Current Journal of Applied Science and Technology

39(47): 11-20, 2020; Article no.CJAST.64299
ISSN: 2457-1024
(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)

Design and Development of Self-Propelled Power Unit for Cono Weeder

B. Krishna Kanth[1*], A. K. Shrivastava[2] and Jitendra Bairwa[2]

[1]Department of FMPE, Dr. NTR College of Agricultural Engineering, Bapatla, India.
[2]Department of FMPE, College of Agricultural Engineering, Jabalpur, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author BKK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author AKS guided me during the research and managed the analyses of the study approved the final draft. Author JB managed the final manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2020/v39i4731182
Editor(s):
(1) Dr. Tushar Ranjan, Bihar Agricultural University, India.
Reviewers:
(1) Joko Pitoyo, Indonesia Center for Agricultural Engineering Research and Development (ICAERD), Indonesia.
(2) Dusit Athinuwat, Thammasat University, Thailand.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64299

Original Research Article

Received 25 October 2020
Accepted 30 December 2020
Published 31 December 2020

ABSTRACT

Weeds are the major reason for economic losses in paddy production. Despite advances made in weed control, they continue to cause serious crop losses. Presently in India, majorly weeding in machine transplanted paddy fields was done by manually operated cono weeder which is labor-intensive and time-consuming. The objective of this research was to design and develop a self-propelled unit for manually operated cono weeder. A self-propelled power unit is developed at the workshop of CAE, JNKVV, Jabalpur, with the power by the Honda engine of 1.3 (hp) petrol engines. It is a compact low weight machine, self-propelled with a positive drive system by using a chain and sprocket transmission system. The working width of the developed weeder was 150mm. It was found that the self-propelled power unit with cono weeder has a field capacity of 0.033ha/h with 73.92% weeding efficiency and 89 % field efficiency. Similarly, for manually operated cono weeder has a field capacity of 0.0202 ha/h with 76.68 % weeding efficiency and 86 % field efficiency. Among the two weeders, man-hours are required for a hectare field is 30.35 man-h/ha for a self-propelled unit with a cono weeder as compared with a manually operated cono weeder i.e., 49man-h/ha. The operational cost of weeding was maximum in manually operated cono weeder of 1531.25 Rs/ha as compared with self-propelled unit cono weeder of 1403.43 Rs/ha.

**Corresponding author: E-mail: krishnak173@outlook.com;*

Keywords: Self-propelled; power weeder; cono weeder; power unit; weeder; paddy.

1. INTRODUCTION

Rice (*Oryza sativa L.)* is a staple food for more than 60% of the world population. Asia holds the share of 90% from worlds rice production and utilization. India holds 2nd place in rice production and share added about 21.65% of total rice production of the world. In India, rice is cultivated in an area of 43.19 million hectare, annually with a production of 163.70 million tonne and yield of 3790 kg/ha [1]. In Madhya Pradesh rice is grown in an area of 2.06 million hectares with production of 4.12 million tonne with yield of 2026 kg/ha. Weeds are major reason for economic losses in crop production. In spite of advances made in weed control, they continue to cause serious crop losses. In paddy production, weeds are controlled by herbicides but these may have environmental and human health problems, such as groundwater contamination, residual toxicity in foods or development of herbicide resistance on paddy weeds.

The estimated yield loss due to weed about 16-42 % based on type of crop and location and in terms of cultivation cost it was estimated about one-third of the total cost of cultivation [2]. Weeding and hoeing are generally done 15-20 days after sowing. Based on the weed density, about 20 to 30 per cent yield loss is quite usual which may increase up to 80%, if suitable crop management practice is not adopted.

Technologies based on resource conservation are becoming progressively important in rice system because these technologies will increase net profit of farmers and cut the production cost [3]. Low cost of weeding is always preferable from the point of view of economic consideration. Proper weeding technology is also an important factor to the farmers. Removal of weed by mechanical method is one of the methods frequently used in agricultural fields. Mechanical weeding reduces competition with weed and improves root growth by increasing soil aeration and root pruning which ultimately results in an increased number of tillers per plant [4]. Mechanical weed control method reduces drudgery involved in manual weeding. Nowadays, the agricultural sector requires non-chemical weed control methods which ensures food safety.

Weeding in developing countries is performed manually with traditional hand tools khurpi and spade. These tools are operated in squatting and bending postures. In these postures, the energy consumption for a given load is 30-50% more as compared to standing/sitting posture [5] and may lead to musculoskeletal disorders [6]. For these reasons, anthropometric body limitation of both the genders have to be taken into consideration before design a machinery to perform a specific agriculture operation. This will help to increase output and safety, as the man machine interface decides the ultimate performance of the machinery/equipment.

Presently in India, manual weeding operation was done with a simple tool such as cutlass, hoe, etc. which is labor-intensive and time-consuming. Thus, there is a need to design a manually operated power weeder for intensive and commercial farming system in India. This can be reduced by using mechanical weeder. As the time period available for weeding is limited, improved mechanical weeders are to be used to complete the weeding operation in due time at low cost. All the designs are region specific to meet the requirements of soil type, crop grown, cropping pattern and availability of local resources. It is also concluded that manual method of weeding operation requires more time and also increase the physiological response of the worker. Therefore, the operator cannot operate for a longer period of time without fatigue. There are many manual operated rotary weeders available in market. The objective of this research was to design and develop a self-propelled unit for manually operated cono weeder.

2. MATERIALS AND METHODS

2.1 Design Considerations

During the development of the self-propelled unit for wetland rotary weeders, it was designed in the view that the equipment suitable for farm women would inevitably suit to men workers [3].

2.1.1 Engine mounting frame

The frame of 720 mm length, 200 mm width and 400 mm in height was made from (25 x 25 mm) hollow square bar of mild steel having a thickness of 2 mm. This frame was mounted on the ground wheel at lower end and mounting the engine at the upper portion with brackets to hold the engine.

2.1.2 Selection of engine

Assuming the power requirement for manually operated engine assisted light weight weeder, when it is operated at 1 to 1.5 cm, was 0.25 to 0.35 hp reported by Rai [7]. So, the engine capacity of 1.3 hp was taken for a self-propelled power unit with around 3 times of the factor of safety.

2.1.3 Design of transmission shaft

Assuming the shaft was 200 mm long, and this shaft was attached to the chain sprocket and drive wheel. The weight of the power unit was act the force on shaft a 20-25 kg by weight and sprocket act two-type force torsion and bending force.

2.1.4 Power transmission system

The power is transmitted from the engine to drive wheel, a chain and sprocket mechanism was selected. The average walking speed of the human in the field was 2.5 km/h, so the maximum speed of the operation was considered 2.5 km/h (41.66 m/min).

The velocity ratio of a chain drive was calculated by using the equitation (1).

$$V.R. = \frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (1)$$

Where,

N1= number of revolutions of the smaller sprocket in r.p.m
N2= number of revolutions of the larger sprocket in r.p.m
T1= Number of teeth on the smaller sprocket
T2= Number of teeth on the larger sprocket

The final rpm for a designed wheel of 40 cm diameter was calculated by following equation (2)

$$rpm\ final = \frac{\text{Target speed (41.66 m/min)}}{\text{the perimeter of the ground wheel}} \quad (2)$$

$$rpm\ final = \frac{41.66(^{\text{m}}/_{\text{min}})}{3.14\times0.4\ \text{m}} = 33.168 \approx 33\ \text{rpm}$$

The engine operated at 5000 (rated rpm), however, at 1/3 throttle position of the accelerator, the speed of the engine was found to be 1800 rpm at no-load condition. To get the required rpm(33), To get the required ground wheel rpm (33 rpm), the chain and sprocket mechanism was designed in such a way that rpm reduced three steps reduction with a reduction ratio of 4.

Rpm reduction from power source (engine) to first shaft is

rpm at shaft number 1 = $\frac{\text{Engine rpm}}{\text{Reduction ratio}} = \frac{1800}{4} =$ 450

Rpm reduction from first shaft to second shaft

rpm at shaft number 2 = $\frac{450}{4}$ = 112.5

rpm at ground wheel = $\frac{112.5}{4}$ = 28.125 ≈ 29

The theoretically calculated rpm at ground wheel is less than the required rpm at ground wheel, so the power unit weeder can operate within the required operating speed.

2.1.4.1 Length of chain

The power transmission of the self-propelled unit is designed by the chain and sprocket mechanization. The length of the chain was calculated by using the equation (4)

$$L = \frac{p}{2}(T_1 + T_2) + 2x + \frac{\left(\frac{p}{2}\text{cosec}\left(\frac{180}{T1}\right) - \frac{p}{2}\text{cosec}\left(\frac{180}{T2}\right)\right)2}{x} \quad (4)$$

Where,

L = Length of chain, mm
P = Pitch of chain, mm
T_1 = Number of teeth on drive shaft
T_2 = Number of teeth on driven shaft
x = Centre to centre distance between two sprockets, mm

2.1.5 Design of handle

Length of handle and angle of inclination with the horizontal Surface are interdependent. The angle of operation was based on the functional design and geometry of the tool. The recommended handle grip diameter is 30 to 35 mm. Length of handle based on average standing elbow height of the male and female worker. The average elbow height of male and female workers is 1027 mm and 960 mm respectively [8]. by using the above data (i.e. angle and height of handle from base) find the length handle(l_h)).

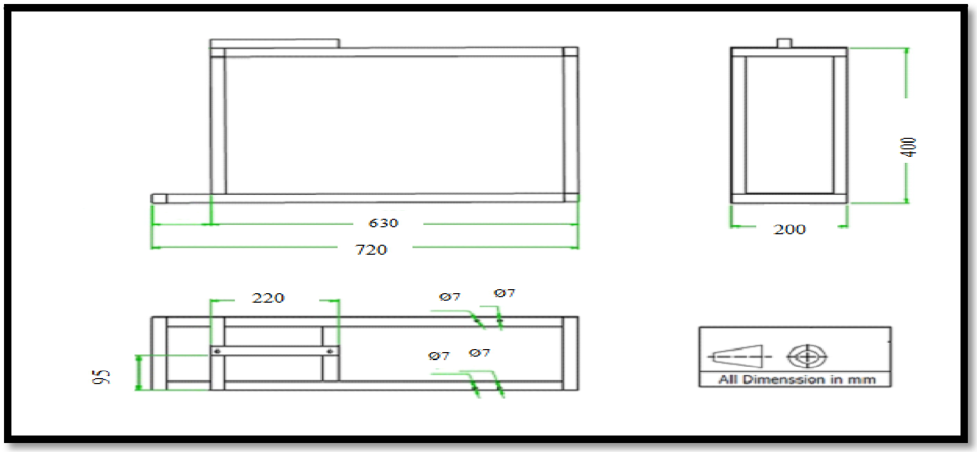

Fig. 1. Orthographic view of frame

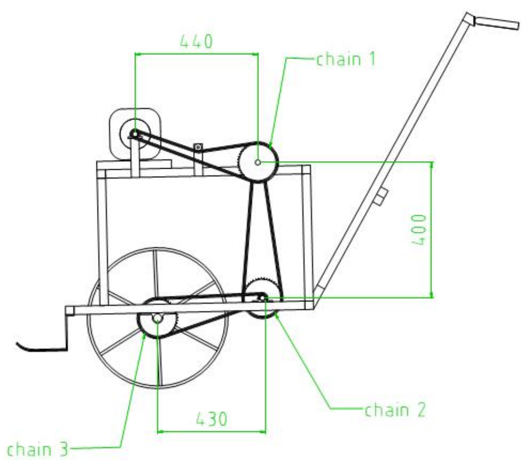

Fig. 2. Schematic diagram of power transmission system

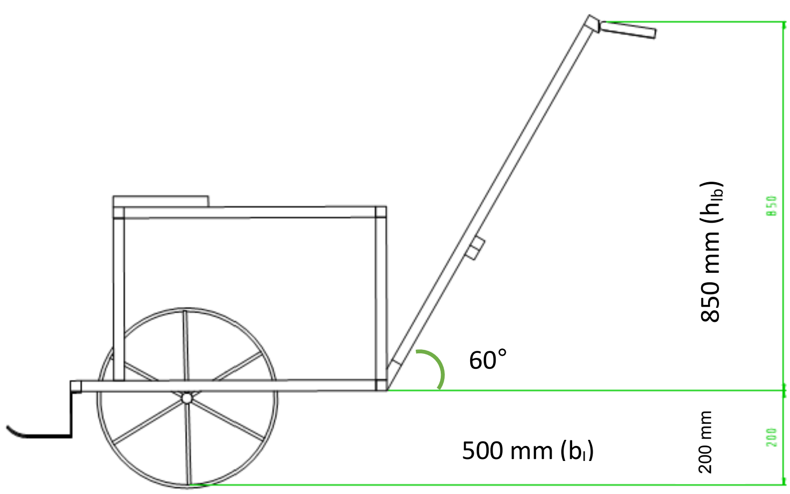

Fig. 3. Handle length of power unit

2.1.6 Drive wheel

The load on the wheel was small, the supporting wheel made up of 8 mm diameter rod having a wheel diameter of 400 mm is sufficient. Since the height of plants after 20-25 days after transplantation is around 15-18 cm. Therefore, the wheel radius of 20 cm is sufficient for the development of self-propelled power unit weeder.

2.1.7 Cono weeder

It is developed by CIAE, Bhopal, with weeding width of 150 mm. The weeder entails the following components handle, two conical rotors with serrated, frame, fastener, floater and L-shape pipe for supporting the float. The frame and handle of the cono weeder were made of MS pipe of 28 mm diameter with 3 mm thickness; blade and support were made of MS flat of 1 mm in thickness. It consists of two conical rotors mounted in tandem with opposite orientation. Smooth and serrated blades welded alternately on the rotor.

2.2 Machine Parameters

2.2.1 Travel speed (km/h)

To determine the travel speed of the machines during weeding operation, the time required for covering 10 m row length was recorded. Three measurements were recorded in each operation and the average value was calculated. A digital stopwatch was used to record the time in seconds to cover a 10 m distance by weeders. The sensitivity of the stopwatch is 0.01 seconds.

2.2.2 Effective working width (mm)

The effective width of the weeder shall be the effective width of the weeding. In the case of weeder having provision for width adjustment, the minimum and maximum width shall be measured. The working width of the developed weeder was 150 mm but it was found that the effective width was a little less than the theoretical actual width. To measure the actual width of the weeding, a measuring tape of 5 m length was used.

2.2.3 Theoretical field capacity (ha/h)

Theoretical field capacity is the rate of field coverage that would be obtained if the weeder was operating without interruptions. It is based on theoretical width and speed. The theoretical field capacity was calculated by using the equation.

$$\text{Theoretical field capacity (ha/h)} = \frac{\text{Width of the implement (m) x Speed of operation (km/h)}}{10} \quad (5)$$

2.2.4 Actual field capacity (ha/h)

The actual field capacity is the actual average rate of field coverage. It includes turning losses, choking, making adjustments, etc. It is recorded in hectare/hour.

The actual field capacity was calculated as per the following equation:

$$\text{Actual field capacity (ha/h)} = \frac{\text{Actual width of field coverage (m) X Length of field coverage (m)}}{\text{Time for covering total area (h)X 10000}} \quad (6)$$

2.2.5 Field efficiency (%)

The field efficiency was calculated using equation:

$$\text{Field efficiency (\%)} = \frac{\text{Actual field capacity (ha/h)}}{\text{Theoretical field capacity (ha/h)}} \times 100 \quad (7)$$

2.2.6 Weeding efficiency (%)

To determine the weeding efficiency at four places of each plot a frame of 1 × 1 m was thrown in the field randomly and the numbers of weeds were counted before and after weeding operation. The weeding efficiency of the weeders was calculated by the following equation [8]:

$$\text{WE} = \frac{\text{N1}-\text{N2}}{\text{N1}} X\ 100 \quad (8)$$

Where,

WE= Weeding efficiency of the weeder (%);
N_1 = Total number of weeds before weeding.
N_2 = Total number of weeds after weeding.

2.2.7 Draft measurement

Draft is defined as the horizontal vector of the pull, parallel to the line of motion. The S-type load cell was used to measure the draft. Which could measure the draft up to the range of 1000 kg & least count of load cell was 0.01 kg. As the load cell was fitted horizontally in the line of pull, therefore, it gave the value of draft directly in kgf. Load cell was placed between power tiller and power unit. Power tiller pulled the power unit at a speed of 2.5 km/h.

2.2.8 Fuel consumption (l/ha)

Fuel consumptioopn was measure by using the top up method. The fuel tank was filled to full capacity before and after test. Amount of refueling after the test was recorded. The measuring flask capacity of 1 liter was used to measure the fuel.

$$\text{Fuel consumption} = \frac{\text{Fuel consumption (ml/s)}}{\text{Area covered } (\text{m}^2/\text{s})} \times 10 \quad (9)$$

2.3 Cost of Operation

In order to compare weeding cost, fixed and variable cost were calculated.

2.3.1 Fixed costs

In this study, fixed costs like costs of insurance, taxes and shelter are considered negligible.

2.3.2 Depreciation

This cost mirrors the reduction in worth of a machine with use (wear) and time (obsolescence). While actual depreciation would rest on on the sale price of the machine after its use. straight-line method was used to calculate the depreciation value.

$$D = \frac{\text{P}-\text{S}}{\text{L}} \quad (10)$$

Where,

D = depreciation cost, average per year;
P = cost price of the machine;
S = residual value of the machine; and
L = useful life of the machine in years.

The depreciation value per hour can be assessed by dividing D by the number of hours the machine is anticipated to be utilized in a year. Residual value (S) of the machines may be taken as 10 % of the Actual cost price.

2.3.3 Interest

An annual charge of interest was calculated taking 12 percent of average purchase price as basis. Average purchase price was calculated using the formula given below.

$$\text{A} = \frac{\text{P}+\text{S}}{2} \quad (11)$$

Where

A = average purchase price;
P = purchase price of the machine; and
S = residual value of the machine.

2.3.4 Variable cost

Variable costs include fuel, lubricant, repair and operator costs and are directly related to the amount of work done by the machine. Repair cost for the weeders was considered 5% of purchase value and lubricant cost was accounted to be 3% of fuel cost [9].

2.3.5 Fuel

The actual fuel consumption in each treatment was observed and estimation was done accordingly.

2.3.6 Wages and Labour charges

The cost of labor was estimated to take the prevailing rate of 22.87 per hour or 250 per day.

3. RESULTS AND DISCUSSION

3.1 Self-Propelled Power Unit

A self-propelled power unit is developed at the workshop of CAE, JNKVV, Jabalpur, with the power by the Honda engine of 1.3 (hp) petrol engines. It is a compact low weight machine, self-propelled with a positive drive system by using a chain and sprocket system. It consists of a frame, handle, engine, wheel, cono weeder, chain, sprocket, bearing hub, throttle system, etc. The engine operated at 5000 (rated rpm), however, at 1/3 throttle position the speed was found to be 1800 rpm at no-load condition. Overall dimensions developed self-propelled power unit was shown in Fig. 4. The brief specifications of the self-propelled power unit in Table 1.

3.2 Field Performance of Weeder (Manual and Power Operated Cono Weeder)

Details of the performance evaluation conducted for manually operated cono weeder (T1) and power operated cono weeder (T2) are shown.

3.2.1 Field capacity and field efficiency

Table 2 revealed that the mean value of the actual field capacity of T1 and T2 were found to be 0.033 and 0.0202 ha h-1 respectively. The maximum field capacity (i.e. 0.033ha h-1) was obtained with T1 treatment followed by T2 (i.e. 0.0202 ha h-1). power unit with cono weeder (T1) the operational speed is more than manually operated cono weeder weeding method. Among the two methods the power unit with cono weeder had highest field capacity because of its operational speed. The statistical analysis of data revealed that the two treatments differ significantly for the field capacity.

The mean value of field efficiency of T_1 and T2 were found to be 89 and 86 percent respectively. The field efficiency, which indicates ratio of useful working time to the total working time, was obtained maximum in T_1 (89 %) treatment and minimum in T_1 (86 %) treatment. Similar finding were reported by Parida [10], Tajuddin [11], Remesan et al. [9].

3.2.2 Travel speed

The travel speed of the two treatments is presented in Table 3. The result revealed that the higher travel speed was found in power unit with cono weeder i.e. 2.86 km h^{-1} and lowest travel speed in manually operated cono weeder i.e.1.59 km h^{-1}. Similar findings were reported by Parida [10], Tajuddin [11], Remesan et al. [9].

3.2.3 Weeding efficiency

Fig. 6 revealed the weeding efficiency of T_1 and T2 and were found to be 73.92 and 76.68 respectively. The highest weeding efficiency with T_2 may be due push and pull action in manual cono weeder operation.

3.2.4 Draft of the power unit with weeders

From the experiment, it is found that the draft of the power unit with and without weeder attachment was 20.514 and 9.475 kgf. The actual draft required for weeder attachment i.e. cono weeder was 11.039 kgf. A similar opinion was also reported by Anantachar et.al [12]. The maximum towed force found in the at a slip of 15 % was 33.7 kgf.

3.3 Labour Requirement and Cost of Operation in Different Weeding Methods

Table 4. shows that the total manual working hours and cost of weeding operation of different weeding methods. The minimum time for controlling weeds was (30.35man-h/ha) with treatment T1 (power unit with cono weeder) and the maximum time for controlling weeds was (49 man-h/ha) with treatment T2 (manual rotary weeding). The time required for controlling the weeds by Manual weeding method taken as base period and calculated the labor-saving for different mechanical methods. Table 4 reveals that the time saving was a maximum of 81.77% for the T1 (power unit with cono weeder) and a minimum of 70.57 % for the T4 (manually operated cono weeder).

Table 4 shows that the weeding operation cost of different weeding methods. The operating cost of T1 and T2 was 1403.43 and 1531.25 Rs/ha respectively. The weeding operation cost for the manual weeding method was taken as the base period and calculated the labor-saving for different mechanical methods. By using the self-propelled power unit with cono weeder, the cost of weeding operation was reduced to 73.03%.

3.4 Fuel Consumption

It is evident from the experiment that the fuel consumption in weeding operation by the power unit with cono weeder at the speed of 2.28 km/h was found to be 6.5 l/ha.

Table 1. Brief specification self-propelled power unit

Sl.No	Details	Particulars
1	Overall dimension (L x B x H), mm	1650 x 200 x 1156
2	Weight in kg	20
3	Height of Handle from ground, mm	1050
4	Width of handle, mm	460
5	Speed of operation, km/h	2.5
6	Size of float (L x B x H), mm	150 x 200 x 100
7	Diameter of ground wheel, mm	400

Table 2. Comparison of field capacity and field efficiency of the power unit with cono weeder and manual cono weeder

Treatment	Theoretical field capacity(ha/h)	Effective field capacity(ha/h)	Field efficiency (%)
T1	0.0375	0.033	89
T2	0.0235	0.0202	86

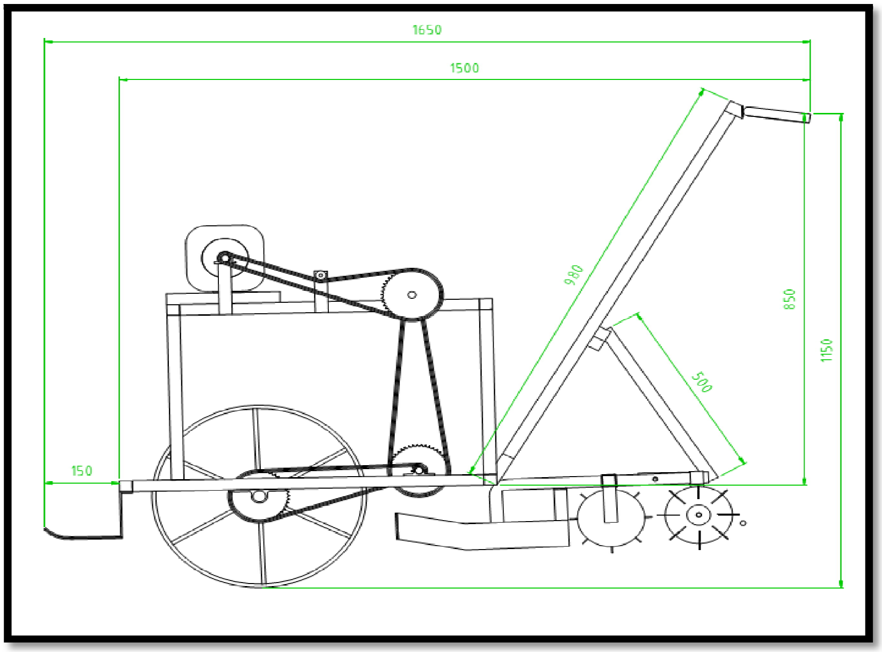

Fig. 4. Orthographic view of power unit with cono weeder

Plate 1. Developed self-propelled power unit

Table 3. Comparison of the average operating speed of cono weeder with and without self-propelled power unit

Treatments	Distance (m)	Avg.Time (sec)	Operating speed (m/s)	Operating speed (km/h)
T_1	10	15.77	0.634	2.28
T2	10	22.52	0.444	1.59

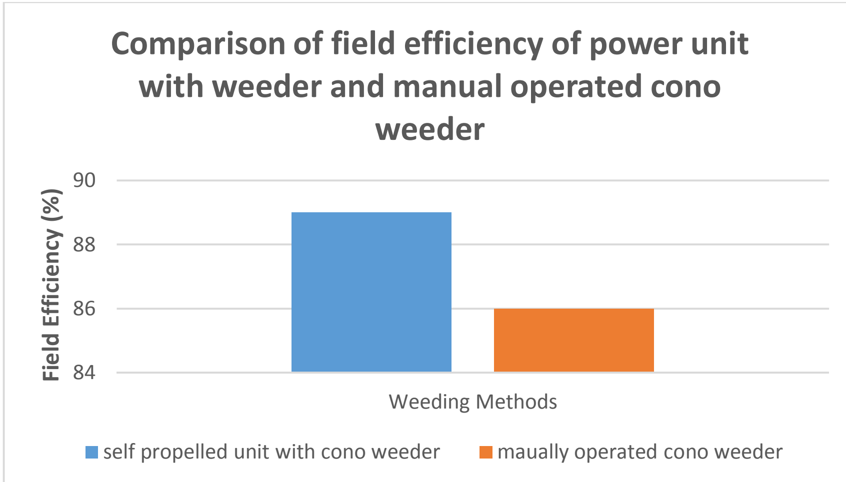

Fig. 5. Field efficiency of weeding method

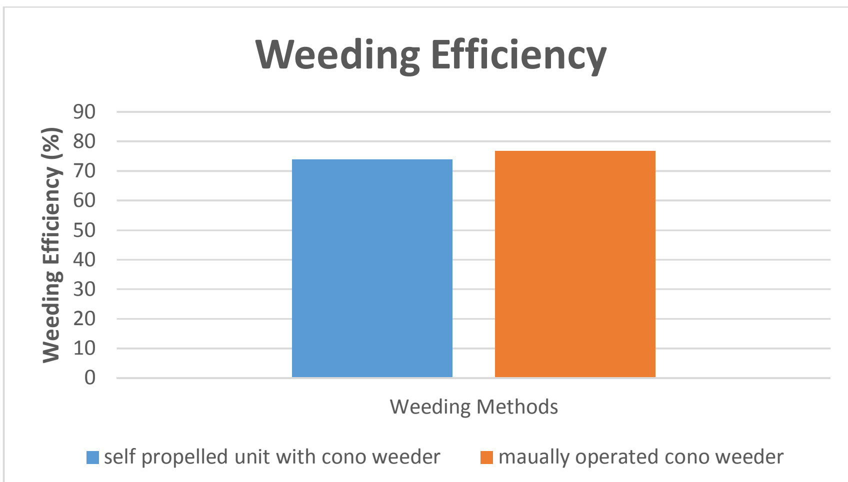

Fig. 6. Weeding efficiency of weeding methods

Table 4. Labour required in different weed control methods (man-hha^{-1}) and cost of operation(Rs/ha)

Treatments	Labour required (man-h/ha)		Cost of operation		
	Weeding (man-h/ha)	Labour time saving (%)	Labour cost (Rs/ha)	Operation cost(Rs/ha)	Operation cost saving (%)
Hand weeding*	166.5	Base	5203.12	5203.12	Base
T1	30.35	81.77	948.43	1403.43	73.03
T2	49	70.57	1531.25	1531.25	70.57

** Remesan et al., [9]*

4. CONCLUSIONS

The performance of the developed self-propelled unit with cono weeder was compared with the manually operated cono weeder which was developed by ICAR – CIAE, Bhopal. The different mechanical parameters were measured which include field capacity, field efficiency, travel speed, labor required, weeding efficiency, cost of operations.

1. Amongst the two weeders (i.e. power unit with cono weeder and manual cono weeder) field capacity was found to be maximum i.e. 0.033ha/h for power unit with cono weeder and a minimum of 0.0202 ha/h for manual cono weeder.
2. Amongst the two cono weeders (i.e., self-propelled and manual) field efficiency was found higher in self-propelled unit cono weeder having 89% which is higher than the manual operated cono weeder of 86 %.
3. Minimum manual work hours required for controlling the weed were related in self-propelled unit with cono weeder i.e., 30.35 man-h/ha as compared with manually operated cono weeder i.e. 49man-h/ha.
4. The operational cost of weeding was maximum in manually operated cono weeder of 1531.25 Rs/ha as compared with self-propelled unit cono weeder of 1403.43 Rs/ha.
5. For cono weeders weeding efficiency was found to be higher in manually operated cono weeder of 76.68 % while that of self-propelled unit cono weeder was 73.92 %.
6. The draft was found higher in self-propelled unit cono weeder having 11.09 kgf.

The result indicates that self-propelled unit cono weeder contributes maximum efficiency with least fatigue.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Agricultural Statistics at a glance; 2014. Available:http://eands.dacnet.nic.in/
2. Rangasamy K, Balasubramanium M, Swaminathan KR. Evaluation of power weeder performance. Agricultural Mechanisation in Asia, Africa and Latin America.1993;24(4):16-18.
3. Singh SP, Singh MK, Solanki RC. Design and development of four-wheel weeder for wide-row crops. Indian Journal of Agricultural Sciences. 2016;86(1):42–49.
4. Vijayakumar MS, Chandrasekaran RB, Thiyagarajan TM. Influence of system of rice intensification (SRI) practices on growth characters, days to flowering, growth analysis and labor productivity of rice. Asian Journal of Plant Sciences. 2006;5(6):984-989.
5. Grandjean E. Fitting the task to the man. Taylor and francis,London. 1988;4:363 .
6. Rainbird G, O'Neill DH. Occupational disorders affecting agricultural workers in tropical developing countries. Appl Ergon.1995;26:187–193.
7. Rai M. DARE/ICAR annual report; 2004. Available:http://www.icar.org.in/files/ar0304/08-agricultural%20engineering%20and%20technology.pdf.
8. Sharma DN, Mukesh S. Farm machinery design. jain brother publication. New Delhi. 2013;195-196.
9. Remesan R, Roopesh MS, Remya N, Preman PS. Wet land paddy weeding- A comprehensive comparative study from South India. The CIGR journal. Manuscript PM 07011. 2007;9:1-21.
10. Parida BC. Development and evaluation of star-cum cono weeder for rice. Agricultural Mechanisation in Asia, Africa and Latin America. 2002;33(3):21-22.
11. Tajuddin NM, Tarmizi RA, Konting MM, Ali WZ. Instructional efficiency of the integration of graphing calculators in teaching and learning mathematics. International Journal of Instruction. 2009;2(2):11-30.
12. Anantachar M, Sushilendra Lokesh, Sunil Shirw AI, Ragha Vendra, Mareppa. Performance evaluation of cono weeder for paddy in farmer's field. Engineering and Technology in India. 2013;4(1):14-16.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/64299