International Journal of Agriculture, Environment and Biotechnology
Citation: IJAEB: 10(2): 217-221, April 2017
DOI: 10.5958/2230-732X.2017.00025.0

AGRICULTURAL ENGINEERING

Development and Evaluation of Mechanical Weeder for Finger Millet Crop

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Paper No. 570 Received: 24-10-2016 Accepted: 23-3-2017

ABSTRACT

Finger millet (*Eleusine coracana)* is a main field crop in southern part of Karnataka commonly called ragi as it provides both stable food for the region and good fodder for cattles. Weeds management is a major problem in finger millet crop and are responsible for drastic reduction of yield. Weeding by traditional methods are laborious and time consuming which leads to high cost of production. Pertaining to this, blade type simple mechanical weeder was developed and evaluated under finger millet crop with 2 and 4 blade harrows for weeding 2 and 4 rows at a time respectively. The results obtained at 2 rows and 4 rows weeding condition, the weeding efficiency (88 & 85 %), plant damage (2.5 & 3.6 %), effective field capacity (0.108 & 0.144 ha/h), field efficiency (90 & 60 %), fuel consumption (4.181 & 3.424 L/ha) and cost of weeding (₹ 572 & ₹ 447.42 ha) respectively.

Highlights

- Mechanical weeding of finger millet crop improves production and productivity as well by ensuring the effective and timeliness weeding with minimum crop damage (2 to 3.5 %).
- Use of multi row mechanical weeder is a superior alternative to the manual weeding of finger millet crop as it requires only about one third of cost of manual weeding.

Keywords: Development, evaluation, finger millet, mechanical weeder, ragi, weeder

Agriculture is the backbone of Indian economy. One of the major reasons for decreased productivity of agricultural field crops in the country is due to lack of mechanization from sowing to harvesting especially at critical stages *viz*., weeding and intercultural operations. Weed is an everyday term usually to describe a plant considered undesirable (Gavali and Kulkarni, 2014). The losses caused by weeds exceed the losses caused by any other category of agricultural pests. In India about ₹ 4200 million is being lost in the form of nutrients loss annually due to weeds. An average of one third of the cost of cultivation (i.e. ₹ 945 per ha) is being incurred on weeding out of the total cost of cultivation of ₹ 3000 per ha for agriculture crops. Weeds may be unwanted for a number of reasons; an important one is that they interfere with food and fodder production in agriculture, wherein they must be controlled in order to prevent lost or diminished crop yields (Gavali and Kulkarni, 2014). Weeding can be done by manual, chemical and mechanical methods. Due to high time consumption, less work capacity and tediousness, the chemical and mechanical weed control methods are viable alternatives to manual weeding. However, expensiveness, selectiveness and environmental impact of herbicides made chemical method unsustainable for weeding (Mayande *et al*., 2004, Olukunle and Oguntunde, 2006 and Ratnaweera *et al*., 2010).

Introduction of an effective mechanical weeder is expected to encourage subsistent farmers leading to increased production and hence reducing poverty (Olukunle and Oguntunde, 2006). Mechanical weed control is effective in controlling weeds as well as it benefits the crop by breaking up the surface crust, aeration of soil, stimulating the activity of soil microflora, reducing the evaporation of soil moisture and facilitating the infiltration of rainwater (Ratnaweera *et al*., 2010 and Hegazy *et al*., 2014). In developed countries, multi purpose machines have been developed and successfully implemented for weeding and intercultural operations. Use of such machines in the Indian agricultural scenario is difficult as most the Indian farmers are small scale farmers as area under their control is small. Mechanical weeders range from basic hand tools to sophisticated tractor driven or self-propelled devices (Gavali and Kulkarni, 2014).

Finger millet (*Eleusine coracana*) is an annual herbaceous plant, originated in East Africa (Ethiopian and Ugandan highlands) and came to India (Hallur region of Karnataka) around 2000 BCE, widely grown as a cereal crop in the arid and semiarid areas in Africa and Asia (Anon., 2015). The production, productivity and area under finger millet in India during 2011-12 was recorded as 1.1758 million tons, 1641 kg/ha and 1.9292 million ha respectively. Among the major finger millet growing states in India, Karnataka occupies 57.83 % of total grown area with a share of 65.93 % to the total production (Anon., 2016). Weeds are the major biotic stresses for finger millet cultivation. Its seeds are very small, which leads to a relatively slow development in early growing stages and makes finger millet a weak competitor for light, water and nutrients compared with weeds (Anon., 2015). The row cropping of finger millets farming is currently practiced in southern part of Karnataka. Weeds grown between the rows arises very serious issues as it leads to lower productivity. Hence there is a need to introduce a mechanical weeder to overcome from above issues. The objective of this paper is to develop and evaluate the simple blade type multi row mechanical weeder as an attachment to the customised propelled IC engine [single cylinder, 3 hp dual powered (petrol start kerosene engine) and pegged wheels] under finger millet crop field.

MATERIALS AND METHODS

The development of mechanical blade type row crop weeder for finger millet crop was carried out in the department of agricultural engineering, university of agricultural sciences, GKVK, Bangalore. The performance of the developed weeder was evaluated in the university farm where the soils of the site belong to the red sandy loam with good moisture retention and infiltration rate. The main aim of the developed weeder was to remove or uproot the weeds without or with very negligible crop damage and with least cost of weeding operation.

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, etc. The blades of the weeder were made from cast iron and all other components were made from mild steel. The main components of the weeder were shown in Fig. 1 and 2. The specification of the developed mechanical weeder is given in Table 1.

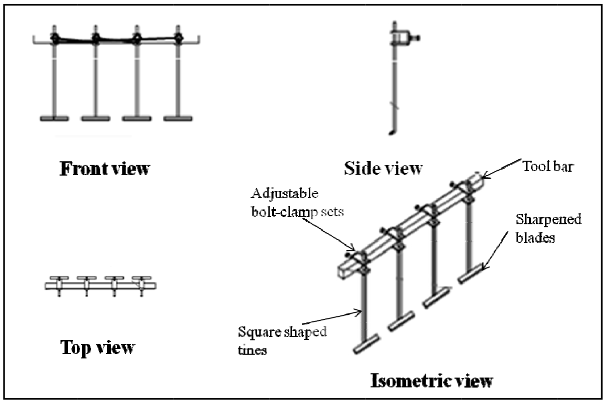

Fig. 1: Schematic diagram of the developed mechanical weeder

Fig. 2: Dissembled (left) and assembled view (right) of mechanical weeder

Table 1: Specifications of developed mechanical weeder

Sl. No.	Components	Description/ Dimension	Construction material
1	Power source	3 hp petrol start kerosene IC engine	—
3	Tines	Square rod (2×2 cm) of 50 cm length	Mild steel
4	Blades	Flat of 20 cm length, 3 cm width 0.4 cm thickness (sharpened at cutting edge)	Cast iron
5	Tool bar	Square hollow pipe (5 cm × 5 cm) of 0.5 cm thickness and 120 cm length	Mild steel
6	Bolt-clamp set	U-shaped clamps having dimensions as same as tool bar with bolting arrangement for adjusting depth and width of weeding by moving tines accordingly	Mild steel

The parameters recorded before weeding operation were the crop parameters (plants height and row to row spacing) and field parameters [type of soil, moisture content (MC), bulk density (BD) and cone index (soil strength) of soil and length and width of the field]. The plants height was recorded by measuring the height of the crop randomly in the field. Row to row spacing and length and width of the field were measured directly by using standard measuring tape. The soil was sampled (core sampled increase of BD measurement) randomly at different places within the experiment field to determine the MC and BD of the soil. Gravimetric method was used for moisture determination and weight by volume method was used for bulk density measurement. The cone penetrormeter method was used to determine the cone index (soil strength) of the soil. The following formulae were used to determine the MC, BD and cone index of the soil respectively.

$$MC = \frac{w_1 - w_2}{w_1} \times 100 \qquad \ldots(1)$$

$$BD = \frac{m}{v} \qquad \ldots(2)$$

$$CI = \frac{F}{A} \qquad \ldots(3)$$

Where,

MC= moisture content in wet basis, %

W_1 = weight of the wet sample, g

W_2 = weight of the oven dry sample, g

BD = bulk density of soil, g/cm^3

m = weight of core sampled soil after laboratory drying, g

V = volume of cylinder core, cm^3

CI = cone index, kg/cm^2

F = force applied detected in penetrormeter, kg

A = area of cone base, cm^2

The performance of weeder attached to the single cylinder IC engine (3 hp petrol start kerosene engine) was evaluated under the finger millet field (4 weeks after sowing) at two operating conditions (two and four row weeding condition) to determine their effects on weeding efficiency, plant damage, effective field capacity, field efficiency, fuel consumption and cost economics of weeding operation. The forward speed of mechanical weeder at weeding was maintained constant by placing the acceleration throttle knob to its full range (forward speed of weeder at no load condition was recorded as 2 km/h at acceleration throttle in full range).

The weeding efficiency and plant damage in per cent were calculated by using formulae given below (Goel *et al.*, 2008, Gavali and Kulkarni, 2014, Kumar *et al.*, 2014).

$$WE = \frac{n_1 - n_2}{n_1} \times 100 \qquad \ldots(4)$$

$$PD = \frac{Q_1}{Q_2} \times 100 \qquad \ldots(5)$$

Where,

WE = weeding efficiency, %

n_1 = number of weeds before weeding

n_2 = number of weeds after weeding

PD = plant damage, %

Q_1 = number of injured plant in 10 m row length after weeding

Q_2 = total number of plant in 10 m row length before weeding

The effective field capacity, field efficiency and fuel consumption of the mechanical weeder were determined by using following formulae (Alizadeh, 2011, Silas and Abu, 2015 and Hossen *et al.*, 2015).

$$EFC = \frac{\text{area covered (ha)}}{\text{time taken (h)}} \quad \ldots(6)$$

$$\eta = \frac{\text{effective field capacity}}{\text{theoritical field capacity}} \times 100 \quad \ldots(7)$$

$$F_C = \frac{\text{fuel consumed while weeding (L)}}{\text{area covered (ha)}} \quad \ldots(8)$$

Where,

EFC = effective filed capacity, ha/h

η = field efficiency, %

F_c = fuel consumption, L/ha

The cost of weeding operation was calculated by using standard procedure. The necessary assumptions were made (which includes bill of material used for development of weeder, fixed and operational cost of engine, labour cost and fuel cost) wherever it felt essential to analyze cost of weeding operation.

RESULTS AND DISCUSSION

The parameters recorded before actual mechanical weeding is presented in the Table 2. The results obtained from performance evaluation of the mechanical weeder under two row weeding and four row weeding condition are presented in Table 3 and discussed below. The forward speed achieved under full acceleration at 2 rows and 4 rows weeding operation were recorded as 1.8 km/h and 1.2 km/h respectively. The maximum speed of the engine at no load condition with full acceleration was recorded as 2 km/h. The theoretical field capacity of the mechanical weeder were 0.12 and 0.24 ha/h respectively at forward speed of 2 km/h for 2 rows and 4 rows (60 cm and 120 cm width respectively) of weeding. The depth of 4 to 6 cm and width of 20 cm per blade were observed and recorded for both 2 and 4 rows of mechanical weeding.

It was observed from Table 3 that the weeding efficiency was highest for 2 rows weeding condition accounting about 88% with less plant damage (accounting about 2.5%) as compared to 4 rows weeding which has high plant damage and less weeding efficiency (of about 3.6 % and 85 % respectively).

Table 2: Parameter recorded before mechanical weeding operation

Sl. No.	Parameter	
1	Type of soil	Red sandy loam
2	Moisture content of soil, %	15.6
3	Bulk density of soil, g/cm^3	1.42
4	Cone index of soil, kg/cm^2	2.65
5	Plant height, cm	18
6	Row to row spacing, cm	30
7	Length and width of field, m	30 × 20

Note: *All values in the table are average of four replications*

The reason behind this lower weeding efficiency and higher plant damage under 4 rows weeding condition may be due to instability of operator that caused by heavy load on weeder which made operator incapable to handle the weeder firmly. The similar trend was also reported by Srinivas *et al*. (2010), Kumar *et al*. (2014) and Hossen *et al*. (2015) for blade type mechanical weeder.

Table 3: Results obtained from performance evaluation of mechanical weeding

Sl. No.	Parameters	Weeding condition	
		2 rows weeding	4 rows weeding
1	Weeding efficiency, %	88	85
2	Plant damage, %	2.5	3.6
3	Effective field capacity, ha/h	0.108	0.144
4	Field efficiency, %	90	60
5	Fuel consumption, L/ha	4.181	3.424
6	Cost of weeding, Rs/ha	572	447.42

Note: *All values in the table are average of four replications*

The effective field capacity was found highest for 4 rows weeding but as shown in Table 3, the field efficiency, fuel consumption, and cost of operation were found highest for 2 rows weeding. The reason for this higher field capacity, less fuel consumption and less cost of operation of 4 rows weeding was that the number of rows weeded in a single pass was just double the number of rows weeded in 2 rows weeding condition. The reason behind least field efficiency under 4 rows weeding as compared to 2 rows weeding was may be that the wheel slip occurred due to heavy load and excessive time lost during turning at the end of the field. The results of field capacity, field efficiency and fuel consumption were matched with results of Srinivas *et al*. (2010), Hegazy *et al*. (2014), Kumar *et al*. (2014) and Hossen *et al*. (2015).

It found from Table 3 that the cost of weeding was highest for 2 rows weeding as compared to 4 rows weeding. The time required and fuel consumption per unit area for weeding was higher for 2 rows weeding has compared to 4 rows weeding. As a result, cost of weeding was found higher for 2 rows weeding. The results of cost of weeding found similar to results of Srinivas *et al*. (2010) and Hossen *et al*. (2015). The essential assumptions made for calculation of cost of weeding were total fixed cost of weeder, cost of fuel (kerosene *i.e*., ₹ 40/L) and operator cost (₹ 25/h).

CONCLUSION

It can be concluded that the 4 rows, blade type mechanical weeder can be recommended for weeding in finger millet crop as it is useful in weeding up to plant height of 30 cm and has higher field capacity, lower cost of weeding with weeding efficiency and plant damage of 85 and 3.6% respectively, which are comparable to the conventional weeding operation.

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