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Development and evaluation of an engine-powered sugarcane single-bud cutter

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Abstract

The Sustainable Sugarcane Initiative (SSI) is an innovative method of sugarcane cultivation that aims to minimize the use of seeds, water, fertilizers and land while maximizing yields. One of the SSI's key principles is the single bud chip technique, which helps produce uniform tillers, increases the number of tillers and results in more millable canes per plant. To support this, an engine-powered single-bud sugarcane sett cutter was developed. The machine comprises a main frame, engine, rotary shaft, cutting discs, stacker, delivery chute, frequency counter, vibration mounts and transport wheels. The machine's performance was tested at four cutting disc speeds (1400, 1800, 2200 and 2600 rpm) and two disc diameters (200 mm and 250 mm), while three different sett cut lengths (30, 35 and 40 mm) were also evaluated. The highest number of single bud setts was achieved with the cutting discs set at 2200 rpm and a 200 mm diameter, resulting in a cutting rate of 1700 setts per hour. For optimal germination, a sett length of 35 mm was recommended. The cost of cutting setts with this machine was 1000 INR per hectare, compared to 6250 INR per hectare for using a traditional bud chipper, offering savings of 84 % in cost and 94 % in time. Additionally, the machine demonstrated impressive germination results, with a 95 % germination rate in a pro-tray nursery and a 90 % germination rate under actual field conditions.

Keywords

cutter; engine; mechanized farming; single bud; sugarcane; sustainable agriculture

Introduction

Sugarcane is cultivated in more than 115 tropical and subtropical countries worldwide, covering an area of 26.54 million hectares and achieving a productivity of 71 tonnes per hectare. India has the second-highest area under sugarcane, next to Brazil. In India, sugarcane is cultivated in an area of 4.5 m ha with an average productivity of around 79 t/ha. In the northern region, approximately 40000 to 60000 three-budded setts are required to plant one hectare, while in the southern region, the requirement is between 25000 to 40000 setts. Approximately 0.5 million people are employed in sugar mills and 7.5 million sugarcane farmers and many agricultural labourers depend on sugarcane cultivation and related activities, accounting for 7.5 % of the rural population (1, 2). Studies by the National Agricultural Technology Project on Sugarcane Mechanization, conducted by the Indian Council of Agricultural Research in New Delhi, show that sugarcane growers are gradually adopting modern machinery for specific operations like tillage and planting through ownership or custom hiring. Labour availability for cutting sugarcane has become a significant constraint due to the physically demanding nature of manual cutting, which is classified as "hard work" (3). A rotary cutting device with blades is preferred for cutting thicker stalks such as sugarcane. The shape of the cutting blade is a key factor influencing the cutting force and power required (4). Compared to smooth knives, serrated knives required less cutting power and produced superior cut-quality of sugarcane setts (5-8). The diameter of commonly grown sugarcane varieties varies from 26 mm to 36 mm, with the mean diameter and mean dynamic shear strength of 28.5 mm and 66.7 kPa, respectively. The force required to cut the sugarcane is the product of the dynamic shear strength of the sugarcane and the mean cross-sectional area of the sugarcane, which was 40.6 N. The torque was computed as 5.08 Nm and the power was calculated to be 1.2 kW per cutting disc. Allowing for frictional losses, a commercially available 3 kW diesel engine was selected as the prime mover for operating two cutting discs of sugarcane setts cutting machine (9). For planting one hectare, 12500 single-budded chips are required. Due to manual cutting, 5 % to 6 % of damage is caused to the nodes and 10 to 11 labourers are required to cut setts for one hectare (10).

Tamil Nadu leads the country in sugarcane productivity, with an average yield exceeding 100 t/ha. However, the output-to-input ratio for sugarcane is declining due to rising seed and labour costs and productivity-related challenges. Sugarcane is typically planted using setts at a rate of 6 to 8 t/ha, constituting approximately 10% of the production used as planting material. This substantial quantity of planting material poses logistical challenges regarding the transportation and storage of seed cane. The Sustainable Sugarcane Initiative (SSI) presents a viable solution to address these issues. SSI is an innovative approach to sugarcane cultivation that utilizes a minimal number of buds, reduced water consumption and optimal use of fertilizers and land to enhance yields by improving the productivity of water, land and labour. One of the core principles of SSI is raising nurseries in trays using single-bud chips, which promotes uniform tillering, a more significant number of tillers and more millable canes per plant (11, 12).

Sugarcane bud chips are susceptible to damage, making it challenging to separate them without losses. Even minor scratches can damage the buds, preventing proper germination and leading to spoilage (13). The cutting force required for slicing sugarcane stalk depends on the physio-mechanical characteristics of the sugarcane stock and the knife properties and the force needed to cut sugarcane stock varies according to the cut position of the bottom, middle, or top of the stalk. Additionally, cutting forces increase with the increase in the diameter of the stalks (14, 15). Conventional handheld sugarcane bud chip cutting tools put stress on the hands and thumb of workers, waste material and injure plants with slanting cuts. These limitations highlight the need for developing a sugarcane bud-cutting machine to improve efficiency, ensure uniform cuts and reduce labour strain (16, 17). Sugarcane single bud sett cutting is tedious, time-consuming and expensive. Traditionally, sugarcane buds are cut using tools available in the market. However, an engine-powered sugarcane single-bud setts cutter was developed to reduce cutting costs, minimize labor and achieve uniform cuts without causing damage.

Materials and Methods

The engine-powered sugarcane setts cutter was developed with the key components of the main frame, engine, power transmission unit, cutting discs, safety cover, sugarcane stacker, delivery chute, frequency counter& timer, vibration mounts and transport wheels (Fig. 1-2). The development details of the single bud sugarcane setts cutter and the procedure adopted for evaluating the machine's performance are given below.

Development details

The machine's main frame was constructed using a 32 × 32 × 6 mm mild steel (MS) L-angle. The engine was mounted at the bottom with a suitable arrangement, while the cutting blades were attached to a 20 mm diameter MS shaft, 1200 mm in length, which served as the rotor shaft. This shaft was supported by three pillow bearings, securely fitted to the main frame, to transmit power to the cutting blades while minimizing vibration and friction. A 150 mm V-pulley was mounted on one end of the rotor shaft to transfer power from the engine. On the opposite end, two 200 mm diameter steel cutting discs were fitted, with adjustable arrangements to adjust the spacing between the blades at 30, 35 and 40 mm. For safety, a shield was added to cover the rotating cutting discs. An acrylic sheet (190 × 100 × 5 mm) was incorporated into the cutting side of the shield to facilitate easier operation. A 20 mm thick thermocol layer was placed between the main frame and the rotor shaft to reduce vibration during the cutting process further.

The top of the machine was designed with provisions to hold all the sugarcane stalks, making feeding easier and more secure. A delivery chute, made from mild steel (MS) sheet, was provided at a 30° angle. To minimize damage to the setts as they slide down the chute after cutting, thermocol was applied along the entire chute length. A 12V battery-powered electronic frequency counter and timer were incorporated into the machine to count the number of setts falling through the delivery chute. MS plates (125 × 95 × 5 mm) were welded to the bottom of the frame's four legs, with vibration mounts installed beneath them to stabilize the machine. For improved portability, the machine was equipped with four wheels.

Methodology of testing

Trials were conducted to assess the machine's output at four different speed levels, two cutting disc diameter sizes and three sett length variations. The number of setts cut per hour was recorded with three replications for each combination. The rotational speed of the machine's engine was measured using a digital tachometer. At the same time, the number of setts cut was determined through a frequency counter after operating the machine for a known time interval. A stopwatch was used to track the time. Statistical analysis was performed on the obtained results. Additionally, the cost of the machine and its operation was calculated according to the specifications of the Bureau of Indian Standards. Based on this data, the operational cost for cutting 1000 setts was compared to manual sett cutting.

Statistical analysis

The data analysis obtained through experiments was tested statistically using Statistical Analysis Software (AgRes.). The software determines the effect of independent parameters on the proposed dependent parameters. ANOVA was used to test

Table 1. ANOVA for the effect of cutting disc of 200 mm diameter, 35 mm length of cut and 2200 rpm on a number of setts cut per hour fissures in sets and germination percentage

Source	df	SS	MS	F	Prob
TOT	71	2463.319444	34.694640	1.5637	
Trt	23	1407.319444	61.187802	2.7577	0.002 **
Rep	2	35.361111	17.680556	0.7969	
Err	46	1020.638889	22.187802	1.0000	
B	1	4.013889	4.013889	0.1809	0.673 NS
S	3	575.597222	191.865741	8.6474	0.000 **
L	2	99.361111	49.680556	2.2391	0.118 NS
BS	3	21.930556	7.310185	0.3295	0.804 NS
SL	6	364.527778	60.754630	2.7382	0.023 *
BL	2	66.694444	33.347222	1.5030	0.233 NS
BSL	6	275.194444	45.865741	2.0672	0.076 NS
Err	46	1020.638889	22.187802	1.0000	
C.V. (Treatment): 9.09%					

the data in Table 1. The probability for its significance at a 5 % level of significance was checked.

Results and Discussion

The engine-powered sugarcane single bud setts cutting machine was successfully developed at the Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute (Tamil Nadu Agricultural University), Trichy (Fig. 1-2). The performance of the developed prototype sugarcane single bud setts cutter was tested with leading sugarcane varieties, CoSi (Sc) 6 and CoC 24, in the Trichy district. The testing was conducted at four different cutting disc speeds (1400, 1800, 2200 and 2600 rpm), two cutting disc diameters (200 mm and 250 mm) and three sett lengths (30, 35 and 40 mm). The study also focused on evaluating the smoothness of the cut, the presence of fissures in the setts and the germination percentage.

As shown in Fig. 3, the effect of the rotational speed of the 200 mm cutting disc on machine output increased with speeds of 1400, 1800 and 2200 rpm but began to decrease at 2600 rpm. A similar trend was observed with the 250 mm diameter disc (Fig. 4), where the output followed the same pattern of increasing from 1400 to 2200 rpm, but the number of setts cut per hour was lower than the 200 mm diameter disc. Regarding cut quality, the expected smooth cutting with no fissures in the sugarcane setts (Fig. 5) was more prominent with the 200 mm diameter cutting disc at a rotational speed of 2200 rpm, compared to the 250 mm disc. The smaller diameter cutting blade performed better than the larger diameter during sugarcane sett cutting operations (9).

The observed data indicate slight variation in machine output across the three sett length levels (30, 35 and 40 mm) at the different rotational speeds of the cutting discs, as shown in Fig. 3 - 4. The sett germination test results revealed that the germination percentage increased with 30 mm and 35 mm sett lengths, but there was no significant difference with the 40 mm length. Based on these results, a sett length

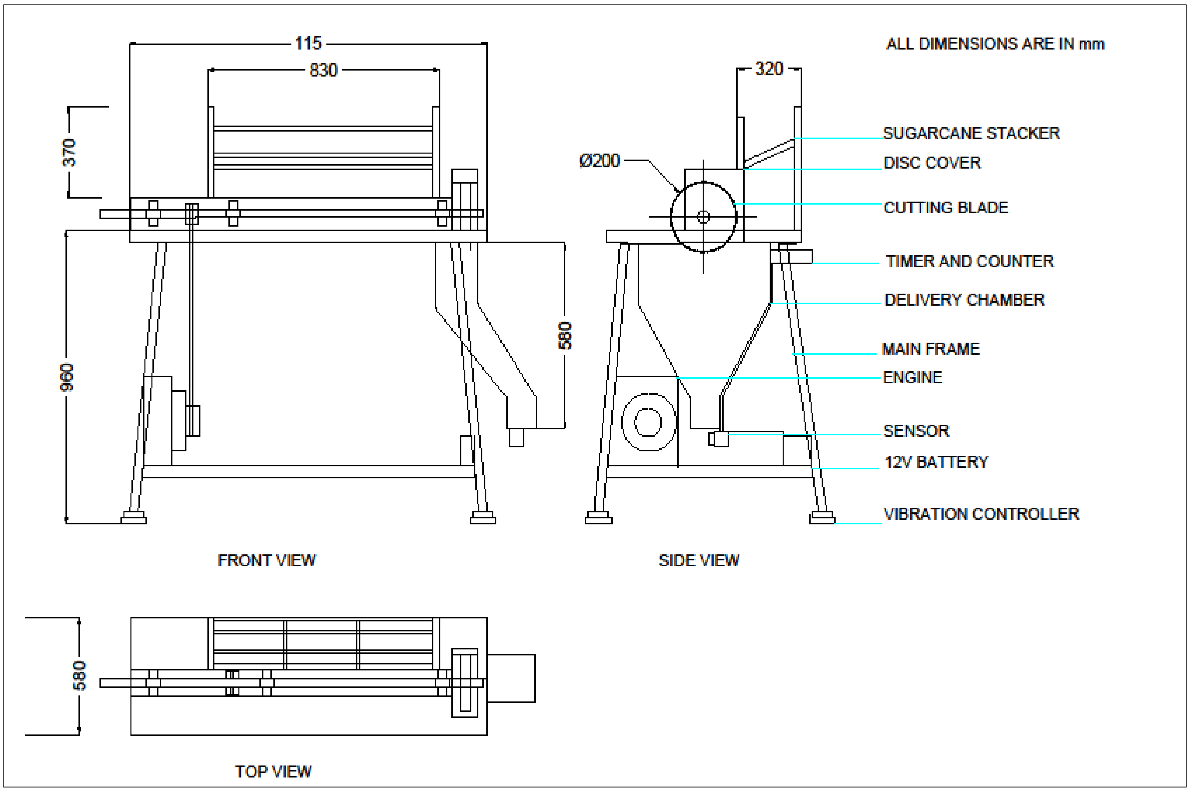

Fig. 1. Engine-powered sugarcane single bud setts cutting machine.

Fig. 2. Prototype of engine-powered sugarcane single bud setts cutting machine.

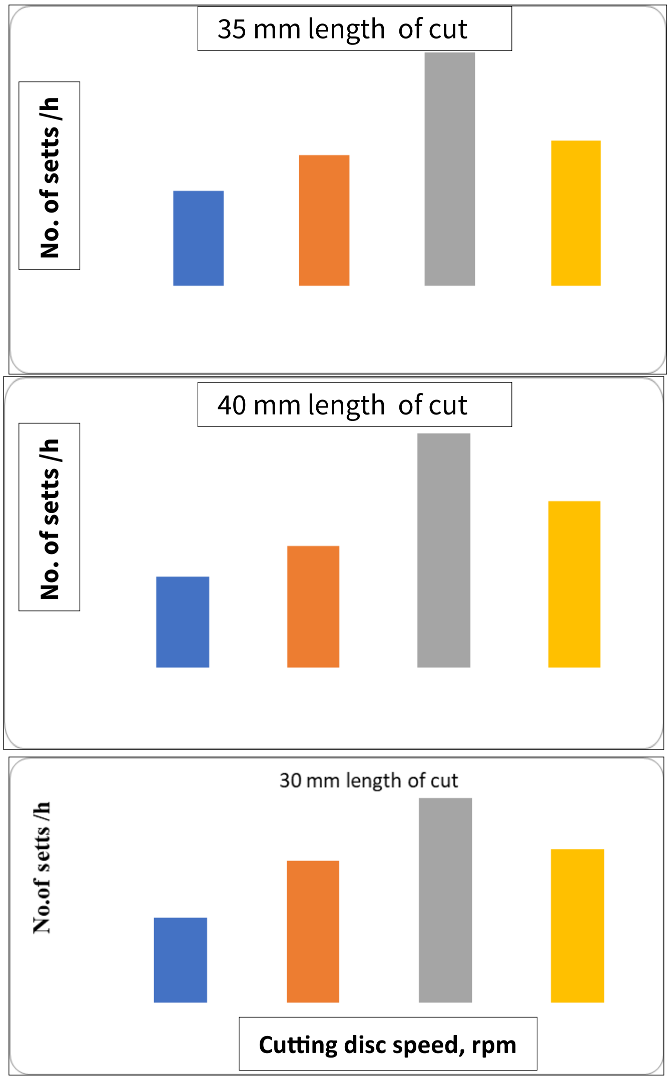

Fig. 3. Performance evaluation of setts cutter with 200 mm diameter of cutting discs.

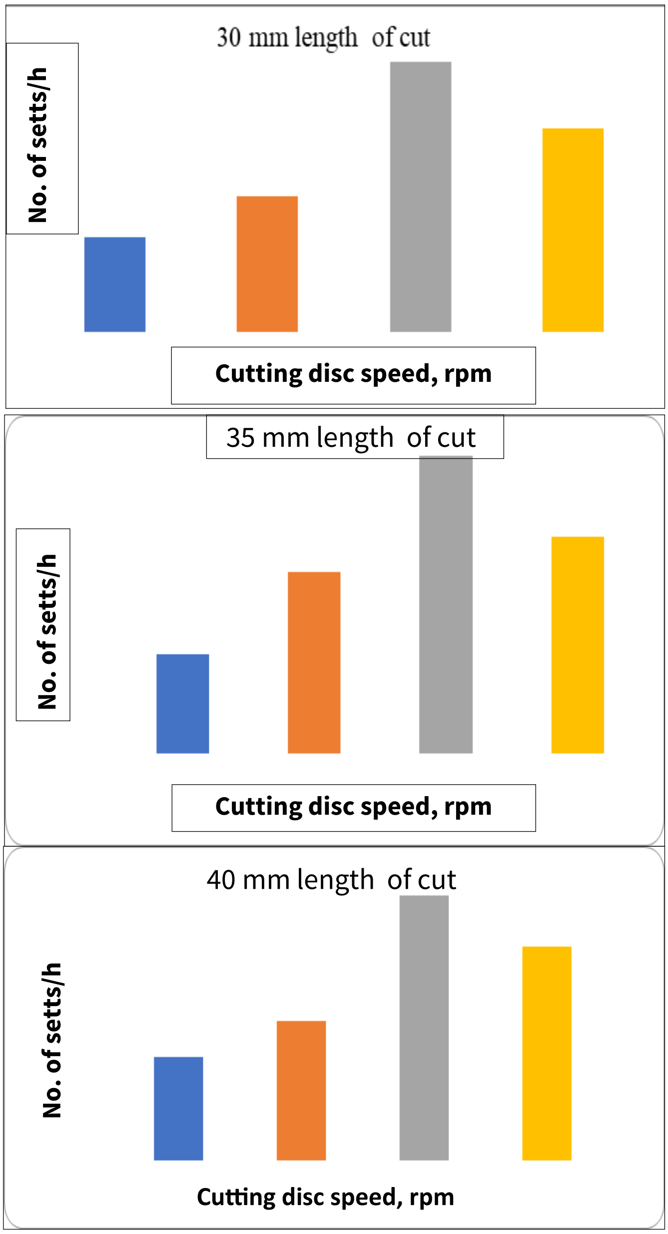

Fig. 4. Performance evaluation of setts cutter with 250mm diameter of cutting discs.

Fig. 5. 35 mm length single bud sugarcane setts at 2200 rpm with 200 mm diameter of cutting blade.

of 35 mm was optimized for the cutting operation. However, sugarcane setts can be cut at 30, 35, or 40 mm lengths, depending on the variety of sugarcane, with the appropriate spacer size selected for each case.

The optimal operating conditions for the sugarcane sett cutting machine were a rotational speed of 2200 rpm, a 200 mm diameter cutting disc and a 35 mm sett length. These parameters were chosen based on the machine's output, the quality of the cuts (i.e., smoothness and the presence of fissures) and the germination percentage. For the experiment, seven-month-old sugarcane stalks were cut using the engine-powered sugarcane sett cutter. The setts were then treated by soaking them in a solution containing urea, Bavistin and lime for 10-15 min to prevent infestation. After treatment, the setts were dried under shade for 2-3 hr and placed in pro-tray nurseries. Decomposed coco-pith was used to cover the buds, ensuring that the bud side faced upwards for optimal growth. The pro-trays were wrapped in polyethene sheets to protect the setts from water, air and sunlight. The germination rates observed were 95% in the pro-tray nursery and 90 % under actual field conditions (Fig. 6).

The cost of sugarcane sett cutting by the machine was calculated at 135 INR per hour, including depreciation, interest, fuel, lubricating oil, repairs, maintenance and operator wages, significantly reducing operational costs compared to manual methods. The desired output of the machine was found to be 1700 setts per hour. The cost of cutting the whole cane into setts for planting purposes using the engine-powered sugarcane sett cutter was calculated as 80 INR per 1000 setts compared to 500 INR per 1000 setts for bud chipper. Cutting setts using the machine was 1000 INR per hectare, significantly lower than the 6250 INR per hectare cost of utilizing a bud chipper. The machine is priced at 50000 INR, offering a cost-effective solution for farmers.

Conclusion

The performance of the developed cutter was evaluated. Optimal settings for the cutting disc were 2200 rpm and a 200 mm diameter, based on factors such as setts cut per hour, sett integrity and germination rates. The cutter could produce setts in 30, 35 and 40 mm lengths by adjusting the spacer between the cutting discs, making it suitable for various sugarcane varieties. Germination success in the pro-tray nursery was recorded at 95 %.

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Authors' contributions

KP conceived, developed a statistical analysis, and drafted the manuscript. AT participated in the sequence alignment.

Nursery in portray

Nursery in field

Fig. 6. Germination percentage of 35 mm of single bud, 200 mm diameter of blade at 2200 rpm.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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