

Development and evaluation of E-brush cutter for harvesting of pigeon pea crop

ABSTRACT

Aims: To develop a battery-operated variable speed electric brush cutter (E-brush cutter) for Indian farmers with small size landholdings to reduce the fuel consumption and ultimately the cost of cultivation.

Place and Duration of Study: ICAR-Central Research Institute for Dryland Agriculture, Hyderabad 500 059, India.

Methodology: The developed e-brush cutter consisted of one rotary blade as cutting unit, DC motor, gearhead, drive shaft, shoulder belt, handle assembly, motor controller, battery pack. The experiment was conducted to study the power requirement under control conditions and compare the performance of engine operated and e-brush cutter at field condition. The control parameter testing was carried out with developed E-brush cutter in the pigeon pea field. In controlled parameter study, cutting trials were conducted on three range of plant stem diameter (10-12, 17-19 and 24-26 mm), three ranges of cutting blade speed (46, 53, 60 m/s) and two ranges crop moisture content (47% and 37%). Further, comparative evaluation of both the brush cutters was conducted to find out average effective field capacity, cutting efficiency, grain loss, energy consumption.

Results: The average power requirement of e-brush cutter for harvesting pigeon pea irrespective of blade speed changes from 97.22-99.89, 134.22-158.11 and 151.67-184.11 W as moisture content reduces from 47% to 37% at stem diameter ranges from 10-12, 17-19 and 24-26 mm, respectively. Similarly, net power requirement varies from 21.89-24.56, 58.89-82.78 and 76.33 -108.78. Further, the average effective field capacity of 0.034 ha/h and 0.037, cutting efficiency of 95.66 % and 96.66% and grain loss of 1.47% and 1.55% was observed with engine operated brush cutter and e-brush cutter respectively at modified field condition. The energy consumption of 68.80 MJ/ha was recorded with developed electric brush cutter which is just 13% of engine operated brush cutter.

Conclusion: The performance evaluation and energy saving percentage revealed that adoption of electric brush cutter can be a technically feasible, energy efficient and eco-friendly.

Keywords: Electric brush cutter; battery; DC motor; power requirement; cutting efficiency

1. INTRODUCTION

Pigeon pea (*Cajanus cajan*) is an international good in most Asian and African countries. Globally, pigeon pea is grown in an area of 6.03 million hectares with a production of 5.33 million tonnes during 2022 [1]. In India, it is the second most important pulse crop next to chickpea, covering an area of around 4.9 million hectares, with a production of 5.32 million tonnes and a productivity of about 861 kg/ha[1]. The pigeon pea plant is tall, bushy, lodge-prone, and its stem is woody in nature. So, the harvesting of this crop involves drudgery and becomes time-consuming. It was estimated that the harvesting operation of crop consumes

about 25–30 percent of the total labour requirement of the crop production system. Further it also stated that total 176 man-hours per hectare were required to harvest pigeon pea crop [2]. At present, in India, this crop is harvested manually with a sickle, and after that, the crop is left in the field in the form of heaps for 7–10 days for sun drying. After sun drying, the crop is threshed with a suitable thresher [3].

The adoption of high level of mechanization leads to improved cropping intensity and productivity but incurs high fuel consumption. However, promotion of eco-friendly agricultural implements and machines is increasing with the aim of optimal-utilization of the available sources with a reduced drudgery level at various agricultural operations [4]. Eco-friendly technology and alternate power sources are the identified mechanization gaps for small farm mechanization[5]. In India, small and marginal farmers are the most vulnerable to climate change and price inflation. Hence, the development of electric energy-based, smaller equipment for harvesting the crop can help them to make agriculture sustainable in both ways, i.e., economically and environmentally. It is also stated that any modification that can increase fuel efficiency or that may cut down fuel consumption and reduce CO₂ emissions may result in reduction of energy consumption and environmental pollution, thereby contributing to cleaner production [6]. Presently, engine-operated brush cutters are well popular among farmers for various operations like paddy harvesting [7], grass cutting, etc. The brush cutter is mostly run with fossil fuels like petrol. However, depletion of fossil fuels, day-by-day increase in their price, and pollution are the main challenges in the use of fossil fuels [8]. Further it is stated that existing brush cutters suffer from high fuel consumption rates, a high level of engine noise, and high operator fatigue in the long run [9]. It is also reviewed from different test reports of brush cutters, weed trimming, wheat, and paddy harvesting, which consume 10–30 litres of petrol per hectare. It shows that there is a need to modify existing brush cutter with less noise, less vibration, and minimum or zero fuel consumption.

Many researchers are developing electric equipment for agricultural purposes. The recent scenario has increased the scope of battery technology for carrying out some agricultural activities like weeding, harvesting, etc. Further, it was observed that most battery-operated machinery has less noise and vibration compared to engine-based machinery. An electric vertical conveyor reaper for cereal crops was developed and tested for paddy harvesting [10]. The developed e-reaper did not produce any exhaust emission. Moreover, the noise and vibration were lower by 4.34% and 49.89%, respectively, when compared with an engine-operated reaper. The cost of operation was 63% less than the traditional method of harvesting. It also reviewed that the estimation of charging cost of battery per unit time was found to be generally lower than the cost incurred by the internal combustion engine type. Another battery-operated small-scale reaper was developed with standard cutter bar which cuts the crop by impact and shear action and useful for wheat and paddy [11]. Furthermore, a battery-powered brush cutter was developed to reduce vibration, noise, energy consumption, etc [12]. The developed brush cutter was tested in the laboratory for its performance, like voltage, current, speed, motor temperature, etc. It was observed that the proposed electric brush cutter would be very suitable for people who want to execute the cutting work at home, but a field study was not conducted for any crop[12]. Further, the operation parameters of tangential axial flow type combine harvester was optimized for mechanized harvesting of pigeon pea in sole cropping [3]. Pigeon pea crop is widely planted as intercropping crops with legumes, cereals, oilseed crops, etc. which restricts the efficient use of combine harvester at some extent. Hence, manual harvesting of pigeon pea is still being practiced by farmers. Moreover, it was observed that in a remote place with low acreage, the service providers of the combine harvester are not ready to give their service because of the high transportation charge or to compensate that they demand more money. By considering all the facts and figures mentioned above, there is a need to bring partial mechanization that can be adopted by small farmers, so that developed intervention will reduce the labour requirement, energy requirement, and drudgery. Therefore, it was decided to develop a

battery-operated variable speed electric brush cutter (E-brush cutter) for Indian farmers with small landholdings to reduce fuel consumption and the cost of cultivation and enable farmers to harvest pigeon pea crop in time.

2. MATERIAL AND METHODS

The proposed E-brush cutter was developed and fabricated in research workshop and performance evaluation was carried out in the pigeon pea field of ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India. The details of development of prototype, components, specifications, experimental design, etc. were given below;

2.1 Development of E-Brush Cutter Prototype

The commercially available brush cutters are petrol engine operated, useful for most of plant cutting operations carried out in agricultural fields, thus prevalent among the Indian farmer. To develop battery operated brush cutter, engine of commercially available brush cutter was replaced with compact DC motor and necessary fitments were developed.

2.1.1 Development of Fitments

A circular plate was developed to fix with motor hub with mounting bracket of brush cutter. The developed circular plate was 70 mm in diameter and 3 mm thickness. A 10 mm diameter hole was formed at the centre of plate for motor shaft. Further, three equidistant holes were formed on the plate to tighten the motor hub with plate. Further, additional equidistant four holes were created on circular plate to tighten the mounting bracket with circular plate at distance of 40 mm from centre. A splined connector was developed to connect and transmit the power from motor shaft to drive shaft of the brush cutter.

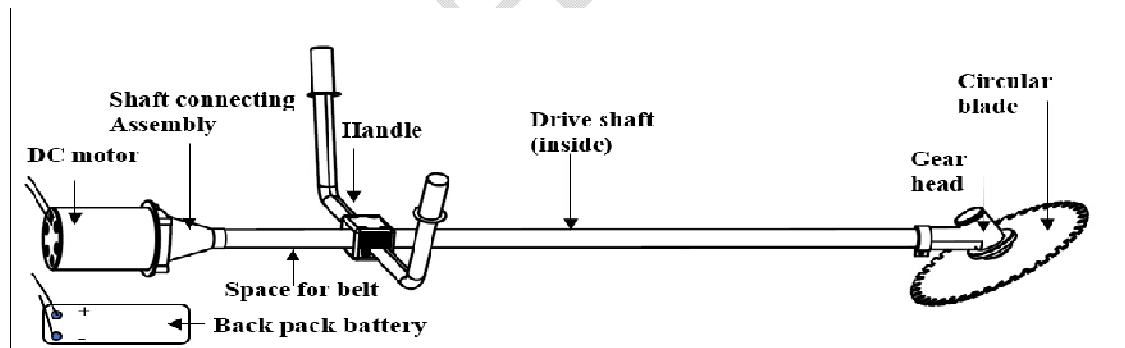


Fig. 1. Parts in E-brush cutter

2.1.2 Dynamic Balancing of E-brush Cutter

Dynamic balancing of developed E-brush cutter is necessary because in this developed prototype, engine was replaced by low weight DC motor. So, balance of developed brush cutter was disturbed. The methodology for dynamic balancing of engine operated brush cutter is available [7]. The same methodology in reverse manner was followed for dynamic balancing of developed E-brush cutter. Therefore, to maintain the balance of machine, the point on hollow shaft where handle was fixed was considered as centre of mass. Details of weight distribution as given below.

M_1 = Weight of circular blade, M_1 = 330 grams
 M_2 = Weight of gear head, M_2 = 430 grams
 M_3 = Weight of guider, M_3 = Nil
 M_4 = Weight of DC Motor including all fittings, M_4 = 2000 grams
 M_5 = Weight of shaft with pipe between gear case and handle, M_5 = 1363 grams
 M_6 = Weight of shaft with pipe between motor and handle, M_6 = 781 grams
 W_1 =Maximum weight of attachment can be added towards motor side
 L_1 = Length of rod between motor and handle (630mm)
 L_2 = Length of rod between gear case and handle (960 mm)
 W_2 = Weight of attachments on gear case side = $M_1+M_2+M_3+M_5=2123$ grams
 $W_1=?$

$$W_1 \times L_1 = W_2 \times L_2$$

$$W_1 \times 630 = 2123 \times 960$$

$$W_1 = 3369 \text{ grams}$$

Therefore, maximum weight of attachments required for balancing, $W_1=3369$ grams

W = Weight already added towards motor side.

W = Weight of DC Motor including all fittings + Weight of shaft with pipe between motor and handle.

$$W = 2000 + 781 = 2781 \text{ grams}$$

$$\text{Difference of weight, } W_D = 3369 - 2781 = 589 \text{ grams}$$

It was calculated that there was a 589-gram weight difference. It implies that it can be added for balance towards the motor side. However, it has been noted that adding more weight may make the brush cutter heavier overall. Moreover, this weight differential is minimal and can be adjusted with a high-quality harnessing belt. In another sense, the modified E-brush cutter's design was safe since the mass of the attachments added to the motor side was less than the mass that could be added to the gear case. Additionally, difference in weight, W_D (589 grams) may provide kinetic energy during impact, improving cutting efficiency. Consequently, using this design has the added benefit of reducing the weight of brush cutter ergonomically.

2.1.3 Selection of DC Motor and Battery

In conventional brush cutters, cutting blade is generally driven by an internal combustion, two or four stroke engine through a steel shaft. In the newly developed prototype, engine of brush cutter is replaced with permanent-magnet DC motor. It is compact in size, lower in weight and affordable in price. Permanent-magnet DC motor produces constant magnetic intensity which helps in maintaining controlled/constant rotational speed of the brush cutter blades. Moreover, speed of DC motor can also be controlled easily with speed controller without any complexity [12]. Therefore, by considering the advantages of DC motor, it was adopted as the driven motor in E brush cutter. E-brush cutter was developed with 120 W DC permanent magnet motor weighing 1.5 kg. A lithium-ion rechargeable battery of 12 V and 18 AHS was used as power source.

2.1.4 Motor Controller

A Motor controller consists of micro-controller, resistors, sensors, pulse width modulation (PWM) generator circuit, MOSFET, signal acquisition and processing circuit, over-current and under-voltage protection circuit etc. PWM generator which gives voltage from 12 to 24 volt was used in developed prototype to control the rotational speed of cutting blade. It gives provision to operate E-brush cutter with variable speed.

2.1.5 Drive Shaft Assembly

The developed E-brush cutter consists of a splined steel shaft with a length of 150 cm and a diameter of 8 mm covered by an aluminium hollow sleeve. One end of shaft was connected to DC motor using specially developed splined connector and other end was connected to the cutting head through bevel gear (1:1.5). A plate was fabricated to attach the motor with shaft assembly.

2.1.6 Cutting Head Assembly

Cutting head has multi tool system with different types of attachments like Nylon feed head, circular saw blade etc. This cutting head consisted of two bevel gears fixed at oblique angle with a small bearing. One bevel gear was attached at the end of splined shaft as mentioned earlier and another bevel gear was attached to the cutting blade. The shaft angle in bevel gear, was fixed in such a way that when the machine is carried on shoulder with cutter shaft would be in a plane parallel to the ground.

2.2 Experimental Design

The study was carried out in two parts i.e. (i) controlled field conditions to determine the various power requirements and, (ii) real field conditions for crop parameters and associated machine performance. In controlled field conditions, cutting trials were conducted on selected range of plant stem diameter, cutting blade speed and crop moisture content. The details of controlled field condition parameters are given in Table 1. Experimental field trials were conducted in RBD with three replications in the pigeon pea field (100 m² for each replication). Details of machine specifications and crop parameters are given in Table 3 and Table 4 respectively.

Table 1. Details of operational and performance parameters for control field condition

Independent variables	Levels	Details	Dependent variables
Moisture content of stem, %	2	47 (M1) and 37 (M2)	1. Power requirement, W (Watt)
Dia. of stem, mm	3	10-12 (D1), 17-19 (D2) and 24-26 (D3)	2. Net power requirement, W
Blade speed, m/s	3	46 (S1), 53 (S2) and 60(S3)	

Table 2. Details of operational and performance parameters for field experiment

Independent variables	Levels	Details	Dependent variables
Type of machine	2	1. Electric brushcutter	1. Effective field capacity, ha/h
		2. Engine brushcutter	2. Cutting efficiency, %
Crop condition	2	1. Regular, (R)	3. Grain loss, %
		2. Modified (M)	4. Energy consumption, MJ/ha

A field experiment was planned to compare the performance of newly developed prototype i.e. E-brush cutter with engine operated brush cutter at field level conditions. The details of independent variables and performance parameter are given in Table 2. In this experiment, performance of both the brush cutters were studied at two crop standing status i.e. (i) regular and modified status. The crop status is considered as independent variable based upon actual crop condition during the harvesting of pigeon pea crop. The regular status indicates the natural standing position of crop. Modified status which indicates sets of two crop rows by bending them towards each other.

2.2.1 Controlled Field Condition

2.2.1.1 Determination of Power Consumption Parameters

A high precision power, watt meter that may be compatible was connected in between the power source and E-brush cutter motor through a controller to measure the electric energy consumption (kWh) per unit area and power requirement (Watt). The peak power requirement was determined with various load conditions in terms of wattage by using watt meter. Further, net power requirement was calculated based on the difference between the power required to run the brush cutter with load and no load.

2.2.2 Variable Field Condition

2.2.2.1 Effective field Capacity, ha/h

The effective field capacity is the actual rate of coverage of field by the machine, based on the total field time taken. Both the machines were operated with almost fixed speed for a fixed time and the area covered during the period was measured to determine the average area covered per hour [13][7].

$$F_c = \frac{A}{T_o}$$

Where, F_c = Effective field capacity, ha/h, A =Area Covered, ha; T_o =Total Operating time, h

2.2.2.2 Cutting Efficiency, %

Cutting efficiency (Ce) was calculated based on the number of pigeon pea stems/plants got full cut in single impact in area 1 m² during the cutting operation[7].

$$Ec, \% = \frac{P1 - P2}{P1} \times 100$$

Where, P1 = No. of plants before operation per m² area; P2 = No. of plants got full cut in single impact per m² area; Ec= Cutting efficiency, %.

2.2.2.3 Grain Loss, %

The grain loss percentage was determined based on pre-harvest and post-harvest loss. It was determined based on samples collected from each treatment. The results were then expressed in the form of percentage of grain loss.

$$Grain\ loss, \% = \frac{(G_2 - G_1),\ kg/ha}{Yield,\ kg/ha} \times 100$$

where, G₂=losses during and after harvesting (kg/ha); G₁ = losses occur before harvesting (kg/ha)

2.2.2.4 Energy Consumption, MJ/ha

Energy consumption was calculated from actual energy input used i.e. electricity and petrol consumed for harvesting of 100m² pigeon area using electric brush cutter and engine operated brush cutter. Further, it was converted into MJ/ha by using standard energy equivalent i.e.11.93 and 48.23 MJ/unit for electricity and petrol respectively[14].

2.3 Statistical Data Analysis

All the recorded data were analysed separately for control field condition and variable field condition. The control field experiment was analysed with completely randomized block design and variable field was analysed with randomized block design at a 5% significance level. ANOVA was conducted to evaluate effect of stem diameter, blade speed and moisture content on power requirement and net power requirement. Further, two way analysis was done to study the effect of machine type and crop erectness under variable field condition. Details of performance parameter of both experiments are mentioned in Table 1 and Table 2.

Table 3: Detail specifications of Engine and Electric brush cutter

Particulars	Specification	
Machine type	Enginebrushcutter	Electric brushcutter
Weight, kg	9.1	4.90 (10.6 kg includingbattery)

Fuel/Battery capacity	0.65 lit	12 volt 18 Ah
Engine/Motor Type	Petrol operated	DC motor,
Power, watt	1500	120 (for experimental purpose)
Engine/Motor speed, rpm	6000	2700-4500 rpm, Variable
Length of shaft, m	1.5	1.5 m
Handle type	Bike style	Bike style
Harnessing belt	Single shoulder strap	Backpack style

Table 4: Field crop parameters

Crop Parameters	Details
Name of crop	Pigeon pea
Cropping system	Raised bed
Height of crop, cm	120
Crop density, plant/m ²	15
Row to row spacing on bed, cm	90
Row to row spacing near to furrow, cm	45
Plant to plant spacing, cm	15-30

Stem diameter, mm	10-30
Average number of pods per plant	200



Fig. 2. Harvesting of pigeon pea with electric brush cutter

3. RESULTS AND DISCUSSION

3.1 Controlled Field Evaluation

The effect of stem moisture content, stem diameter and blade speed on all the dependent parameters are mentioned below with the statistical analysis given in Table 5.

3.1.1 Power requirement, watt (W)

The average power requirement obtained during control field evaluation of the electric brush cutter at different level of independent parameter are represented in Fig. 3a. The power requirement was found to increase with an increase in level of stem diameter and blade speed. The maximum mean peak power requirement of 214.33 watt was observed at M2 (37%), diameter D3 (24-26) and blade speed S3 (60 m/s) while, minimum mean power requirement of 69 W was observed at moisture content M1 (47%), diameter D1 (17-19 mm) and blade speed S1 (46 m/s). The sub mean of power requirement irrespective of blade speed varied from 97.22-99.89, 134.22-158.11 and 151.67-184.11W as moisture content reduced from 47% to 37%, at stem diameter of 10-12, 17-19 and 24-26 mm respectively. Similarly, sub mean of power requirement irrespective of stem diameter varied from 106.8-112.22, 125.56-157.00 and 150.67-172.89W as moisture content reduced from 47% to 37%

at blade speed of 46, 53 and 60 m/s respectively. From the statistical analysis it was depicted that moisture content, stem diameter and blade speed were significantly ($p < 0.05$) affected the power requirement. Further, none of the interactions of operating parameters were found to be significant. It was also observed that power requirement was inversely proportional to stem moisture content i.e. power requirement decreased with increase in stem moisture content irrespective of blade speed and stem diameter. The moisture content was observed to have an increasing effect on force. Increasing moisture content leads to decreased force of pigeon pea stem up to 45% moisture content [15]. It may be due to pigeon pea stem having vascular bundles of the stem that are collateral and arranged in form of a ring [16]. Moreover, the power requirement increased with increase in blade speed. It may be due to more voltage required to speed up the blade that may increase power requirement. Further, it is also observed that as diameter of pigeon pea stem increases, power requirement also increases which may be due presence of more vascular bundles. More maturity gives more strength to stem.

3.1.2 Net Power requirement, watt (W)

The graphical representation of average net power requirement corresponding to three levels of blade speed, three levels of diameter and two levels of moisture content is given in Fig. 3b. The maximum mean net power requirement of 136.66 W was observed at M2 (37%), diameter D3 (24-26) and blade speed S2 (53 m/s) while the minimum net power requirement of 13.00 W was observed at moisture content M1 (47%), diameter D1 (17-19 mm) and blade speed S1 (46 m/s). Further, with every increase in the level of stem diameter, net power requirement varied from 21.89-24.56, 58.89-82.78 and 76.33-108.78W and moisture content reduced from 47% to 37%, irrespective of blade speed. Similarly, with an increase in level of blade speed, net power requirement varied from 50.89-56.22, 53.56-85.00 and 52.67-74.89 W and moisture content reduced from 47% to 37%, irrespective of stem diameter. The statistical analysis of net power requirement showed that, the model was significant with $F = 5.62$ ($P < 0.05$) as shown in Table 6. Similarly, moisture content and stem diameters were statistically significant with $P < 0.05$. However, blade speed was not significant with $F = 11.54$ and $P = 0.22 > 0.05$. It was observed that net power requirement was inversely proportional to stem moisture content i.e. net power requirement decreased with an increase in stem moisture content irrespective of blade speed and stem diameter. In case of stem diameter, net power requirement increased with diameter and it may be due presence of more vascular bundles as explained earlier. Further, in case of blade speed, maximum net power requirement was observed at blade speed of 53 m/s irrespective of moisture content and diameter.

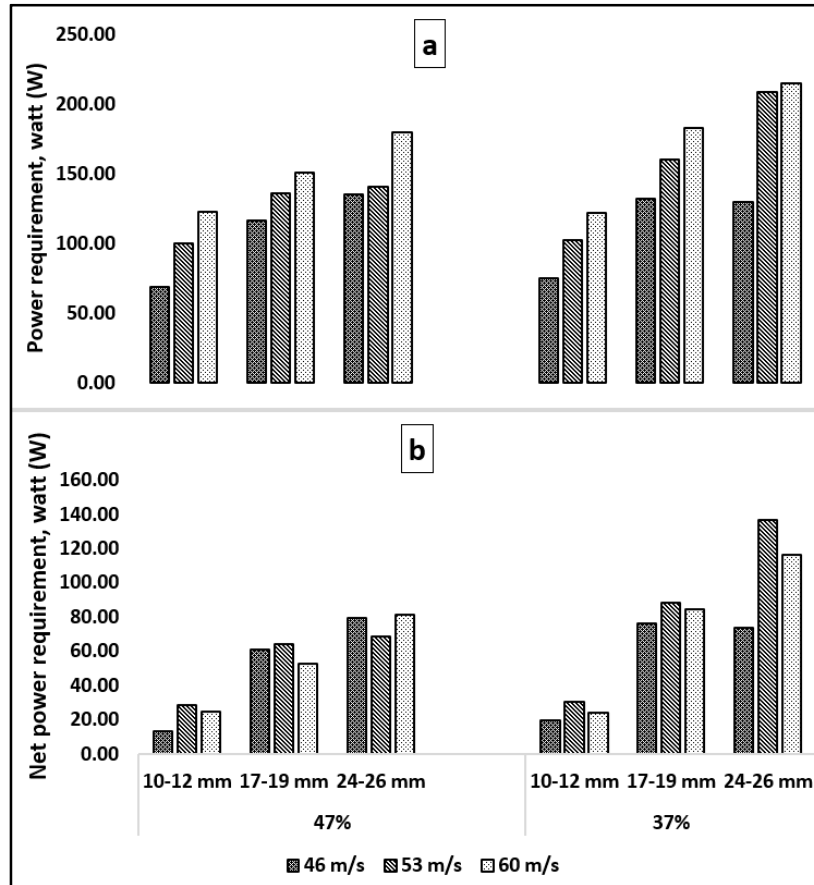


Fig. 3. Effect of stem diameter (mm), blade speed (m/s) and moisture content (%) on (a) power requirement, watt and (b) net power requirement, watt.

Table 5 ANOVA for effect of independent parameters on performance parameters of control field condition (F and P values)

Source	Power requirement, watt (W)		Net power requirement, watt (W)	
	F value	P value	F value	P value
Model	7.87	<.0001	5.72	<.0001
Moisture	8.44	0.0062	8.44	0.0062
Dia	36.61	<.0001	36.61	<.0001
Blade Speed	20.15	<.0001	1.85	0.1714
Moisture*Dia	1.71	0.1952	1.71	0.1952
Moisture*Speed	1.28	0.2915	1.28	0.2915

Dia*Speed	0.37	0.8262	0.37	0.8262
Moisture*Dia*Speed	1.11	0.3661	1.11	0.3661

3.2 Comparative Evaluation under Variable Field Condition

The graphical representation and statistical analysis (F values) of comparative evaluation of engine and electric brush cutter given in Fig. 4 and Table 5 respectively.

3.2.1 Effective Field capacity, ha/h

The statistical analysis of effective field capacity showed that the crop erectness was statistically significant with $P < .05$. However, machine type (electric and engine brush cutter) and interaction of both independent parameters were not significant with $F = 4.486$ ($P = .078 > .05$) and $F = .66$ ($P = .45 > .05$) respectively. The mean effective field capacity of 0.033 and 0.037 was observed for electric brush cutter at regular and modified field condition, respectively. Further, mean effective field capacity of 0.030 and 0.034 ha/h was observed for engine brush cutter at regular and modified field conditions, respectively. The maximum effective field capacity of 0.037 and 0.034 ha/h was observed for electric brush cutter and engine operated brush cutter, respectively in modified crop condition. The lowest field capacity of 0.033 and 0.030 was observed for electric and engine operated brush cutter in regular crop condition, respectively. It may be due to crop lodged conditions creating an hindrance for operator to move freely into the field of regular crop stand.

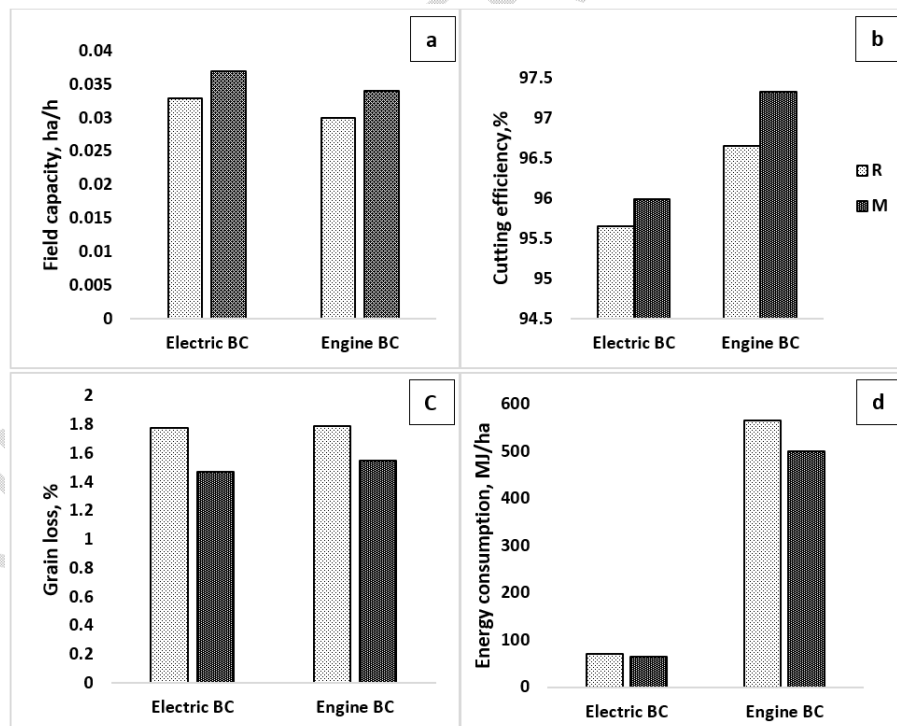


Fig. 4. Comparison of electric and engine operated brush cutter (BC) under regular (R) and modified crop condition (M) on (a) Field capacity, ha/h (b) Cutting efficiency, % (c) Grain loss % (d) Energy consumption, MJ/ha

3.2.2 Cutting efficiency, %

The results of statistical analysis showed that harvesting machine had significant impact on cutting efficiency. The crop erectness and its interaction had non-significant effect on cutting efficiency. The mean cutting efficiency of 96 % and 95.67 % was observed for electric brush cutter at regular and modified field conditions, respectively. Further, it was 97.33 % and 96.67% for engine brush cutter at regular and modified field conditions, respectively. The maximum cutting efficiency of 96.00 and 97.33 percent were observed for electric brush cutter and engine operated brush cutter, respectively at regular crop condition. For engine operated brush cutter, higher cutting efficiency was observed. It may be due to higher power and rpm of engine operated brush cutter.

3.2.3 Grain loss, %

The statistical analysis of percent grain loss showed that the both the independent parameters and their interaction were not statistically significant with $F = .025$ ($P > .05$), $F = .91$ ($P > .05$) and $F = .013$ ($P > .05$). The mean percent grain loss of 1.78 and 1.47% was observed for electric brush cutter and 1.79 and 1.55% was observed for engine brush cutter at regular and modified field conditions, respectively. The maximum percent grain loss of 1.78 and 1.79 percent was observed for electric brush cutter and engine operated brush cutter respectively at regular crop condition. The lowest percent grain loss of 1.47 and 1.55 percent was observed for electric and engine operated brush cutters at modified crop condition, respectively. Overall percentage of grain loss of 1.62 and 1.67 was observed for electric and engine operated brush cutter respectively.

3.2.4 Energy consumption, MJ/ha

From the statistical analysis of energy consumption, it was observed that treatments of machine type, crop erectness and their interaction were significantly different with $F = 2701$ ($P < .05$), $F = 16.579$ ($P < .05$) and $F = 11.288$ ($P < .05$) respectively. During the operation of electric brush cutter, maximum energy consumption of 71.58 MJ/ha was observed at regular crop stand and the minimum energy consumption of 65.61 MJ/ha was occurred at modified crop status. It may be due the modified crop erectness that provided enough space to move without obstacles covering more area and reducing the energy consumption. Moreover, in case of engine operated brush cutter, the maximum mean value of energy consumption of 566.43 MJ/ha was observed for regular crop stand; while the minimum mean value of energy consumption of 500.02 MJ/ha was observed for modified crop. The overall mean energy consumption of 68.59MJ/ha and 533.22 MJ/ha were observed for electric brush cutter and engine operated brush cutter, respectively.

Table 6. ANOVA for effect of independent parameters on performance parameters of variable field condition (F values)

	DF	Effective field capacity	Cutting efficiency	Percent grain loss	Energy consumption, MJ/ha
Source					
Replication	2	F-Calculated			
Machine type	1	4.486 ^{NS}	12.789*	0.025 ^{NS}	2,701.08*
Crop erectness	1	19.352 *	1.421 ^{NS}	0.919 ^{NS}	16.579 *
Machine type* Crop erectness	1	0.664 ^{NS}	0.158 ^{NS}	0.013 ^{NS}	11.288*
Error	6	-	-	-	-
Total	11	-	-	-	-

*: Significant at 5% level. ^{NS}: Not significant. DF: Degree of Freedom.

4. CONCLUSIONS

Battery-operated E-brush cutter was developed and its performance was presented in this paper with an objective to eliminate the fuel consumption and reduce cost of operation. The developed E brush cutter showed that blade speed, stem diameter and moisture content has significant effect on power requirement. The overall power requirement and net power requirement of 137 W and 62 W was observed for cutting pigeon pea stem, respectively. During comparative evaluation, the effective field capacity and percent grain loss observed in both the machine was not significantly different. The maximum cutting efficiency of 95.67% was observed under Electric brush cutter. Energy consumption in case of engine brush cutter was 533.33 MJ/ha whereas it was 68.59 MJ/ha only in case of E-brush cutter. Further, the field evaluation showed that E brush cutter has potential to be a good alternative to save the fuel consumption which ultimately reduced the cost of operation and eliminated the direct emissions of harmful exhaust gases.

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