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Participatory Evaluation of Mechanical Hand Weeders in Rain-Fed Lowland Rice Production Ecosystems in North Western Ethiopia

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Abstract: Rice is a main field crop in Fogera rain fed lowland ecosystem as stable food and straw is mainly used for cattle feed. Weed is a major constraint for rice production causing a subsequent drastic reduction of yield. Manual weeding method is extremely labor intensive and time consuming which conveys to high cost of production. The study ambition was to test different mechanical weeders with farmers to acquire their preference. Pertaining to this, four prototype mechanical weeders were developed and evaluated under rainfed lowland rice production ecosystem at Fogera. The recommended planting space of rice in the experimental area was 20cm between rows and mechanical weeders were developed 18cm wide. The rice was sown in rice field with 20cm row spacing which allows for the use of manual weeders. On the first day, one representative farmers field was identified for evaluation. The researchers together with DA's went to the village and selected 30 farmers who had willing to participate in the evaluation practice in the following day. Before selection, farmers were asked generally whether they are volunteer to participate in this weeder evaluation activity in their own rice field or not. Based on this information, the targeted number of women and men were selected. Rotary weeder, star rotary weeder, finger-push weeder and push weeder were developed and gauged to get farmers preference. Selected weeders were gender sensitive and equal number of men and women were participated in the evaluation of mechanical weeders. Data on cropping system, crop establishment method, weed infestation and type, weeding efficiency, effective field capacity and damaged plants were collected. From this evaluation activity, two mechanical hand weeders rotary weeder and finger-push weeder were selected and distributed to farmers for future use. Women were selected finger push weeder while men have selected rotary weeder. The maximum weeding efficiency (90.2%) was observed from the rotary weeder whereas the weeding efficiency of finger-push weeder was (82.8%). However, push weeder had provided (51.3%) weeding efficiency while star rotary weeders brought (42%) of weeding efficiency. The least cost but high-cost reduction amongst the mechanical hand weeders were found from the rotary weeder while the highest cost and minimum cost reduction were attained from the push weeder. Rotary weeder and finger-push weeder generate to decrease the total cost and express very effective weeding technologies in the clay soil and ponded water level for aquatic and grass weeds in the testing sites.

Keywords: Mechanical Weeder, Weeding Efficiency, Farmer's Preference, Low Land Rice Ecosystem, Weed Type

1. Introduction

Rice (*Oryza sativa* L.) is one of the leading food crops in the world. In Asia where 95% of the world's rice is produced and consumed, it contributes 40 to 80% of the calorie's intake of the population. Rice is grown throughout the tropics in rainfed uplands, seasonally deep flooded areas, and in rainfed and irrigated lowlands. Ethiopia is endowed with about 30 million ha of land, of which 5.6 million ha are categorized as highly suitable and another 25 million ha as suitable for rain-fed rice production. In addition, about 3.7 million ha are deemed as suitable for irrigated rice production. These are distributed around the ten river basins in the country [12]. The area coverage in domestic rice production has increased considerably linked with expansion of production in the wetland and upland areas with the introduction of suitable rice varieties for the agro-ecologies. One of the main reasons for low productivity of field crops in Ethiopia is due to lack of a support by mechanization from sowing to harvesting especially at critical stages to beat weed and for intercultural operations.

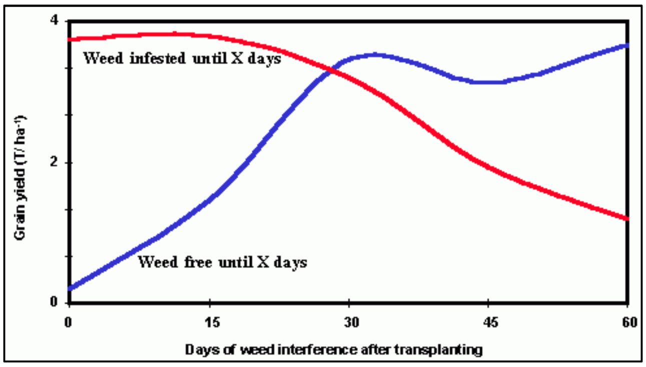
Weeds are plants wrongly grown in anytime and anywhere which is thought to be harmful. Weeding at critical stages is one of the main activities in rice cultivation otherwise they affect yield and quality of rice [2]. It reduces crop yields from 15 to 50% depending on species, density and weeding time through competition with main crop for light, water and nutrition [6, 13]. Results stated that losses caused by weeds exceed the losses caused by any other category of agricultural pests [18]. Weeds compete with crop plants for nutrients and other growth factors and in the absence of an effective control measure, remove 30 to 40 per cent of applied nutrients resulting in significant yield reduction [15]. Mechanically controlling of weed has multi advantages other than eradicating weeds such as soften superficial soil and improve aeration of soil. In rice paddy field the labor requirement varies depending up on the intensity and species of weed.

The factors considered while developing the mechanical weeder were variety of crop, its cropping pattern (row to row spacing), height of crop at the time of weeding, average root zone area of crop, time of weeding after sowing, depth of weeds root zone, water availability etc.

The nutrient uptake by the weeds was found to be directly related with weed population and inversely related with grain yield [4].

The nutrient uptake by the weeds was found to be directly related with the weed population and inversely related with grain yield [5]. Manual weeding is an effective method for weeds control. However, this is labor intensive and is not practical for large areas. Smallholder rice farmers require efficient, affordable and labor-saving weed management technologies [9]. In Fogera area rice production is increasing but due to lack of technologies like mechanical weeder and combined harvester the productivity is still limited compared to the world average productivity. Weeds are a main constraint to rice production in sub-Saharan Africa [8]. Wild rice (zurha), Aquatic weeds and grasses are widely growing weed types in Fogera rice production ecosystem.

Mechanical weeder is the best and effective method for controlling weeds and has multiple advantages to the crop to break up the surface coating, aeration of soil, stimulating the activity of the microflora, declining the evaporation of the soil moisture and facilitating the infiltration of rainwater [16], [7] Weeds are the major biotic stresses for paddy rice cultivation. Weed seeds are quite small, however, fast growth and development in early growing stage makes the rice crop a weak competitor for light, water and nutrients [1].



Source: [3]. Effect of weed interference on lowland rice yield.

Figure 1. *Effect of weed interference on lowland rice yield.*

Large reductions in yield are due mainly to the limited number of effective and affordable weed management practices available to farmers [10]. The higher competitive nature of weeds compared to crops is posing serious threat to crop yield [14]. In order to increase the productivity per unit area of small land holdings and considering the economic condition of Ethiopian farmers, it is quite necessary to have suitable agricultural equipment which farmers can use particularly in rice production. However, mechanical weeding is typically more economical to use than manual labor because it involves the use of tillage implements and uprooting of weeds [19]. Therefore, the objective of the study was investigating farmers preference among different mechanical hand weeders and evaluating the cost-effective technologies sustainable rice production in Fogera rice production area.

2. Materials and Methods

2.1. Description of the Study Area

The study was caried out in 2015 main cropping season in rain-fed lowland rice production ecosystem. Five representative villages (Kuhar Michael, Kuhar Abo, Woreta Zuria, Tehuazana Kena & Abuana Kokit) in south Gondar zone Fogera district were selected. The trial fields were selected based on the availability of water, wide range of soil texture, weeds and landscape position. The area was located between 11° 57' N and 12° 30'N latitude and 37° 35' E and 37° 58'E longitude. The study area had a very flat land, which is known by Fogera plan, adjacent to the eastern coast of Lake Tana. The mean annual rainfall was 1430mm and mean monthly values varies between 0.6mm (January) and 415.8mm (July), which indicates poor temporal distribution of rainfall. The mean monthly temperature of the area was about 19°C, monthly mean maximum temperature was about 27.3°C, and monthly mean minimum temperature 11.5°C [21].

2.2. Description of Mechanical Weeders

The development of mechanical weeders for row planted rice was manufactured by Mulat Engineering Plc in Bahir Dar, Ethiopia. The recommended planting space of rice during the study was 20cm between rows and mechanical weeders were developed by 18cm wide. After fields were selected, site characterization was done. Field was tilled four times via oxen ploughing and leveling was performed very well. Planting was done at a seed rate of 100 $kgha^{-1}$ by row sowing at 20cm spacing which allows using manual weeders. The rice variety X-jigina was sown to perform the study. The field should be due for (first) weeding.

Figure 2. *Participatory testing of weeders with farmers.*

Figure 3. *Finger-push Weeder.*

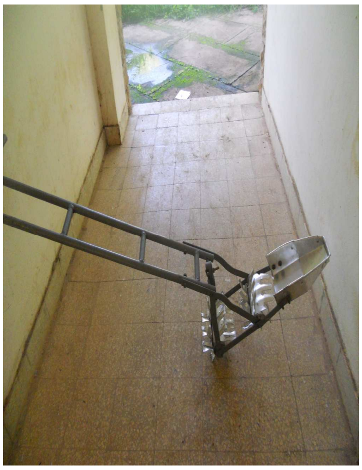


Figure 4. *Rotary weeder.*

2.3. Participatory Testing of Mechanical Weeders

Participatory evaluation of weeders was done in the target rice growing environments of rain fed lowland rice ecosystems in Fogera districts.

Two days were required for participatory evaluation for one location. At the first day, one appropriate field was identified for evaluation. The researchers together with DA's went to the village and selected 30 farmers who were willing to participate in the evaluation in the next day. Before any selection, farmers were asked generally whether they are volunteer for weeder evaluation on their fields. Based on this information, the targeted number of women (15) and men (15) and a total of 30 farmers were selected. Farmers were selected randomly. The next day, researchers visited to the fields together with farmers, and explained how to use one weeder, and asked all the farmers to test. Then, once all the weeders were tested, farmers freely tested by themselves which ever weeder they like to get a better impression. Enumerators were collecting data about farmers' preferences. To determine the weeding efficiency in four places of each plot. A wooden frame of 1 m × 1 m quadrant was thrown randomly and the number of weeds was thoroughly counted. The weeding efficiency of the weeders was calculated by the following [17] calculation methodology.

$$\mathrm{WE} = \frac{W1-W2}{W1} * 100 \quad (1)$$

Where, *WE* are the weeding efficiency of the weeders (%), *W1* and *W2* are the number of weeds before and after weeding respectively.

$$\mathrm{Pd}\ (\%) = \frac{A}{B} * 100 \quad (2)$$

Where Pd (%) is plants damaged in percent, A is number of injured plants in sample plot and B is total number of plants in sample plot.

$$\mathrm{EFC} = \frac{\text{Area Covered (ha)}}{\text{Time taken (h)}} \quad (3)$$

Where: EFC is effective field capacity, ha is hectare and h is hour.

2.4. Data Collection

Data on rice production system, crop establishment method, soil characteristics, water status, weed infestation, plant density, weeding method, characteristics of weeder, weeding efficiency, number of injured plants and effective field capacity in 1 m^2 were collected.

3. Results and Discussion

Mechanical hand weeders for drill row planted crop establishment method of rice was efficiently thru weeding. The weeders were very effective particularly on clay soil characteristics and ponded water level. The study showed that wild rice, grasses and aquatic weeds were identified as mainly grown in the test area and mechanical weeders capably done weeding. In the study area, rain-fed lowland and direct seeded rice in row sowing crop establishment method was common rice cultivation practices. Participatory weeder selection showed that farmers choice to weeder relied on water regime, efficiency of weeder and ease of operation. From the four fabricated and provided mechanical hand weeders two were identified and selected based on their weeding efficiency and flexibility for further use by the farmers. Finger push weeder and rotary weeder were found the most suitable weeder in rainfed lowland rice because of higher weeding efficiency in direct seeded rice. Rotary weeder was selected by men whereas finger-push weeder was selected by women. Rotary weeder and finger push weeders were very effective weeding technologies in the clay soil and ponded water level for aquatic weeds and grass in particular.

3.1. Weed Infestation and Types of Weeds

As the results indicated that in the study area aquatic weeds (chanfa), wild rice (zurha), grasses, sedges and broad-leaved weeds were dominantly grown. However, aquatic weeds were enclosed the highest ranking followed by wild rice weeds (Figure 2).

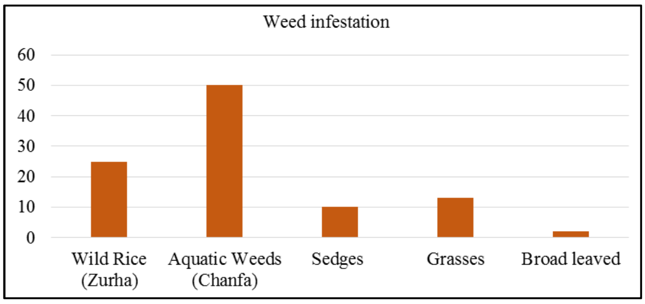


Figure 5. Weed infestation raking by weed coverage.

3.2. Weeding Efficiency

The maximum weeding efficiency (90.2%) was observed from rotary hand weeder whereas the weeding efficiency of finger push weeder was (82.8%). However, push weeder had achieved (51.3%) weeding efficiency whereas star rotary weeders provided (42%) weeding efficiency. The weeding efficiency of weeders were significantly different according to the growth stage and types of weeds grown in the experimental area. Wild rice (zurha) was one of the major weeds grown and significantly reduce the effectiveness of weeders during testing. In the contrary, aquatic weeds (Chanfa) was widely grown weeds in rice field having wet soil and effectively removed by finger- push weeder during testing.

3.3. Damaged Plants

Damaged plants were higher in the use of mechanical weeders compared to manual weeding method. According to the present study the lowest percentage of plant injury percentage (2.2%) and the highest weeding efficiency (96.66 %) was observed in manual weeding method. This showed that the injury of rice crop during weeding by manual weeding (hand weeding) was insignificant. Weeds grown within crop rows and closer to crop plants escape the control [20]. Weeds grown within crop rows incur much higher losses to crops than those grown between crop rows [11]. Damaged plants were higher (9%) in the star rotary weeder compared to the other mechanical hand weeders. However, 7%, 4.5 % and 3% damaged plants were recoded from push weeder, star rotary weeder and finger-push weeder respectively.

3.4. Effective Field Capacity

As the results explained effective field capacity (hah^{-1}) was showed significant difference between locations (Table 1). The highest effective field capacity was attained from hand weeding in all locations. Among the mechanical hand weeders, the highest effective field capacity (0.034) at Kuhar Michael was recorded from the rotary weeder followed by finger-push weeder (0.025). Similarly, at Kuhar Abo, Woreta Zuria, Tehuaza Kena & Abuana Kokit the highest effective filled capacity was found from the rotary weeder followed by finger-push weeder. Non-significant difference for effective field capacity was exhibited between star rotary and push weeders in all locations except at Kuhar Abo testing sites.

Table 1. Average values of effective field capacity for mechanical hand weeders at different testing sites.

Types of weeders	Kuhar Michael	Kuhar Abo	Woreta Zuria	Tehuaza Kena	Abuana Kokit
Star rotary weeder	0.018	0.020	0.022	0.023	0.015
Rotary weeder	0.034	0.044	0.044	0.035	0.028
Finger-push weeder	0.025	0.027	0.033	0.030	0.022
Push weeder	0.020	0.016	0.017	0.022	0.016
Hand weeding	0.0075	0.0084	0.0085	0.0079	0.0070

The travel speed was measured between two human powers for each location during testing and the mechanical hand weeders were effectively tested.

3.5. Cost-Benefit Analysis

Despite the considerable potential of rice production in Fogera area is high the labor-intensive activities (particularly for weeding) and becomes a bottle neck to exploit the potential and causes for the drastic reduction of rice yield. Labor cost is snowballing from year to year and it will not be manageable in future rice cultivation system unless the adoption of mechanical hand weeders enhanced and optional technologies developed. During the study (mechanical weeder's evaluation) period, the daily wage for weeding per day was 50 Ethiopian Birr (ETB). The operational cost for the use of rotary weeder was found maximum (birr 1518 ETB) followed by star rotary weeder (845 ETB), Finger-push weeder (619 ETB) and push weeder (485 ETB). Due to its minimum weeding efficiency and difficulty of weeder flexibility during testing the cost of operation for rotary weeder weeding cost was maximum. However, annual operation of the weeders was determined for 160 h based on 20 days actual annual use in paddy field and daily 8 h useful operation. Annual area coverage was achieved from multiplication of the effective field capacity and annual hours of operation. In mechanical weeders, the cost of machine operation is the sum of fixed and variable costs. The total cost of weeding is attained from all machine operation cost and labor cost for weeding between rows for direct seeded rice.

Table 2. *Basic cost calculation methods for different mechanical hand weeders.*

Type of weeders	Initial cost (ETB)	Salvage Value (ETB)	Use-full life (Yr.)	Annual Operation (h)	EFC (hah^{-1})	Area coverage ($haYr^{-1}$)
Star rotary weeder	845.00	450.00	5	160	0.02	3.2
Rotary weeder	1518.00	500.00	6	160	0.037	5.92
Finger-push weeder	619.00	300.00	6	160	0.027	4.32
Push weeder	485.00	235.00	6	160	0.018	2.88
Hand weeding	ND	ND	ND	160	0.0079	1.26

ETB = Ethiopian Birr, ND= Not defined, ha = hectare, Yr = Year, h= hour

The system for evaluating and comparing weeding cost in various mechanical hand weeders and hand weeding method are shown in Table 3. Yearly operation of the weeders was determined for 160h based on 20 days actual annual use in rice paddy field and daily 8 h useful operation. However, hand weeding method was costly (7100 $ETBha^{-1}$) compared to mechanical hand weeders followed by push weeder which costs (5399 $ETBha^{-1}$). Among the mechanical weeders the highest fixed cost accounted 486.4 $ETBha^{-1}$ from rotary weeder whereas the least cost 148.8 $ETBha^{-1}$ was pertained from the push weeder. The average number of labors for each mechanical weeders was varied due to the flexibility and efficiency of weeders but the daily operational labor cost (150 ETB) for all types of weeders. The conventional hand weeding requires 142 $manha^{-1}$ and costs 50 ETB per day. Among the mechanical weeders the least cost 3487 $ETBha^{-1}$ went to for the use of rotary weeder whereas the highest cost 5399 $ETBha^{-1}$ incurred for the use of push weeder followed by star rotary weeder (4787 $ETBha^{-1}$) and 3953 $ETBha^{-1}$ for finger-push weeder. Based on the results obtained in this study, weeding cost incurred by using push weeder, star rotary weeder, finger-push weeder and rotary weeder was reduced by 17%, 23.1%, 31.5% and 36.1% respectively, as compared to the conventional hand weeding.

Table 3. *Weeding cost to different mechanical hand weeders.*

Type of Weeder	Fixed cost ($ETBha^{-1}$)	No of labor ($manha^{-1}$)	Labor cost (ETB/day)	Variable cost ($ETBha^{-1}$)	Total cost ($ETBha^{-1}$)	Cost Reduction compared to hand weeding (%)
Star rotary weeder	286.4	30	150	4500	4787	23.1%
Rotary weeder	486.4	20	150	3000	3487	36.1%
Finger-push weeder	203.2	25	150	3750	3953	31.5%
Push weeder	148.8	35	150	5250	5399	17.0%
Hand weeding	ND	142	50	7100	7100	Base

ETB= Ethiopian Birr, ND= Not defined, ha= hectare

4. Conclusions and Recommendation

Mechanically controlling of weed has multi advantages other than removing weeds such as soften superficial soil and improve aeration in the crop root zone. Among the tested weeders, the highest weeding efficiency was found from the rotary weeder on clay soil texture with the available ponded water followed by finger-push weeder. In the participatory testing of mechanical hand weeders, rotary and finger-push weeders were selected by small-scale rice producing men and women farmers based on their weeding efficiency, cost operation and flexibility to use respectively. The weeder efficiency relied on weed species, weeder type, availability of water, soil type, crop establishment method and crop growth stage. Sundry mechanical weeders offered to farmers based on water regimes, weed pressure level and crop stages. water status and weed infestation level in the testing sites were the characteristics identified for explaining changes in farmers' preferences for the mechanical hand weeders.

In rice paddy field, the labor requirement varies depending up on the intensity and species of weed. Rotary weeder and finger push weeders were very effective weeding technologies in the clay soil and ponded water level for aquatic weeds and grasses in the testing sites. Among the mechanical hand weeders rotary weeder was found the highest weeding area coverage than the rest of weeders per hectare. The least cost but high-cost reduction from the mechanical weeders were found from the rotary weeder while the highest cost and minimum cost reduction were gained from the push mechanical weeder.

Based on the results of the present study the use of mechanical hand weeders can improve the benefit from rice production compared to the use of conventional hand weeding method. Mechanical hand weeders offer effective approach for weed management, particularly for small-scale rice farmers and enables to minimize labor cost and effectively toil for aquatic weeds in particular. Rotary weeder presents the lowest total weeding cost whereas push weeder accompanying the highest weeding cost. Enhanced effective filled capacity and weeding efficiency was obtained by rotary and finger-push weeders which can be recommended for the study area and similar agroecology's.

However, mechanical hand weeders should be improved based on nature of the crop, planting space, weed type and species and growth stage to enhance their flexibility (ease of operation) and adoption.

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