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Development and Ergonomic Assessment of Women Friendly Stirrup Hoe

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ABSTRACT

A field experiment was conducted during Rabi season at ICAR Research Complex for Eastern Region to evaluate stirrup hoe for intercultural operation in maize crop (*Zea mays* L.). The mean values of age, weight, height, body mass index (BMI), lean body mass (LBM), body surface area (BSA) and basal metabolic rate (BMR) of the subjects were 37.83 years, 51.67 kg, 152.50 cm, 22.20 kg/m^2, 1.36 m^2 and 1233.98 kcal/day, respectively. The mean of heart rate (HR), energy expenditure rate (EER) and oxygen consumption rate (OCR) during operation of stirrup hoe and khurpi were 113.08 and 97.13 beats/min, 9.26 and 6.72 kJ min^{-1} and 0.61 and 0.43 l/min. Weeding efficiency, plant injury and effective field capacity for stirrup hoe were 84.57%, 1.85% and 0.007 ha/hr whereas, for khurpi these were 96.95%, 0.74% and 0.002 ha/hr. The cost of operation of khurpi was 3.5 times costlier than stirrup hoe. The body part discomfort score (BPDS) of stirrup hoe was 26.8 whereas that of khurpi was 20.8.

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INTRODUCTION

Maize is considered as the third most important food crop among the cereals in India and contributes to nearly 9% of the national food basket and 5% to world's dietary energy supply.

Bihar is one of the largest maize producing state and a round 7.2 lakh hectares is under maize cultivation, accounting for about 7.3 per cent of Gross Cropped Area (GCA) in the state. The state has produced about 3.84 million MT in the year 2016-17 with an average productivity of 5.335 t/ha (Singh *et al*, 2018). The area under Rabi maize is gradually increasing in Bihar due to growing market demand by feed and starch industry and increase in minimum support price. Due to wider row spacing, winter maize suffers from severe competition of weeds resulting in 28-100% yield losses (Patel *et al*, 2006). Besides yield losses, weeds also deplete 30-40% of applied nutrients from soil (Mundra *et al*, 2003). The critical period for crop weed competition in winter maize varies from 15-60 days after sowing (DAS). Thus, it is imperative to eliminate weeds at proper time with appropriate methods. Timely weeding is an important aspect of achieving the optimum yield (Singh *et al*, 2019). Managing weeds with the use of improved weeding tools/implements not only uproots weed between crop rows but also makes surface soil loose, ensuring better soil aeration and water intake capacity. There are many types of weeders that have been developed for weeding but all these designs are region specific to meet the requirement of soil type, crops and availability of the local resources (Goel *et al*, 2008). The use of improved weeders reduces time and drudgery in maize field (Shekhar *et al*, 2010; Sarkar *et al*, 2016). Raut *et al* (2013) also reported that there is a need to give more stress on working posture and ergonomic constraints for male and female workers. Out of the various methods presently in use for weeding, mechanical weeding has a wide scope using small implement to reduce the cost of labour and energy. Hand weeding is still most common but time consuming, costly and involved lots of drudgery. In order to reduce the drudgery of female workers need was felt to develop and popularize a manual stirrup hoe for intercultural operations. Hence, the present study is undertaken to develop a stirrup hoe and its ergonomic evaluation in winter maize.

MATERIALS AND METHODS

The field experiment was conducted at ICAR Research Complex for Eastern Region, Patna (25° 35′ 30″ N latitude, 85°05′ 03″ E longitude and elevation 52 m msl) during rabi season of 2019-20 in Eastern Indo-Gangetic Plain of Bihar. The climate of the experimental site was sub-tropical exhibiting high humidity and medium rainfall. The soil of the experimental plot was clay loam (sand: 23.7%, silt: 39.3% and clay: 37.0%) The maize variety 'Daftari' was sown on 14 November 2019. The crop was dibbled seeded at a spacing of 50 × 20 cm with a seed rate of 15 kg/ha. The weed samples were collected using a quadrate of 1×1 m at 30 and 60 DAS. The moisture content in soil was recorded at weeding time before using the weeding tools from 0-15 and 15-30 cm soil depth. The mean moisture content of the experimental plot varied from 12.7-23.9%. The monthly mean maximum and minimum temperature during the crop growing period ranged from 22.17 - 32.69 ^{0}C and 8.72-18.31 ^{0}C, respectively. The mean relative humidity during the month of November-December, 2019 was 69.1-74.6 %. After 155 days, yield was obtained 9637 kg/ha in conventional tillage.

Six female agricultural workers free from any disease were selected for operating the developed weeder. The subjects

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were in the age group of 30 to 50 years and were chosen at random to perform weeding operation by stirrup hoe and khurpi. The subjects were familiarized with working of stirrup hoe by working with it for 5-10 minutes each. The weeding operation was done with stirrup hoe and khurpi in maize crop with a row to row spacing of 50 cm and plant to plant spacing of 20 cm. Three replications were taken for the subjects for the experimental activity. Every subject was provided with three equal plots of (6m×8m) to carry out weeding activity with both the weeding tools. Field observations like speed of operation, moisture of soil, temperature and humidity during the activity were recorded. Data collected during the field evaluation trials were analyzed to determine the actual field capacity, weeding efficiency and plant damage. Separate timings and heart rate (HR) were recorded during the experimental activity using Polar Heart Rate Monitor (RS-400, Finland). The physiological parameters like OCR and EER was calculated using HR values during the activity.

Design and fabrication of stirrup hoe

The stirrup hoe consists of three parts: blade, housing frame and handle (Figure 1). The blade was made up of spring steel (200×50×5 mm) with a cutting-edge thickness of 0.8 mm, the frame structure was made up of mild steel flat and handle was fabricated from MS hollow pipe (25 mm OD). The housing frame has a top width of 170 mm; bottom blade width of 200 mm and height between blade and top width is 120 mm. The blade was fitted with a housing frame with mechanical fasteners (M8 bolt) on both sides. For easy movement and operation, two sliding slots (18 × 9 mm) were made on both sides of the housing and just below a standard hole (8 mm). The slot helps in changing the tool working angle depending on the operator height. A clamp (Angle: 60^0) was welded on top of the frame where the handle was fixed with fasteners. The detailed specification is given in Table 1 .

Table 1: Specifications of stirrup hoe

Sl. No.	Components	Specifications
1	Length of blade	200 mm
2	Width of blade	50 mm
	Blade thickness (centre) Side thickness	5 mm 1 mm
3	Weight of blade	465 gm
4	Blade material:	Spring steel
5	Length of handle	1520 mm
6	Diameter of handle	25 mm
7	Working height of handle	1100mm
8	Weight of handle	1155 gm
9	Cutting edge angle	25^0
10	Weight of tool	2.35 kg

Subject Details

Subject details like age, weight, stature, body mass index (BMI), lean body mass (LBM), body surface area (BSA) and basal metabolic rate (BMR) were calculated using equation 1,2,3 and 4, respectively.

Body mass index (BMI) calculated using (WHO,2006)

$$BMI = \frac{Weight\ (kg)}{height\ (m^2)} \quad (1)$$

Lean body mass (LBM)

The lean body mass LBM (for female) was calculated (Equation (2))by Hume (1966) Hume (1966).

$$LBM = (0.29569 \times W) + (0.4181 \times H) - 43.2933 \quad (2)$$

Where, W is body weight in kilograms and H is body height in centimeters.

Body surface area (BSA)

The body surface area (BSA) was calculated (Equation (3)) by Schlich and Schlich (2010). BSA is expressed in m^2.

$$BSA = 0.000975482 \times W^{0.046} \times H^{1.08} \quad (3)$$

Where weight (W) in kg and height (H) in cm.

Basal metabolic rate (BMR)

The formula for calculating basal metabolic rate (BMR) for female subjects was given by Roza and Shizgal (1984), which re-calculated the Harris Benedict Equation (Equation 4) earlier used for BMR calculation. It is also termed as metabolism and may be defined as the number of calories required to keep one's body functioning at rest, also known as the metabolism. It is affected by gender, body mass, age, weight and height. $BMR(Women) = 447.593 + (9.247 \times weight\ in\ kg) + (3.098 \times height\ in\ cm) - (4.433 \times age\ in\ years)$(4)

Oxygen Consumption Rate

Oxygen consumption rate (OCR) was calculated (Equation (5))based on Singh *et al* (2008).

$$OCR\ (l/min) = 0.0114 \times HR - 0.68 \quad (5)$$

Energy Expenditure Rate

Energy expenditure rate (EER) was estimated using Equation (6) given by Varghese *et al* (1994).

$$EER(kJ/min) = 0.0159 \times Avg.\ HR - 8.72 \quad (6)$$

Weed count (No./m^2)

In each treatment, a quadrant of 1.0 m × 1.0 m was earmarked in the plot for recording weed count. From the quadrant, weeds were removed, identified, counted and recorded.

Weed dry weight (g/ m^2)

The weeds present within the quadrant area were uprooted, identified, counted and similar weeds were separated and transferred to brown envelopes. Thereafter, the weeds were dried in the hot air oven at 60^0 C until constant weights were obtained.

Weeding efficiency (%)

The weeders used during the study were measured for weeding efficiency (Equation (7)) using (Rangasamy *et al*, 1993).

$$Weeding\ efficiency\ (\%) = \frac{W_1 - W_2}{W_1} \times 100 \quad (7)$$

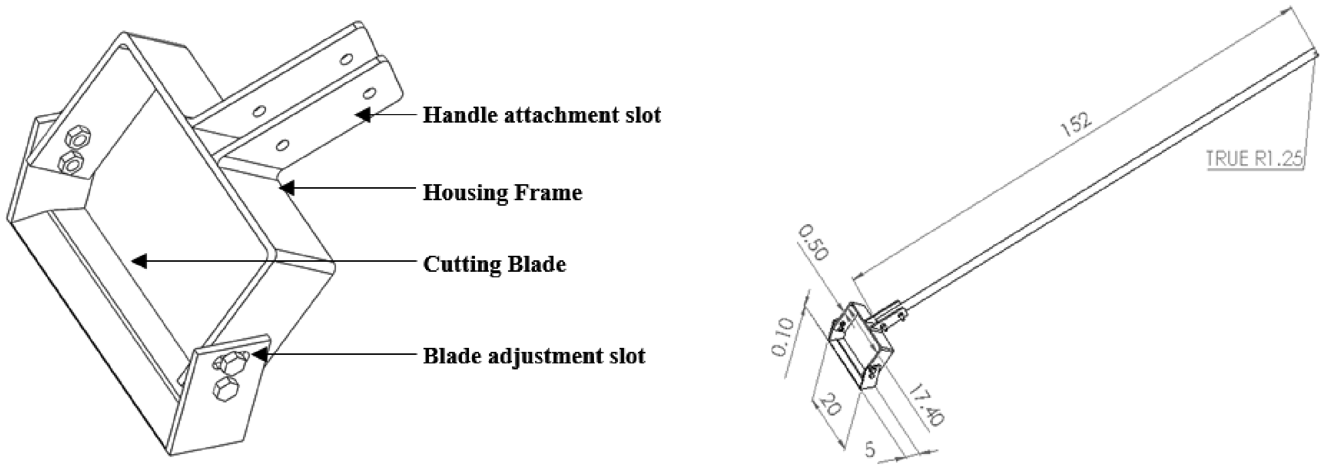

Fig. 1: Different parts and dimensions of stirrup hoe

Where, W_1 = No. of weeds before weeding, W_2= No. of weeds after weeding

Plant injury (%)

Plant damage was calculated by counting the number of plants in 10 rows before weeding and number of the plant damaged in 8 m row length (Equation (8))after weeding (Biswas and Yadav, 2004).

$$Plant\ injury(\%) = \frac{A}{B} \times 100 \quad (8)$$

Where,

A= No. of cut/injured plants in 8 m rows

B= Total no. of plants in 8 m rows

Effective field capacity (%)

Effective or actual field capacity was calculated using Equation (9). (Mehta *et al*, 2005)

$$Effective\ field\ capacity = \frac{A}{T_p + T_{np}} \quad (9)$$

Where, A= Area (ha), T_p= productive time (hr), T_{np}= non productive time (hr)

Body Part Discomfort Score (BPDS)

Body part discomfort score (BPDS) was calculated using the technique given by Corlett and Bishop (1976). In this technique, the subject's body was divided into 27 parts. During and after the activity, the subjects were asked about all body parts with discomfort, starting with the most painful, in descending order till all the body parts experiencing discomfort had been recorded. The intensity levels of discomfort were categorized in groups and were assigned a numerical value calculated based on total intensity levels. The body part discomfort score was derived using formula (Equation (10)) given by J;Awasthi *et al* (2020).

$$BPDS = SX_i \times S(3.40) \quad (10)$$

where, X_i = Number of body parts, S = Discomfort score(6 to 1)

RESULTS AND DISCUSSION

The six participating female farm workers were in the age range of 30-45 years (Figure 2). The mean±SD values of age, weight, height, BMI, LBM, BSA and BMR of the subjects were 37.83±7.52 years, 51.67±4.32 kg, 152.50±2.43 cm, 22.20±1.52 kg/m^2, 35.75±2.06 kg, 1.36±0.07 m^2 and 1233.98±45.55 kcal/day, respectively. Similar results were reported by Bajpai *et al* (2018) where average age, height and weight of 20 female respondents were 37.5 years, 153.5cms and 48.5 kg; Singh *et al* (2013) reported physical characteristics of 150 farm women such as L.B.M., B.M.I. and B.M.R as 34.54 kg, 21.01 kg/m^2 and 1122.45 kcal/day respectively. The BMI values suggest that all the subjects were in a healthy (normal) range of 18·5–24·9 kg/m^2 .

Fig. 2: Ergonomic evaluation of stirrup hoe in maize field.

The physiological responses like heart rate (HR), energy expenditure rate (EER) and oxygen consumption rate (OCR) of the subjects are presented in fig. 3. The average work pulse rate for subjects was 113.08±1.94 and 97.13±2.46 beats/min during operation of stirrup hoe and khurpi, respectively. It was also observed that the cardiovascular demand for weeding by khurpi was slightly lower than weeding by stirrup hoe. However, variations in the work pulse rate among the subjects for both the weeding methods were small. Mean of EER of subjects during work on the stirrup hoe and khurpi were 9.26±0.31 and 6.72±0.39 kJ/min. The oxygen consumption rate of all the subjects for weeding by stirrup hoe and khurpi was observed to be 0.61±0.02 and 0.43±0.03 l/min. Stirrup hoe was operated in standing-pulling posture whereas khurpi was operated in sitting-squatting posture thereby contributing to the variation in physiological responses. Upendar *et al* (2018) conducted ergonomic evaluation of power weeder and reported heart rate and oxygen consumption rate of operators as 131.0 - 145.5 beats/min and 0.80 - 0.98 l/min, respectively. According to J;Awasthi *et al* (2020), the average EER and OCR values during weeding operation with hand hoe in wheat crop was 5.31kJ/min and 0.36 L/min.

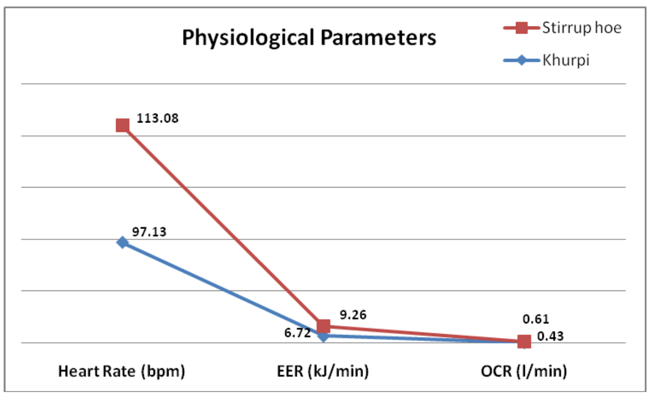

Fig. 3: Physiological parameters during weeding operation

Weed flora

At 30 DAS, minimum weed density was noticed for stirrup hoe with a value of 16.36 no./m^2 while it was 17.10 no./m^2 and 18.55 no./m^2 for khurpi and control, respectively. Irrespective of weeding implements used, most dominant weeds were *Anagallis arvensis* L. (9.15) followed by *Launae anudicaulis* (7.89), *Solanum nigrum* (7.16). Similar trend was observed for weed dry weight also and maximum and minimum weed dry weights were noted for control (6.57) and stirrup (5.38), respectively. After first weeding at 30 DAS second weeding was done at 60 DAS. At 60 DAS, the stirrup method registered minimum weed density (13.37) followed by khurpi (16.84) and control (18.10). During that time, most dominant weed species were *Anagallis arvensis* L. (8.81), *Cyperus rotundus* (6.81) and *Solanum nigrum* (5.98).

Weeding efficiency

The weeding efficiency observed with khurpi (96.95%) was greater than that of a stirrup hoe (84.57 %). The results are in agreement with Tiwari et al (1991) where weeding efficiency of khurpi was 95.4 %, of spade the values were 92.5 % and for 3-tine hoe it was 78.4%. Shekhar *et al* (2010) also reported the weeding efficiency of khurpi as 99.40% in maize crop. The weeding efficiency of khurpi was higher than stirrup hoe because of its ability to be used between plant to plant spacing in rows. However, stirrup hoe can be used for weeding but they cannot be used much closer to the plants as this is operated in standing posture and may cause plant injury when worked very close to plants. For this reason, stirrup hoe has lower weeding efficiency as compared to khurpi.

Plant damage/injury

A higher percentage of plant injury was found in the case of a stirrup hoe (1.85%) followed by khurpi (0.74%). Stirrup hoe recorded a higher percentage of plant injury mainly because of the higher speed of operation done in standing posture and the female workers not being very familiar in its operation as this implement was introduced for the first time among workers. It is expected that plant injury will reduce further when workers use this implement more often and make themselves comfortable with it. Plant injury from power weeder wheel hoe grubber and khurpi was 1.94%, 1.01%, 0.76% and 0.46% (Shekhar *et al*, 2010).

Effective field capacity

The effective field capacity of a stirrup hoe (0.007 ha/hr) was found to be higher than that of khurpi (0.002 ha/hr). Shekhar et al (2010) Shekhar *et al* (2010) reported field capacity of power weeder, wheel hoe, grubber and khurpi was 0.067, 0.009, 0.008 and 0.002 ha/hr respectively. A considerable difference in the effective field capacity of both the tools under study is because of the blade width and forward speed. Stirrup hoe was operated in the standing posture by a push and pull action thereby facilitating the worker to move faster. Khurpi is operated in sitting-squatting posture and the forward speed is very less, thereby minimizingthe field capacity of the tool during intercultural operation.

Yield and c ost of operation

The cost of operation of khurpi (Rs 15,750/ha) was considerably high when compared to stirrup hoe (Rs 4,500/ha. The cost of operation by khurpi is around 3.5 times costlier. The cost of weeding was calculated based on present local labour charges i.e. Rs. 250/- per day (for eight hours of useful work). As we observe that the field capacity of khurpi is very less, weeding operation by it is a labour intensive and costly affair. The use of khurpi in small fields can be done but its use in larger agricultural fields increases labour cost manifold and its use is not recommended. Shekhar *et al* (2010). The cost of operation of khurpi, grubber and wheel hoe was Rs. 4051/ha, Rs. 1158/ha and Rs. 1152/ha.

Body part discomfort score (BPDS)

In the present study, a BPDS difference of 22.39 % was observed during the operation of khurpi and stirrup hoe. BPDS of khurpi (20.80) was less than that of a stirrup hoe (26.80), which implies that khurpi use was comfortable as compared to stirrup use. J;Awasthi *et al* (2020) reported similar results for BPDS during weeding operation with hand hoe i.e., 19.5 in wheat crop. Since the difference is very less, stirrup can address the requirement of intercultural operation in larger plots (2-4 ha).

CONCLUSION

The present study helps in distinguishing the best manual weeding equipments for women. The cost of operation of khurpi was 3.5 times costlier than stirrup hoe. The body part discomfort score (BPDS) of stirrup hoe was 26.8 whereas that of khurpi was 20.8. The BPDS score demand for more modification in the design of stirrup hoe.

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