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Physiological cost of work while using manually operated weeders developed in ANGRAU

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Abstract
The experiment was conducted to measure the physiological cost of work while using six types of manually operated weeders including one wheel multi-pronged weeder, one-wheel straight pronged weeder, one-wheel curve pronged weeder, two-wheel multi-pronged weeder, two-wheel straight pronged weeder, and two-wheel curve pronged weeder was compared to the conventional hand weeding work with local made khurpi. Farm women aged between 13 and 52 years actively involved in weeding operations during the last year were formed the sample. The physiological cost of weeding was the lowest for hand weeding. Among the weeders, the physiological cost of weeding was less for the two-wheel straight pronged weeder followed by one-wheel straight pronged weeder. The difference in the mean was significant (P= < .0001) among the weeders in the physiological cost of work. A highly significant mean difference was observed in the physiological cost of work between traditional hand weeding and all the other six weeders selected for the study.

Keywords: Agriculture, experiment, farm women, heart rate, manually operated weeders, physiological cost of work, weeding

1. Introduction

Weeding is one of the most important and necessary intercultural operations in the crop production system. In the same way, it is a labour-intensive agricultural operation. It has been observed that of the total labour involved in agricultural work during the cultivating season, as much as 15%, is spent in cutting weeds from irrigated or drylands (Vyavahare and Kallurkar, 2012) [5].

The most common methods of weed control are mechanical, chemical, biological, and cultural methods. Chemical control involves the use of herbicides. Out of these four methods, mechanical weeding either by hand tools or weeders are relatively effective in dry land as well as wetland (Chanakyan and Mohanty, 2017) [1].

Weeding is mostly done by women. A greater part of the farm women does weed control using hand tools like a sickle, khurpi, and so on. Hand weeding requires more energy and more time which may ultimately lead to a higher cost of weeding. While doing these activities women adopt bending and squatting body posture as a result of which their physiological workload increases and also, they face many types of musculoskeletal problems. The efficiency of women to work decreases to a great extent as a result of their ill-health (Shahi *et al.*, 2018) [3].

Efforts have been made by organizations such as ICAR-CRIDA, Hyderabad, and ICAR-CIAE, Bhopal to bring out the weeders to reduce the drudgery of the operator. However, these weeders have not been accepted as they were not user-friendly. Manual weeding is effort demanding because the person involved in weeding has to bend down and use their hand to take out weeds. This bending posture of the worker will lead to injury causing pain in the back due to stressful working posture. Hence, appropriately designed implementation for weeding is essential to safeguard the health of the women involved in weeding. Ergonomic interventions are essential to design equipment without touching the health and safety of the worker.

With this background, an ergonomic evaluation of hand-operated weeders in dry land was carried out taking the parameters such as field performance, human comfort, and safety into consideration during the year 2016-17 by the Department of Resource Management and Consumer Sciences, College of Home Science, ANGRAU, Guntur, AP.

None of the weeders selected for that study were found fitting to the task. It was understood from the study that the design of weeders was not as per the ergonomic requirements of subjects. Therefore, during the year 2017-18 the Department of Resource Management and Consumer Sciences, College of Home Science, ANGRAU, Guntur, AP, designed and fabricated six weeders with different blades and wheels as per the anthropometric measurements of Indian Agricultural Labour and the desirable design features of weeders.

Before recommending the weeders, it is fundamental to evaluate the design, performance, and comfort in operation. Hence, the present study was undertaken to conduct physiological cost of work while using manually operated weeders designed in ANGRAU.

2. Materials and Methods

The field experiment was conducted at Dr. Y.S.R Horticulture University, Horticulture Research Station, Lam, Guntur. A sub-sample of 10 out of 30 farm women aged between 13-52 years participated in this study. The subjects participated in the research willingly and the selection of the workers was purposive sampling method. The soil selected was black cotton soil. The size of the experimental plot was 4X3m. Chilies were the crop selected for weeding. The distance between the two rows of the crop was 75 cm. The height of the plants at the time of the experiment ranged between 60 to 125 cm. The experiment was conducted during 2018-19 Rabi season.

Fig 1: Weeding with one wheel multi-pronged weeder

Fig 2: Weeding with one wheel straight pronged weeder

Fig 3: Weeding with one wheel curve pronged weeder

Before the actual experiment, the subject was allowed to operate the weeder till she got acquitted with the operation of the weeder. Initially resting heart rate of the subject was measured using a polar heart rate monitor. Five readings within five minutes with one-minute intervals were taken. From these five readings average resting heart rate was computed. Then, the subject was allowed to operate the weeder and carry out the weeding operation for 30 minutes. During working with the weeder, six readings of the subject's heart rate for every five minutes were recorded. Then average working heart rate was computed. Then, the subject was allowed to take a rest till she attained a normal heart rate. From the data, the physiological cost of work was measured.

2.1 Physiological Cost of Work

The muscle effort or physical effort involved while performing an activity is considered a physiological workload. The physiological cost of work was assessed from the heart rate of the workers. The physiological workload of the respondent was determined by recording the heart rate at rest, during work, and after completion of the work (http://krishikosh.egranth.ac.in/handle/1/93164). The physiological cost of work was measured by using the following formula developed by Verma *et al*. (2013).

Physiological cost of work (PCW) =Total cardiac cost of work / total time of the activity.

Following formulae were used for calculation of the physiological cost of work

1. Average Working Heart Rate (AWHR) = (average working heart rate -average resting heart rate)
2. Cardiac Cost of Work (CCW) =AWHR x Duration of the activity
3. Cardiac Cost of Recovery (CCR) = (average recovery heart rate - average resting heart rate) x Duration of recovery
4. Total Cardiac Cost of Work = Cardiac Cost of Work + Cardiac Cost of Recovery

2.2 Data Analysis

Analysis of variance (ANOVA) was carried out using SAS PROC MIXED (SAS v9.4) procedure, considering weeder as fixed and respondent, replication as random means. [Best Linear Unbiased Estimators (BLUEs)] were calculated for weeders from ANOVA and also performed pair-wise comparisons using t-statistics for significant weeder effects. The statistical model for ANOVA was as follows:

The sample observations z_{ijk} on weeder i in subject j of replication k modeled as:

$$Z_{ijk} = \mu + w_i + f_j + r_{ijk} + \varepsilon_{ijk}$$

Where μ is the grand mean; w_i is the fixed effect of weeder i; f_j is the random effect of farmer j and is ~ NID(0, σ_f^2); r_{ijk} is the random effect of k^{th} replication of j^{th} farmer in i^{th} weeder and is ~ NID (0, σ_r^2); and ε_{ijk} is the random residual effect and ~ NID(0, σ_ε^2) (SAS Institute Inc. 2015.)

Fig 4: Weeding with two-wheel multi-pronged weeder

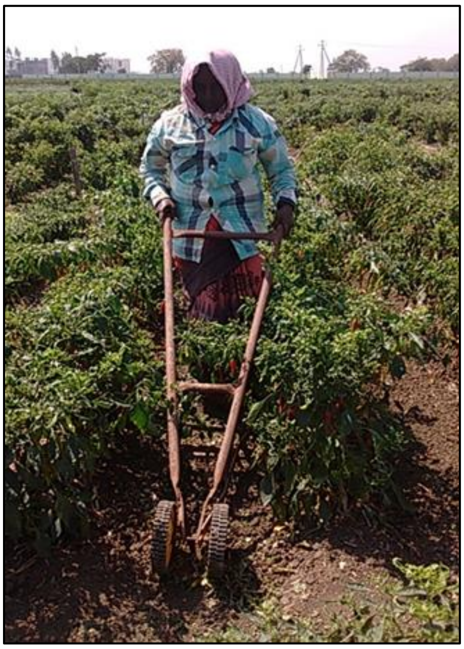

Fig 5: Weeding with two-wheel straight pronged weeder

Fig 6: Weeding with two-wheel curve pronged weeder

3. Result and Discussion
3.1 Physiological cost of work
It was found that hand-weeding was found less tiring. Since the woman was more accustomed to the activity they carried out the activity without exerting any force. But in the case of weeders, as they were new to weeding with weeders, women perceived it as difficult and tiring. But after getting familiar with the weeder they performed weeding with much ease.
The physiological cost of weeding work with the six weeders and traditional hand weeding was presented in Table 1. The physiological cost of weeding was the lowest for hand weeding. Among weeders, the physiological cost of weeding was less for the two-wheel straight pronged weeder followed by one wheel straight pronged weeder.

3.2 Mean differences among weeders on Physiological cost of work
The physiological cost of work was assessed from the heart rate of the worker. Significant variance (P=0.0519) among respondents was observed (Tables 2) while using different weeders under the study.
There was a significant mean difference (P= < .0001) among weeders in the physiological cost of work. Further to understand the significant mean difference among the weeders pair-wise mean comparisons were computed (Table 3).
There was a highly significant mean difference in the physiological cost of work between traditional hand weeding and all the other six weeders selected for the study.
From the mean physiological cost of work scores, it was found that excluding the traditional hand weeding, physiological cost of work was less for two-wheel straight pronged weeder followed by one wheel straight pronged weeder, two-wheel curve pronged weeder, Two-wheel multi-pronged weeder, one wheel multi-pronged weeder and one-wheel curve pronged weeder. Straight pronged weeders were found superior to other weeders concerning the physiological cost of work.

Fig 7: Traditional hand weeding

Table 1: Distribution of weeders and traditional hand weeding by Physiological cost of weeding

S. No	Weeder	Physiological cost of weeding			
		Minimum physiological cost of weeding	Maximum Physiological cost of weeding	Mean physiological cost of weeding	S.D
1	One wheel multi-pronged weeder	26.65	57.67	40.24	10.98
2	One wheel straight pronged weeder	25.93	64.49	38.29	12.74
3	One wheel curve pronged weeder	23.72	69.40	41.10	12.24
4	Two-wheel multi-pronged weeder	17.83	65.08	40.73	14.03
5	Two-wheel straight pronged weeder	18.43	60.43	35.62	14.83
6	Two-wheel curve pronged weeder	17.10	61.83	38.50	13.18
7	Traditional hand weeding	11.25	46.67	18.79	10.47

Table 2: Analysis of variance in the weeders concerning the Physiological cost of work

Random effect

Covariance Parameter Estimates				
Covariance Parameter	Variance component	Standar Error	Z Value	Pr Z
Replications	-0.4576	1.4508	-0.32	0.7524
Respondents	71.2804	36.6732	1.94	0.0519
Sample error	90.7251	11.3165	8.02	<.0001

Fixed effect

Type 3 Tests of Fixed Effects				
Effect	Numerical DF	Denominator DF	F Value	Pr > F
Weeder	6	130	12.03	<.0001

Table 3: Means and Pairwise comparisons for weeders concerning the Physiological cost of work

Means			Pairwise comparison				
Weeder	Physiological cost of work	Standard Error Mean	Weeder 1	Weeder 2	Difference of Means	t Value	Pr> |t|
W1	40.24	3.3487	W1	W2	1.9459	0.69	0.4938
W2	38.29	3.2871	W1	W3	-0.8616	-0.29	0.775
W3	41.10	3.4472	W1	W4	-0.49	-0.17	0.8675
W4	40.73	3.3523	W1	W5	4.6178	1.52	0.13
W5	35.62	3.4437	W1	W6	1.7393	0.61	0.5429
W6	38.50	3.3242	W1	W7	21.4448	6.95	0.0001
W7	18.79	3.5241	W2	W3	-2.8075	-0.95	0.3456
			W2	W4	-2.4358	-0.85	0.3948
			W2	W5	2.6719	0.9	0.3702
			W2	W6	-0.2066	-0.07	0.9415
			W2	W7	19.4989	6.39	0.0001
			W3	W4	0.3716	0.12	0.9022
			W3	W5	5.4794	1.76	0.0812
			W3	W6	2.6009	0.87	0.385
			W3	W7	22.3064	6.98	0.0001
			W4	W5	5.1077	1.69	0.0936

			W4	W6	2.2293	0.77	0.4426
			W4	W7	21.9347	7.04	0.0001
			W5	W6	-2.8785	-0.96	0.339
			W5	W7	16.827	5.24	0.0001
			W6	W7	19.7055	6.45	0.0001

W1= One wheel multi-pronged weeder; W2=One wheel straight pronged weeder; W3= One wheel curve pronged weeder; W4= Two-wheel Multi-pronged weeder; W5= Two-wheel straight pronged weeder; W6= Two-wheel curve pronged weeder; W7= Traditional hand weeding.

4. Conclusions

There was a significant mean difference (P= < .0001) among weeders in the physiological cost of work. There was a highly significant mean difference in the physiological cost of work between traditional hand weeding and all the other six weeders selected for the study.

The physiological cost of weeding was the lowest for hand weeding. Among weeders, the physiological cost of weeding was less for the two-wheel straight pronged weeder followed by one-wheel straight pronged weeder, two-wheel curve pronged weeder, two-wheel multi-pronged weeder, one wheel multi-pronged weeder, and One-wheel curve-pronged weeder.

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