Int.J.Curr.Microbiol.App.Sci (2021) *10*(08): 636-652

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 10 Number 08 (2021)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2021.1008.074

Performance Evaluation of Manually Operated Weeders Developed in ANGRAU

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ABSTRACT

Keywords

Agricultural operation, hard work, monotony, time consuming

Article Info

Accepted:
25 July 2021
Available Online:
10 August 2021

The present study was undertaken to conduct performance evaluation of manually operated weeders. The six weeders selected for the study were 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, two wheel curve pronged weeder. Besides the six weeders the conventional hand weeding with local made kurpi was also considered as one of the methods of weeding. Women aged between 13 to 52 years were employed for this study. The Performance evaluation was done by taking into consideration the field capacity, plant damage percent, weeding index percent and human energy required to operate the weeder. There was highly significant mean difference in the field capacity of weeders (P=<.0001). The study revealed that the one wheel straight pronged weeder was superior to all the other weeders with reference to field capacity. Highly significant mean difference was found between one wheel straight pronged weeder and rest of the weeders. In case of plant damage mean difference among weeders was found significant. The mean plant damage percent was low in case of traditional hand weeding followed by one wheel straight pronged weeder and one wheel curve pronged weeder. There was no significant mean difference among weeders with reference to weeding index percent. The mean weeding index per cent was highest for conventional hand weeding, followed by two wheel straight pronged weeder, one wheel multi pronged weeder and one wheel straight pronged weeder. The difference in the mean energy spent by the subjects while performing conventional method of weeding against mean energy spent by the subjects when weeding was done with the rest of the weeders selected in the study was found significant. Other than that there was no significant mean difference in energy expenditure while using any other weeders was found. Mean energy expenditure was less in case of traditional hand weeding. Among the weeders mean energy expenditure was less in case of two wheel straight pronged weeder. There was a significant mean difference in the performance index of the weeders (P= <.0001). The mean difference in performance index between one wheel straight pronged weeder and all the other weeders together with traditional hand weeding was highly significant. The performance index score was maximum for one wheel straight pronged weeder and minimum for traditional hand weeding. Overall performance was high for one wheel straight pronged weeder followed by two wheel straight pronged weeder and straight pronged weeder.

Introduction

Weeding is an important and necessary intercultural operation in crop production system. In the same way it is labour intensive agricultural operation. In terms of labour requirement weeding takes up to twenty five per cent in the labour requirement during a cultivation season (Yadav and Pund, 2007).

Weeding has been reported as one of the most laborious activities with a drudgery scale value of 2.01 followed by other agricultural operations as professed by women (Gupta *et al.,* 2002). Out of total man hours involved in crop production15 to 20 per cent are taken away by weeding alone (Nag, 2004**).**

Drudgery is a term used to denote the intolerable incidents that restrain work performance in any activity (Technical module, 2009). It can be reduced by using appropriate farm tools and equipment's. In fact, drudgery is termed for hard work, monotony, time consuming, use of traditional tools with inappropriate working posture in field (Sridhar *et al.,* 2015).

Not using appropriate machines and implements is one of the major barrier to improve the productivity of agriculture. The research result of many studies brought out the fact that time and energy consuming works that are more fatiguing are taken up by women. Since these activities are done manually they cause drudgery and health problems. The main reason for their suffering is lack of knowledge and traditional method of doing work, resistance to change the attitude (Badiger *et al.,* 2006b). Improved productivity and health are normal benefits out of drudgery reduction programmes carry out through technology interventions. Therefore, it is essential to select suitable technologies directed by recognized drudgery experience (Mrunalini *et al.,* 2010).

At present, various hoes and weeders are available in India. For effective weeding the design of these blades should be based on the soil type, soil-tool-plant interaction. The overall designing of the weeding tool should be based on the ergonomic principles, then the efficiency of the operator using the weeder can be improved.

Ergonomics involve fitting the job to the human being. Ergonomics deals with human behaviour, capabilities, limitations and other characteristics to the design of tools, machines, systems, for effective human use (Chapanis, 1985). Relationship between the worker, farm and the farm task environment involves ergonomics. The design features of the tool and work methods add to ergonomic problems. Ergonomically designed implements exhibit potential and encouraging results by lifting up the operating competence, without compromising on their health and safety. The consideration of ergonomic principles in the design of agricultural implements has been not there. Therefore, working with these tools increase the chances of injury due to excessive force demanded by the task or may lead to a taxing working posture and high load. Further the tools are physically demanding and they are difficult to use at ease for particular task.

The major hindrance for the adoption of the implements or tools may be the physiological and muscular fatigue they induce in the beginning.

Conventional method of weeding takes hold of more time. Women generally assume squatting and bending posture while performing the activity and maintain the same posture for longer hours may contribute towards developing musculoskeletal disorders (Sharma, 1999). On the other side manual weeding requires massive labour force which is usually 900 to 1200 man hours/hectares. In a country like India weeding operation is mostly carried out manually with cutlass or hoe that call for high labour input. It is a very tedious and time consuming process. 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 implement for weeding is essential to safeguard the health of the women involved in weeding. Ergonomic interventions are essential to design equipment without touching health and safety of the worker.

Therefore, during the year 2017-18 the Department of Resource Management and Consumer Sciences, College of Home Science, ANGRAU, Guntur AP, designed and constructed six weeders with different blades and wheels as per the anthropometric measurements of Indian Agricultural Labour and the desirable design features of weeders.

Before popularizing the weeders it is fundamental to evaluate the performance and comfort in operation. Hence, the present study has been undertaken to evaluate the performance of these weeders.

Materials and Methods

A person who is actively involved in weeding operation during last year was the criteria for selection of the sample. Thus, for conducting the field experiment, a sub-sample of 10 farm women out of 30 farm women who were actively involved in weeding operation during the last year were selected using purposive sampling method.

Field Experiment

Field experimentation attempts to simulate as closely as possible the conditions under which a casual process occur. Behaviour in the field experiment is more likely to have higher ecological validity than a lab experiment (Alan and Donald 2013). Field experiments offer researcher a way to answer research questions with higher external validity because they simulate real-world occurrences (Duflo, 2006).

The field experiment was conducted at Dr. Y.S.R Horticulture University, Horticulture Research Station, Lam, Guntur. The soil was black cotton soil. The size of the experimental plot was 4 meters by 3 meters. Chillies was the crop in the field. Distance between the two rows of the crop was 75 cm. The experiment was conducted during 2018-19 Rabi season. The height of the plants at the time of experiment ranged between 60 to 125 cm.

Before 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 polar heart rate monitor.

Five readings within five minutes with one-minute interval was taken. From these five readings average resting heart rate was computed. Then the subject was allowed to operate the weeder and carry out weeding operation for a duration of 30 minutes. During working with weeder, six readings of suject's heart rate for every five minutes were recorded. Then average working heart rate was computed. Then the subject was allowed to take rest till she attained normal heart rate. From the data human energy required to operate the weeders was measured.

Performance Evaluation of the Weeder

Performance evaluation of the six weeders selected for the study was done based on the following parameters.

Performance Index

The performance of the weeder was evaluated by using the performance index formula developed by Gupta (1981).

The parameters measured were field capacity of the weeder, plant damage percent, weeding index percent and human energy required to operate the weeder.

Performance Index, % = aqe/E

Where,

a = field capacity of the weeder, hectare/hour

q = plant damage percent (100-PDF)

e = weeding index, percent

E = human energy required to operate the weeder in KJ/min

Field Capacity of the Weeder

Field capacity of the weeder was measured in terms of the area covered by the weeder in an hour in the field. Thus, the field capacity of the weeder is expressed in hectares per hour.

The field capacity of the weeder was measured using the following formula suggested by Bhavin *et al.,* (2016).

$$\text{Field Capacity} = \frac{\text{Area Covered (hectare)}}{\text{Time taken (hour)}}$$

Plant Damage Percent

To measure the plant damage percent, the number of plants in a 10 meter row were counted before and after each weeding operation. Plant damage was measured using the following formula suggested by Shakya *et al.,* (2016).

$$PDF = (\mathbf{Q_2/Q_1}) \times 100$$

Where,

PDF = Plant damage factor

Q_1 = Number of plants in a 10-meter row length before weeding

Q_2= Number of plants damaged along a 10-meter row length after weeding

Plant damage percent (q)= 100–PDF

Weeding Index Percent

Weeding efficiency of weeder is the number of weeds that can be removed by a specific weeder in a given period of time. Weeding index was measured using the following formula suggested by Goel *et al.,* (2008).

$$e = [(W1-W2)/W1] \times 100$$

Where,

e = Weeding Index, per cent

W1 = number of weeds/m^2 before weeding

W2 = number of weeds/m^2 after weeding

Human Energy Required to Operate the Weeder

The energy expenditure rate indicates the level of body stress in relation to heavy work. It can be used to assess the level of effort to workout necessary rest periods and to compare the efficiency of different tools (Upender *et al.,* 2018). Heart rate is one of the most accurate means of studying the energy expenditure while performing any activity (Hasalkar *et al.,* 2004). Energy expenditure of the worker was assessed by measuring the heart rate of the workers. Heart rate was recorded by using the Digital Heart rate monitor. Energy expenditure required to operate the weeder was calculated using the following formulae suggested by Verghese *et al.,* (1994).

Energy expenditure of worker (Kj/min)
= 0.159X Average Heart Rate (bpm)-8.72

Where,

$$\text{Average heart rate} = \frac{\text{Reading } (1^{st}+2^{nd}+3^{rd}+4^{th}+5^{th})}{\text{Number of times the reading were taken}}$$

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 is,

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)

Results and Discussion

Performance Evaluation

Each of the six weeders selected for the study were evaluated to understand its performance.

Performance of the weeders was evaluated in terms of field capacity, plant damage percent, weeding index percent and human energy required to operate the weeder and performance index. The data is presented below and discussed.

Field Capacity

From table (1) the mean area covered in weeding with one wheel straight pronged weeder was the highest among all the weeders. The area covered by hand weeding was the lowest.

The difference in the area covered by hand weeding and by using the other weeders was large. Next to one wheel straight pronged weeder, one wheel multi pronged weeder covered large area, however the S.D is more. Next place was for two wheel straight pronged weeder.

Plant Damage Percent

From table (2) Minimum plant damage was nil for all weeders except one wheel straight pronged and two straight pronged wheel weeders.

The lowest maximum plant damage was observed in case of these two weeders. The straight pronged blade was found more efficient with reference to plant damage.

From the values of mean plant damage per cent and standard deviation it is understood that there was variation between individual readings. The plant damage depends upon the person who was operating the weeder.

Weeding Index Percent

From table (3) the mean weeding index per cent was highest for traditional hand weeding, followed by two wheel straight pronged weeder, one wheel multi pronged weeeder and one wheel straight pronged weeder.

The standard deviation in the values was more in case of one wheel straight pronged weeder. The efficiency of the weeder depends upon the efficiency of the operator some extent.

Human Energy Required to Operate the Weeder

From table (4) mean energy expenditure for traditional hand weeding was minimum as for one wheel straight pronged weeder was maximum.

Though traditional hand weeding cause body discomforts due to the squatting posture and movement on knee, the actual energy expenditure was found minimum.

Next lowest energy requirement was for two wheel straight pronged weeder. There was not much difference in the mean energy expenditure scores among other weeders.

Performance Index

From Table (5) the performance index score was maximum for one wheel straight pronged weeder and minimum for traditional hand weeding. Overall performance irrespective of field capacity, plant damage percent, weeding index percent and human energy required was maximum for one wheel straight pronged weeder followed by two wheel straight pronged weeder. After the straight pronged weeders, one wheel multi pronged weeder, two wheel curved pronged weeder, two wheel multi pronged weeder and one wheel curved pronged weeder performed well.

Means and pair wise comparisons for weeders with reference to Field capacity

There was no significant variation among the respondents while operating the weeder (Table 6). There was highly significant mean difference in the field capacity of weeders (P=<.0001).

To understand the significant mean differences among weeders pair wise mean comparisons were computed. Significant mean difference with reference to field capacity was observed between one wheel multi pronged weeder and one wheel straight prong weeder and traditional hand weeding.

There was a significant difference between one wheel straight pronged weeder and all the other weeders selected for the study in the field capacity. One wheel curve pronged weeder, two wheel multi pronged weeder, two wheel straight pronged weeder and two wheel curve pronged weeder differed significantly on their mean field capacity with only the traditional hand weeding

The study revealed that the one wheel straight pronged weeder was superior to all the other weeders with reference to field capacity. The mean field capacity score was much higher than the mean field capacity score of other weeders. Highly significant mean difference was found between one wheel straight pronged weeder and rest of the weeders. The one wheel straight pronged weeder removed weed faster than the other weeders.

Means and pair wise comparisons for weeders with reference to Plant damage

Data in table 7 show that No significant variation in the respondents was found (P=0.877). Significant mean difference among weeders was found with reference to plant damage percent. According to the means and pairwise mean comparisons, it was found that the hand weeding method differed significantly with all the weeders with reference to plant damage percent.

The study revealed that mean plant damage percent was low in case of traditional hand weeding followed by one wheel straight pronged weeder (W2), one wheel curve pronged weeder (W3), two wheel curve pronged weeder (W6), one wheel multi pronged weeder (W1) was found to causing relatively more plant damage than other weeders. Traditional hand weeding was with low mean damage percent.

Means and pair wise comparisons for weeders with reference to Weeding index

Weeding efficiency of weeder is the number of weeds that can be removed by a specific weeder in a given period of time.

Significant variation (P=0.0452) among the respondents with reference to weeding index percent was found. There was a significant mean difference (P=0.0012) in the weeding efficiency of different weeders selected for the study.

Further to understand the significant mean differences among weeders, pair wise mean comparisons were computed. One wheel multi pronged weeder differed significantly on mean weeding index percent with only one wheel curve pronged weeder. Significant mean difference in the weeding index percent was found between one wheel straight pronged weeder and one wheel curve pronged weeder; one wheel curve pronged weeder and two wheel straight pronged weeder; There was highly significant mean difference between traditional hand weeding and all the other weeders under the study. The data presented in the table 8 show The mean weeding index percent was high for traditional hand weeding followed by two wheel straight pronged weeder (W5), one wheel multi pronged weeder (W1), one wheel straight pronged weeder (W2), one wheel curve pronged weeder (W3), two wheel multi pronged weeder (W4) and two wheel curve pronged weeder (W6). There was no significant mean difference among weeder with reference to weeding index percent. Straight blade was found more efficient in removing weeds.

With reference to effective weeding hand weeding was found best followed by one wheel multi pronged weeder. The difference was not significant.

Means and Pairwise comparisons for weeders with reference to Energy expenditure of respondent

Heart rate is one of the most accurate means of studying the energy expenditure while performing any activity (Hasalkar *et al.*, 2004).

Significant variation (P=0.0376) among respondents with reference to energy expenditure was found (Table 9). There exists highly significant mean difference (P= <.0001) with reference to energy expenditure while operating different weeders selected for the study.

Significant mean difference in energy expenditure of the subjects while performing traditional method of weeding against weeding activity performed with the weeders selected for the study was found. Other than that there was no significant mean difference in energy expenditure while using any other weeders was found.

Mean energy expenditure was less in case of traditional hand weeding. Among the weeders mean energy expenditure was less in case of two wheel straight pronged weeder.

Table.1 Distribution of weeders and traditional hand weeding by Field capacity

S.No	Weeder	Field capacity (Hectares/hour)			
		Minimum area covered (Hectares)	Maximum area covered (Hectares)	Mean area covered (Hectares)	S.D
1	One wheel multi pronged weeder	0.0022	0.0123	0.0065	0.0033
2	One wheel straight pronged weeder	0.0037	0.0133	0.0089	0.0028
3	One wheel curve pronged weeder	0.0025	0.0107	0.0053	0.0025
4	Two wheel multi pronged weeder	0.0019	0.0104	0.0054	0.0024
5	Two wheel straight pronged weeder	0.0029	0.0099	0.0060	0.0023
6	Two wheel curve pronged weeder	0.0027	0.0076	0.0057	0.0018
7	Traditional hand weeding	0.0011	0.0034	0.0022	0.0008

Table.2 Distribution of weeders and traditional hand weeding by Plant damage percent

S. No	Weeder	Plant damage percent			
		Minimum plant damage percent	Maximum plant damage percent	Mean plant damage percent	S.D
1	One wheel multi pronged weeder	0.0000	13.2479	2.06	4.94
2	One wheel straight pronged weeder	0.37	1.33	0.80	0.28
3	One wheel curve pronged weeder	0.00	4.55	0.83	1.84
4	Two wheel multi pronged weeder	0.00	7.40	1.12	2.57
5	Two wheel straight pronged weeder	0.29	0.99	1.08	0.23
6	Two wheel curve pronged weeder	0.00	5.14	0.86	2.08
7	Traditional hand weeding	0.00	7.94	2.90	2.32

Table.3 Distribution of weeders and traditional hand weeding by Weeding index percent

S.No	Weeder	Weeding index percent			
		Minimum weeding index percent	Maximum weeding index percent	Mean weeding index percent	S.D
1	One wheel multi pronged weeder	83.07	97.29	94.85	4.45
2	One wheel straight pronged weeder	37.20	133.32	94.81	28.46
3	One wheel curve pronged weeder	74.23	96.99	90.50	6.88
4	Two wheel multi pronged weeder	76.99	97.70	93.09	6.04
5	Two wheel straight pronged weeder	79.98	100.00	95.11	6.22
6	Two wheel curve pronged weeder	73.24	98.57	92.02	6.87
7	Traditional hand weeding	91.71	99.57	97.40	2.56

Table.4 Distribution of weeders and traditional hand weeding by of Energy expenditure while operating

S. No	Weeder	Energy expenditure (Kj/min)			
		Minimum energy expenditure	Maximum energy expenditure	Mean energy expenditure	S.D
1	One wheel multi pronged weeder	6.71	13.28	10.52	2.33
2	One wheel straight pronged weeder	6.12	14.93	10.96	2.88
3	One wheel curve pronged weeder	6.08	15.89	10.30	2.96
4	Two wheel multi pronged weeder	6.34	16.30	10.84	3.06
5	Two wheel straight pronged weeder	6.24	15.50	9.85	2.98
6	Two wheel curve pronged weeder	6.08	13.56	10.45	2.37
7	Traditional hand weeding	5.82	11.10	8.07	1.88

Table.5 Distribution of weeders and traditional hand weeding by Performance index

S. No	Weeder	Performance index			
		Minimum performance index score	Maximum performance index score	Mean performance index score	S.D
1	One wheel multi prongedweeder	1.50	11.01	5.61	3.27
2	One wheel straight pronged weeder	3.59	13.57	8.14	3.21
3	One wheel curve pronged weeder	1.36	13.07	4.96	3.28
4	Two wheel multi prongedweeder	1.26	9.52	5.15	2.68
5	Two wheel straight pronged weeder	2.41	12.02	6.34	3.47
6	Two wheel curve pronged weeder	1.51	9.16	5.45	2.30
7	Traditional hand weeding	1.36	5.06	2.75	1.13

Table.6 Means and pair wise comparisons for weeders with reference to Field capacity

Means			Pair wise comparisons				
Weeder	Field capacity	Std Error Mean	Weeder 1	Weeder 2	Difference of Means	t Value	Pr> |t|
W1	0.65	0.06032	W1	W2	-0.2437	-3.95	0.0001
W2	0.89	0.06032	W1	W3	0.1154	1.87	0.0632
W3	0.53	0.06032	W1	W4	0.1028	1.66	0.0978
W4	0.54	0.06032	W1	W5	0.04977	0.81	0.4213
W5	0.60	0.06032	W1	W6	0.07256	1.17	0.2415
W6	0.57	0.06032	W1	W7	0.4257	6.89	0.0001
W7	0.22	0.06032	W2	W3	0.3591	5.81	0.0001
			W2	W4	0.3464	5.61	0.0001
			W2	W5	0.2935	4.75	0.0001
			W2	W6	0.3162	5.12	0.0001
			W2	W7	0.6694	10.84	0.0001
			W3	W4	-0.01267	-0.21	0.8377
			W3	W5	-0.06566	-1.06	0.2891
			W3	W6	-0.04287	-0.69	0.4884
			W3	W7	0.3103	5.02	0.0001
			W4	W5	-0.05299	-0.86	0.392
			W4	W6	-0.0302	-0.49	0.6254
			W4	W7	0.323	5.23	0.0001
			W5	W6	0.02279	0.37	0.7126
			W5	W7	0.3759	6.09	0.0001
			W6	W7	0.3532	5.72	0.0001

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

Table.7 Means and Pairwise comparisons for weeders with reference to Plant damage percent

Means			Pairwise comparisons				
Weeder	**Plant Damage percent**	**Stdandard Error Mean**	**Weeder 1**	**Weeder 2**	**Difference of Means**	**t Value**	**Pr> |t|**
W1	2.06	0.218	W1	W2	0.4531	1.76	0.0803
W2	0.80	0.218	W1	W3	0.4399	1.71	0.0895
W3	0.83	0.218	W1	W4	0.3236	1.26	0.2109
W4	1.12	0.218	W1	W5	0.3369	1.31	0.1928
W5	1.08	0.218	W1	W6	0.4281	1.66	0.0983
W6	0.86	0.218	W1	W7	-0.2435	-0.94	0.3459
W7	2.90	0.218	W2	W3	-0.01322	-0.05	0.9592
			W2	W4	-0.1296	-0.5	0.6157
			W2	W5	-0.1163	-0.45	0.6524
			W2	W6	-0.02499	-0.1	0.9229
			W2	W7	-0.6966	-2.7	0.0075
			W3	W4	-0.1163	-0.45	0.6522
			W3	W5	-0.1031	-0.4	0.6897
			W3	W6	-0.01177	-0.05	0.9636
			W3	W7	-0.6834	-2.65	0.0087
			W4	W5	0.01329	0.05	0.9589
			W4	W6	0.1046	0.41	0.6854
			W4	W7	-0.5671	-2.2	0.029
			W5	W6	0.09129	0.35	0.7236
			W5	W7	-0.5804	-2.25	0.0255
			W6	W7	-0.6717	-2.61	0.0099

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

Table.8 Means and Pairwise comparisons for weeders with reference to Weeding index percent

Means			Pairwise comparisons				
Weeder	**Weeding Index Percent**	**Stdandard Error Mean**	**Weeder1**	**Weeder2**	**Difference of Means**	**t Value**	**Pr> |t|**
W1	94.85	0.0323	W1	W2	0.000886	0.02	0.9802
W2	94.81	0.0323	W1	W3	0.08437	2.37	0.0187
W3	90.50	0.0323	W1	W4	0.0375	1.05	0.2933
W4	93.07	0.0323	W1	W5	-0.00603	-0.17	0.8669
W5	95.11	0.03266	W1	W6	0.05745	1.61	0.1081
W6	92.02	0.0323	W1	W7	-0.06696	-1.88	0.0614
W7	97.40	0.0323	W2	W3	0.08348	2.35	0.02
			W2	W4	0.03662	1.03	0.3048
			W2	W5	-0.00691	-0.19	0.8476
			W2	W6	0.05656	1.59	0.1136
			W2	W7	-0.06784	-1.91	0.0581
			W3	W4	-0.04686	-1.32	0.1894
			W3	W5	-0.0904	-2.52	0.0126
			W3	W6	-0.02692	-0.76	0.4503
			W3	W7	-0.1513	-4.25	0.0001
			W4	W5	-0.04353	-1.21	0.2269
			W4	W6	0.01995	0.56	0.5758
			W4	W7	-0.1045	-2.94	0.0037
			W5	W6	0.06348	1.77	0.0787
			W5	W7	-0.06093	-1.7	0.0914
			W6	W7	-0.1244	-3.5	0.0006

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

Table.9 Means and Pairwise comparisons for weeders with reference to Energy expenditure of respondent

Means			Pairwise comparisons				
Weeder	**Energy Expenditure**	**Stdandard Error Mean**	**Weeder 1**	**Weeder 2**	**Difference of Means**	**t Value**	**Pr> |t|**
W1	10.52	0.7725	W1	W2	-0.447	-1.16	0.2469
W2	10.96	0.7725	W1	W3	0.2146	0.56	0.5777
W3	10.30	0.7725	W1	W4	-0.3268	-0.85	0.3968
W4	10.84	0.7725	W1	W5	0.6662	1.73	0.085
W5	9.85	0.7725	W1	W6	0.06537	0.17	0.8653
W6	10.45	0.7725	W1	W7	2.4477	6.36	0.0001
W7	8.07	0.7725	W2	W3	0.6616	1.72	0.0872
			W2	W4	0.1201	0.31	0.7553
			W2	W5	1.1132	2.89	0.0043
			W2	W6	0.5123	1.33	0.1847
			W2	W7	2.8947	7.52	0.0001
			W3	W4	-0.5415	-1.41	0.161
			W3	W5	0.4516	1.17	0.2421
			W3	W6	-0.1493	-0.39	0.6985
			W3	W7	2.2331	5.8	0.0001
			W4	W5	0.993	2.58	0.0106
			W4	W6	0.3922	1.02	0.3094
			W4	W7	2.7746	7.21	0.0001
			W5	W6	-0.6008	-1.56	0.1201
			W5	W7	1.7815	4.63	0.0001
			W6	W7	2.3824	6.19	0.0001

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

Plate.1 Different types of weeders used in the field for data collection

Table.10 Means and pairwise comparisons of weeders with reference to Performance Index

Means			Pairwise comparisons				
Weeder	**Peformance Index**	**Standard Error Mean**	**Weeder 1**	**Weeder 2**	**Difference of Means**	**t Value**	**Pr> |t|**
W1	5.61	0.7568	W1	W2	-2.5346	-4.16	0.0001
W2	8.14	0.7569	W1	W3	0.6413	1.07	0.2854
W3	4.96	0.7481	W1	W4	0.4513	0.74	0.4614
W4	5.15	0.7578	W1	W5	-0.7382	-1.22	0.2239
W5	6.34	0.7524	W1	W6	0.1567	0.25	0.8012
W6	5.45	0.7666	W1	W7	2.8557	4.66	0.0001
W7	2.75	0.7594	W2	W3	3.176	5.3	0.0001
			W2	W4	2.9859	4.88	0.0001
			W2	W5	1.7965	2.97	0.0034
			W2	W6	2.6913	4.33	0.0001
			W2	W7	5.3903	8.81	0.0001
			W3	W4	-0.1901	-0.32	0.7525
			W3	W5	-1.3795	-2.32	0.0214
			W3	W6	-0.4847	-0.79	0.4287
			W3	W7	2.2144	3.69	0.0003
			W4	w5	-1.1894	-1.97	0.0507
			W4	W6	-0.2946	-0.47	0.637
			W4	W7	2.4044	3.89	0.0001
			W5	W6	0.8948	1.45	0.1489
			W5	W7	3.5938	5.89	0.0001
			W6	W7	2.699	4.32	0.0001

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

Plate.2 Traditional hand weeding

Means and Pairwise comparisons for weeders with reference to Energy expenditure of respondent

The performance index for six weeders and traditional hand weeding were computed. Significant variance in the performance of respondents (P=0.0463) was observed while operating different weeders (Table 10). There was a significant mean difference in the performance index of the weeders(P= <.0001). Further to understand the significant mean differences among weeder pair wise mean comparisons were computed. With reference to performance index, W1 (One wheel multi pronged weeder) significantly differed from W2 (One wheel straight pronged weeder) and W7 (Traditional hand method). One wheel straight pronged weeder was found superior to one wheel multi pronged weeder.

Highly significant difference in the performance index was found between W2 (One wheel straight pronged weeder) and all the other weeders including traditional hand weeding. Weeder 3 (One wheel curve pronged weeder) differed significantly in performance index from weeder5 (Two wheel straight pronged weeder) and W7 (Traditional hand method).

Weeder 4 (Two wheel multi pronged weeder) differed significantly from weeder 5 (Two wheel straight pronged weeder) and weeder 7 (Traditional hand weeding). Weeder 4, weeder 5 and weeder 6 differed significantly with traditional hand weeding method in their performance index.

According to the result of the study, the one wheel straight pronged weeder earned higher mean performance index score followed by two wheel straight pronged weeder.

The least mean performance index score was earned by hand weeding, one wheel curve pronged weeder, two wheel multi pronged weeder, two wheel curve pronged weeder and one wheel multi pronged weeder.

The straight pronged weeders were found superior to other weeders with reference to performance index. There is a significant difference among weeders with reference to performance index.

From the performance evaluation, it was understood that the straight pronged weeders were the best.

The study revealed that the one wheel straight pronged weeder was superior to all the other weeders with reference to field capacity.

The mean field capacity score was much higher than the mean field capacity score of other weeders. Highly significant mean difference was found between one wheel straight pronged weeder and rest of the weeders. The one wheel straight pronged weeder removed weed faster than the other weeders.

There was a significant difference between one wheel straight pronged weeder and all the other weeders selected for the study in the field capacity.

The hand weeding method differed significantly with all the weeders with reference to plant damage percent.

There was highly significant mean difference between traditional hand weeding and all the other weeders under the study on weeding efficiency.

There was no significant mean difference among weeder with reference to weeding index percent. Straight blade was found more efficient in removing weeds.

There was no significant mean difference in energy expenditure among the weeders under the study was found.

One wheel straight pronged weeder was found superior to all the other weeder. Weeding with this weeder was more comfortable and economical.

Implications of the study

The results of the study can serve as input to make a decision on the selection of weeder for weeding in dry land agriculture.

Weeder with straight blade can facilitate labour to perform the activity fast

One wheel weeders were superior in performance over two wheel weeders.

Area of future research

Using the same methodology similar type of research can be taken up in other states of Andhra Pradesh

The weeders can be tested in different soils.

The weeders can be tested in different crops.

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How to cite this article:

Sandhya Devi, K., T. Neeraja and Prasuna, V. 2021. Performance Evaluation of Manually Operated Weeders Developed in ANGRAU. *Int.J.Curr.Microbiol.App.Sci.* 10(08): 636-652.
doi: https://doi.org/10.20546/ijcmas.2021.1008.074