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Development and Fabrication of Manually Push-Pull Type Conical Weeder for Bangladesh Condition

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Abstract

In Bangladesh, the use of machinery in agriculture production is fast rising. Researchers are developing technology to replace traditional hand weeding to manage weeds in rice fields. The present study has been taken to increase weeding efficiency and reduce the drudgery in weeding and mulching. A line-to-line distance of 20 cm, the operation is push-pull, and field operating condition at 2 - 4 cm standing water (for softening the field) was the designed hypothesis. The weeder consists of a skid/float, float holder, float adjuster, main body frame, rotor, axel, bush, rotor holder, rotor holder adjuster, handle, handle griper, handle holder, handle height adjuster, nut, bolt, etc. The designed weeder was fabricated using MS sheet, MS pipe, MS flat bar, MS nut-bolt, etc. When the rotors perform back and forth, the weeder's two conical rotors with six plain blades and six serrated blades work together to uproot and bury the weeds. It also contains a 2 mm thick float assembly with a precise angle of 22 degrees. Weeds are uprooted by the weeder's blades and buried in the muddy soil. It causes topsoil disturbance and enhances aeration. The weeding efficiency and capacity of the conical weeder were 81.92% and 0.0203 ha/h respectively. With a push-pull operation, the weeder can uproot and bury the weeds in a single row at a time. The pushing force and weight of weeder were 43.42 N and 5.6 kg respectively. Farmers can use this weeder to increase their comfort and reduce the drudgery associated with weeding and mulching in their fields.

Keywords

Conical Weeder, Field Capacity, Weeding Efficiency, Weed, Paddy

1. Introduction

Bangladesh is an agriculture-based country, and the agriculture sector plays a vital role in the country's economy. The agriculture sector in Bangladesh has gone through significant changes in recent years, with modernization and technological advancement playing a critical role in the transformation. In recent years, Bangladesh has been adopting modern technology in agriculture to increase productivity and efficiency. The government has been promoting climate-resilient agriculture practices, such as the use of drought-resistant crops and flood-resistant seed varieties. The use of modern machinery in agriculture has been increasing in Bangladesh, such as tractors, power tillers, and harvesters. This has helped farmers to increase their productivity and efficiency. Weeding is a vital farm operation in the crop production system [1]. Its removal is necessary to increase crop yield. Unless weeds are controlled at the early stages of crop growth, the crop yield may reduce drastically. Chinnusamy *et al.* [2] stated that it was necessary to maintain a weed-free cycle for up to 45 days after transplantation to increase medium-term rice yields. 30 - 60 days after the sowing cycle in rain-fed lowland rice was considered a crucial period for crop weed competition to avoid losses of grain yield [3]. Singh *et al.* [4] found that retaining weed-free status until maturity resulted in substantially higher grain yield due to more panicles per m^2 and lower weed density and dry weight. Hasanuzzaman *et al.* [5] stated that weeding is one of the critical stages in rice cultivation and affects the yield and quality of rice. Weeds decrease crop yields from 15% to 50% depending on species, density, and weeding time through competition with the main crop for light, water, and nutrition.

Moreover, due to high labor requirements, many farmers do not weed their fields and sometimes use fire as a controlled means. In the biological method of weed control, certain living organisms, insects, or pests that destroy the weeds are utilized as a source of weed control [6]. Due to the lack of suitable weed control technology, weeds are a major problem in Bangladesh's Agriculture. In Bangladesh conditions, farmers are adopting mechanical weeding, which undoubtedly accomplishes the job effectively but it is costlier and painstaking. Weed control demands a lot of human labor, sometimes several weeding is required to keep the crop weed-free. Mechanical weeding is preferred because manual weeding is time-consuming, tedious, and costly [7]. Mechanical weeding is done either by a manually-operated weeder or a power-operated weeder. Manually operated weeders have found acceptability due to their low cost but involve drudgery. Weeding with the use of manual tools requires a high labor force. Mechanical weeders are used to complete the weeding operation in due time at less cost. Environmental pollution caused by chemicals is also reduced by the use of mechanical weeders [8].

One-third of the cost of cultivation is spent on weeding alone when carried out with manual labor. The arduous operation of weeding is usually performed manually with traditional hand tools in an upright bending posture, inducing back pain for most laborers. Losses caused by weeding cotton range from 40% to 75% depending upon the nature and intensity of the weeds. Weed control is becoming an expensive operation in crop production [9]. Pattanayak, Jena [10] reported that hand-weeding rice twice at 21 and 42 DAS (days after sowing) contributed to the highest weed control efficiency and increased grain and straw yield of the rice crop. The weed control cost was maximum for hand weeding (two hands weeding at 30 and 45 DAT) and the lowest for chemical weed management [11]. Randriamiharisoa, Barison [12] noticed that the mechanical weeding using a rotating hoe with small toothed wheels increased the soil pores so that roots and microbes could more easily gain access to oxygen and also significantly increase the tiller production.

The main goal of this research is to design and develop a conical-shaped weeder that will be used mostly on rice fields. Through the differential displacement action of blades mounted on a revolving conical-shaped roller or "Conical-Weeder", soils are tilted, weeds are uprooted, and weeds are buried. The majority of Bangladeshi farmers in the rice field manage weeds by hand weeding. In addition to pulling the weed between the crop rows, mechanical weed control often makes the soil surface lose, ensuring better aeration of the soil and water intake capacity. Manual weeders were imported from Japan in the 1960s and introduced to Bangladesh. Comilla co-operative karkhana first introduced the Japanese type of push weeder [13]. Farmers only operate these Japanese weeders in small areas since they are difficult to operate in heavy soils. The Japanese weeders are inaccessible to female employees. As a result, the Bangladesh Rice Research Institute (BRRI) developed the BRRI weeder and BRRI Kishan weeder. The BRRI weeder and BRRI Kishan weeder are very effective at uprooting weeds. Weeds in Bangladesh are manually managed by pulling or using simple tools such as niranee, Japanese rice weeder, BRRI weeder, and chemical means (herbicides) etc.

Hand weeding requires higher labor input and increased weight; operational difficulties in the puddled field and design complexity with many working parts have been identified as major drawbacks in power weeders. Japanese paddy weeder and conical weeder were found better than hand weeding in terms of weeding efficiency but, the conical weeder churns the soil and incorporates weeds into the soil more effectively than the Japanese paddy weeder, which in turn serves as organic manure. It facilitates aeration into the root zone resulting in higher tillering and ultimately more yields [14]. As a result, farmers will need weeders with a high uprooting capacity so that they can facilitate aeration into the root zone in higher tillering and ultimately more yields. Effects to suppress the weed infestation with a simultaneous increase in crop production through improved cultivation require the introduction of an improved weeder that will have high weed uprooting capacity. Considering the above point, the experiment of development and fabrication of manual push-pull type conical weeder for Bangladesh condition has been taken to reduce the drudgery in weeding, and increase comfortability and weeding efficiency.

2. Materials and Methods

2.1. Materials Required

A design was made with locally available low-cost materials. Materials required for fabricating the weeder were procured from the local market. Most of the parts of the weeder were developed and fabricated in the workshop. MS sheet (18 gage), MS flat bar and MS shaft, MS pipe, nut, and bolts were used to fabricate the weeder. Engineering design was done with the help of Solid works programming and a prototype was fabricated according to the design in the Farm Machinery and Post-Harvest Technology divisional research workshop at Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. The fabricated weeder was tested in the BRRI research field.

2.2. Data Were Collected and Calculated

The following data were collected to calculate the walking speed (km/hr), weeding efficiency (%), plant damage (%), and field capacity (ha/hr):

- ❖ Time required to travel 100 m distance in the field during weeding.
- ❖ Counting the number of weeds in a 1 m^2 area of the land before weeding and the number of weeds in a similar area after weeding.
- ❖ Counting the number of plants in a 1 m^2 area of the land before weeding and the number of damage-free plants in a similar area after weeding.
- ❖ Weeding time including losses in hr. and area of weeding in decimal.
- ❖ During operation, it should be comfortable and trouble-free.

2.3. Design Considerations

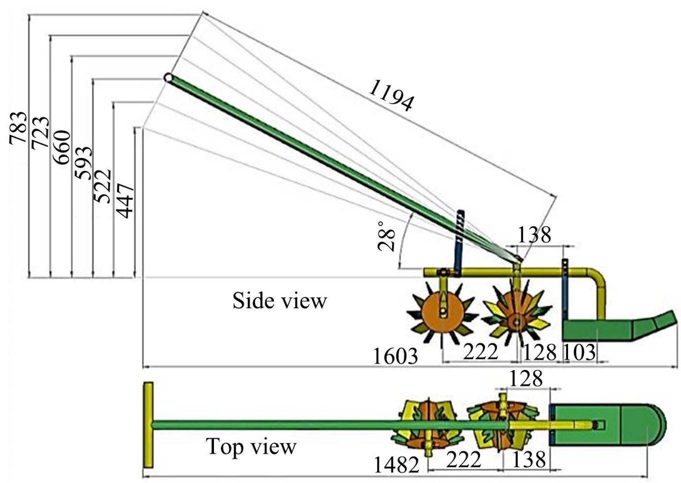
Mechanical weeders' main responsibilities are to uproot and cut weed plants, then spread them on the soil surface or bury them in the soil. For weeding operations in wetland paddy crops, manually operated weeders are the best alternative. Considered the following factors in developing conical weeder:

- ❖ Ease of weeding.
- ❖ Easy and simple in operation and maintenance.
- ❖ Distance between row to row.
- ❖ It should be a minimum force required for the operation in the field.
- ❖ It should have simple and easy adjustment.
- ❖ Locally available materials should be used to minimize the fabrication cost.
- ❖ Lightweight for easy handling.
- ❖ It should be easy to repair and maintain.
- ❖ The cost of weeder must be within the capacity of small and medium farmer.
- ❖ It should be suitable for operation by a single person.

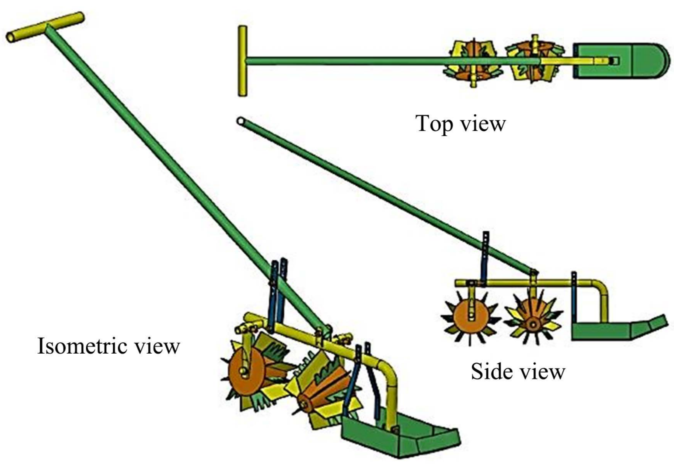
2.4. Development and Fabrication of Different Parts of the Weeder

The developed weeder is a hollow cylinder that has blades fixed on it in alternate arrangements. The complete, different views and bill of materials of the BRRI conical weeder are shown in **Figures 1-3**. The manual push-pull type conical weeder was designed and fabricated in the Farm Machinery and Postharvest Technology (FMPHT) divisional research workshop of Bangladesh Rice

Figure 1. Photographic view of the conical weeder.

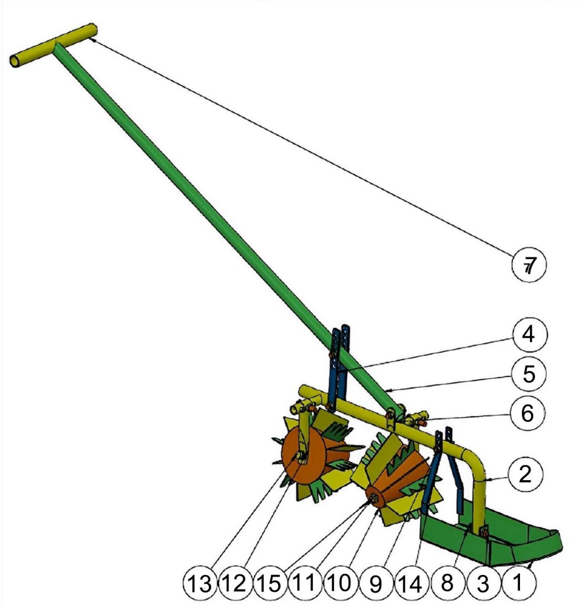


(a)



(b)

Figure 2. Different views of the designed conical weeder.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Skid	Sheet metal	1
2	Main Body Frame	MS pipe	1
3	Float holder	Flat bar	2
4	Handle height adjuster	Flat bar	2
5	Handle	MS pipe	1
6	Handle Holder	Flat bar	2
7	Handle Griper	MS Pipe	1
8	Bolt(Small)	MS	8
9	Nut(Small)	MS	8
10	Rotor	Sheet metal	2
11	Axel	MS shaft	2
12	Rotor Holder	MS pipe	2
13	Nut (Big)	MS	2
14	Float adjuster	Flat bar	2
15	Bush		2

Figure 3. Bill of materials (BoM) of the designed conical weeder.

Research Institute (BRRI), Bangladesh. The manual push-pull type conical weeder consists of the following major parts: skid/float, float holder, float adjuster, main body frame, rotor, axel, bush, rotor holder, rotor holder adjuster, handle, handle griper, handle holder, handle height adjuster, nut, bolt, etc. During design, all components of the weeder were modified by the trial and error method. The conical weeder is made with MS sheet, MS, pipe, MS flat bar, MS nut-bolt, etc. The descriptions of different parts are given herein:

2.4.1. Skid or Float

The front of the weeder had a skid or float constructed of mild steel sheet with a thickness of 2 mm. The skid or float protects the weeder from penetration into soft, muddy soil while also allowing it to move smoothly. The skid also helps to distribute the weeder's weight load. The skid's overall length and width, 344 and 124 mm, were specifically selected. Moreover, the inclination part length was 142 mm. The inclined component of the skid, as well as the skid holder and skid adjuster, are all part of the skid. To make it easier for the weeder to run, the front inclined section was set up at 22-degree angles with the skid. Also, the skid holder holds the skid with the main body frame of the weeder. "L" shape 54 mm length, 4 mm thickness flat bar with 10 mm diameter two holes welded with skid. The mainframe and skid are detained together by a nut-bolt joint in this skid holder. The skid adjuster is built of MS flat bar with a thickness of 4 mm and three holes of 10 mm. The skid adjuster facilitates the smooth functioning of the skid by adjusting the skid angle with the soil surface. The sidewall height of the float was 64 mm helps to prevent the entry of mud from sidewalls and the length of the float was 344 mm to ensure easy floating action of the weeder during operation. Different views of the skid are shown in **Figure 4** and **Figure 5**. The

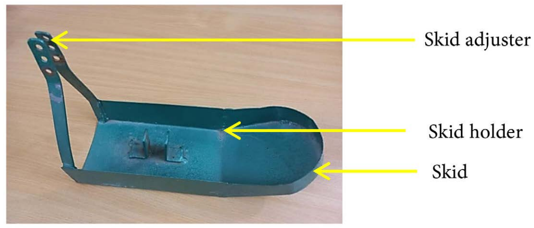
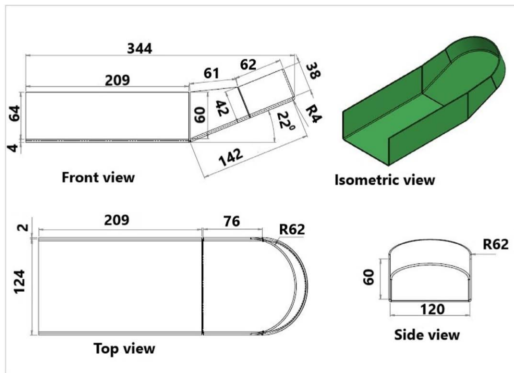
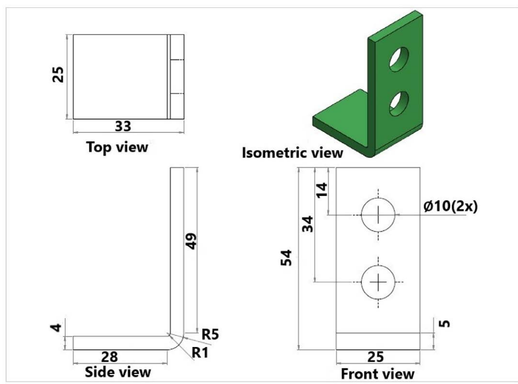


Figure 4. Photographic view of a skid of the weeder with skid holder and skid adjuster.



(a)



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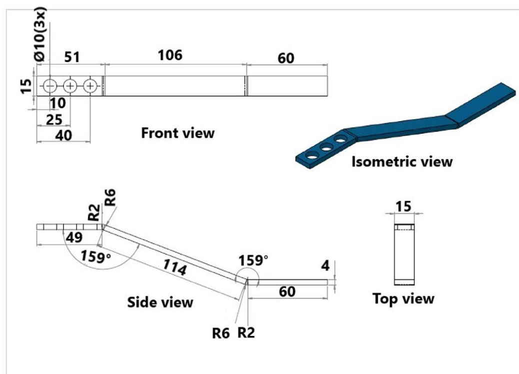


(c)

Figure 5. Different views of the skid of the weeder (all dimensions are in mm). (a) Different views of float; (b) different views of skid holder; (c) different views of skid adjuster.

float was attached to the front of the mainframe at a 22-degree angle of inclination part to the horizontal so that it could manage the depth of operation, slide freely over the soil, and reduce the weeder's draft demand.

2.4.2. Main Body Frame Assemble

The frame is an essential component for holding different parts such as a skid, handle, and rotors of the weeder. The rotor holder adjuster and the handle holder are part of the mainframe (**Figure 6**). In the frame of the conical weeder, 26 mm diameter round MS pipe and 20 mm round MS pipe are welded together and four 10 mm diameter holes were provided on the round MS pipe for adjustment height of the handle pipe, skid adjustment, and skid holder. Three 10 mm diameter holes were also provided on a 75 mm length of 20 mm round pipe of the mainframe for mounting the rotor holder (arms) to adjust the required width of operation. This component was made of mild steel pipe whose diameter was 27 mm. The height of the main body from the middle point of the float was 217 mm. The length of the straight main body frame was 547 mm. The MS pipe was bent at 90˚ angles to attach to the float and the mainframe. The precise adjustment is not possible in height of the weeder and width of the weeding operation due to three holes made at intervals of some fixed distances. The mainframe was tightened with skids and rotors using a nut and bolt. The length of the handle holder was 50 mm, and one 10 mm diameter hole was provided for the nut-bolt joint which was welded on the mainframe. Different views of the main body frame are shown in **Figure 7**. To hold the handle on the mainframe 10 mm nut-bolt joint made it tightly with the mainframes.

2.4.3. Rotor Assemble (Drum, Plain Blades, Serrated Blades, Axle/Spindle, Bush)

The conical weeder is equipped with two conical rotors mounted in tandem with opposite orientations. The conical drum component of the rotor, as well as the plain/smooth blades, serrated blades, axle or spindle, and nut, are all part of the rotor assembly. The rotors were cone-shaped frustums with smooth, serrated metal blades welded around their circumference that could be removed. The amount of soil manipulation and the best coverage area between two rows were taken into consideration when designing rotating cones. The cone was made of an M. S. 18-gauge sheet and the blades were made of mild steel (MS) as well. Initially, the M. S. sheet was cut to the required size and shaped into a cylindrical shape. The greater and smaller diameter of the cone was 120 mm and 55 mm respectively (**Figure 8**). The sheet metal rotors were kept hollow to increase the flotation in soft soil. The roller was made up of a mild steel sheet of 119 mm in width. Subsequently, the blades which were cut before measurement had to be welded. As the rotor moves forward, the smooth and serrated blades are mounted alternately on the rotor to uproot and bury the weeds in the soil. It allowed the manual conical weeder to perform satisfactory weeding in a single forward pass without push-pull motion. The six plain blades were fabricated

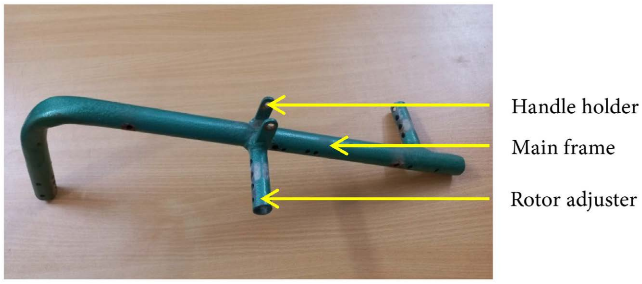
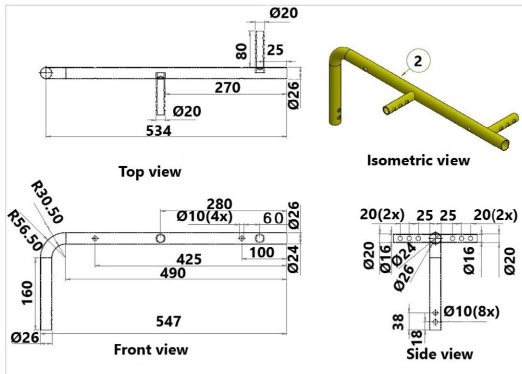


Figure 6. Photographic view of the main body frame of the weeder.



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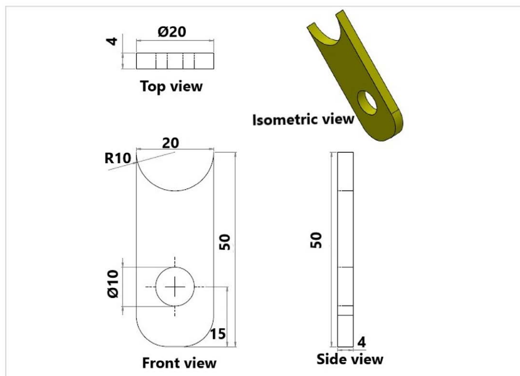
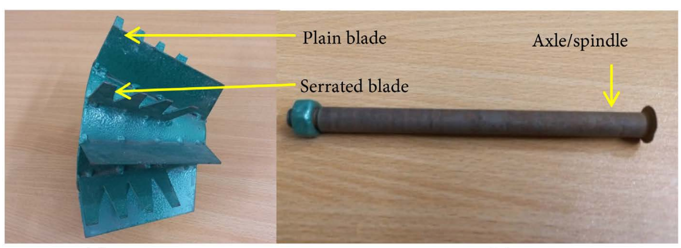


(b)

Figure 7. Different views of the main body frame assemble of the weeder (all dimensions are in mm). (a) Different views of the main body frame; (b) different views of the handle holder.



(a) (b)

Figure 8. Photographic view of the rotor of the weeder with a plain, serrated blade, axle or spindle, and bush.

from a 2 mm thickness MS sheet of 125 mm length and 45 mm width and mounted on a drum surface with a blade inclination of 15˚. The six serrated edge blades were also fabricated from a 2 mm thickness MS sheet of 85 mm length and 45 mm width and mounted on a drum surface with a blade inclination of 15˚ as well (**Figure 9**) Two axles or spindles, two bushes were designed and

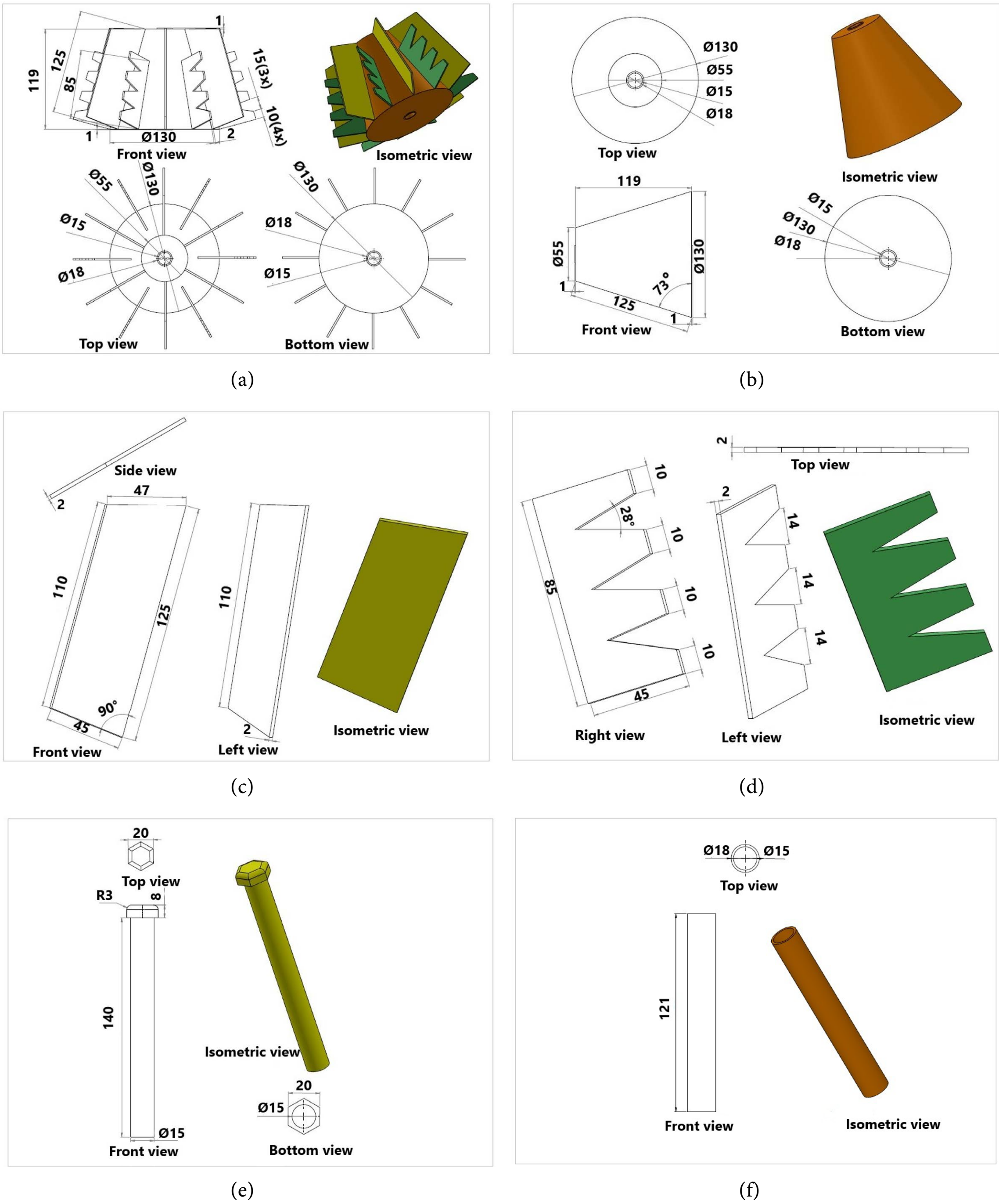


Figure 9. Different views of the rotor assembly of the weeder (all dimensions are in mm). (a) Different views of the rotor; (b) different views of the drum; (c) different views of the plain blade; (d) different views of the serrated blade; (e) different views of axle/spindle; (f) different views of the bush.

fabricated. The diameter and length of the spindle were 15 mm and 140 mm respectively while the head diameter of the spindle was 20 mm. Bushes were designed and used in the conical shape rotor. The outer diameter and length of the bushes were 18 mm (inner diameter 15 mm) and 121 mm respectively. Bushes were welded with the conical rotor.

2.4.4. Handle Assemble (Handle, Handle Griper, Handle Height Adjusting Leaver)

The length of the handle and the angle of inclination with the horizontal surface are interdependent. The angle of operation was based on the functional design and geometry of the tool. Length of handle based on average standing elbow height of the male and female worker. An adjustable handle was decided to be fabricated so that the length of the weeder can cover the optimum height of people and it eliminates back strain and provides comfort to the operator for continuous operation in standing posture. The handle arm was fabricated from a 2 mm thickness of MS pipe. MS pipe of 1194 mm length was welded at the middle of 250 mm long handle crossbar of 26 mm diameter MS pipe in such a way that it can make an angle of 90˚ between them (**Figure 10**). The handle griper was made from the same MS pipe. Drawing views of the handle are shown in **Figure 11**. The handle of the weeder was made of a 26 mm diameter MS pipe and fitted to the frame. Handle maximum height was kept at 783 mm with the provision of adjustment as per the convenience of the operator. There is an adjustment lever to control the height of the handle from ground level with six options. The height of the handle from the ground level was 638 mm when the adjustment lever was at a lower position. On the other hand, it was 974 mm when the adjustment lever was at the upper position. The length of the handle (1194 mm) and height from ground level are directly related to the force required to operate the weeder and the comforts of the operators.

2.4.5. Rotor Holder

The conical weeder's mounting rotor holder was used to hold the weeding unit to the mainframe. Two 147 mm long rotor holders (arms) were made from 22 mm diameter MS pipe and 20 mm diameter MS pipe inclined at 90 degrees downward to the soil (**Figure 12**). One 10 mm hole was given on the upper end

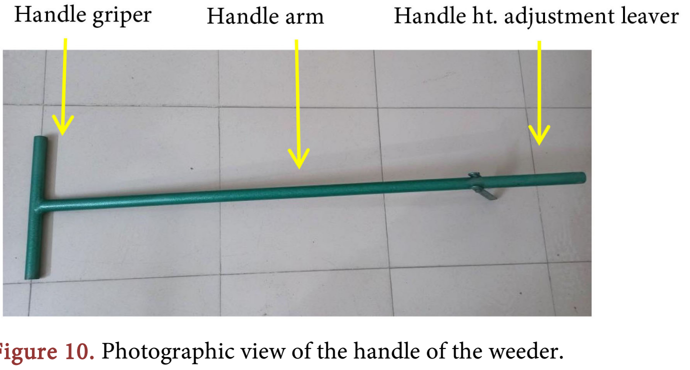
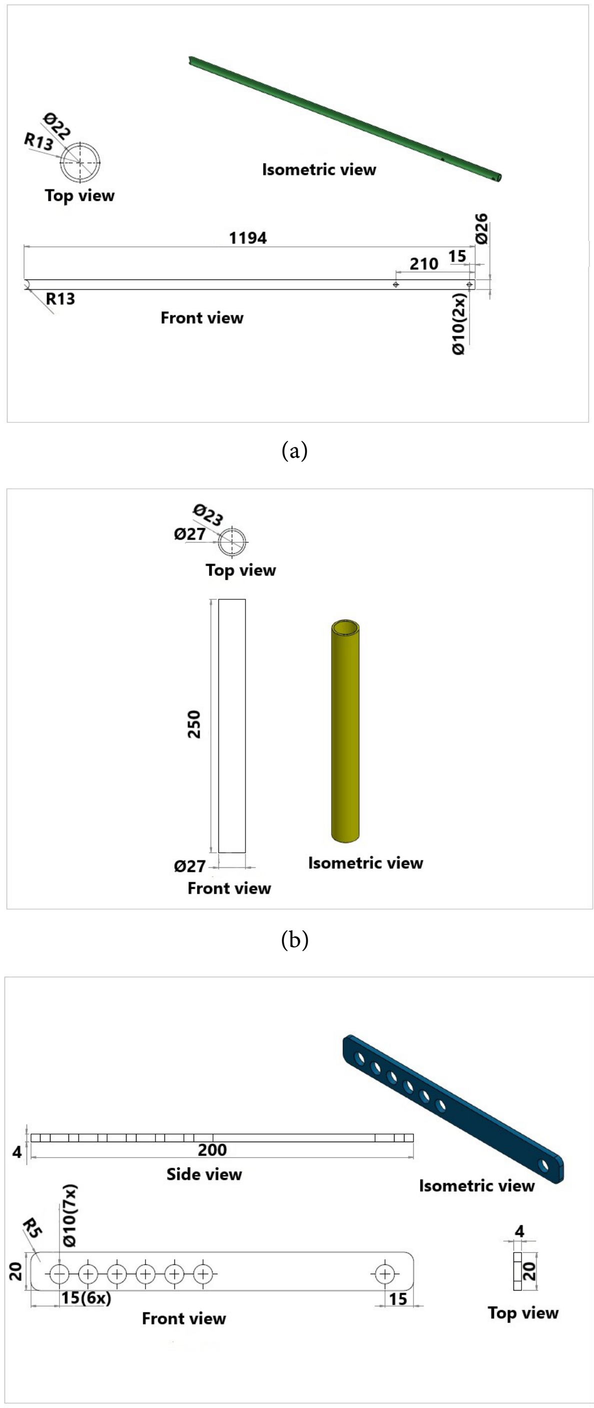


Figure 10. Photographic view of the handle of the weeder.



(a) (b) (c)

Figure 11. Different views of the handle of the weeder (all dimensions are in mm). (a) Different views of handle arm; (b) different views of griper; (c) different views of handle height adjusting lever.

of each arm to modify the width of the operation, and one 15 mm hole was provided on the lower end of each arm to suit the wedding drums at a 15˚ angle. Isometric views of the mounting rotor holder are shown in **Figure 13**.

Figure 12. Photographic view of the rotor holder of the weeder.

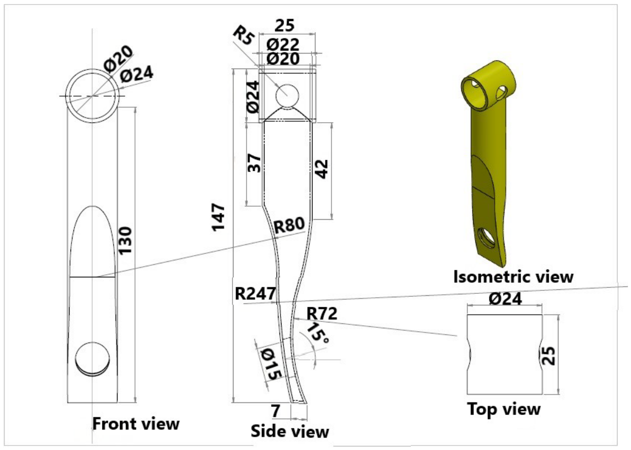


Figure 13. Different views of the rotor holder of the weeder (all dimensions are in mm).

2.5. Operational Pre-Conditions

For better performance, several functioning procedures should be followed, such as:

- Handle height differs from the operator's height, so height adjustment is a significant issue for effective operation in the field.
- The conical weeder design force is pushing and pulling. Any kind of pushing and pulling force will create weeding.
- Minimum standing water (2 - 4 cm) needs to maintain during field operation. It will help to keep the soil soft that help the weeder for smooth running with proper weeding.
- The walking speed should be standard (1.72 km/h).

2.6. Working Principles of Conical Weeder

Two weeding conical-shaped rotors are fixed to the right and left sides of the mainframe of the push-type weeder. A float is added to the front end of the weeder to keep it from sinking in moist soil. The primary frame is extended by a handle with a provision for height adjustment. The handle height must be adjusted before the operation so that the operator feels comfortable using the weeder. On the other hand, adjustment of handle height is also important considering the operator's height, force requirement, and ease of operation. Weeding is made easier with this hand-operated manual weeder. With the push-pull operation, it may be weeding a single row at a time. One thing to keep in mind is that this conical weeder is a wetland weeder, which means the area must have enough water. When the rotors perform back and forth, the weeder's two conical rotors with six plain blades and six serrated blades work together to uproot and bury the weeds. It also contains a 2 mm thick float assembly with a precise angle of 22 degrees to ensure that the float assembly does its job effectively. Weeds are uprooted by the weeder's blades and buried in the muddy soil by the push and pull operations. It causes topsoil disturbance and enhances aeration. The crop will be able to grow in a better environment as a result of this. When utilizing the weeder, the soil should be moist and compact.

2.7. Theoretical Considerations

The weight of a weeder, its capacity, the depth of the blade in the soil, cutting leaves, walking speed, field capacity, field condition, ease of operation, weeder adjustment, soil type, land topography, field size, and shape are all important factors to consider when evaluating the performance of a conical weeder.

2.8. Evaluation Procedure

2.8.1. Site Characterization and Experimental Setup

The field experiment was conducted at Bangladesh Rice Research Institute (BRRI) and Jogitola, Gazipur, Bangladesh. The soil was characterized as silt loam. The field was prepared by using one operation of a power tiller. Hand transplanting was done and row spacing of 20 cm was used to evaluate the performance of weeding in a rice field. Grassy weeds were more dominant in the experimental field. There was 2 - 4 cm of standing water in the field. The height of the plants was 17 - 22 cm (**Table 1**).

Table 1. Condition of the field.

Parameters/Items	Jogitola, Gazipur	BRRI, Research field
Type of Soil	Clay Soil	Clay loam Soil
Depth of standing water (cm)	2 - 4	2 - 3
Type of predominant weed	*Scirpus maritimus*	*Scirpus maritimus*
Size of weeds (cm)	11 - 15	10 - 14
Stage of maturity of crop, days	24	22
Row spacing of crop, cm	20	20
Plant height (cm)	17 - 20	18 - 22

2.8.2. Machine Parameters

To efficiently operate the designed weeder in the field, a trained operator was chosen. Weeding was done 22 - 24 days after the crop was planted. According to the equations, the influence of blade width, operational speeds, depth of operation on-field capacity, plant damage, and weed control efficacy was investigated. Walking speed was recorded without loss to calculate the weeder's theoretical field capacity. Total field operation time was reported to calculate the weeder's actual field capacity with turning loss, operator loss, and loss during field operation for system adjustment and troubleshooting losses. The number of weeds and tiller numbers were counted before and after each field operation in a pre-selected 1 m^2 area. The following formula was used to figure out the weeding capacity, weeding efficiency, and the number of tillers/hills injured.

1) Travel/Walking Speed (Km/H)

The time required to cover a 10 m row length was recorded to determine the machine travel speed during the weeding operation. In each operation, five measurements were taken, and the average value was determined. A digital stopwatch was used to record the time in seconds.

2) Effective Working Width (mm)

The weeder's effective width is equal to the Weeding's effective width. The tested weeder's real working width was 150 mm, but the effective width was determined to be slightly less than the theoretical actual width. The exact width of the weeding was measured with 5 m steel tape.

3) Actual Field Capacity

During operation in the study areas, the fabricated weeder's actual field capacity was measured. To measure the actual field capacity of the weeder, the machine operating period included the time needed during the weeder's turning, the operator's time, adjustment time, re-starting time, etc. It is the proportion of the machine's real average field coverage rate to the total time during operation [15] [16]. Therefore,

$$C = A/T \tag{1}$$

where,

C = Actual field capacity in ha/hr.

A = Area of weeding in hector.

T = Time of weeding in hr.

4) 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 using the relationship given below [17]: -

Theoretical field capacity = (Width of the implement (m) × speed of operation (km/h))/10

5) Field Efficiency (%)

The field efficiency was calculated using the equation [18]:

Field efficiency (%) = (Actual field capacity (ha/h))/(Theoretical field capacity (ha/h)) × 100

6) Weeding Efficiency

The average number of weeds present per square meter area before weeding should be determined. Similarly, the number of weeds left out per square meter can be counted. 5 days after the weeding test is completed. The difference between the two will give the number of weeds eliminated and the efficiency of the weeder can be computed using the following equations [9].

Weeding efficiency = (Number of weeds eliminated per m^2)/(Total number of weeds present per m^2) × 100

$$\text{WE} = \left(\left(W_1 - W_2\right)/W_1\right) \times 100 \quad (2)$$

where,

WE = Efficiency of weeding in percentage.

W_1 = Population of weeds before the operation.

W_2 = Population of weeds after the operation.

7) Damaged Tiller Rate

The percentage of rice tiller breakage was determined using the following equation:

$$\text{DTR} = \left(\left(T_1 - T_2\right)/T_1\right) \times 100 \quad (3)$$

where,

DTR = Damage of tiller in percentage.

T_1 = Tiller number before weeding.

T_2 = Tiller number after weeding.

2.8.3. Weight Measurement

The weeder's weight is important for both carrying and smooth functioning. The weeder's weight was measured with a balance in the FMPHT division's workshop at BRRI, and the data was recorded. The weight of the weeder is 5.6 kg.

2.8.4. Pushing Force Measurement

The force required for operation was determined in the field with the help of a spring balance, rope, and three people (**Figure 14**). One person pulled the

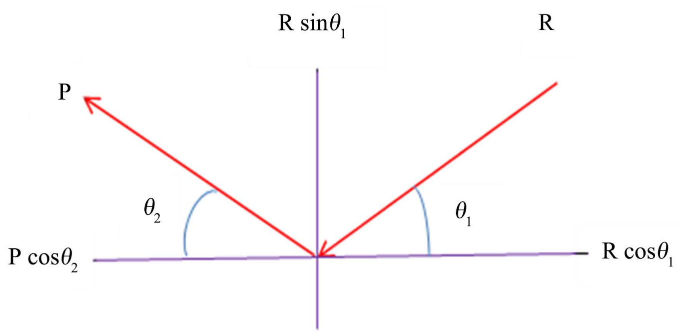


Figure 14. Pushing force measurement.

weeder, while another recorded the data of spring balance, and a third person just holds the weeder handle along with a line of action during the time of pull of the weeder [19].

3. Results and Discussion

3.1. Field Performance of the Weeder

The performance of the weeder (Figure 15) is given in Table 2 and Table 3. The output of the machine affected the person to person. The individual area coverage (m^2), time required, theoretical field capacity, actual field capacity, field efficiency, weeding efficiency, and plant damage/leaves damage during weeding operation with a conical weeder were calculated and tabulated.

Figure 15. Field performance of the conical weeder.

Table 2. Field performance of the weeder.

Sl. No.	Actual/Effective field capacity (ha/h)	Degree of weeding/weeding efficiency (%)	Plant damage (%)	Walking speed (k/h)
Operation in Jogitola, Gazipur				
01	0.020	82.55	1.64	1.52
02	0.019	82.23	1.57	1.58
03	0.017	82.41	2.30	1.53
04	0.022	80.26	3.03	1.56
05	0.021	80.96	1.46	1.48
Average	**0.0198**	**81.68**	**2**	**1.53**
Operation in BRRI research field, Gazipur				
01	0.021	81.15	1.57	1.58
02	0.020	79.65	1.83	1.55
03	0.021	85.21	2.45	1.57
04	0.020	81.96	2.15	1.61
05	0.022	82.82	3.16	1.59
Average	**0.0208**	**82.16**	**2.23**	**1.58**

Table 3. Field capacity and efficiency of the weeder.

Sl No.	Location	Theoretical field capacity (ha/h)	Actual field capacity (ha/h)	Field Efficiency (%)
1	Jogitola, Gazipur	0.0229	0.0198	88.82
2	BRRI research field, Gazipur	0.0237	0.0208	87.76
	Average	**0.0223**	**0.0203**	**88.29**

3.2. Capacity of the Weeder

The field capacity of the developed weeder during field activity was calculated in two locations in the Gazipur district. The theoretical and actual field capacity of the conical weeder has been measured during operation to calculate the field efficiency. Theoretical field capacity varied with the forward speed of the operation of the weeder, while actual field capacity varied with the condition of the soil, soil softness, density of weeds, forward speed, loss of turning time, etc. It was found that the traveling speed of the conical weeder was 1.53 - 1.58 km/h. The effective field capacity of the weeder was found 0.0198 $ha \cdot h^{-1}$ in the farmer's field. In the BRRI research field, the effective field capacity was found 0.0208 $ha \cdot h^{-1}$. The average field capacity was found 0.0203 ha/h (**Figure 16**).

3.3. Field Efficiency

The field efficiency of the technologies varied with the variation of total turning time losses. 87.76% field efficiency was found for conical weeder in the BRRI research field whereas it was observed 88.82% in farmer's field respectively (**Figure 17**). The average field efficiency was found 88.29%.

3.4. Weeding Efficiency or Degree of Weeding of the Weeder

The weeder's weeding efficiency (WE) depended on weed severity, soil moisture, weeding regime, operator conditions, and soil conditions. The weeding efficiency or degree of weeding of the weeder was found 81.68% and 82.16% in the farmer's field and BRRI research field respectively (**Figure 18**).

3.5. Plant or Tiller Damage

The plant damage or tiller damage of the weeder was found 2% and 2.23% in the farmer's and BRRI research fields, respectively. The average tiller damage was found 2.12 percent (**Figure 19**).

3.6. Pushing Force of Weeder

The pushing force of the weeder was measured by using a spring-type balance. weeder's average pushing force was found around 43.42 N (**Table 4**).

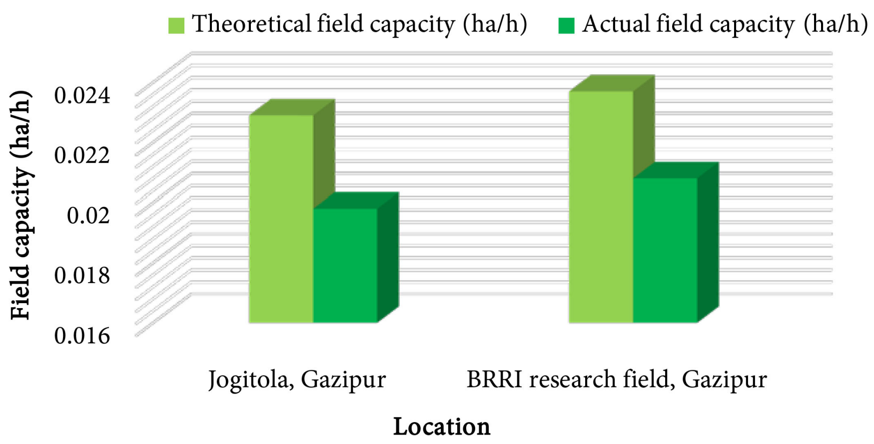


Figure 16. Capacity of the conical weeder.

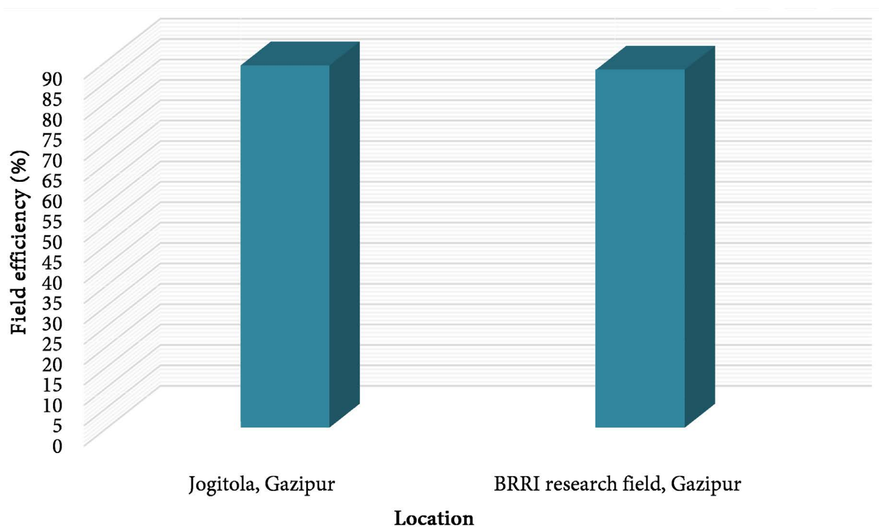


Figure 17. Field efficiency of the conical weeder.

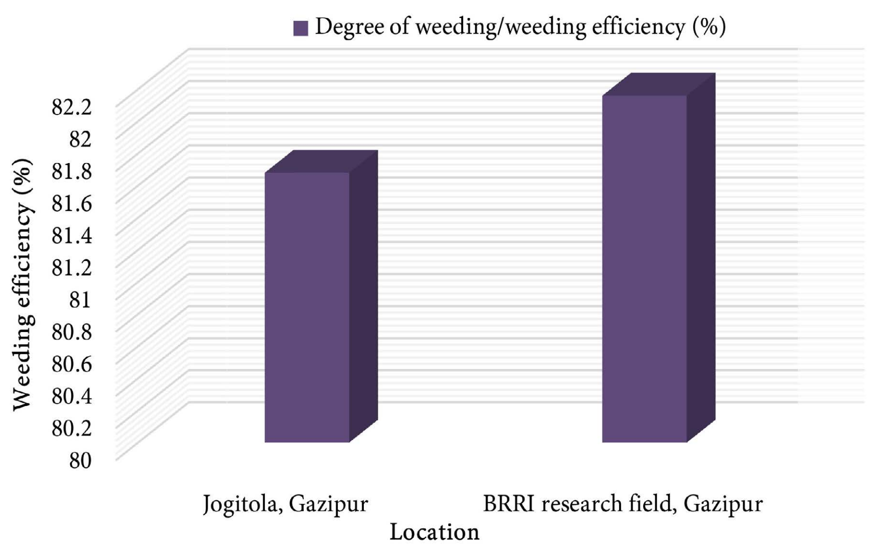


Figure 18. Weeding efficiency of the conical weeder.

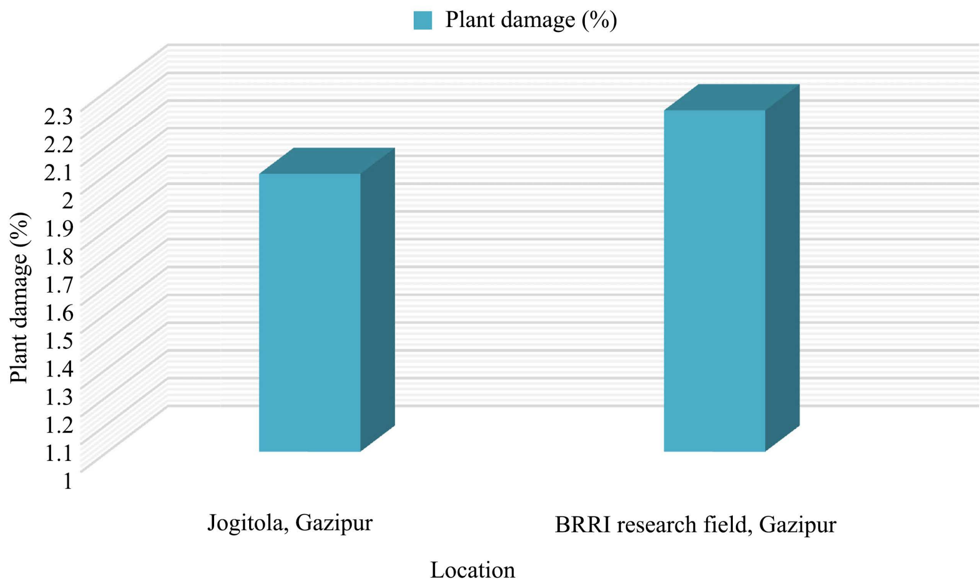


Figure 19. Plant damage of the conical weeder.

Table 4. Pushing force measurement of the weeder.

Obs. No.	Pulling force (kg)	Pulling angle (˚)	Pushing angle (˚)	Pushing force (N)	Average pushing force (N)
1.	4	0	30	45.31	
2.	3.5	0	30	39.65	**43.42**
3.	4	0	30	45.31	

3.7. Cost of Operation

The price varies with the quality of M. S. pipe, M. S. flat bar M. S. sheet, plain sheet, and nut-bolt. The estimated price of the conical weeder is about Tk. 1500. The cost of operation of the conical weeder was calculated in terms of field capacity. In **Table 5**, the total operating cost based on fixed and variable costs in terms of Tk/h for conical weeder was found 50.77. The operating cost is based on Tk/ha for conical weeder 2432.

3.8. General Specifications

General features and detailed specifications of the conical weeder

The weight of the weeder is 5.6 kg, which is easy to push and pull between two rows of the rice field. Consequently, one man or woman can use the weeder very easily. The fabrication of the weeder is also easy and simple. It has the advantage of necessarily less energy and easy to adjust and operate. The general features and specifications of the weeder were presented in **Table 6** and **Table 7** respectively.

Table 5. Cost items and operating cost of single-row conical weeder.

Items	Parameter	Amount	
		Tk	US$
Fixed cost items	Purchase price of weeder (P),	1500	17.65
	Salvage value(S), (10% of P)	150	1.76
	Working life (L), yr	5	-
	Average working hours per year	480	-
Variable cost items	Labour (Tk or US$/hr)	50	0.59
	Repair and maintenance (Tk or US$/yr)	0	-
	Field capacity (ha/hr)	0.0203	-
	Calculations		
Fixed costs	Annual depreciation, D = (P − S)/L Tk or US$/yr	270	3.18
	Interest on investment, I = (P + S)/2 * I, where the rate of interest is 12%	99	1.16
Total fixed cost	(Tk or US$/yr)	369	4.34
Total fixed cost	(Tk or US$/hr)	0.77	9.06×10^{-3}
Total fixed cost	(Tk or US$/ha)	36.61	0.43
Variable cost	Labour (Tk/hr)	50	0.59
	Repair and maintenance (Tk/hr)	0	-
Total variable cost	(Tk or US$/hr)	50	0.59
Total variable cost	(Tk or US$/ha)	2380.95	28.01
Operating cost	(Tk or US$/hr)	50.77	0.597
Operating cost	(Tk or US$/ha)	2431.72	28.61

Note: Average work day = 8 hr at 0.0203 ha per hr.; Labor/operator charge = 400 Tk/day, 1 US$ = 85 BD TK.

Table 6. The general features of the BRRI conical weeder.

Sl. NO.	Particulars	Specification
1	Function	For weeding in between rows of line sowing paddy crop
2	Power	Manually operated
3	Number of operators	One person
4	Type of operation	Push-Pull Operation
5	Operating Condition	Water must be more in the field at the time of weeding
6	Number of rows	Single row
7	Weight	5.6 kg.
8	Width of operation	130 - 150 mm

Continued

9	Number of cones (rotors)	2 Nos. Cones are made of a 20-gauge M. S. sheet.
10	Blades	2 mm thickness Each cone has the following blades (18 gages M. S. sheet) a) 6 numbers of plain blades & b) 6 numbers serrated blades
11	Cone rotor holder	2 Nos. 22 mm dia and 130 mm length with 24 mm diameter clamp
	Spindle/axle	15 mm dia and 140 mm length with 20 mm diameter head on the top of the spindle/axle
12	Skid/float Assembly	2 mm thickness of 18-gauge M. S. sheet used Size: 344 × 124 × 64 mm with front 142 mm length of skid apex Float angle 22 Degrees.
13	Handle	Main Pipe: Dia: 26 mm Length: 1194 mm Griper/Cross Bar: Dia: 26 mm; Length: 250 mm
14	Height adjustment lever	2 Nos Length: 200 mm; width 20 mm; thickness: 4 mm
15	General Information	The BRRI conical weeder has two cone shape rotors mounted in tandem with opposite orientations. Smooth and serrated blades are mounted alternately on the rotor to uproot and bury weeds when the rotors create a back-and-forth movement in the top 3 cm of soil.

Table 7. The detailed specifications of the BRRI conical weeder.

Sl. No.	Name of the components	Number	Size (mm)	Materials used
1	Handle	01	Length: 1194 and Dia: 26	26 mm dia. MS pipe
2	Handlebar/griper	01	Length: 250 and Dia: 26	26 mm dia. MS pipe
3	Rotor	02	Length: 119, Larger Dia: 130, and Smaller Dia: 55	18-gauge M. S. sheet
4	Rotor to Rotor distance	-	222	-
5	Blade in each rotor	12 (6 Plain blades and 6 serrated blades	Plain blade Length: one side 125 and another side 110, Width: 45 & Thickness: 2 Serrated blade length: 85, Width: 45	18-gauge M. S. sheet
6	Blade angle	-	90 degrees toward motion from the vertical line	
7	Main axle or spindle in each rotor	01	Length (L): 140, Dia of top: 20 & Dia of axle/spindle: 15	M. S. Shaft

Continued

8	Bush in each rotor	01	Bush Length:121, Inner dia: 15, and Outer dia:18	M. S. Shaft
9	Height adjustment lever	02	Length = 200, width 20 with 4 mm thickness	M. S. flat bar
10	Joint nut-bolt	08	Dia 10	-
11	Skid	01	Width: 124, Length: 344, Front 142, 22 degree up from the baseline. Sidewall height 64, front side wall 38, front radius 62	18-gauge M. S. sheet

4. Conclusion

The conical weeder was fabricated using locally available materials and conducted its performance tests at two locations in the Gazipur districts. The conical weeder was found suitable to control weeds in the line transplanted field. The weeding efficiency of the conical weeder was 81.92%. The effective field capacity of the conical weeder was 0.0203 ha/h. The weeder can uproot and bury the weeds in a single row at a time with a push-pull operation. Maximum weeds uproot only by pushing the weeder in the forward direction. Moreover, the weeder's fabrication cost is not expensive. Therefore, farmers can make use of this weeder in their fields to get better comfort when mulching and weeding.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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