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Development and Performance Evaluation of Solar Power Operated Brush Cutter

M. Vinayak[1], B. Madhu[2], V. Sai Krishna[3], G. Dinesh Subrahmanyam[2]

[1,3] Assistant Professor, Department of Agricultural Engineering, Aditya University, Surampalem-533440.
[2]Assistant Professor and UG Student, Department of Agricultural Engineering, Siddharth Institute of Engineering and Technology, Andhra Pradesh, India
Corresponding author maid id: vinayakm@adityauniversity.in and saikrishnav@adityauniversity.in

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Abstract— *The solar power-operated brush cutter offers a promising solution for sustainable agriculture, emphasizing reduced environmental impact and cost-effectiveness. Its design prioritizes performance, reliability, and user-friendliness, with carefully selected components ensuring optimal functionality under diverse conditions. This solar-powered solution showcases the feasibility and effectiveness of clean energy technologies in agriculture, promoting a greener and more sustainable future for farming practices. The solar power operated brush cutter consists of Main frame, Ground Wheel, Handle, Switch, Solar Panel, Motor, Battery, Inverter, Cutting Blade. The developed solar power operated brush cutter performance evaluation was carried out calculated theoretical field capacity (ha/h), actual field capacity (ha/h), Field efficiency (%) cutting efficiency and power consumption.*

Keywords— ***solar power, brush cutter, sustainable agriculture, field efficiency, clean energy.***

I. INTRODUCTION

Grass growth in India is influenced by a combination of factors including diverse climatic conditions, varying soil types, seasonal rainfall patterns, and agricultural practices. In tropical regions like the south, species like Bermuda grass and Kikuyu grass thrive in high temperatures, while temperate zones in the north favor grasses like Kentucky bluegrass and fescue. Soil quality, ranging from fertile alluvial soils to lateritic soils, also impacts grass growth, with well drained soils supporting healthy vegetation. Rainfall, influenced by the monsoon, dictates the lushness of grasslands, with heavy rainfall promoting growth and dry seasons leading to dormancy.

Indian livestock industry is growing at a fast rate and contributing 31.6% to the national agricultural gross domestic product. India produces nearly 22% of global milk with Cumulative Annual Growth Rate of around 6.35% in the last 5 years. According to NITI Ayog, milk production in the country can go up to 330 MMT by 2034. Livestock census trend indicates that the number of cross bred female cattle has increased by 43.6% and the female buffaloes have increased by 12.71% in the last 7 years indicating higher demand for quality feed and fodder. In the farm maintenance of a dairy, it is estimated that feed and fodder cost is around 65%. However, the country is facing 23.4% deficit in dry fodder and 11.24% deficit in green fodder. A number of technologies have been developed for fodder production, preservation and assessment of animal feed requirement. There is a vast scope of private investment and development of small business models in the sector. New ideas, technologies and capitals are required in a mode that can be utilized to cater to the needs of rural business involving SHG, women, youth (male and female) and developing suitable models in the form of start-ups, entrepreneurship, enterprises etc (Sai Krishna. *et al.*2024)

The area under fodders is around 9.0 million ha, which account for 4.8-5% of the total area under cultivation in the country. The area under permanent pasture and other grazing land is around 15 million ha. At present the country faces a shortage of green fodder, dry fodder and concentrates. Estimates vary from agency to agency and methods of estimation; some agencies put it at a net deficit of 35 % green fodder, 11 % dry forages, and 44 % concentrates. One recent study by the ICAR-AICRP on Forage Crops, considering the factors of the animal census and dry, green and concentrates requirement of animals based on their age, sex, mulching, work nature etc. has estimated 23% deficit in dry fodder and 11% deficit in green fodder.

over the last three decades, the paddy cultivation area in Andhra Pradesh decreased by 24.4 percent, with a Compound Annual Growth Rate (CAGR) of -0.43%, and production increased by 22.9% (CAGR of 0.76%). The annual average productivity increased by 62.6%, with a CAGR of 1.27%.

At present, in India, this crop is harvested manually with a sickle in majority of small holding farms and 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 like combine harvester may lead to improve cropping intensity and productivity which may incur high fuel consumption. However, promotion of ecofriendly agricultural implements and machinery are 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 portable harvester (brush cutter) developed for wheat worked satisfactorily with an average value of 1.23% for post-harvesting losses with the actual field capacity of 0.038 ha/h and the field efficiency was 62.99% [8]. Many researchers are modifying the brush cutter ergonomically for multipurpose operations.

II. MATERIALS AND METHODS

The various factors involved such as collection of anthropometric dimensions of agricultural workers, design, development and conducting experiments regarding cutting operation in well prepared field. For the fabrication of the solar power operated brush cutter, the workshop facility of the siddharth institute of engineering technology, puttur was used. In the month of March 2024, the brush cutter was tested from mechanical point of view. The developed brush cutter was tested under field condition.

2.1 Development of solar operated brush cutter

The commercially available petrol engine operated brush cutters are used mostly for plant cutting operations carried out in agricultural fields, thus they prevalent among the Indian small farmers. Development of Solar Power Operated Brush Cutter The developed solar power operated brush cutter consists of Main Frame, Ground Wheel, Handle, Cutting Blade, D.C Motor, Power Transmission Unit, Solar Photovoltaic Panel, Battery, Power Management System (Control Panel, Inverter, Ammeter, Switch).

The main frame in a solar power-operated brush cutter serves as the backbone of the entire machine, playing a pivotal role in ensuring structural integrity, stability, and functionality. Its importance lies in providing robust support for critical components such as the cutting mechanism, motor, solar panels, and energy storage systems. Finally a prototype was developed as shown in Fig. 2.2.

2.2 Ground wheel

Ground wheel of 220 mm diameter was used to support the motor and its mounting frame. Mild steel round bar of 8 mm diameter was used for the fabrication of ground wheel. The ground wheel, usually located at the base of the brush cutter, helps stabilize the machine during operation. It ensures that the cutter maintains a consistent height above the ground,

Fig.2.1. Ground wheel

2.3 Handel

A standard light weight M.S. 27.5 mm outside diameter conduit pipe is used for handle of the tool carrier. Length of handle is calculated based on average standing elbow height of female worker. Average standing elbow height of women workers is 100 cm.

2.4 Solar photovoltaic panel

Solar photovoltaic panels are integral components of solar power-operated grass cutters, harnessing the sun's energy to provide sustainable power for these devices. A Solar photovoltaic panel provided at the top of the sprayer on inclined position to collect solar rays and converts into electrical energy. This electricity was then connected to a 12Volts12Amperessealed Lead acid battery via charging circuit. This battery stores DC electricity and gives power supply to a dc motor which directly drives a sprayer pump assembly.

Battery In a solar-powered grass cutter, the battery serves as a crucial component, acting as the energy reservoir that stores electricity generated by the solar panels during periods of sunlight. The Battery is an electric device that is used to store current which is produced from the solar panel and supplied to the corresponding loads. The number of batteries required depends on the load requirement.

2.5 DC Motor and Micro controller

A 12V, 200 RPM geared DC motor was used to operate the fertilizer metering shaft. The DC motor was mounted on the frame. The wired connection accomplished from tractor battery through the DC Voltage regulator. Table.1 show specifications of the DC motor.

Table.2.1 specifications of the DC motor

Parameter	Description
Name	xcluma
Type	Geared
Max RPM	200
Min RPM	180
Voltage	12 V
Torque	8.15 kg-cm

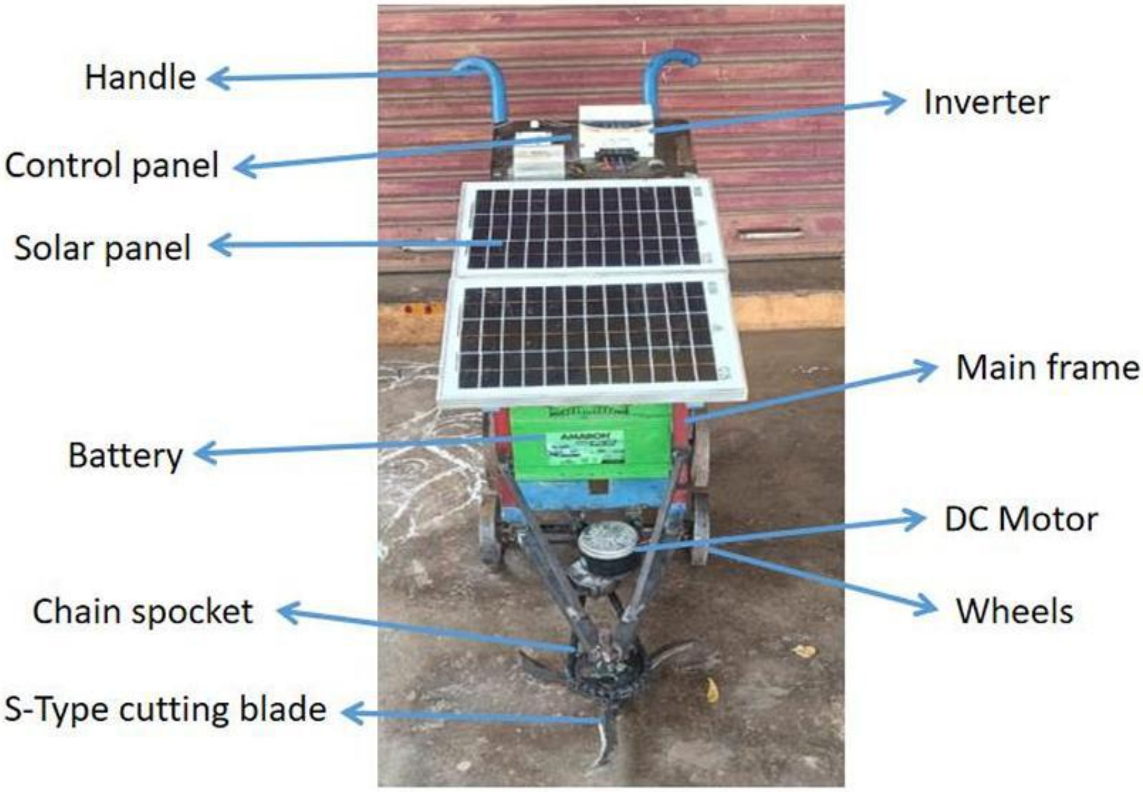

Fig.2.2. Developed solar operated brush cutter

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 the prototype to control the rotational speed of cutting blade. It gives provision to operate E-brush cutter with variable speed during evaluation.

Chain and Sprocket In a solar power operated grass cutter, the chain and sprocket system play a pivotal role in converting the rotational motion generated by the solar-powered motor into the linear motion necessary for cutting grass effectively. The sprocket, typically attached to the motor shaft, transfers power to the chain, which in turn drives the cutting blades. This mechanism ensures efficient power transmission and precise control over the cutting action, allowing the grass cutter to operate smoothly and effectively.

Experimental design the study was carried out in fodder filed. During evaluation of field two types of blades were used. i.e. (i) S type and, (ii) Stright blade for crop parameters and associated machine performance. The cutting trials were conducted on selected range of cutting blade speed and crop moisture content in controlled field conditions. The details of controlled field condition parameters are given in Table 1. Experimental field trials were conducted in RBD (Randomized Block design) with three replications in the fodder field (100 m^2 for each replication). Details of machine specifications and crop parameter.

Table.2.2. Details of operational and performance parameters for control field condition

Independent variable	levels	Details	Dependent variables
Moisture content	2	40 (M1) and 30 (M2)	Power requirement (W)
Blade speed,	3	40 (S1),60 (S2) and	Actual field capacity (ha/h)
(RPM)		80 (S13)	
Blade shape	2	S type (L1) and Stright blade (L2)	Cutting efficiency (%)

Table.2.3. Detail specifications of engine and electric brush cutter

S. No	Particulars	Dimensions
1	Overall dimension (L×B×H), mm	1920 × 500 × 950
2	Working width, mm	30
3	Number of rotors	1
4	Height of handle from ground, mm	950
5	Number of blades in rotor	Serrated blades - 3
6	Blade thickness, mm	1.4
7	Width of handle, mm	460
8	Size of float (L×B×H), mm	160 × 90

III. RESULTS AND DISCUSSION

The effect of stem moisture content, blade shape and blade speed on all the dependent parameters are mentioned below with the statistical analysis given in Table 2.

3.1 Power requirement, watt (W)

A three-way analysis of variance (ANOVA) was conducted to investigate the effects of Moisture Content, Blade Speed, and Blade Shape on the required Power (kW). The results indicated that all three main effects moisture content, blade speed, and blade shape—had statistically significant influences on power consumption. specifically, blade speed exhibited the most substantial impact ($F = 156.61$, $p < 0.0001$), followed by Blade Shape ($F = 49.00$, $p < 0.0001$) and Moisture Content ($F = 20.64$, $p = 0.0022$). In contrast, the interaction effects between Moisture Content and Blade Speed ($p = 0.7585$), Moisture Content and Blade Shape ($p = 0.9222$), Blade Speed and Blade Shape ($p = 0.3721$), and the three-way interaction among Moisture Content, Blade Speed, and Blade Shape ($p = 0.9959$) were all found to be statistically insignificant. These findings suggest that each factor independently affects power consumption without significant interactive influences. Furthermore, the low error variance relative to the total variance highlights a good model fit. Overall, Blade Speed emerged as the most critical factor influencing the power requirement, followed by Blade Shape and Moisture Content.

Table 5. ANOVA for effect of independent parameters on power requirement (F and P values)

Source of Variation	SS (Sum of Squares)	df	MS (Mean Square)	F	p-value
Moisture Content (M)	96.04	1	96.04	20.64	0.0022
Blade Speed (S)	1456.71	2	728.35	156.61	<0.0001
Blade Shape (L)	228.04	1	228.04	49.00	<0.0001
M × S (Interaction)	2.71	2	1.35	0.29	0.7585
M × L (Interaction)	0.04	1	0.04	0.01	0.9222
S × L (Interaction)	10.71	2	5.35	1.15	0.3721
M × S × L (Interaction)	0.04	2	0.02	0.004	0.9959
Error	32.67	7	4.67		
Total	1826	17			

3.2 Effective field capacity, ha/h.

A three-way ANOVA was conducted to assess the effects of Moisture Content, Blade Speed, and Blade Shape on Field Capacity (ha/h). The analysis revealed that all three main effects were statistically significant. Moisture Content showed a significant effect on field capacity ($F = 15.97$, $p = 0.0047$), indicating that changes in moisture level substantially influence field performance. Blade Speed had the most prominent impact ($F = 28.08$, $p = 0.0004$), suggesting that adjusting the rotational speed of the blades greatly enhances field capacity. Additionally, Blade Shape significantly affected field capacity ($F = 6.74$, $p = 0.0362$). Conversely, all interaction terms including Moisture Content × Blade Speed, Moisture Content × Blade Shape, Blade Speed × Blade Shape, and the three-way interaction were statistically insignificant ($p > 0.05$), implying that each factor operates independently without notable combined effects.

Table 6. ANOVA for effect of independent parameters on field capacity

(F and P values)

Source of Variation	SS (Sum of Squares)	df	MS (Mean Square)	F	p-value
Moisture Content (M)	0.000102	1	0.000102	15.97	0.0047
Blade Speed (S)	0.000358	2	0.000179	28.08	0.0004
Blade Shape (L)	0.000043	1	0.000043	6.74	0.0362
M × S (Interaction)	0.000011	2	0.000006	0.94	0.4290
M × L (Interaction)	0.000001	1	0.000001	0.18	0.6860
S × L (Interaction)	0.000008	2	0.000004	0.66	0.5430
M × S × L (Interaction)	0.000001	2	0.0000005	0.09	0.9120
Error	0.000045	7	0.0000064		
Total	0.000568	17			

The relatively small error variance relative to the total variance suggests that the model fits the data well. Overall, Blade Speed emerged as the most critical factor, followed by Moisture Content and Blade Shape, in optimizing the field capacity.

3.3 Graphical Representation of effect of operational parameters

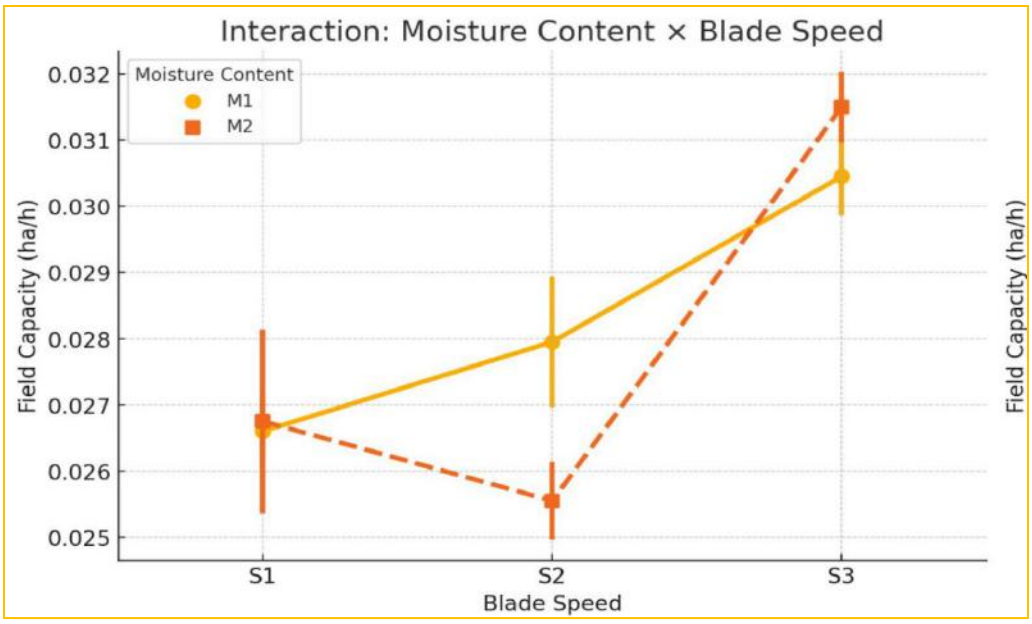

Fig.2.1. Moisture content and blade speed effect on field capacity

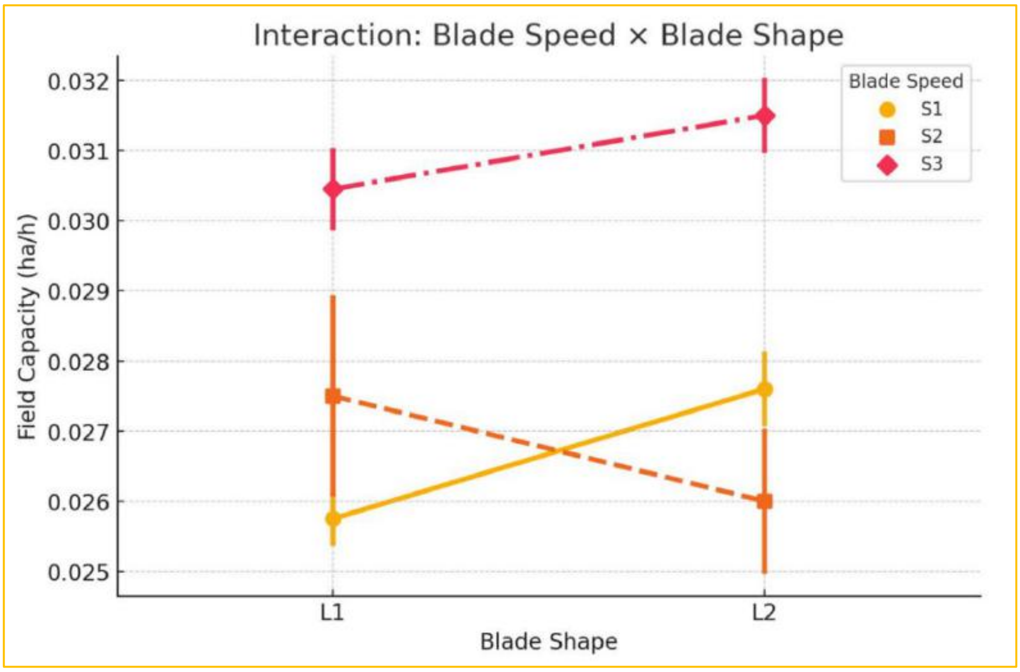

Fig.2.2. Blade speed and blade shape effect on field capacity

3.3 Cutting Efficiency (%)

The results of statistical analysis showed that harvesting machine had significant impact on cutting efficiency. The crop standing status and its interaction had non-significant effect on cutting efficiency. The mean cutting efficiency of 85 % and 90.67 % was observed for electric brush cutter at regular field conditions, respectively. compare with traditional method higher cutting efficiency was observed.

IV. CONCLUSIONS

A battery-operated electric brush cutter was designed and evaluated in this study with the primary aim of minimizing fuel usage and lowering operational costs. The performance analysis revealed that blade speed, stem diameter, and moisture content significantly influenced the power requirement. The cutter required an average total power of 1826 W. The electric brush cutter achieved a maximum cutting efficiency of 90.67%. Field trials highlighted the electric model's strong potential as a sustainable alternative, offering considerable fuel savings, reduced operational costs, and elimination of direct exhaust emissions. Furthermore, the ergonomic design helped reduce user fatigue and hand-arm vibration compared to traditional engine-driven units. This makes the electric brush cutter particularly well-suited for small-scale farming operations. Nevertheless, future research should focus on integrating long-duration batteries to further enhance its practicality and adoption.

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