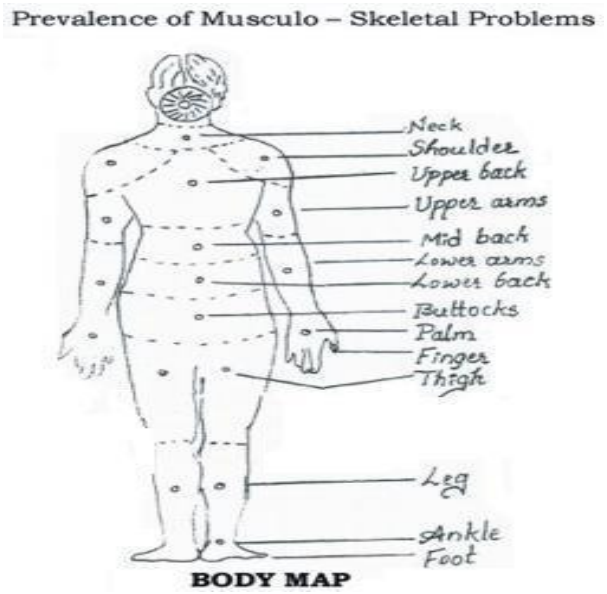

Fig. 2. Body map (Corlett and Bishop, 1976)

Results and discussion

To evaluate the weeding operation from ergonomic point of view, ten female farm workers in the age group of 25 to 45 years were selected at random and average age of the respondents engaged in maize weeding operation was counted as 32.50 years measuring body height of 156.50 cm and weight as 46.50 kg, respectively (Table 1).

Table 1. Physical characteristics of selected female farm workers(N=10)

S.No	Physical characteristics of female farm workers	Mean±Standard deviation
1.	Age (years)	33.30±9.25
2.	Height (cm)	149±7.18
3.	Weight (Kg)	45.4±5.72
4.	Body mass index (BMI)	20.58±2.03

Physiological workload in the weeding operation of maize crop was determined on the basis of various parameters like average heart rate during work and rest, energy expenditure and physiological cost of work while performing the activity. Figure 3 indicates different types weeders used for this study.

Figure 3. Different types of weeders used in the study

Physiological workload of the female farm workers during weeding operation in maize crop

Field experiments were carried out to assess the physiological cost of the subjects in terms of heart rate (HR), oxygen consumption rate (OCR) and Energy expenditure rate (EER) during weeding operation in maize crop with three types of manual weeders viz., khudali,

Pratap wheel hand hoe, wheel hand hoe. The level of variation between these implements on increase in heart rate (HR) and oxygen consumption rate (OCR) were evaluated statistically. The increase in heart rate (HR) is expressed as difference in working heart rate and resting heart rate. The increase in oxygen consumption rate (OCR) is expressed as difference in working oxygen consumption rate and resting oxygen consumption rate.

Performance evaluation of different parameters during the weeding operation of maize crop

Physiological workload during the weeding operation of maize crop was determined on the basis of various parameters like average heart rate during work and rest, oxygen consumption rate, energy expenditure rate, physiological cost of work while performing the activity and physical workload was determined on the basis of Overall discomfort rating (ODR) (before and after the operation), Rating of perceived exertion (RPE) and BPDS. The evaluation of performance data of different parameters of the farm women while performing weeding operation in maize crop is given clearly in table 2.

Table 2 Evaluation of performance data of different parameters of the farm women while performing weeding operation (N = 10) in maize crop

Particulars	Mean±Standard deviation			CD	
Type of tool used	Khudali	Pratap wheel hand hoe	Wheel hand hoe	P=0.01	P=0.05
Time of operation per subject (hours)	1	1	1	-	-
Average working heart rate (beats/min)	113.66±5.78	115.52±6.02	116.11±5.71	5.86	4.17
Average resting heart rate (beats/min)	81.62±1.61	80.93±2.81	82.31±2.47	2.89	2.04
Average recovery heart rate (beats/min)	94.96±2.69	95.32±2.48	95.58±2.01	2.76	2.44

ΔHR (working HR - resting HR) (beats/min)	32.04±6.61	34.58±6.43	33.8±5.14	5.28	3.68
Area covered/output (m^2 /h)	62.44±3.84	105.93±6.75	105.68±6.94	4.83	3.94
Energy Expenditure Rate (kJ/min)	11.95±0.51	13.88±0.86	14.40±0.71	5.20	4.49
Oxygen consumption rate, Working OCR, l/min	0.573±0.02	0.665±0.04	0.690±0.03	3.45	2.94
Cardiac cost of work (beats/m^2)	31.18±6.45	19.97±2.94	19.34±3.64	4.61	3.74
Overall discomfort rating (ODR) at the starting of work	1.68	1.41	1.47	2.05	1.44
Overall discomfort rating (ODR) at the end of the work	8	6.8	6.81	3.51	2.46
Overall discomfort rating (ODR)(start-end)	6.32	5.39	5.34	2.96	2.32
Rating of perceived exertion (RPE)	4.35	3.35	3.4	3.19	2.96
Reduction in drudgery (%)	-	35.95	37.97	-	-

Heart rate response of the subjects during weeding operation in maize crop

The mean of resting heart rate, working heart rate and recovery heart rate of *Kudali* was observed as 81.62±1.61, 113.66±5.78 and 94.96±2.69 beats/min. The mean increase in heart rate was observed as 32.04±6.61 beats/min. The mean of resting heart rate, working heart rate and recovery heart rate of Pratap wheel hand hoe was observed as 80.93±2.81, 115.52±6.02 and 95.32±2.48 beats/min. The mean increase in heart rate was observed as 34.58±6.43

beats/min. The mean of resting heart rate, working heart rate and recovery heart rate of wheel hand hoe was observed as 82.31±2.47, 116.11±5.71 and 95.58±2.01 beats/min. The mean increase in heart rate was observed as 33.8±5.14 beats/min.

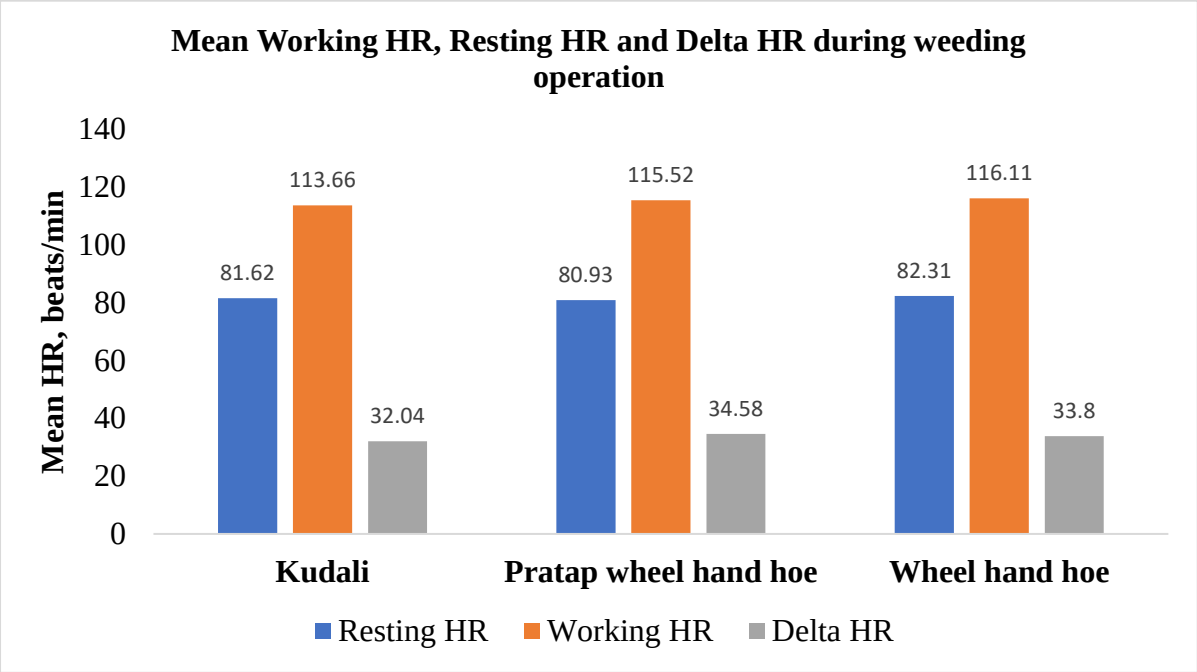

Figure 4 Mean WHR and Delta HR in weeding operation

Mean ΔHR value during weeding operation with *kudali*, Pratap wheel hand hoe and wheel hand hoe shown in figure 4, was observed as 32.04, 34.58 and 33.80 beats/min respectively. Mean ΔHR value for Pratap wheel hand hoe and wheel hand hoe were slightly higher when compared to weeding operation with khudali. Hasalkar *et al.* (2003) concluded that while weeding operation, the overall cardiac cost of work was 6165.87 beats per minute, and the physiological cost of work was 14.67 beats per minute.

According to ANOVA results, the mean working heart rate of wheel hand hoe was significantly ($P<0.01$) higher than Pratap wheel hoe and *kudali* and there was no significant difference between Pratap wheel hoe and wheel hand hoe during weeding operation. The ΔHR of Pratap wheel hand hoe was significantly ($P<0.01$) higher than wheel hand hoe and *kudali* and there was no significant difference ($P=0.77$) between Pratap wheel hoe and wheel hand hoe during weeding operation.

Cardiac cost of work of the selected subjects during weeding operation

The increase in Cardiac cost of the work in beats/m^2 of area covered during weeding operation with manually operated Khudali, Pratap wheel hand hoe and Wheel hoe was 31.18,

19.97 and 19.34 beats/m^2 as given in table 3. The area covered by Pratap wheel hand hoe and Wheel hand hoe was more when compared to Khudali.

Oxygen consumption rate of the selected subjects during weeding operation

The mean Resting OCR for khudali was 0.140 l/min and mean working OCR was 0.573 l/min. The mean value of ΔOCR ranged from 0.432 l/min. The mean Resting OCR for Pratap wheel hand hoe was 0.168 l/min and mean working OCR was 0.665 l/min. The mean ΔOCR ranged from 0.493 l/min. The mean Resting OCR for wheel hand hoe was 0.156 l/min and mean working OCR was 0.690 l/min. The mean ΔOCR ranged from 0.534 l/min.

The mean ΔOCR of the subjects during weeding operation is shown in figure 5. The ΔOCR was highest in case of wheel hand hoe (0.534 l/min) followed by Pratap wheel hand hoe (0.493 l/min) and khudali (0.432 l/min). According to classification suggested by Sen *et al.* (1969), working OCR for weeding operation with khudali, Pratap wheel hand hoe and wheel hand hoe could be rated in "light" category of workload.

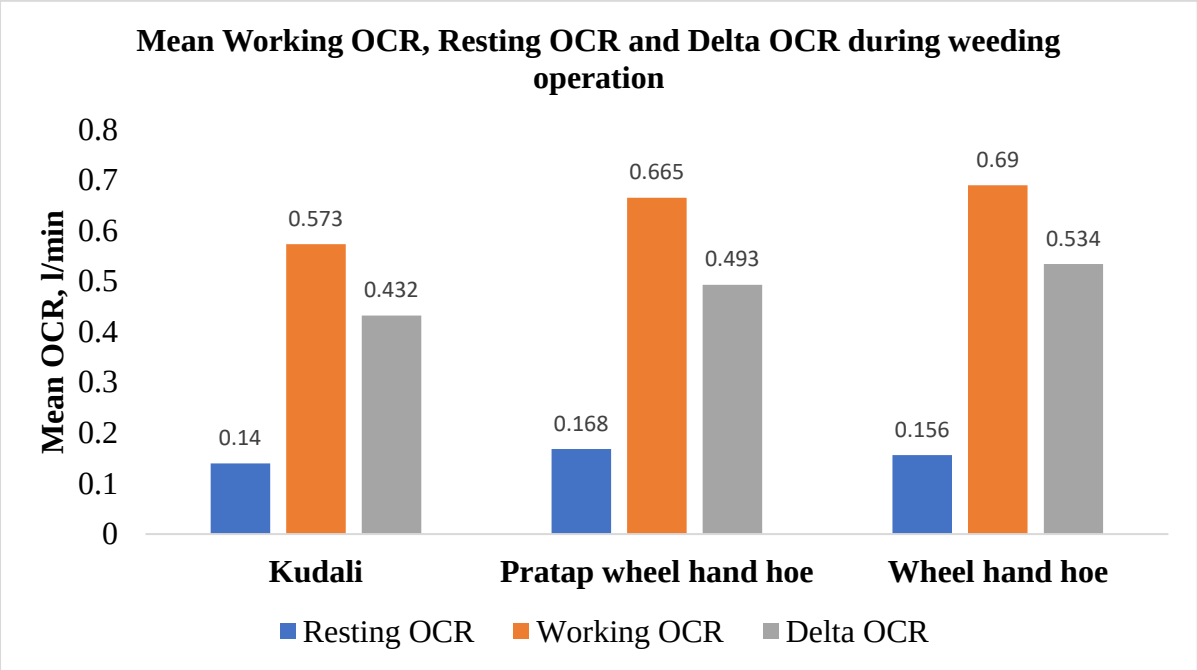

Figure 5 Mean Working OCR, Resting OCR and Delta OCR during weeding operation

Energy Expenditure Rate (EER) of the selected subjects during weeding operation

The Energy expenditure rate (EER) for female subjects during weeding operation using Khudali, Pratap wheel hand hoe and wheel hand hoe, which was calculated from oxygen consumption rate (OCR). Since OCR is a better parameter than heart rate, the energy expenditure rate was estimated by multiplying the working OCR with the calorific value of oxygen as 20.88 kJ/l (Nag and Dutt, 1980).

The EER for khudali, Pratap wheel hand hoe and wheel hand hoe was 11.95±0.51, 13.88±0.86 and 14.40±0.71.

The mean Energy expenditure rate (EER) of the subjects during weeding operation is shown in table 3 and figure 6. The Energy expenditure rate (EER) was highest in case of wheel hand hoe (14.40 kJ/min) followed by Pratap wheel hand hoe (13.88 kJ/min) and khudali (11.95 kJ/min). Tiwari and Philip (2003) reported that the female farm workers in West Bengal spend a lot of energy on various agricultural activities. They recorded 15.69 kJ/min during weeding operation. According to classification suggested by Sen *et al* (1969), Energy expenditure rate for weeding operation with *kudali* could be rated in "light" category of workload whereas, weeding operation with wheel hand hoe-I and wheel hand hoe-II could be rated in "light" category of workload. Gite *et al.* (1992) and Gite (1993) also got higher values of EER with *kudali* when compared to manual weeders.

According to ANOVA results, the mean EER of wheel hand hoe was significantly ($P<0.01$) higher than Pratap wheel hoe and khudali and there was no significant difference ($P=0.08$) between Pratap wheel hoe and wheel hand hoe during weeding operation.

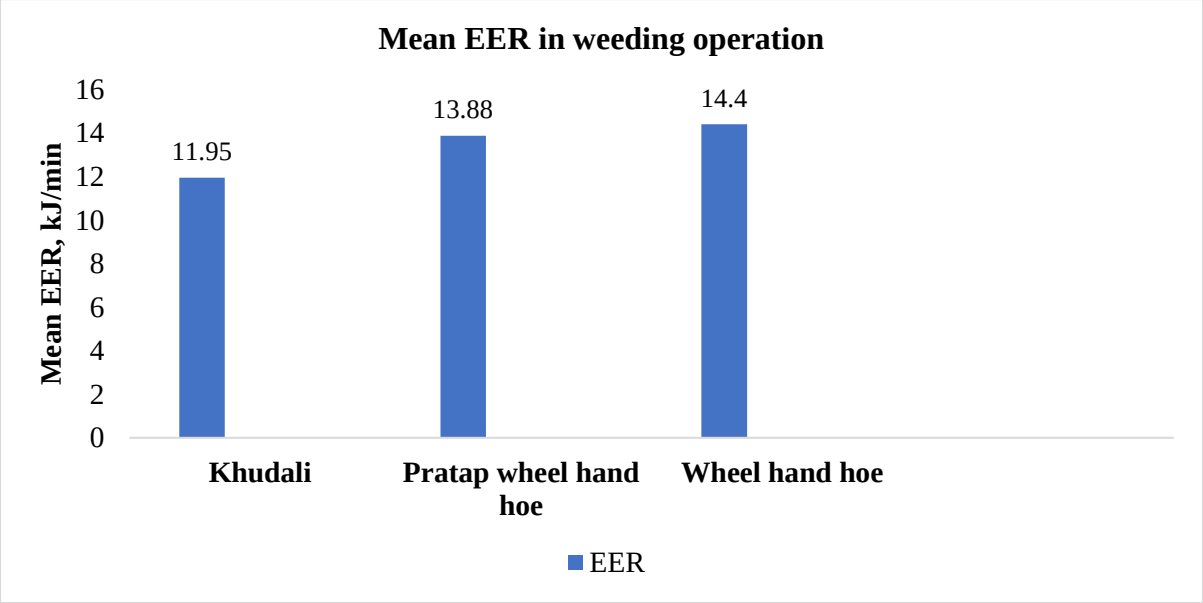

Figure 6 Mean Energy expenditure rate (EER) in weeding operation

Physical cost of the female farm workers during weeding operation in maize crop

Observations were taken during field experiments to assess the physical workload viz., overall discomfort rating (ODR), Musculo-skeletal problem and rating of perceived exertion (RPE) experienced by the selected female farm workers as per the procedure given in materials and methods for maize weeding.

Overall discomfort rating (ODR) of the female farm workers during weeding operation

ODR experienced by the selected female farm workers was taken before and after weeding operation by khudali, Pratap wheel hand hoe and wheel hand hoe in maize crop. The mean ODR of the subjects before weeding operation for khudali, Pratap wheel hand hoe and wheel hand hoe was 1.68, 1.41, 1.47 respectively in figure 7. Almost all the three manual weeders before starting the weeding operation was same.

The mean ODR of the subjects after weeding operation for khudali, Pratap wheel hand hoe and wheel hand hoe was 8, 6.8, 6.81 respectively in figure 7. Maximum ODR was observed in by using khudali because of continuous bending posture. The ODR for Pratap wheel hand hoe and wheel hand hoe was nearly same because both the manual weeders has no bending posture and operated in standing posture only.

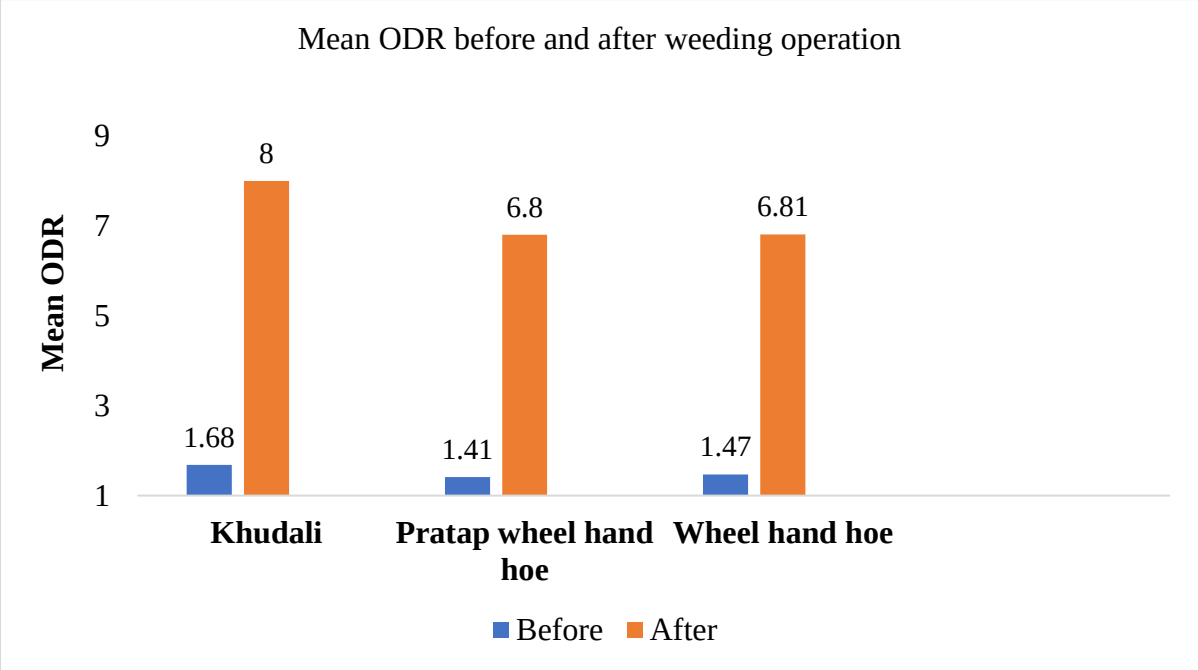

Figure 7 Mean overall discomfort rating of the female farm workers

Rating of perceived exertion (RPE) during weeding operation

Experiments were carried out in order to assess RPE of female farm workers during weeding operation in maize crop. The mean RPE for khudali, Pratap wheel hand hoe and wheel hand hoe was 4.35, 3.35, 3.4 respectively. The maximum mean RPE for female farm workers was high in case of khudali. The mean RPE for Pratap wheel hand hoe and wheel hand hoe was almost same. Responses on Musculo-skeletal problems and Rating of perceived exertion (RPE) of the female farm workers in weeding operation is given in Table 2.

Musculo-skeletal problem during weeding operation

Experiments were carried out in order to assess the musculo-skeletal problem of female farm workers during weeding operation. The mean score card for *kudali*, Pratap wheel hand

hoe and wheel hand hoe was 71.2, 61.8, 63.1 respectively. The maximum mean Musculo-skeletal problem for female farm workers was high in case of *kudali*. The mean BPDS for Pratap wheel hand hoe and wheel hand hoe was almost same.

The majority of discomfort was observed at lower back, mid back, right shoulder, left shoulder, right hand, left hand, right leg ,left leg, neck, clavicle left and clavicle right for almost all the subjects during weeding operation with khudali. This was mainly due to the application of force for raising and lowering the khudali for removing the weeds in continuous bending posture. The majority of discomfort was observed at left and right shoulders, left and right arms, left and right clavicle for both Pratap wheel hand hoe and wheel hand hoe. This discomfort was mainly due to the push-pull force given by the workers for removing the weeds. However, the discomfort was quietly reduced with both Pratap wheel hand hoe and wheel hand hoe. The responses on Musculo-skeletal problems and Rating of perceived exertion (RPE) of the female farm workers during weeding operation in maize crop is given clearly in table 3.

Table 3 Responses on Musculo-skeletal problems and Rating of perceived exertion (RPE) of the female farm workers during weeding operation in maize crop

Weeding tool	**Musculo-skeletal problems**	**Score card**	**Rating of perceived exertion (RPE)**
Kudali	lower back, mid back, right shoulder, left shoulder, right hand, left hand, right leg, left leg, neck, clavicle left and clavicle right	71.2	Heavy
Pratap wheel hand hoe	left shoulder, right shoulder, left arm, right arm, left clavicle and right clavicle	61.8	Moderately Heavy
Wheel hand hoe	left shoulder, right shoulder, left arm, right arm, left clavicle and right clavicle	63.1	Moderately Heavy

The performance evaluation of data given in Table 3 clearly indicated that the Pratap wheel hand hoe saved nearly 36% of the cardiac cost of the worker per unit of output and wheel hand hoe saves nearly 38% of the cardiac cost of the worker per unit of output which is reduction in drudgery by 36% and 38% by both the weeding tools over khudali. Area covered with Pratap wheel hand hoe and wheel hoe were 1.70 and 1.69 times more over khudali.

Statistical analysis for manual weeding operation

Correlation coefficient computed against variables of Pratap wheel hand hoe and wheel hand hoe . Analysis of data for Pratap wheel hand hoe has given the impression that the average weight of the subjects showed significant at (P<0.01), moderately negatively correlated with ΔHR (r(9)=-0.47) and also with cardiac cost (r(9)=-0.40). Analysis of data for wheel hand hoe has given the impression that the average weight of the subjects showed significantly (P<0.05) inversely correlated with ΔHR (r(9)=-0.21) and also with cardiac cost at (P<0.01), (r(9)=-0.14), which means that the working capacity decreases with increase in weight of the subjects.

Analysis of data for Pratap wheel hand hoe and wheel hand hoe showed that the cardiac cost is significant at (P<0.01) strongly positively correlated with ΔHR (r(9)=0.98, r(9)=0.95). Singh et al (2010) also reported positive relationship of cardiac cost with average HR during maize shelling with tubular maize sheller.

Table 4 Correlation coefficient computed between different variables and energy expenditure with three different tools (N = 10).

Particulars	**Energy expenditure rate (EER) (kJ/s)**		
Type of tool used	Khudali	Pratap wheel hand hoe	Wheel hand hoe
Age (years)	-0.15**	-0.37**	-0.08
Height (cm)	0.38	0.11	0.39
Weight (kg)	0.28	0.19	0.34
Average working heart rate (beats/min)	0.53	0.09**	0.16
Average resting heart rate (beats/min)	0.19**	0.48**	0.37
Average recovery heart rate (beats/min)	0.31**	0.11**	0.19
ΔHR (beats/min)	0.51*	0.42**	0.44**
Area covered/duration (m^2 /hr)	-0.51	-0.40	-0.60
Physiological cost of work (beats/m^2)	0.61**	0.43	0.32

*Correlation at P<0.05, **Correlation at P<0.01

Table 4 shows the correlation coefficient computed between different variables and energy expenditure. It reveals that the delta HR of the respondents showed significant (P<0.05) positively correlated (r(9)= 0.51, r(9)= 0.42, r(9)= 0.44) with energy expenditure rate and

physiological cost also showed significant ($P<0.05$) moderately correlated ($r(9)= 0.61$, $r(9)= 0.43$, $r(9)= 0.32$) with energy expenditure rate for khudali, Pratap wheel hand hoe and wheel hand hoe which means that increase in HR is responsible for effecting Energy expenditure rate of the work. Remaining all the parameters showed both positive and negative correlation with energy expenditure rate. Crouter et al (2006) also stated that HR can predict energy expenditure rate in subjects vary depending upon age, weight and height.

Conclusion

Pratap wheel hand hoe and Wheel hand hoe when compared to khudali is more women friendly following all the ergonomic considerations for reducing the drudgery of the women farm workers by 36% and 38% . It also reduces the Musculo-skeletal problems as indicated in mean score using the body map during the harvesting operation and also provides safety and reliability to the farm workers due to lower weight, easy to handle and better construction. This not only reduces the drudgery but also reduces the fatigue, tiredness, exertion when proper work-rest cycle and proper posture is followed in hot sunny atmosphere. This also eliminates the bending posture. Proper training regarding the operating of Pratap wheel hand hoe and Wheel hand hoe is very important to to avoid the Musculo-skeletal problems associated.

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