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Development and Performance Evaluation of Manually Operated Cono-Weeder for Paddy Crop

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Abstract: Weeding in wetland paddy is largely done by hand weeder "*Khurpi*" in middle Gujarat region. Another method is the use of mechanical weeders. Study was conducted to know the design features of manually operated weeders for paddy weeding. The results of the study revealed that japanese paddy weeder required more numbers of labours and incorporation of weeds into the soil, aeration to the root zone of crop and churning capacity was found very poor than TNAU conoweeder. Even though, it was found drudgerious, time consuming and faced operational instability with frequent clogging of soil around weeding cone and blades.
To offset this problem, cono-weeder was developed considering different design parameters. Serrated bladed weeding unit of 100 mm cone diameter and 30° blade angle was chosen and it was fabricated from standard materials. The comparison of the performance in terms of different dependent parameters was carried out by field experiment in three replications. It was ergonomically evaluated to calculate physiological work load and its suitability in the region. The results of the experiment revealed that the developed cono-weeder was found more suitable for paddy weeding due to highest weeding efficiency 87.77 %, field capacity 0.026 ha h^{-1} and maximum soil volume disturbed 6.49 m^3 h^{-1}. Plant damage, numbers of clogging and cost of operation were found lower as 4.58 %, 3 and 1107.90 ₹ha^{-1} respectively than TNAU conoweeder. The overall performance of equipment can be computed in term of performance index which was found highest as 2300 of the developed cono-weeder. The effect of equipment on crop growth parameters was found non-significant.
The working heart rate for male and female subjects were observed higher as 148 beats min^{-1} and 152 beats min^{-1} respectively for weeding with TNAU conoweeder as compared the developed cono-weeder. The average energy expenditure rate of male and female subjects for weeding by developed cono-weeder were calculated as 16.86 kJ min^{-1} and 17.82 kJ min^{-1} which was less than TNAU conoweeder. Thus, the work with the developed cono-weeder falls under moderate heavy work, which is under acceptable limits of male and female subjects (100-120 beats min^{-1}) in wetland weeding operation.

I. INTRODUCTION

Rice is an important staple food for about 50 per cent of the world's population providing 66-70 per cent body calories intake to the consumers (Barah and Pandey, 2005). Paddy is grown on about 44 per cent of the total area under cereals and contributes about 45 percent of the total cereals production in India. India ranks first in area (43.3 million ha) and second in terms of production (85.32 million tonnes) and represents about 10% (225 million) of the total workforce in agriculture (Nag and Nag, 2004). In Gujarat, rice is grown on an average 6.5 to 7.25 lakh ha of land and accounts for around 14 % of the total food grain production of the state. The total production of rice in the state is about 9.0 to 10.5 lakh tonnes with productivity of 1500 to 1800 kg ha^{-1} (Anonymous, 2010a).

Almost all the operations of rice production attained the desired level of mechanization. However, harvesting and weeding specially for SRI cultivation are yet to be fully mechanized to attain the desired level of power utilization and to ease the rice cultivation. Weeding is more tedious, laborious and time consuming operation as it is estimated that one third to half of the labour used in rice cultivation is for weed control alone with an average figure of 30-40% labour-day ha^{-1} (Hobbs and Belinder, 2004). In transplanted paddy cultivation, traditional seedbed-based rice cultivation consumes 15.3 -23.7 % energy for weed management in India because traditional farmers give their higher priority to hand weeding (Chaudhary *et al*., 2006).

Mechanical weed control not only uproots the weeds between the crop rows but also keeps the soil surface loose, ensuring better soil aeration and increase water intake capacity and mechanical weeders perform simultaneous job of weeding and hoeing and can reduce the time spent on weeding (man hours), cost of weeding and drudgery involved in manual weeding. In SRI, weeds are seen as growth promoters when they are appropriately managed. The wider and equal spacing between the plants allow easy operation of mechanical weeders. This process incorporates the weeds into the soil as green manure crops. It helps build up of soil organic matter and subsequently large and diverse microbial population in the soil. Thus mechanical weeding operation facilitates the process of aeration in the soil. This in turn mobilizes the micro nutrients required for the healthy growth of the rice plant.

In many parts of India, the hand weeder is a tool used in agriculture and allied activities to keep control of weeds in rice and other crop cultivation. Many different weeders have been designed, selected or proposed again with no clear definition of salient characteristics and no "definitive" design. From available literature, weeder is called push weeder, rotary weeder, mechanical hand weeder, rotary hoe or cono-weeder. All these designs are region specific to meet the requirements of soil type, crop grown, cropping pattern and availability of local resources (Goel *et al*., 2008). Hand weeding requires higher labour input and increased weight; operational difficulties in puddle field and design complexity with many working parts have been identified as major drawback in power weeders. Japanese paddy weeder and conoweeder found better than hand weeding in terms of weeding efficiency but, the conoweeder churns the soil and incorporates weeds into the soil more effectively than Japanese paddy weeder, which in turn serves as organic manure. It facilitates aeration into root zone results in higher tillering and ultimately more yields. There is a large demand to improve manually operated mechanical weeders and a clear need for an improved and optimized technology especially for wet land farming in India.

Keeping the above aspects in view, the research work on Development and performance evaluation of manually operated cono-weeder for paddy crop was undertaken with the following objectives:

1. Study of manually operated weeders for paddy crop
2. Design and development of cono-weeder
3. Performance evaluation of the developed cono-weeder

II. MATERIALS AND METHODS

- **Design Considerations**:

The design aspects like theoretical, agronomical, functional and engineering aspects were considered in the development of the cono-weeder. The basic functions of mechanical weeders are uprooting and cutting of the weed plants and spreading of them on soil surface or burial into soil. Manually operated weeders are the best option for weeding operation in wetland paddy crop. Star- wheel type, peg-tooth type, rotary drum type, rollers and discs type weeding units have less resistance to their forward motion during weeding operation in dry land conditions. But, these weeding units are more likely to get covered with soil, when soil moisture is higher like as in wetland paddy field. Keeping this in mind, the truncated rollers type or conical shape type of weeding unit was considered for development of the weeder as in TNAU conoweeder.

- **Design of Main Components:**

The design aspects of the main components of manually operated cono-weeder for paddy crop are described as under:

1. Main frame:

In the frame of TNAU conoweeder, round MS pipe and square MS tube are welded together and three holes were provided on round MS pipe for adjustment of handle pipe. Three holes were also provided on square tube of main frame for mounting brackets (arms) to adjust required width of operation. The precise adjustment is not possible in height of weeder and width of weeding operation due to three holes made at interval of some fixed distances.

To offset this problem, the main frame of the TNAU conoweeder was modified and fabricated from 20 x 20 x 2 mm MS square tube (Fig.1). Holes were removed and hex bolts were used for precise adjustment of handle pipe and cone mounting brackets (arms). Two 90 mm long MS square tube bars (20 x 20 x 2 mm) were welded at 270 mm distance apart from each other on the main frame tube in such a way that two mounting brackets (arms) inclined at 90° downwards to the soil can be adjusted as per required width of operation. Float was fixed at front end and handle was fitted at rear of the main frame.

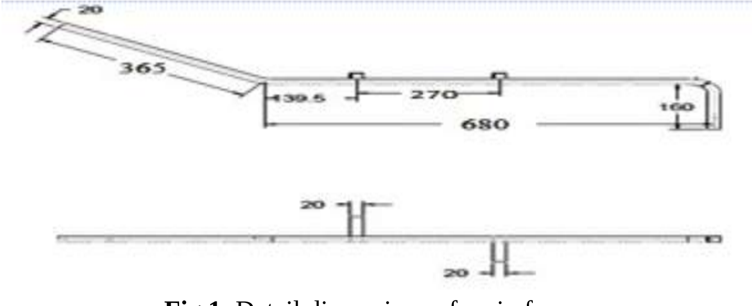

Fig.1: Detail dimensions of main frame

2. Weeding unit:

In this study, push type ground driven weeder was taken into consideration. In ground driven push type weeder weeding drums and blades are considered as the major components of the weeding unit.

2.1 Weeding drum:

Rotating cones were designed as per requirement of volume of the soil manipulation and optimum coverage area between two rows. Soil adhering to the weeding cone can form a body of soil that acts as a part of the tool in higher moisture paddy soil. If the co-efficient of soil-soil friction is greater than soil-metal friction along weeding drum, draft force required may increase (Gill and Vanden Burg, 1968). So, it was considered that the shape of weeding drum facilitate easy and free forward movement of the weeder. Different designs of weeding cones of diameters 40 mm, 55 mm, 70 mm, 85 mm and 100 mm were developed considering angle and length of the weeding cone were kept unchanged i.e. 40° and 130 mm respectively. They were fabricated from 2 mm thick MS sheet, 25 mm diameter MS round bar and bearings as shown in Fig.2.

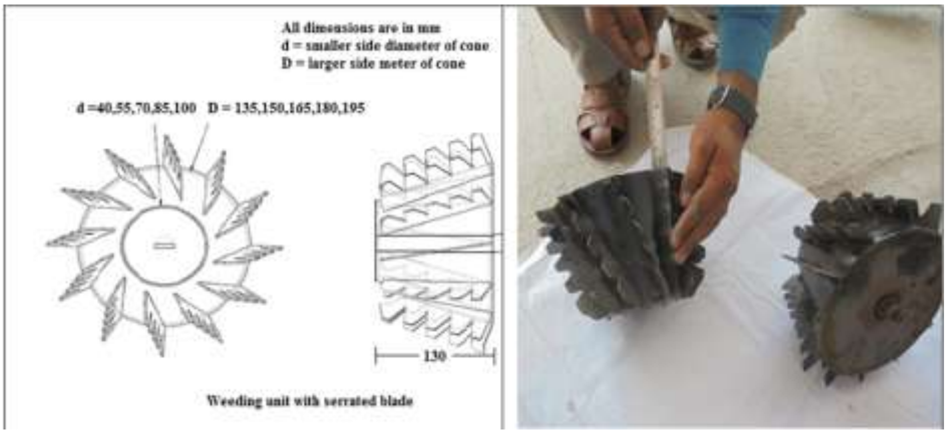

Fig.2: CAD view and developed model of serrated bladed weeding units

2.2 Weeding blades:

The geometry of the blades can materially affect the draught as well as vertical and lateral components of soil forces. Notched and plain blades have different edge shape, but same macro shape (Kepner *et al*, 1987).

To solve the problem of soil mass sticking on blade surface, it is necessary to reduce the soil contact area of the blade. For this, serrated edge blades were fabricated from 2 mm thick MS sheet of 120 mm length and 35 mm width and mounted on drum surface with blade inclination of 30° (Fig.3)

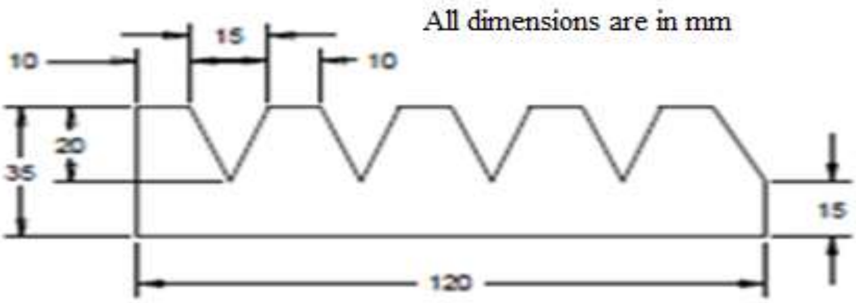

Fig. 3: Serrated edge shape of blades

3. Float

The float of the developed cono-weeder was fabricated with some modification in the float of TNAU Cono-weeder. Side wall height of the float was increased to prevent entry of mud from side walls and length of float was reduced without changing soil contact area of the float to ensure easy floating action of the weeder during operation. Front, top and isometric views are shown in Fig.4.

A flat rectangular float of 315 x 70 mm size with a wedge-shaped leading edge was fabricated from 2 mm thick MS sheet. The float was welded at the front of main frame making an angle of 35° with horizontal so that it can control depth of operation, slide easily on soil and reducing draft requirement of the weeder.

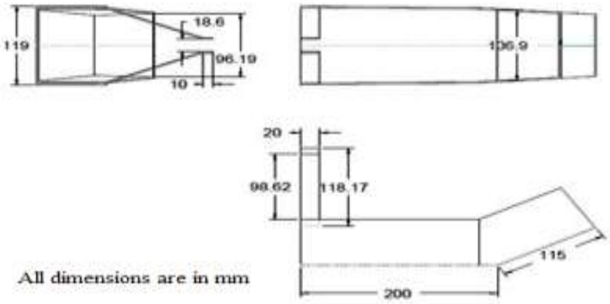

Fig.4: Detailed dimensions of float

4. Mounting brackets (arms)

Mounting brackets of the TNAU conoweeder were used to mount conical shaped weeding unit to the main frame. Two brackets (arms) of 185 mm length were fabricated from 25 x 25 x 2 mm MS square tube and 20 mm diameter MS pipe inclined at 90° downward to the soil. One hole of 10 mm was provided on upper end of the each arm to adjust the width of operation and one hole of 10 mm was provided at lower end of each arm to fit the weeding drums. Isometric views of the mounting brackets are shown in Fig.5.

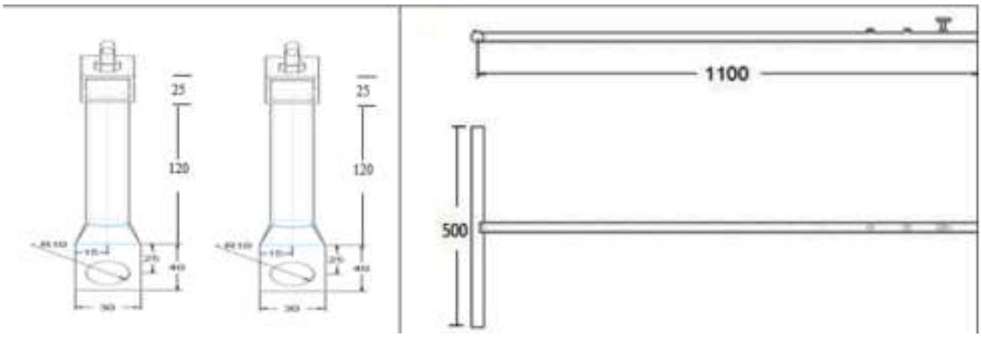

Fig.5: Detailed dimensions of mounting brackets and handle of the cono-weeder

5. Handle

An adjustable handle was decided to fabricate so that the length of the weeder can cover 5th to 95th percentile population and it eliminates back strain and provides comfort to the operator for continuous operation in standing posture. The handle was fabricated from 2 mm thick MS pipe and MS square tube. MS square tube of 2 mm thick (25 x 25 mm) of 1100 mm length was welded at the middle of 500 mm long handle cross bar of 26 mm diameter MS pipe in such a way that it can make angle of 90° between them. CAD views of the handle are shown in Fig.5.

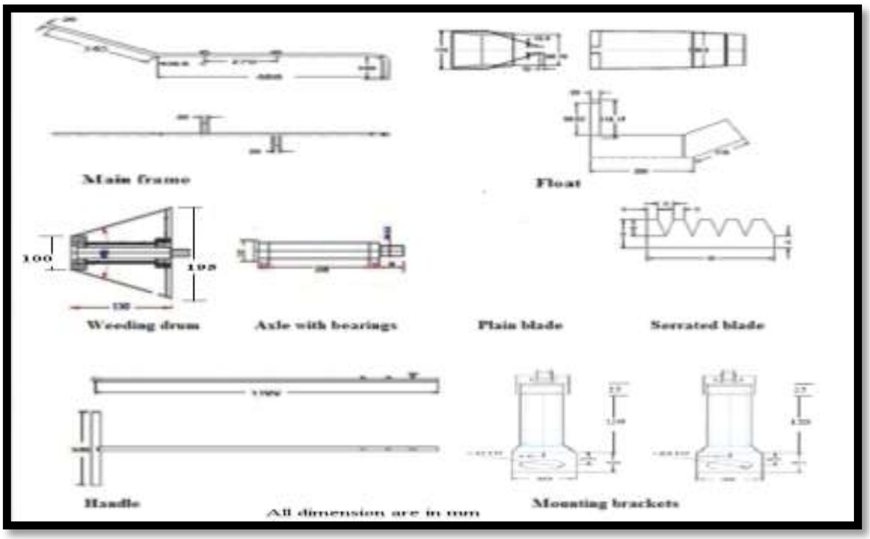

Fig.6: Major components of the developed cono-weeder

- **Experimental Techniques**

All the parameters were measured and recorded in line with the RNAM test code and ISI test code: 7927-197. The rice seedlings were manually transplanted at 25 x 25 cm plant to plant and row to row distance in the field. The experiments were conducted in three replications of net treatment plot size 1.25 m x 25 m. All agronomical parameters and agricultural operations were accomplished uniformly as per best recommendations laid down in the region and SRI guidelines for rice crop.

To compare the performance of the developed cono-weeder with the existing TNAU conoweeder, field experiments were conducted at Main Rice Research Station, Anand Agricultural University, Nawagam during 2015. Field experiments was conducted on preferable various dependent parameters as draft, power, field capacity, weeding efficiency, plant damage factor, clogging, soil volume disturbed, performance index and cost of operation and crop growth parameters like plant height, panicle length and yield were measured as per standard procedure mentioned below:

- **Field parameters**

Moisture content and bulk density of the test plot were calculated as per the standard methods.

Moisture content of the soil:

The soil moisture content of the experiment field at the time of weeding was determined on dry basis with standard method as 19.13 %

Bulk density of the soil:

The bulk density of the soil of experiment field was determined by standard methods as 1.45 g cm^{-3}.

Depth of operation:

The depth of operation was measured by the vertical distance between the horizontal soil surfaces to the bottom of dugout soil with the help of steel scale.

Width of operation:

The width of operation was measured by the horizontal length of cut made by two weeding cones perpendicular to the row with the help of measuring tape.

Working speed:

The speed of the weeder was determined by observing the time required to travel 20 m distance with the help of stopwatch. The average speed of weeder for each treatment plot was recorded separately.

Time loss in turning, cleaning and adjustment:

The time taken in turning of the weeder at the end of each row was observed and recorded. The time taken in cleaning the blades at the time of clogging and time for making adjustments, were recorded for each treatment plots separately.

Draft:

Draft exerted by the weeder was measured by developed draft force measuring device. Draft was calculated as follows:

$$\text{Draft} = \text{Force recorded X Cos } \theta \qquad \text{... (1)}$$

Where, θ is the angle made between line of push and a line parallel to the direction of forward movement of the weeder.

Power:

Power used by the weeder was calculated by the formula as below:

$$\text{Power (hp)} = \frac{\text{Draft X Speed}}{75} \qquad \text{... (2)}$$

Where, Draft in kgf and Speed in m s^{-1}

Field capacity:

Theoretical field capacities, effective field capacities and field efficiencies were calculated from following formulae

$$\text{Theoretical field capacity} = \frac{\text{Working widt h X Speed}}{10} \qquad \text{... (3)}$$

Where, Working width in metre and speed in km h^{-1}

Effective field capacity is an average output of the weeder per hour, calculated from the total area weeded in hectares and the total work time which includes time loss in turning at headlands, rests and for any breakdown or adjustments.

$$\text{Effective field capacity (ha/h)} = \frac{\text{Area covered by weeder}}{\text{Total time taken X 10000}} \qquad \ldots (4)$$

Where, Area covered in m^2 and total time in hour

Field efficiency was determined by following formula

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \text{ X 100} \qquad \ldots (5)$$

Weeding efficiency:

A square loop (0.25 m^2) was randomly thrown to the field and number of weeds including in loop will be counted before and after weeding (Rangasamy et al., 1993). Five sets of observations were taken and average value of weeding efficiency was calculated as below.

$$\text{Weeding efficiency } (\%) = \frac{W1 - W2}{W1} \text{ X } 100 \qquad \dots (6)$$

Where, W_1= Number of weeds before weeding
W_2 = Number of weeds after weeding

Plant damage:

Plant damage is the measure of damage on crop plants during weeding operation. Plant damage was observed in terms of buried plants by soil mass as well as cutting of plant leaves/tops by rotating action of weeding drums and blades.

Number of plants in 10 m row length before and after weeding was observed and the plant damage factor was calculated by using following relation (Gupta, 1981).

$$\text{Plant damage factor (PDF) } (\%) = \frac{Q2}{Q1} \text{ x } 100 \qquad \dots (7)$$

Where, Q_1 = Number of total plants in 10 m row length before weeding
Q_2= Number of plants damaged along 10 m row length after weeding

Clogging of the weeder:

When the weeder is operated, there are chances of clogging soil around the weeding unit. The soil clogs around the cutting blades due to sticking nature of soil because of adhesive and cohesive forces acting between soil and material. To access this, number of events of clogging in 20 m run of the weeder was note down and average value for five sets of observations was calculated.

Soil volume disturbed:

Soil manipulation was calculated in terms of soil volume disturbed by the weeder. Five sets of observations were taken randomly from the test plot for each treatment and soil volume disturbed was calculated by relation (Ahaneku et al, 2007).

$$\text{Soil volume disturbed } (m^3\ h^{-1}) = F \text{ x } EFC \text{ x } D \text{ x}10^4 \qquad \dots (8)$$

Where,
F = Correction factor for row crop weeding operation
EFC = effective field capacity, ha h^{-1}
D = depth of weeding, m

Performance Index:

The performance factor was assessed through performance index (PI) by using the following relation as suggested by Gupta (1981).

$$\text{Performance Index} = \frac{a \text{ x } q \text{ x } e}{P} \qquad \dots (9)$$

Where, a = effective field capacity, ha h^{-1}
q = 100 - PDF
e = weeding efficiency, %
p = power required to operate the weeder, hp

Cost of operation:

Cost of operation was calculated by simple straight line method. This method was used for depreciation and cost estimation in this study. Salvage value of the weeders was assumed negligible. Taxes, shelter, fuel charges and insurance are not applicable in the case of hand weeders. With these assumptions, the equations for cost of operation can be written as below:

$$\text{Cost of operation} = \frac{P\left(\frac{1}{Y} + 0.5I\right) + RM + AL}{AC} \qquad \dots (10)$$

Where, P = Purchase price (₹)
I = rate of interest (assumed as 12% per year)
Y = estimated life (year) (assumed 10 years)
RM = repair and maintenance costs (assumed as 5% of purchase price)
C = field capacity (ha h^{-1})
L = labour cost (₹ h^{-1}) (assumed as 200 ₹ per day)
A = annual working hours (assumed as 150 h per year)

III. RESULT AND DISCUSSION

- **Comparison of developed cono-weeder with TNAU conoweeder**

The developed cono-weeder having serrated bladed weeding unit gave best performance at 100 mm cone diameter and 30° blade angle (Fig.7). The values of different dependent parameters on this was compared with one of the most popular manually operated weeder i.e. TNAU conoweeder (Fig.8).

Different dependent parameters under study were observed and presented in Table 1 and Table 2. The comparison of the performance of developed cono-weeder with existing TNAU conoweeder in terms of different dependent parameters draft, power, field capacity, weeding efficiency, plant damage factor, clogging, soil volume disturbed, performance index and cost of operation are as below:

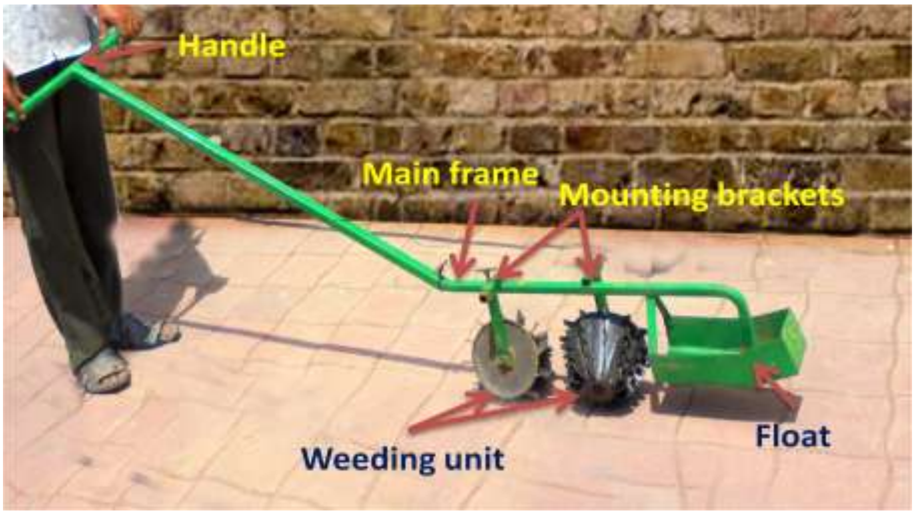

Fig.7: Developed cono-weeder

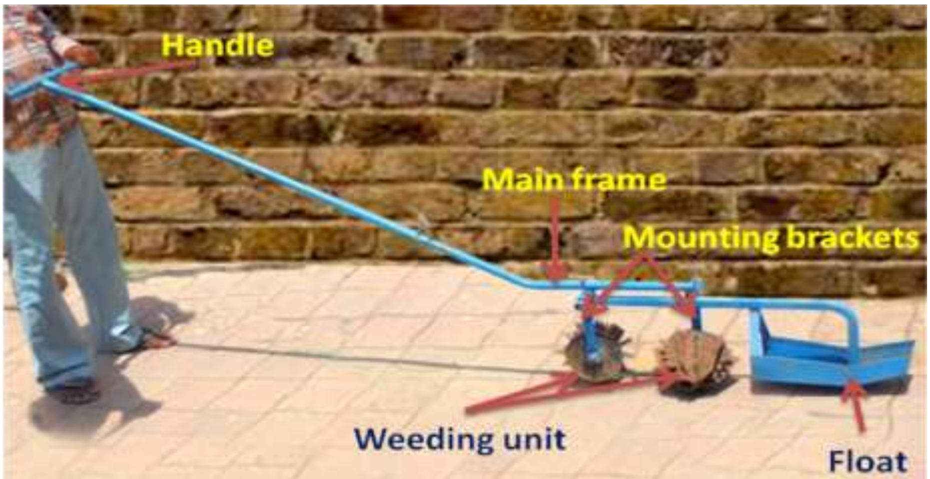

Fig.8: TNAU conoweeder

Table 1: Comparative performance results of TNAU conoweeder and developed cono-weeder

REPl.	Draft (kgf)	Speed (m s^{-1})	Effective field capacity (ha h^{-1})	Weeding Efficiency (%)	Plant damage (%)	Number of clogging	Soil volume disturbed (m^3 h^{-1})	Performance index	Cost of operation (₹ ha^{-1})
Developed cono-weeder:									
R1	18.72	0.392	0.026	87.96	6.25	3.0	6.49	2168.82	1107.07
R2	17.94	0.400	0.026	88.07	3.75	4.0	6.65	2339.65	1079.20
R3	17.16	0.385	0.025	87.27	3.75	2.0	6.31	2391.60	1137.47
Mean	**17.94**	**0.392**	**0.026**	**87.77**	**4.58**	**3.0**	**6.49**	**2300.02**	**1107.91**
TNAU conoweeder:									
R1	28.86	0.286	0.018	77.06	11.25	6.0	4.57	1128.73	1547.52
R2	28.86	0.278	0.018	77.06	8.75	6.0	4.46	1165.49	1584.96
R3	29.64	0.286	0.018	78.10	7.50	4.0	4.59	1166.57	1540.03
Mean	**29.12**	**0.283**	**0.018**	**77.41**	**9.17**	**5.3**	**4.54**	**1153.60**	**1557.50**

3.1. Comparison on the basis of draft and power:

The average value of draft for developed cono-weeder and TNAU conoweeder obtained were 17.94 kgf and 29.12 kgf respectively, which was 38.4 % lower in developed cono-weeder with comparison to TNAU conoweeder. Similarly, the average value of power for developed cono-weeder and TNAU conoweeder obtained were 0.094 hp and 0.11 hp respectively, which was 14.5 % lower in developed cono-weeder with comparison to TNAU conoweeder (Table 1).

This result is in agreement with the finding of Shiners et al., 1993. The difference in the values of draft and power requirement in both the weeders may be due to difference in shape of weeding tools.

3.2. Comparison on the basis of field capacity

The average value of effective field capacity for developed cono-weeder and TNAU conoweeder obtained was 0.026 ha h^{-1} and 0.018 ha h^{-1} respectively, which was 44.4 % higher in developed cono-weeder with comparison to TNAU conoweeder. The efficiency was also higher for developed conoweeder with a value of 72.89 % as compared to 70.78 % for TNAU conoweeder (Table 1).

This result is in agreement with the finding of Garg and Sharma, 1998. The wide difference in the values of field capacity in both the weeders may be due to difference in width of cutting parts (blades) as well as forward speed.

3.3. Comparison on the basis of weeding efficiency

The average value of weeding efficiency for developed cono-weeder and TNAU conoweeder obtained was 87.77 % and 77.41 % respectively, which was 13.40 % higher in developed cono-weeder with comparison to TNAU conoweeder. The similar results was also found by Manjunatha et al., 2014. The wide difference in the values of weeding efficiency in both the weeders may be due to difference in shape of blades because both the conoweeders were tested at same moisture content of the test plot and depth of operation (Table 1).

The same finding was also reported by Srinivas et al., 2010. This may be due to more soil contact and more soil inversion capacity of the developed cono-weeder.

3.4. Comparison on the basis of plant damage and clogging

The average value of plant damage factor for developed cono-weeder and TNAU conoweeder obtained were 4.58 % and 9.17 % respectively, which was 50 % lower in developed cono-weeder with comparison to TNAU conoweeder. Similarly, the average value of number of clogging for developed cono-weeder and TNAU conoweeder obtained were 3 and 5.3 respectively, which was 43.4 % lower in developed cono-weeder with comparison to TNAU conoweeder (Table 1).

3.5. Comparison on the basis of soil volume disturbed

The average value of soil volume disturbed for developed cono-weeder and TNAU conoweeder obtained were 6.49 m^3h^{-1} and 4.54m^3h^{-1} respectively, which was 43 % higher in developed cono-weeder with comparison to TNAU conoweeder (Table 1).

3.6. Comparison on the basis of performance index

Performance index of weeding implements would be directly related to field capacity, weeding efficiency and inversely related to power exerted. The average value of performance index for developed cono-weeder and TNAU conoweeder obtained were 2300 and 1153.60 respectively, which was 99.4 % higher in developed cono-weeder with comparison to TNAU conoweeder (Table 1).

This is due to higher weeding efficiency, higher field capacity and less power observed in developed cono-weeder.

3.7. Comparison on the basis of cost of operation

The average value of cost of operation for developed cono-weeder and TNAU conoweeder obtained were 1107.90 ₹ ha^{-1} and 1557.50 ₹ ha^{-1} respectively, which was 29 % lower in developed cono-weeder with comparison to TNAU conoweeder (Table 1).

3.8. Comparison on the basis of crop growth parameters

Tillage practices including weeding are important factors influencing crop growth and yield. Different parameters like plant height, length of panicle and yield were observed of randomly selected five plants from each plots of developed cono-weeder and TNAU conoweeder separately. Plant height and panicle length were measured and noted down before harvesting, while yield was calculated after threshing operation.

The average value of different crop parameters like plant height, length of panicle and yield were obtained for developed cono-weeder as 84.70 cm, 20.44 cm and 4138.33 kg ha^{-1} and for TNAU conoweeder as

83.18 cm, 20.27 cm and 4125.53 kg ha^{-1}, which indicated that the effect of equipment on crop growth parameters was found non-significant (Table 2).

Table 2: Data obtained for crop growth parameters:

Replications	Plant height (cm)	Panicle length (cm)	Grain yield (kg ha^{-1})
TNAU conoweeder			
R_1	83.20	20.30	4130.60
R_2	83.10	20.10	4120.70
R_3	83.25	20.40	4125.30
Average	**83.18**	**20.27**	**4125.53**
Developed conoweeder			
R_1	84.71	20.44	4133.50
R_2	84.68	20.42	4140.70
R_3	84.71	20.45	4140.80
Average	**84.70**	**20.44**	**4138.33**

3.9. Comparison based on ergonomic evaluation

Weeding operation was performed in paddy crop having 25 x 25 cm spacing with an average weed density 183 weeds m^{-2}. The experiment was conducted from 7.30 am to 1.30 PM with selected three male subjects M1, M2 and M3 and three female subjects F1, F2 and F3 (Fig.9). The anthropometric parameters for all the subjects selected under study are presented in Table 3.

Fig.9: Resting and working HR rate measurement of the subjects

Table 3: Anthropometric parameters for male and female subjects (n = 6)

Sr. No	Particulars	Male subjects				Female subjects			
		M1	M2	M3	Mean	F1	F2	F3	Mean
1	Age, years	26	30	38	31.33	27	30	39	32
2	Stature,cm	163.30	165.20	166.20	164.9	160.20	161.50	162.30	161.33
3	Weight,kg	50	55	58	54.33	45	49	57	50.33
4	Resting HR, beats min^{-1}	65	67	68	66.66	69	67	65	67
5	Blood pressure, mmHg	118/80	120/80	122/80	120/80	116/80	118/80	120/80	118/80

One by one all the subjects were allowed to operate the developed cono-weeeder and TNAU conoweeder and heart rate was recorded at interval of five minutes. This was continued until they complained about fatigue. They were then allowed rest for 20 minutes and during rest period, heart rates were measured at interval of one minute till, the heart rate reached back to normal. After rest, they were further asked to continue the weeding operation. The average working heart rate, recovery time and energy expenditure rate were determined and presented.

3.9.1 Heart rate

The heart rate response of the male and female subjects for weeding operation by developed cono-weeder and TNAU conoweeder is presented in Table 4 and Table 5 respectively.

The working heart rate for male and female subjects were observed higher i.e. 148 beatsmin^{-1} and 152 beats min^{-1} respectively for weeding operation by the TNAU conoweeder as compared to the weeding operation by developed cono-weeder i.e 122 beats min^{-1} and 125 beats min^{-1} respectively.

The lowest value of the heart rate were recorded for male subjects M1 for weeding with developed cono-weeder and highest values of heart rate were recorded for male subject M3 for weeding with TNAU conoweeder. Similarly, the lowest value of the heart rate were recorded for female subjects F1 for weeding with developed cono-weeder and highest values of the heart rate were recorded for female subjects F3 for weeding with TNAU conoweeder.

The mean increase in heart rate of male subjects over rest was 53.66 and 78.67 beats min^{-1} for weeding by developed cono-weeder and for weeding by TNAU conoweeder respectively and the mean increase in heart rate of female subjects was 56.66 and 83.33 beats min^{-1} for weeding by developed cono-weeder and for weeding by TNAU conoweeder respectively (Fig.10).

Thus, the result reveals that the variation in increase of working heart rate of male and female subjects in a particular operation by TNAU conoweeder is higher than by developed cono-weeder.

3.9.2 Energy expenditure rate

The average energy expenditure rate of male and female subjects for weeding operation by developed cono-weeder were calculated as 16.86 kJ min^{-1} and 17.82 kJ min^{-1} respectively, while it was calculated for male and female subjects as 24.14 kJ min^{-1} and 25.59 kJ min^{-1} for weeding operation by TNAU conoweeder respectively.

The lowest and highest energy expenditure rate were observed with male subject M2 (16.48 kJ min^{-1}) and M3 (24.91 kJ min^{-1}) and with female subject F1 (17.36 kJ min^{-1}) and F3 (26.07 kJ min^{-1}) for weeding operation by developed conoweeder and TNAU conoweeder respectively.

The result reveals that work with developed cono-weeder was in moderate heavy work, which is under acceptable limits of male and female subjects (100-125 beatsmin^{-1} HR) in wetland weeding operation (Zander et al,1975).

Table.4: Heart rate and energy expenditure rate of male subjects

Sr. No.	Male subjects	Weeding by developed cono-weeder				Weeding by TNAU conoweeder			
		M1	M2	M3	Mean	M1	M2	M3	Mean
1	Working heart rate, beats min^{-1}	122	119	120	120.33	143	145	148	145.33
2	Energy expenditure rate, kJ min^{-1}	17.36	16.48	16.78	16.86	23.46	24.04	24.91	24.14
3	Heart rate recovery time, min	4	3	3	3.33	6	8	7	7
4	Increase in HR over rest, beats min^{-1}	57	52	52	53.66	78	78	80	78.67

Table 5: Heart rate and energy expenditure rate of female subjects

Sr. No.	Female subjects	Weeding by developed cono-weeder				Weeding by TNAU conoweeder			
		F1	F2	F3	Mean	F1	F2	F3	Mean
1	Working heart rate, beats min^{-1}	122	124	125	123.66	149	150	152	150.33
2	Energy expenditure rate, kJ min^{-1}	17.36	17.95	18.24	17.82	25.20	25.49	26.07	25.59
3	Heart rate recovery time, min	4	4	3	3.66	6	7	7	6.66
4	Increase in HR over rest, beats min^{-1}	53	57	60	56.66	80	83	87	83.33

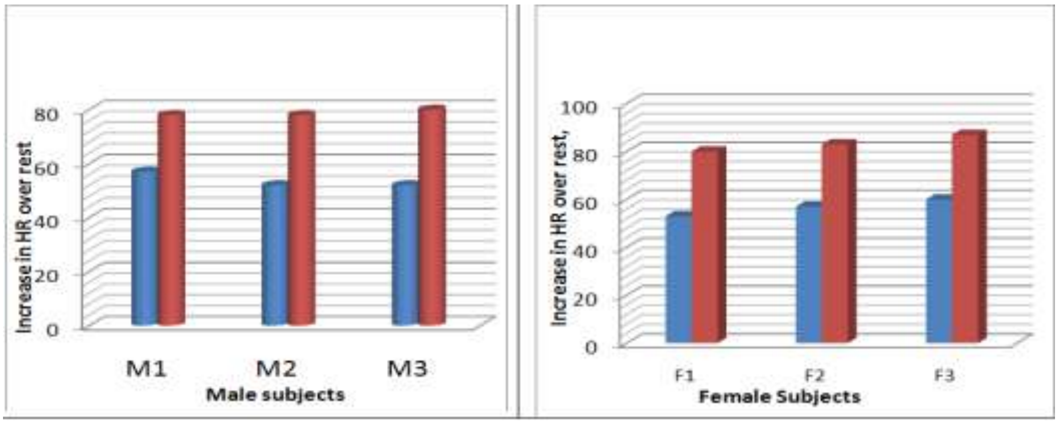

Fig. 10: Increase in HR over rest for male and female subjects

IV. CONCLUSIONS

Based on the results of this study, the following specific conclusions were drawn:

1. The average value of draft and power for developed cono-weeder were 17.94 kgf and 0.094 hp and for TNAU conoweeder were 29.12 kgf and 0.11 hp respectively, which were 38.4 % and 14.5 % lower in the developed cono-weeder than TNAU conoweeder.

2. The average value of effective field capacity for developed cono-weeder and TNAU conoweeder obtained was 0.026 ha h^{-1} and 0.018 ha h^{-1} respectively, which was 44.4 % higher in developed cono-weeder. The efficiency was also higher for developed conoweeder with a value of 72.89 % as compared to 70.78 % for TNAU conoweeder.

3. The average value of weeding efficiency for developed cono-weeder and TNAU conoweeder obtained was 87.77 % and 77.41 % respectively, which was 13.40 % higher in developed cono-weeder.

4. The average value of plant damage and numbers of clogging for developed cono-weeder were 4.58 % and 3 and for TNAU conoweeder were 9.17 % and 5.3 respectively, which were 50 % and 43.4 % lower in the developed cono-weeder than TNAU conoweeder.

5. The average value of soil volume disturbed for developed cono-weeder and TNAU conoweeder obtained were 6.49 m^3h^{-1} and 4.54 m^3h^{-1} respectively, which was 43 % higher in developed cono-weeder than TNAU conoweeder.

6. The average value of performance index for developed cono-weeder and TNAU conoweeder obtained were 2300 and 1153.60 respectively, which was 99.4 % higher in developed cono-weeder than TNAU conoweeder.

7. The average value of cost of operation for the developed cono-weeder and TNAU conoweeder obtained were 1107.90 ₹ ha^{-1} and 1557.50 ₹ ha^{-1} respectively, which was 29 % lower in developed cono-weeder than TNAU conoweeder.

8. The average value of different crop parameters like plant height, length of panicle and yield were obtained for developed cono-weeder as 84.70 cm, 20.44 cm and 4138.33 kg ha^{-1} and for TNAU conoweeder as 83.18 cm, 20.27 cm and 4125.53 kg ha^{-1}, which indicated that the effect of equipment on crop growth parameters was found non-significant.

9. The working heart rate for male and female subjects were observed higher i.e. 148 beats min^{-1} and 152 beats min^{-1} respectively for weeding operation with the TNAU conoweeder as compared to the weeding operation with developed conoweeder i.e 122 beats min^{-1} and 125 beats min^{-1} respectively.

10. The variation in increase of working heart rate of male and female subjects in a particular operation with TNAU conoweeder is higher than by developed conoweeder because mean increase in heart rate of male subjects over rest was 53.66 and 78.67 beats min^{-1} for weeding with developed cono-weeder and with TNAU conoweeder respectively and the mean increase in heart rate of female subjects was 56.66 and 83.33 beats min^{-1} for weeding with developed cono-weeder and with weeding by TNAU conoweeder respectively.

11. The average energy expenditure rate of male and female subjects for weeding operation with developed cono-weeder were calculated as 16.86 kJ min^{-1} and 17.82 kJ min^{-1} which was less than the calculated value for male and female subjects as 24.14 kJ min^{-1} and 25.59 kJ min^{-1} respectively in case of TNAU conoweeder. Thus, the work with the developed cono-weeder falls under moderate heavy work, which is under acceptable limits of male and female subjects (100-120 beats min^{-1}) in wetland weeding operation.

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