GAU Research Journal 46(4) : 89-95 (October 2021)

Performance Evaluation of Battery-Operated Power Weeder

SHEKHAR PANDEY[1]*, G. S. TIWARI[2], AND AJAY KUMAR SHARMA[3]

[1,2,3]Department of Farm Machinery & Power Engineering, College of Technology and Engineering, MPUAT, Udaipur-313001, India

*email: pandeyhs13@gmail.com

Received: 21 March, 2022 **Accept:** 01 June, 2022

Abstract

The mechanical weed management systems hold promise toward reducing the drudging task of hand weeding. A battery-operated power weeder was evaluated in soybean crop for V-type and straight blade. The average weeding efficiency, field capacity, field efficiency, percentage plant damage, and performance index of V-type blade were found 91.42 %, %, 0.051 ha/h, 90.73 %, 2.37 % and 2496.30, whereas straight blade 86.78 %, 0.048 ha/h, 88.50 %, 3.55 %, and 1497.04 respectively at the operating speed of 2-3 km/h. The average power consumption of V-type blade and straight blade was found to be 185.6 and 262.5 W. The average draft force 269 and 391 were observed with V-type and straight blades. The performance of the V-blade was found better over the straight blade. The overall performance of the developed machine was found satisfactory for small farmers.

Keywords: Battery, power weeder, performance, evaluation, soybean

INTRODUCTION:

Manual weeding is the most efficient method of weed management, but its use has reduced due to a labour shortage and increasing labour costs. Mechanical weeding is preferred over the chemical method because weedicides are expensive and harmful to the environment (Biswas, 1984). Weeding removes weeds that consuming key-resources such as soil, water, minerals, and sunlight and affect crop yield (Yadav, and Pund, 2007). The negligence and delay in weeding activity reduce yield by 40-60 percent (Singh, G. 1988). Mechanized weeding allows farmers to reduce weeding costs, aerate the soil, and protect the environment by minimizing the use of herbicides. The shortage of farm labours during peak season reduces the crop yield (Singh, M.U., 2017). The high levels of vibration exposure in existing power weeders add to the operators' drudgery and can cause dynamic health disorders (Heidary, *et al.,* 2014).

The crop grown by small farmers and the area of this category of farms is very less which does not allow the use of large machines due to size and shape of the field (Mehta, *et al.* 2019). Traditional tools and equipment are in practice due to a lack of improved tools, which may have higher working efficiency. The mechanized weeding in small farms is not practiced well, options available for the weeding operation to increase productivity are only small tools and equipment (Alam A., 2007). The eco-friendly technology and alternate power source are the identified mechanization gap for the small farms. The power requirement can be reduced if the major load is shared with a power source which will enhance the machine performance and operator's productivity (Singh, *et al.,* 2019). The application of electric battery vehicles for light agricultural work can convert about 75% of potential chemical energy to mechanical energy (Mousazadeh, *et al.,* 2009). This technology can be used particularly for such field operations which are considered as light draft requirements such as sowing, weeding at low depth and spraying. Thus a battery-operated weeder was developed for small farms.

MATERIALS AND METHODOLOGY

The field performance evaluation of the weeder was carried out at Instructional Farm of College of Technology and Engineering, MPUAT, Udaipur during 2019-20. The battery, DC motor with speed controller, drive wheel, weeding mechanism, main frame and handle are the principal components of the developed machine. The developed weeder was operated in walk-behind mode, this enabled the operator to ease in operation during weeding operation

(Fig. 1). The battery-operated weeding machine's detailed specifications are described in Table 1.



Fig. 1. Figure showing battery- operated weeder (1) DC motor (2) motor controller (3) battery (4) drive wheel (5) weeding drum (6) weeding tools, V-type and straight blade (7) key switch (8)TPS (9) energy meter (10) battery charge-level indicator (11) brake (12) transport wheels

Power source: DC motors are suitable for agricultural operations because the motor can deliver more torque. In DC motors, rpm, current, voltage, and torque are linearly related. (Hazari *et al.,* 2014 and Singh *et al, 2019*). A brush type DC motor of 350 W and 24 V was used. The speed of the motor is controlled by using a throttle positioning sensor which supplies corresponding throttle position voltage to the motor controller. Two 12-V, 24-Ah lead-acid batteries were in series connection to get the required output voltage. A safety switch with a key lock was provided to on-off the machine during weeding operation. The current, voltage, and power consumption were measured by using an energy-meter during field operation.

Power transmission system: The chain sprocket drive was selected for transmission of power from the motor to the drive wheel shaft. The driving and driven sprockets were apart by 350 mm. To get a speed ratio of 5.61, a small sprocket with 12 teeth for the motor shaft and 48 teeth for the drive wheel shaft was provided based on the operational speed of the drive wheel system. The size of the wheel was kept larger 300 × 50 mm with pegs for getting better traction during weeding operation.

Weeding mechanism: The weedding mechanism is a combination of a drum and a tool. The weeding drum is expected to perform two functions simultaneously shear-off the soil into the small segment as well as partial weeding. The drum blade has a conical shape that shears off the soil and provides traction power for forward motion. Moreover, the weeding drum provides stability as well as maintains the uniform depth of operation. Behind the drum, a tool (V-blade/straight blade) penetrates the soil and cuts the weeds. The width of the weeding tool was less than the crop row spacing to avoid any damage to the crops while operating. The weeding tools are shown in Fig. 2.

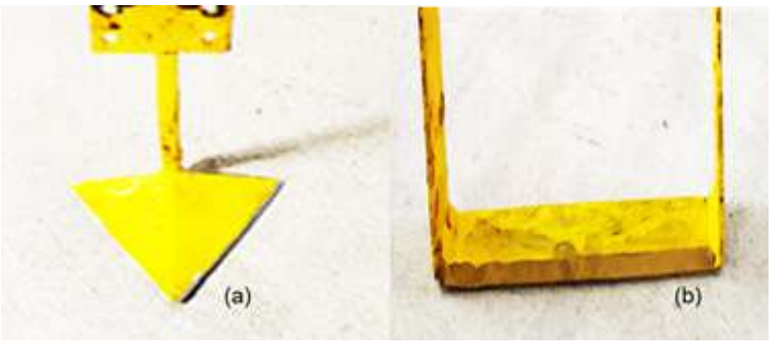

Fig. 2 Weeding blades (a) V type blade and (b) straight blade

Main frame: The main frame provides support for the DC motor, batteries, transmission system, drive wheels, weeding drum and tool, and handle. Two MS flats, each 700 × 50 × 8 mm were used to fabricate the mainframe for the machine. A T-type handle was used for the development of the weeder (Singh *et al.* 2017). The length of the handle was based on the average standing elbow height of male and female operators. So to accommodate 5 to 95% of the operator's two standard MS rectangular conduit pipes 600 × 20 mm were used to fabricate the handle. The handle's operating height can be adjusted from 95 to 105 cm from the ground. A 35 mm outer diameter, 600 mm long plastic handgrip was provided for easy grip and handling of the weeder. Handle height and length were made adjustable to the operator's comfort.

Table. 1. Specifications of battery-operated power weeder

Particulars	Details
Overall dimensions, (l × w × h), mm	765 × 250 × 950
Weight, kg	45
Size of the drive wheel (diameter × width), mm	300 × 50
Handle dimension (l × w), mm	1180 × 200
Size of T- type grip of the handle, (l × dia), mm	20 × 600
Size of weeding drum (total dia × l), mm	245 × 200
No. of blades on the drum	10
Number of weeding tool	1
Cutting width, mm	180
Maximum weeding depth, mm	35
DC motor and controller	350 W, 24 V,
Batteries	2, 12-V, 24 Ah
Energy meter	6.5-100 V, 0-2 kW
Throttle position sensor	0- 4 A, 0-24 V
Transport wheel	2

Field evaluation of machine

The field testing was carried out in soybean crops when the crop was 21-25 days old and the field was infested with the weeds. The main field was divided into six sub-plots each of size 30 m × 10 m. The experiments were laid-out in complete randomized design and three replications of each type of weeding tool. The soil and crop parameters such as soil type, soil moisture content, cone index, bulk density, row spacing, plant height, plant canopy width, weed height were measured at various locations before the experiments. The developed prototype was operated at the forward speed of 2-3

km/h. The different parameters such as power consumption, field capacity, field efficiency, weeding efficiency, percentage plant damage, and performance index were determined.

Weeding efficiency: The number of weeds before and after the weeding operations was counted and the average values were used to determine the weeding efficiency (Yadav and Pund, 2007).

$WE = (N_1 - N_2)/N_2 \times 100$

Where, WE= weeding efficiency of the weeder (%), N_1= number of weeds before weeding operation, and N_2 = the number of weeds after weeding operation.

Percentage plant damage: The percentage of damaged plants, as a quality of work done, is determined (Singh, M.U. 2017).

$D_P = [1- (Q_D/Q_P)] \times 100$

Where, D_P = percentage of plant damage, Q_D = number of plants in 10-meter row length after weeding, and Q_P = number of plants in 10 m row length before weeding.

Field capacity and efficiency: Field capacity (FC) and field efficiency (FE) were determined (Hunt, 1995 and Singh S. 2007).

$$FC = A/ (Tp+Tn)$$

$Ef = (EFC/TFC) \times 100$

Where, FC = field capacity (ha/h), TFC = theoretical field capacity, FE= field efficiency of weeder (%), Tp and Tn productive time, and non-productive time. Total working time includes effective time, time lost for turning, and minor adjustment, rest time.

Power and draft requirement: The draft force of the weeder calculated by measured power and forward speed as follows (Yadav and Pund 2007)

P (kW) = Draft force N/1000 × Speed (m/s)

Performance index: It indicates the overall performance of weeder. Field performance of weeding tools was assessed calculating the performance index as suggested by (Gupta 1981)

$PI = FC [100 – D_P] WE /P$

Where, FC= field capacity (ha/h), D_P=percentage plant damage (%), WE= weeding efficiency (%) and P = power input, W

RESULTS AND DISCUSSION

The experiment was carried out in sandy loam soil. The average soil moisture content, bulk density, and cone index were found as 15.8 % (db), 1.56 g/cc, and 439 KPa respectively. The average plant height, canopy width of plant, plant population, weed count, and weed height were recorded 156 mm, 126 mm, 69, 150, and 95 mm respectively (Table. 2). The developed prototype was operated in crop rows and maintained a safety-zone (distance between the tool edge of the weeder to the crop stem) of about 6 cm to avoid plant damage.

Table 2. Soil and crop parameters of experimental field

Parameters	Value
Crop	Soybean
Type of soil	Sandy loam
Moisture content of soil, % d.b	15.80
Bulk density, g/cc (d.b)	1.56
Cone Index, (KPa)	439
Row spacing, mm	300
No. of plants/m^2	69
Height of plants, mm	156
Plant canopy width, mm	126
Weed count/m^2	150
Weed height, mm	95

Field performance of the weeder

Based on the data, It was observed that the DC motor can take a minimum current of 1.66 A at no load, whereas the consumption of current goes up to 17.08 A during load. The output current characteristics corresponding to the power consumption showed the linear characteristics in load and no-load conditions. In no-load condition, the current drawn and power consumption recorded 1.66-3.89 A and 41.5 to 100.7 W with an average of 2.57 A and 65.29 W. The current drawn and power consumption during field operation of weeder with V-type blade varied from 4.24 to 12.42 A and 105.8 to 307.6 W, whereas with the straight blade it varied from 5.06 - 17.08 and 123.4 - 406.8 W. The average power consumption of V-type blade and straight blade was recorded at 185.62 and 262.53 W respectively. The current and power characteristics of the DC motor are presented in Fig. 3.

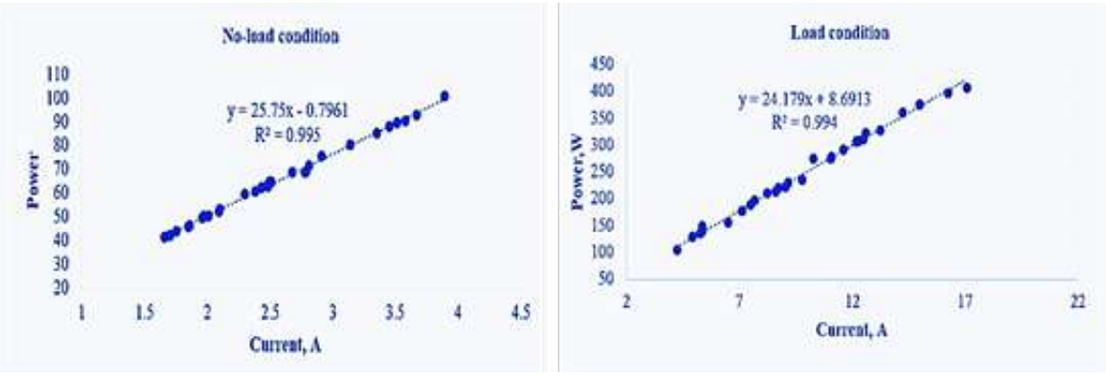

Fig. 3 Current and Power characteristics of the DC motor (No-load and load condition)

The average speed of operation was about 2-3 km/h. The variation in operating speeds were due to field and crop conditions. Weeding efficiency of weeder with V-type blade and straight blade varied from 89.39–93.95 % and 83.78- 90.46 % respectively. The variations in weeding efficiency were due to the undulating surface and the type of tool. The maximum draft force with straight and V-type blade was obtained 391.70 N and 269.50 N respectively. For V-type blades the average operating speed, depth of operation, field capacity, and field efficiency were observed as 2.81 km/h, 30 mm, and 0.051 ha/h, 90.73% respectively. The average weeding efficiency, percentage of plant damage, power consumption, and performance index was observed of 91.42 %, 2.37 %, 262.53 W, and 2496.30 respectively.

In the case of straight blades the average operating speed, depth of operation, field capacity, and field efficiency were observed as 2.66 km/h, 25 mm, 0.048 ha/h, and 88.50 respectively. The average weeding efficiency, percentage of plant damage, power consumption, and performance index was observed 86.78 %, 3.55 %, 185.6 W, and 1497.04 respectively. The weeder with V-type blade and straight blade required 19.60 and 20.83 man-hours per hectare respectively. The weeder field performance presented in Table 3.

Table 3 Field performance of weeding tools

Parameters	V- blade	Straight blade
Speed of operation, km/h	2-3	2-3
Depth of operation, mm	25-35	25-30
Actual field capacity, ha/h	0.051	0.048
Field efficiency,%	90.73	88.50
Labour requirement, man-h/ha	19.60	20.84
Weeding efficiency, %	91.42	86.78
Plant damage,%	2.37	3.55

Draft force, N	269.50	391.70
Power consumption, W	185.60	262.53
Current consumption, A	7.54	10.92
Performance Index	2496.30	1497.04
Labour requirement, man-h/ha	19.60	20.84

The weeder with V- type blade required minimum man-h as compared to the straight blade. During operation, the straight blade weeder tends to entangle with weeds which reduces its efficiency and increases the power consumption. The variations in field capacity were also reflected in-field efficiency which was due to operator, field condition, and moisture content of the soil. Due to use of a combination weeding mechanism (weeding drum and tool) , the possibility of weeds escaping in between the row is reduced and the weeding efficiency increases. The weeder with a V-type blade required minimum power input than a straight blade. However, the maximum performance index was observed for the V-type blade. The weeding efficiency and field capacity of this weeder was found better than the existing wheel hoe 0.022 ha/h, and 79.72% (Singh M.U., 2017 and Singh *et al.* 2016). The higher capacity of the machine due to the higher forward speed and less workload on the operator. The weeder operation in soybean field shown in Fig. 4



Fig 4 : Weeding operation by developed weeder in soybean crop

Battery run time: The battery run time decreased with an increase of current consumption 4-17 A at this load, the power requirement varied from 105 to 406 W. The developed weeding machine consumed 1.6 - 3.7 A during no-load condition while in weeding operation the average current required was 7-10 A. This will allow the developed prototype to run for about 2.5-3 h during weeding operation.

CONCLUSIONS

The developed battery-operated power weeder performed weeding activities with less drudgery and higher efficiency. The performance index was observed higher for V-type blades as compared to straight blades. The V-type blade gave better performance over straight blade with the weeding efficiency of 91.42% and field capacity of 0.051 ha/h at the speed of 2.88 km/h respectively. The average power and current requirement of weeder was obtained 185.60 W and 7.54 A. The man-h requirement of developed weeder is three times less as compared to existing wheel hoe. Weeding efficiency increases as the machine's forward speed increases. The tool type of weeder has a significant effect on the weeding efficiency, field capacity and power consumption. The higher forward speed of the machine is the key explanation for its better performance, as it reduces the operator's workload and minimises turning losses during the weeding operation. For the small size farms, the developed weeding machine found an appropriate technology.

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