Fabrication and field evaluation of a wheel weeder

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Abstract. In general human energy is used in small farms for doing fieldwork (tilling, aerating and weeding). But availability of skilled workers is less during the time of exigencies. Controlling the weeds is one of the laborious steps in crop cycle. With high labour charges and more time needed, complete hand weeding is uneconomical. In the present work comparative evaluation of an ergonomically designed wheel weeder was made with that of conventional weeding tools viz. trench hoe, spade and wheel weeder available in market. Travel speed, field efficiency, field capacity, working capacity, weeding efficiency and plant damage were calculated. Results indicate that ergonomically designed weeder is superior compared to trench hoe, spade and conventional wheel weeder. It reduces drudgery. It is economical and reduces drudgery as well. It operates up to a depth of 22 to 35 mm with a field capacity of 0.0038 ha/h. Hazard occurrence was also low.

Keywords: wheel weeder, field efficiency, field capacity, weeding efficiency

1. Introduction

In general, manual workforce is used in small farms to do field work. But the availability of skilled workers is lower during the time of need. A farmer finds weed management as one of the tiresome works in agriculture. With a high cost of labor and more time needed, manual weeding is unfavorable [1]. From a long time, a variety of weed removal tools were in use [2]. Agricultural implements that reduce heavy work by using tear and tear with torsion were developed.

In manual weeding, the soil is not damaged and fewer weed seeds are brought to the surface, unlike when heavy cultivators or power tractors are used. The cutting action of the wheel cultivator is parallel to the ground and at a constant depth of the ground without stopping.

Wheel weeder is an eco-friendly solution to cultivate and weed the farms. It works in areas where a tractor or a motorized rudder can’t work. It is used in a hoop house or in a high-tunnel greenhouse. Time and energy can be saved. The wheel weeder has a long handle and is operated by pushing and pulling action.

The weeder has a provision to vary the size of the tilling tool. It must have a provision to prevent soil from getting jammed between the teeth / blades and must be equipped with a guard. It must be trouble-free
design and it should work every season. It must be fabricated by local technicians and reasonably priced. There is no universal weeder design. But, it is area specific. Its design varies from one place to another to cater to the needs of crops, cultivation patterns and soil. The need to improve the weeder design continues [3-5]. Therefore, an attempt is made to ergonomically design a weeder to serve the requirements of farmers in Andhra (India).

2. Hardware and methods

2.1 Description

Figure 1 shows CAD model of a wheel weeder. The fabricated manual wheel weeder consists of adjustable handles, wheel(s), frame and a variety of tools. The metal parts are made of powder coated steel.

![Figure 1. CAD model of manual wheel weeder](image)

Frame: All the components are mounted on the main frame. Weight and strength are the two design factors taken into account in the determination of the material required for the frame. The frame is made up of steel to give the required rigidity. It is slotted on back for more implement versatility and to change the operating width of the weeder to suit the row spacing of different crops.

Wheels: The wheels are made of mild steel. The front wheels have many lugs on their periphery that increase traction and reduce slip. The steel wheels will last a lifetime. The user does not need to worry about the air in the tires. Neither flat tires nor rotten tires are a problem. The rubber tire will get dry and deflate if it not in use for a longer period and may require expensive replacement. The weeder has brass bushes impregnated with oil on the wheel that make it easier to push and covered with dust flaps.

The diameter of the wheel is 300 mm Greater stability and a lower center of gravity are provided by the smaller wheel. The high wheel weeders are so unbalanced and shaky. The width of the ring is 25 mm, which reduces the lateral thrust and the 6x25mm flat is used as spokes. The central bush or hub is supported by the spokes. The addition of the second wheel stabilizes the wheel weeder and allows it to span on the row to cultivate until the plants are approximately 150 mm tall. The farmer can work on both sides of the row in a single pass. The number of wheels varies from one to four and the diameter depends on the design (figure 2). The single-wheel weeder can be quickly converted into a double-wheel weeder using shoulder bolt attachment.

Handles: Adjustable handles consist of two telescopic circular pipes of 30 mm dia. and 1.5mm thickness of mild steel each 900 mm long fastened to the frame at two ends. A 20 mm external diameter cross bar of
adjustable length connects the top ends of the handles. This permits the gap between the two handles to be adjusted as per the anthropometric dimensions of the user.

![Figure 2. One, two, three or four wheels can be fitted to the frame as per user's need](image)

A handle with a pistol grip is needed on the manually operated equipment. The handles of the pistol grip are designed to fit the hand and so that the operator's thrust is directly in line with the handle, which facilitates its thrust. The curve in the handle is so sharp that it is practically a 90 degree curve. The sharper curve would make a difference when it comes to comfort and ease of use. The plow-style handles are not right to the weeder handles and are not in any way ergonomically suitable for the push-pull action that is used to operate a wheel weeder. Plow style handles are ideal for grabbing and guiding a tool that is being pulled by an animal. Vertical palm handle design is easy to use. These handles are perfect for individuals with limited hand control or grasp such as arthritis, hand tremors, Parkinson’s or dexterity issues. Ergonomically designed handle avoids high contact forces and static loading, reduces excessive gripping force or pressure, avoids extreme and awkward joint positions, avoids twisting hand and wrist motion. Figure 3 shows the different handle options.

![Figure 3. Different handle styles](image)

Rubber grips are provided on the handles to comfortably push the wheel weeder. The handle assembly has a telescopic arrangement for adjusting the length of the handle to match the height of the farmer. With the handles attached to the front (figure 4), the force is applied to the wheel and only indirectly to the tool that is applied to the ground. This arrangement is preferred in light duty applications. With the handles connected to the back, the force is applied directly to the ground engaging tools. This arrangement is preferred in medium duty applications.

**Bearings:** The bearings are selected based on their load capacity, service life and reliability. The ball bearings are fixed in the bushing provided at the two ends of the frame to support the shaft on which the wheels are attached. They allow carrying considerable load without wear and with a reduced friction. They ensure the proper functioning of the wheels. The material used for the bearing is high speed steel.

**Stand:** When the farmer completes the work in the field or gets tired at that time stand is necessary to take rest. Mild steel solid rod 250mm length and 10mm diameter is used for making the stand.
2.2 Working
The fabricated weeder used in this study is shown in figure 4. During working, the weeder is pushed/pulled by the farmer, who manages the soil, pulling out tiny weeds. The push-pull action allows the components that till the soil and pluck / remove the weeds in crops. This buries the weeds in the ground. He/she can easily maneuver the weeder in between the rows of crops to effectively eliminate weeds. The tool is used to weed, create soil mulch, aerate and conserve moisture and break the soil crust in horticultural crops. The depth of the plough is manipulated using a clamp.

The ability to offset the handles (figure 5) allows the user to work all areas of the bed from the road in a more ergonomic manner. The handles can be turned to the left or to the right, allowing the operator to walk next to the wheel. In this way, the farmer can avoid stepping on the cultivated soil. This facilitates the cultivation of raised beds.

2.3 Tools
The main structure has an arrangement (slots) to fit a variety of tools (figure 6) like duck foot cultivator, ridger, flat blade hoe, mini ridger, T-hoe, cono weeder, etc. and a universal tool holder that can also house a variety of accessories. This versatile equipment enables to use more than one tool in tandem to complete more operations in a shorter time with less strain. The blades are sharpened with a file. Brief description of a few of the tools is as follows.

Figure 4. Developed manual wheel weeder
Figure 5. Ploughing with handles in off-set position

Figure 6. Different soil working tools that can be fitted to the tool holder
**Duck foot tine:** It is widely used in black cotton-type soil areas for the final field preparations and the finer pulverization of the upper soil immediately before planting. It is available in 3 and 5 tines with triangular sweeps (duck shape) in sizes of 25, 38 and 50mm, with or without bar-point in the center, according to the needs and the demand of the farmer. The cutting angle of duck foot as it is more commonly known, is designed for maximum area coverage, with minimal drag on the cultivator and, at the same time, provides even soil spraying.

**Ridger:** It is mainly suitable for making ridges after plowing in the field of beans, vegetables, potatoes, etc. It is convenient to adjust the angle, the height of flange and rows of grooves. It can be easily spaced (widened or narrowed) according to the field requirements. The angle of the wings can be changed according to the requirements. The height of the tool holder can be adjusted for the required ridge height. The tip of the plow is adjustable.

### 2.4 Methodology

The working of the ergonomically designed weeder was tested in the courtyard. The evaluation was carried out in four series of 30min. trials on four subjects as per RNAM (1983) test code [6].

Figure 7 shows the conventional weeding tools (trench hoe and spade), used in different regions of India, selected for field comparison. The selection of subjects plays a vital role in conducting field evaluation. The subjects must be physically and medically fit to undergo the tests. There should not be any major illness, and they should also be a true representative of the operating user population. Age and physical condition are the main criteria for the selection of subjects.

**Figure 7.** Trench hoe and grub hoe used in this study for comparison

Health checkup was carried out to evaluate the medical aptitude of the selected individuals who participated in the investigation. Therefore, of the available volunteers, four male students of the age group 20-22 years were chosen, considering their experience in the operation of the selected farming operations. The criteria used include: travel speed, field efficiency, field capacity, work capacity, weeding efficiency and damage to the plants [7. The experiment was carried out in the courtyard of Department of Mechanical Engineering, Sasi Institute of Technology & Engineering, Tadepalligudem.

Field experiments were carried out with selected tools during the month of December 2019 and February 2020. The temperature and relative humidity varied from 32 to 36°C and from 58 to 64%, respectively, during the evaluation period. The subjects were briefed about the study requirements to obtain their fruitful participation. The work was carried out between 9.00 AM and 4.30 PM. The travel speed, field efficiency, field capacity, weeding efficiency and plant damage were calculated using standard formulae and procedures given below [8,9].

**Travel speed:** The travel speed of the weeder was measured by noting the time necessary to cover 20 m distance between adjacent lines of planting. Four readings were taken in each block.
Field efficiency: The field selected for the trial was planted with groundnut. The average population of crop plants in the area of a square meter was 100. The weed observed was cyrus rotundus. The average height and population of weeds in the area of a square meter were 10 cm and 80, respectively. The average spacing of the rows, the spacing between hills and the height of the crops were 10 cm and 10 cm respectively. The effectiveness of the weeder is defined as ratio between the useful working time and the total time.

Field efficiency,

\[
F_e = \frac{T_u}{T_t} \times 100
\]

(1)

where \(F_e\) is the field efficiency of the weeder (%)

\(T_u\) and \(T_t\) are the total and useful working time (h), respectively

Also, the total time for job fulfillment and wasted time in each plot was recorded.

Effective field capacity

\[
(C_e) = \frac{SWF_e}{100}
\]

(2)

where, \(C_e\) is the effective field capacity (ha/h)

\(S\) is the travel speed of the weeder (km/h)

\(W\) is the width of work (m)

Working capacity: The working capacity or time required for weeding per hectare was calculated using the equation:

\[
W_C = \frac{1}{C_e}
\]

(3)

where, \(W_C\) is working capacity of the weeder (h/ha) and

\(C_e\) is the effective field capacity (ha/h)

Weeding efficiency: The efficiency of weeding was determined by throwing a 1 × 1 m wooden ring at four locations in the courtyard at random and counting the number of weeds [10]. The efficiency of weeding, \(e\) of the weeder was determined as follows:

\[
e = \frac{w_2 - w_1}{w_1} \times 100
\]

(4)

where \(w_1\) is the number of weeds before weeding

\(w_2\) is the number of after weeding

Plant damage: The damage to the plants was determined by counting the number of plants damaged in the test plot and the total number of plants in the sample plot [11]. To determine the plant damage, in three places of each plot, a metal ring of 1×1 m was randomly thrown at the plot and the number of damaged plants in the ring was noted. The damage to the plants was calculated by the following expression.

\[
PD = \frac{A}{B} \times 100
\]

(5)

where, \(PD\) is the plant damage, %

\(A\) is the number of injured plants (cut or damaged) in sample plot

\(B\) is the total Number of plants in sample plot
3. Results and discussions

The field performance parameters are given in table 1. The field efficiency of trench hoe is high (figure 8). This is because there is less wastage of time while moving from one row to the other. The field capacity (figure 9) of ergonomically designed weeder is much higher than conventional tools. This is because the weeder enables the worker to work in standing posture and the angle of bite can be adjusted to optimum value as per soil condition and height of handles can be adjusted to farmer’s requirements.

Table 1. Field Performance Characteristics

| Instrument        | Total Time (TT) | Useful Time (UT) | Field Efficiency (FE) | Field Capacity (Cc) | Working Capacity (Wc) | Weeding Efficiency (WE) | Plant Damage (PD) |
|-------------------|-----------------|------------------|-----------------------|---------------------|-----------------------|------------------------|------------------|
| Trench Hoe        | 37              | 32               | 86                    | 0.0010              | 1026                  | 98.9                   | 2.0              |
| Grub Hoe          | 37              | 30               | 81                    | 0.0014              | 714                   | 95.5                   | 3.0              |
| Conventional Weeder | 37            | 17               | 45                    | 0.0036              | 278                   | 87.5                   | 5.0              |
| Ergo. Weeder      | 37              | 18               | 48                    | 0.0038              | 263                   | 92.2                   | 4.0              |

Figure 8. Field efficiency of different implements

Figure 9. Field capacity of different implements

The working capacity of weeder is much low compared to conventional tools (figure 10). Even though the initial cost is higher, its operational cost would be low and break even occurs in a short period. The weeding efficiency in conventional tools is much higher compared to wheel weeder (figure 11). This is because the farmer directly and prudently uses the tool on the weed where as in case of weeder the tines move in a predetermined path. There are chances for the weeds to escape.

Figure 10. Working capacity of different implements

Figure 11. Weeding efficiency of different implements
The plant damage in conventional tools is much less compared to weeder (figure 12). This is because the farmer directly and prudently uses the conventional tool to avoid the crop where as in case of weeder the tines move in a predetermined path and hence there are chances for the good plants to get damaged. All the results are in agreement with the results of other researchers [1].

![Diagram showing plant damage with different implements](image)

**Figure 12.** Plant damage with different implements

Human-operated weeder take a prominent part in inter cultivation operations. Due to the high performance, they help in the punctuality of operations compared to manual methods and are economical. The weeder will eliminate the weeds between two rows. It can combine multiple operations, so the work will be completed in less time. Therefore, fewer workers are required. It is an eco-friendly solution to cultivate and weed the farms.

4. **Conclusions**

An experimental study on ergonomically designed weeder was conducted at courtyard of Sasi Institute of Technology & Engineering, Tadepalligudem during the winter season of 2019-20. This was carried out on black cotton soil. Results showed that the field efficiency of trench hoe is highest (86%). The field capacity of ergonomically designed wheel weeder was found to be highest (0.0038 ha/h) whereas trench hoe was minimum (0.0010 ha/h). The working capacity of ergonomically designed wheel weeder was found to be least (270 h/ha) whereas that of trench hoe was highest (1034 h/ha). Weeding tools such as trench hoe recorded the highest weeding efficiency (98.9%) followed by spade (95.5%) and wheel weeder (92.2%). Plant damage was found to be lowest (2%) with trench hoe and highest with wheel weeder (4%). Hence, the ergonomically designed wheel weeder was found to be the most efficient and cost effective weeding tool.

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