



Effectiveness of three manually operated weeding tools for farm women

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ABSTRACT: In this study, khurpi, three tyne hoe and twin wheel hoe were evaluated in terms of performance, grade of work and comfort for gram crop with eight farm women (subjects). Weeding operation between the rows of gram crop was carried out with these tools during December-January, when the average ambient temperature and relative humidity were 18°C and 70%, respectively. The result of this investigation indicated that weeding with khurpi and twin wheel hoe could be graded as moderately heavy work, whereas weeding with 3-tyne hoe could be graded as heavy work. However, weeding with khurpi required less energy (9.39 kJ/min) than twin wheel hoe (9.67 kJ/min). High energy expenditure (12.89 kJ/min) was observed in case of 3-tyne hoe. In terms of higher output, twin wheel hoe was observed best (179 man-h/ha) than 3-tyne hoe (302 man-h/ha) followed by khurpi (447 man-h/ha). Khurpi had shown highest weeding efficiency (92.1 to 94.8 %). Improved weeding tools such as twin wheel hoe and 3-tyne hoe reduced physical exertion and fatigue to make farm women comfortable.

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1. INTRODUCTION

The increasing interest in organic and low-input farming systems has revived attention towards alternative methods of weed management, such as the development of innovative mechanical solutions (Avola *et al.*, 2008; Pannacci and Tei, 2014; Melander *et al.*, 2015). Organic and low-input farming systems mainly depended for its crop nutrients on legume crops (De Ponti *et al.*, 2012). Women in India play an important role in shaping the economy of the country. Women play vital role in agriculture –as female agricultural labours, farmers, co-farmers and farm entrepreneurs. Weeding is an important agricultural operation, affecting crop yield. It is, however, labour intensive operation. Most of the farm women do weeding in legume or row crop fields using hand tools like khurpi, sickle, etc. This accounts for about 25% of total labour requirement (900-1200 man-hours/hectares) during a cultivating season (Nag and Dutt, 1979). Therefore timely weeding is very essential for better crop yield; this can only be achieved by mechanical weeding tools which

perform simultaneous job of weeding and hoeing and can reduce the time spent on weeding, cost of weeding and drudgery involved in manual weeding (Goel *et al.*, 2008; Sharma *et al.*, 2016). In weeding operation, mostly farm women are involved. Weeding done by farm women using khurpi and sickle proves useful, but it demands labour and full of drudgery. During these activates farm women adopt bending and squatting posture which results in increased physiological workload. Increased physiological workload creates many types of musco-skeletal problems as result of which the work efficiency of farm women decreases to a great extent. The khurpi is operated in squatting position, the 3-tyne hoe, in bending posture, the degree of bend depend upon the handle. In the case of a 3-tine hoe it is observed to be 145° with respect to the vertical (Tewari *et al.*, 1991). In the case of a twin wheel hoe weeder, it is observed to be almost straight with respect to the vertical and operated in standing position (Mohanty *et al.*, 2016)

In view of the importance of the weeding operation, it is desirable to evaluate which weeding tools are mechanically versed and also take less human energy expenditure during weeding operations. Therefore, in present study the three commonly used hand weeding tools were evaluated in terms of performance, grade of work and farm women comfort. Performance is estimated

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in term of weeding efficiency. Grade of work relates to working heart rate and energy expenditure and comfort is subjective assessment of operating posture.

2. MATERIALS AND METHODS

2.1. Selection of Subjects

Eight farm women with good use experience of selected hand tools in the age group of 20-45 years were selected randomly. Subjects in age of 20-45 years attain their highest strength level (Mc Ardle *et al.*, 2001). All the selected subjects were physically fit and were free from any physical anomalies to perform weeding activities with different weeding tools. The physical characteristics of selected subjects are presented in Table 1.

Table 1.

Average physical characteristics of the eight selected subjects

Variables	Mean $\pm$ SE	Coefficient of variation
Age (years)	41 $\pm$ 1.45	4.1
Body height (cm)	147 $\pm$ 0.99	2.9
Body weight (cm)	49 $\pm$ 0.81	2.3
Resting pulse rate (beats/min)	87 $\pm$ 1.18	3.3

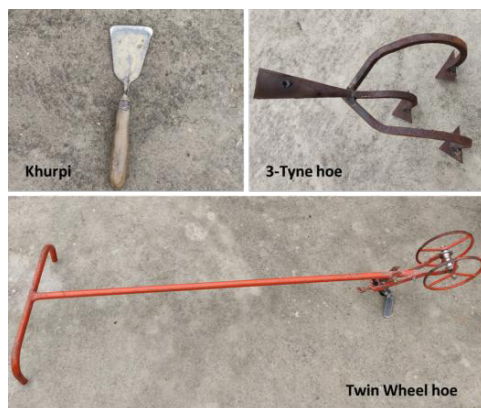


Fig. 1. Hand weeding tools



Fig. 2. Weeding operation with different tools; (a) 3-tyne hoe, (b) khurpi and (c) twin-wheel hoe

2.2. Weeding Tools and Equipment used

Three weeding tools (Fig. 1) namely khurpi, 3-tyne hoe and twin wheel hoe were taken for the study. Heart rate monitor (Mi Band 3) was used for measurement of heart rate at rest and during work.

2.3. Field Experiment

Field tests were conducted at the KVK Farm of Gopalganj district of Bihar. Gram crop (*Cicerarietinum*) was chosen for the test. The row to row spacing and area taken were 300 mm and 120 x 20 square meter, respectively. The weeding operation was performed in between the crop rows. The test was conducted during December to January. The prevailing ambient climatic conditions were recorded as average temperature, 18 $\pm$ 3°C and relative humidity 70 $\pm$ 2%. The average wind speed were recorded to be 1-1.5 kmh⁻¹.

Workers were given rest before starting the work and their initial heart rate was recorded at rest. They were also asked about their health and the weeding operation was started at 10 am and continued up to 5 pm with 1h lunch break. The worker were given weeding tools and asked to operate between the row crops. They continued the operation till they complained fatigue. Subjects were allowed 10 min of rest after which they started work again. This process continued until the completion of work. The process was replicated with all eight subjects for the three selected manually operated weeding tools. The photographic views of weeding with different weeding tools are shown in Fig. 2.

2.4. Physiological Response Measurement and Computation

During the weeding operation and also at rest, the heart rate of all subjects was carefully measured at 5 min interval with the help of digital heart rate monitor. Ten such set of observations were measured for each of the trials and average values were calculated. These heart rate values converted to energy expenditure rate by the equation given by Varghese *et al.* (1994)

$$\text{Energy Expenditure (kJ/min)} = 0.159 \times \text{heart rate (beats/min)} - 8.72 \quad \dots(1)$$

The mean, standard error and standard deviation of all the data were also calculated.

2.5. Field Performance

To know the field performance during weeding operations, working width of cut by weeding tools and area weeded per minute were calculated. Ten set of observations recorded for all subjects with each weeding tools. These data were used to calculate man-hours/hectare and weeding efficiency with each weeding tools. The weeding efficiency is the ratio of numbers of weeds removed by the weeding tools to the total number of weeds present before the operation of the tools in between the row crops.

2.6. Classification of Workload

Workload of activity was categorized as per the classification (Table 2) proposed by Varghese *et al.* (1994).

Table 2.
Workload classification.

Physical work load	Physiological variables	
	Energy expenditure (KJ/min)	Heart beats (beats/min)
Very light	Up to 5.0	Up to 90
Light	5.0-7.5	91-105
Moderate	7.6-10.0	106-120
Heavy	10.0-12.5	121-135
Very heavy	12.6-15.0	136-150
Extremely heavy	15	Above 151

2.7. Overall Discomfort Rate (ODR)

Overall discomfort rating (ODR) developed by Corlett and Bishop (1976) was used for assessment of discomfort felt during weeding operation. It consisted of a 700 mm long graduated scale with its left marked as 0 and right ends 10 which are representing 'no discomfort' and 'extreme discomfort' respectively. All subjects were asked to mark their discomfort rating on ODR scale after each trial. Drudgery was operational physical and mental strain, fatigue, monotony and hardship experience by farm women while doing weeding operation.

2.6. Statistical Analysis

To know the statistical significance in variations of heart rates of different subjects with different weeding tools, analysis of variance (ANOVA) test was carried out. ANOVA, two-way without replication was done with heart rates, different subjects and different weeding tools

to know the effect of these parameters on the heart rates of subjects.

3. RESULTS AND DISCUSSION

3.1. Physiological Responses

The physiological responses of the subjects are shown in Table 3. The three weeding tools used vary in design and need different posture to operate. These factors contributed to the variation in physiological responses. It was observed that the work pulse rate during weeding by 3-tyne hoe was more than the twin wheel hoe and khurpi (Table 3). The average heart rate for all the subjects varied from 106.9 ± 1.65 to 120.9 ± 1.78 beats/min during weeding by khurpi, 131.7 ± 2.61 to 140.2 ± 1.17 beats/min during weeding by 3-tyne hoe and 97 ± 0.71 to 134.5 ± 2.49 beats/min during weeding by twin wheel hoe. The energy expenditure rate varied 8.28 ± 0.26 to maximum of 10.50 ± 0.28 kJ/min with average 9.39 kJ/min in case of khurpi, 12.22 ± 0.41 to maximum of 13.57 ± 0.19 kJ/min with average 12.89 kJ/min in case of 3-tyne hoe and 6.70 ± 0.11 to maximum of 12.65 ± 0.31 kJ/min with average 9.67 kJ/min in case of twin wheel hoe. As regards of the rating of the work load it appears that weeding with khurpi and twin wheel hoe could be graded as moderately heavy work whereas weeding with 3-tyne hoe could be graded as heavy work as per classification given by Varghese *et al.* (1994). These finding also in agreement with those of Nag and Dutt (1979), Tewari (1991) and Barkha (2015).

3.2. Weeding Effectiveness

The effectiveness of three methods of weeding was also studied and results were presented in Table 4. It was observed that the area weeded per unit time was minimum (0.30 to 0.47 m²/min) in case of the khurpi and maximum (0.88 to 0.98 m²/min) for the twin wheel hoe with the 3-tyne hoe giving an intermediate value of 0.5 to 0.6 m²/min. The corresponding widths of cut of the weeding tools were 80, 205 and 140 mm, respectively. It was, however, observed the weeding efficiency was significantly higher (92.1 ± 0.57 to 94.8 ± 0.34) in case of 'Khurpi' followed by twin wheel hoe (75.0 ± 3.67 to 79.5 ± 2.53 %) and 3-tyne hoe (68.0 ± 2.84 to 72.3 ± 3.83 %). The total man-hours involved per hectare in these methods were also computed. It was found that maximum man-hours per hectare (347 to 556) with average 447 ma-hours/ha involved with khurpi followed by three tyne hoe (278 to 333 man-hours/ha with average 302 man-hours/ha) and the twin wheel hoe (170 to 189 man-hours/ha with average 179 man-hours/ha). Hence. It was observed that twin wheel hoe took 60% less labour and three tynehoe took less 41 % less labour as compared to khurpi.

Table 3.
Physiological response* of the selected female farm workers in weeding operations

Selected Subject	Method of Weeding	Average work pulse rate (beat/min)	Energy Expenditure rate (kJ/min)
S1	Khurpi	106.9±1.65 (5.20)	8.28± 0.26 (0.83)
	Three tyne Grubber	140.2±1.17 (3.71)	13.57± 0.19 (0.59)
	Twin wheel hoe	108.2±0.61 (1.94)	8.48± 0.10 (0.31)
S2	Khurpi	113.3±2.32 (7.32)	9.29± 0.37 (1.16)
	Three tyne Grubber	134.8±2.61 (8.24)	12.71± 0.41 (1.31)
	Twin wheel hoe	115.7±0.60 (1.90)	9.68± 0.10 (0.30)
S3	Khurpi	111.3±0.87 (2.76)	8.98± 0.14 (0.44)
	Three tyne Grubber	134.5±2.33 (7.37)	12.67± 0.37 (1.17)
	Twin wheel hoe	97±0.71 (2.24)	6.70± 0.11 (0.36)
S4	Khurpi	110±0.73 (2.32)	8.77± 0.12 (0.37)
	Three tyne Grubber	133.5±2.60 (8.24)	12.51± 0.41 (1.31)
	Twin wheel hoe	129.9±0.85 (2.70)	11.93± 0.14 (0.43)
S5	Khurpi	111.6± 0.94 (2.97)	9.02± 0.15 (0.47)
	Three tyne Grubber	131.7±2.61 (8.25)	12.22± 0.41 (1.31)
	Twin wheel hoe	134.4±1.94 (6.14)	12.65± 0.31 (0.98)
S6	Khurpi	117.5±1.72 (5.43)	9.96± 0.27 (0.86)
	Three tyne Grubber	135±2.14 (6.77)	12.75± 0.34 (1.08)
	Twin wheel hoe	134.5±2.49 (7.89)	12.03± 0.16 (0.50)
S7	Khurpi	120.9±1.78 (5.63)	10.50± 0.28 (0.90)
	Three tyne Grubber	139.5±1.13 (3.58)	13.46± 0.18 (0.57)
	Twin wheel hoe	130.1±0.64 (2.02)	11.97± 0.10 (0.32)
S8	Khurpi	111±1.68 (5.31)	8.93± 0.27 (0.84)
	Three tyne Grubber	138.2±1.32 (4.17)	13.25± 0.21 (0.66)
	Twin wheel hoe	129±1.06 (3.35)	11.79± 0.17 (0.53)

* Values are means ± standard errors with standard deviation shown in brackets

3.3. ANOVA

The effect of subjects on heart beat was found to be non-significant at 5% level, as the calculated F ratio was less than its table value. Whereas the effect of different weeding tools on heartbeat per minutes were found to be significant at 5 % level (Table 5).

3.4. Overall Discomfort Rate

All subjects were asked to share pain felt during weeding operations with each weeding tools to know associated Musculo-skeletal problems. Table 6 shows that weeding with khurpi in strenuous posture cause severe pain in shoulders, upper, back, hands and fingers. The farm women perceived the task as heavy. On the contrary using improved weeding tools like three tyne hoe and twin wheel hoe induced moderate to light discomfort/pain in shoulders, hand and arms. Improved tools eliminated continuous squatting posture and employed standing posture while working the twin wheel hoe and combination of some bending and standing posture in case

of three tyne hoe. The rating of the perceived exertion was also reported as moderate with use of twin wheel hoe and three tyne hoe.

4. CONCLUSIONS

Effectiveness of three popular hand weeding tools viz. khurpi, 3-tyne hoe and twin wheel hoe were evaluated in terms of performance, grade of work and comfort for farm women. The field operation with khurpi and twin wheel hoe could be graded as moderately heavy work whereas field operation with 3-tyne hoe was graded as heavy work. The weeding efficiency of khurpi was observed highest (92.1 to 94.8 %) followed by twin wheel hoe (75.0 to 79.5 %) and three tyne grubber (68.0 to 72.3 %). In terms of work output, the twin wheel hoe was observed to be best, followed by the 3-tyne hoe, with the khurpi being worse. Weeding by khurpi is by far the most labour intensive and this outweighs its other advantages. Therefore, from overall consideration a-twin wheel hoe or 3-tyne are preferable to the khurpi for weeding operation.

Table 4.

Effectiveness of different method of weeding by the selected female farm workers

Selected subject	Method of weeding	Area weeded per unit time (m ² /min)	Working width of cut (mm)	Weeding efficiency	Man-hours/ha
S1	Khurpi	0.31	80	92.1±0.57 (1.81)	538
	Three tyne hoe	0.6	140	69.8±1.36 (4.31)	278
	Twin wheel hoe	0.98	205	78.9±3.02 (9.54)	170
S2	Khurpi	0.4	80	92.6±0.45 (1.43)	417
	Three tyne hoe	0.5	140	70.7±2.46 (7.63)	333
	Twin wheel hoe	0.95	205	76.6±2.46 (8.45)	175
S3	Khurpi	0.47	80	93.6±0.45 (1.43)	355
	Three tyne hoe	0.55	140	69.8±2.98 (9.41)	303
	Twin wheel hoe	0.97	205	76.2±2.81 (8.89)	172
S4	Khurpi	0.32	80	94.6±0.40 (1.28)	521
	Three tyne hoe	0.52	140	68.0±2.84 (8.97)	301
	Twin wheel hoe	0.91	205	75.0±3.67 (11.60)	183
S5	Khurpi	0.48	80	92.9±0.81 (2.55)	347
	Three tyne hoe	0.54	140	71.5±3.66 (11.59)	309
	Twin wheel hoe	0.89	205	76.0±3.28 (10.38)	187
S6	Khurpi	0.37	80	94.8±0.34 (1.08)	450
	Three tyne hoe	0.57	140	72.3±3.83 (12.10)	292
	Twin wheel hoe	0.94	205	79.5±2.53 (8.02)	177
S7	Khurpi	0.42	80	93.7±0.86 (2.72)	397
	Three tyne hoe	0.59	140	68.3±2.88 (9.11)	292
	Twin wheel hoe	0.88	205	77.6±3.69 (11.68)	189
S8	Khurpi	0.3	80	94.7±0.51 (1.62)	556
	Three tyne hoe	0.56	140	71.1±3.31 (10.46)	282
	Twin wheel hoe	0.96	205	78.1±3.49 (10.99)	174

Table 5.

Analysis of variance for heart beat

Source of Variation	SS	df	MS	F	P-value	F _{crit}
Between Subjects	574.19	7	82.03	1.19	0.36	2.76
Between weeding tools	2115.29	2	1057.64	15.33	0.00	3.74
Error	966.07	14	69.00			
Total	3655.56	23				

SS= Sum of Squares; df= degree of freedom; MS= Mean Square

Table 6.

Overall discomfort rating and perceived exertion due to musculo-skeletal problems

Weeding Method	ODR ¹	MSP ²	RPE ³
Khurpi	8.1	Severe pain in fingers, upper back, hands and shoulders	Heavy
Three tyne hoe	6.3	Pain in shoulder, fingers, waist	Moderate
Twin wheel hoe	4.0	Moderate to light pain in shoulder, hands and arms	Moderate

¹Mean value of overall discomfort rating; ²Musculo-skeletal problem; ³Rating of perceived exertion

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