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Development of battery-operated automated sugarcane single bud sett cutter with image processing technology

Kamaraj P[1*], K Balaji[2] & R Thiyagarajan[3]

[1]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Trichy 621 712, Tamil Nadu, India

[2]Department of Renewable Energy Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Trichy 621 712, Tamil Nadu, India

[3]Department of Farm Machinery and Power Engineering, Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Trichy 621 712, Tamil Nadu, India

*Email: kallaikamaraj@tnau.ac.in

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Abstract

Sugarcane is a vital commercial crop in India. In conventional sugarcane cultivation, around 6 to 8 tonnes of sugarcane setts are used as planting seeds. The substantial planting material creates significant transportation, handling and storage challenges, leading to quick deterioration. Additionally, it requires significant labour and negatively impacts germination rates. To overcome this problem, a battery-operated automated sugarcane bud sett cutter was developed with the key components of the main frame, sugarcane stacker, conveyors, serrated disc, cam, battery, DC motors, Raspberry Pi board, Arduino board, ultrasonic sensor, infrared sensor, relay and web camera. The developed machine is designed to reduce the mass of sugarcane setts, with the leftover material being utilized for producing juice, sugar and jaggery. The performance of the sugarcane sett cutter was tested by varying the rotational speeds of two rotary blades, which were mounted on a single shaft with adjustable spacers. The machine could cut 2670 setts per hour at 7000 rpm. The cost of cutting whole sugarcane into setts for planting using the automatic single-bud sugarcane sett cutter is ₹115 per 1000 setts, compared to Rs. 150 per 1000 setts for manual cutting with chopper knives. Using the sett cutter gives a 35 % savings in labour costs and doubled efficiency, with no fissures in the setts. The machine is priced at ₹42000/-.

Keywords

battery operated; mechanized farming; sett cutter; single bud; sugarcane

Introduction

Sugarcane is the worlds' largest crop by production, with 1920 mt produced in 2022. Brazil is the top country in sugarcane production in the world. Brazil is the leading producer of sugarcane, with a production of 650 mt, accounting for 38 % of the worlds' total sugarcane production. India follows as the second-largest producer, producing 49 mt. Approximately 80 % of the worlds' sugar is from sugarcane grown in tropical and subtropical climates. Uttar Pradesh has the highest sugarcane production in the subtropical zone, having an area of about 27.4 lakh ha and a production of 225 mt cane.

In contrast, Tamil Nadu has the highest sugarcane productivity in India. Cultural operations in sugarcane production are highly labour-intensive, particularly during planting, intercultural practices, plant protection and harvesting. Among these operations, planting is labour-intensive and involves considerable human drudgery next to harvesting. The overall requirement of labour for sugarcane cultivation is 3300 man per ha. Sugarcane is a vegetatively propagated crop. The seed materials used are the stem cuttings known as “setts”. Each may have one or several buds. Healthy seeds are essential for successful sugarcane cultivation, as most sugarcane diseases are seed-borne and transmitted through the seed setts. Ultimate plants and yield depends on the type of seed material used. The planting setts should be selected in seven to eight months of crops and should have healthy buds without any damage in handling and transport. To cut 20000 setts for 1 acre, 10 to 11 laborers are needed. (1, 2). Mechanical methods have been developed with varying degrees of success on reducing human strain using manual sugarcane sett cuttings. Including a sett cutting unit resulted in a 40 % reduction in energy and cost requirements compared to the traditional method of planting sugarcane.

The Sustainable Sugarcane Initiative (SSI) method offers practical solutions for improving the productivity of land, water and labour. Key principles of SSI include raising nurseries in trays using single-budded setts, transplanting young seedlings and maintaining wider spacing (150 × 60 cm) in the main field. While single-budded setts generally have good germination under optimal conditions, they are more susceptible to environmental stresses, which can be mitigated through chemical treatments. Buds placed in an upward position result in 72.2 % germination, compared to 69.43 % for sideways and only 23.61 % for downward placement. Downward-placed buds consistently show poor germination and delayed shoot emergence. The SSI method also produces more productive tillers than conventional methods, partly due to cutting off mother shoots 30 days after planting (3, 4).

Manually operated sugarcane bud cutters can cut 500 to 1000 setts per hour, while a reciprocating double cutter chipping machine can cut 30 buds per minute. Approximately 240 kg of seeds are required per acre with SSI, compared to 3 tonnes in traditional methods (5). Enhancing human-powered sugarcane bud-chipping machines addresses rural challenges by streamlining the process and reducing sugarcane wastage, excessive effort and time consumption. Innovations in design, material selection and mathematical modelling boost production rates by efficiently cutting buds, fostering higher productivity in rural areas (6). Engine-operated sugarcane bud cutters are more mechanized, offering increased efficiency. These machines can cut up to 2000 sets/h, reducing the labour and time required for sugarcane propagation. A semi-automated sugarcane single-bud sett cutter operates with a rotary cutting unit, requiring 1 to 2 hp. This machine reduces labour costs by 68 % and has a cutting capacity of 1800 to 2000 buds per h. It cuts more buds in less time, which enhances overall productivity (7).

Technological advancements reduce efforts to achieve desired outputs. Agricultural equipment is increasingly automated due to labour shortages. Designing automatic sugarcane bud-cutting machines to address worker scarcity and minimize wastage. Machine boosts bud production, lowers transportation costs and enhances seeding material quality (8). Sugarcane production is pivotal to its economy, with the predominant pre-cutting planting method despite its quality challenges. Proposed advancements, like the sugarcane-seed-cutting device integrating automatic identification technology, aim to optimize cutting quality and efficiency. Research on RGB colour sensor pulse widths in lab conditions enhances sugarcane node recognition, contributing to improved seed cutting. Leveraging IoT and RGB colour sensors offers cost-effective analytical capabilities, revealing traditional image processing methods for sugarcane seed-cutting automation (9).

A battery-operated automated sugarcane bud set cutter is a modern and efficient tool designed to automate cutting sugarcane buds or setts for propagation. It allows for greater portability, efficiency and convenience compared to other cutters. It is more suitable for small to medium-scale sugarcane propagation operations, balancing automation and ease of use. Automatic sugarcane node cutting machine to control cutting location so that the cut cannot appear on the node (10). The sugarcane seed cutting and anti-damage bud system utilizes machine vision to divide the sugarcane stem into sections and intersections, optimizing its use for sugar production and minimizing waste (11). Mechanized sett-cutting is vital for modern sugarcane farming as it boosts productivity while ensuring long-term sustainability. It improves efficiency, lowers costs and maintains consistent crop quality. These technological advancements are key in tackling challenges like labour shortages and the inefficiencies of traditional farming methods.

Materials and Methods

The battery-operated automated sugarcane single bud sett cutting machine was developed (Fig. 1). The key components of the main frame, sugarcane stacker, conveyors, serrated disc, cam, battery, DC motors, Raspberry Pi board, Arduino board, ultrasonic sensor, infrared sensor, relay and web camera (Fig. 2) and their particulars are given in below.

Components		Particulars
Raspberry Pi 5	:	ARM-based processors and microSD cards for storing sugarcane bud images (8GB). It runs the MySQL database to store the bud images. It interfaces with a webcam for capturing the photos of sugarcane buds.
Arduino Board	:	It receives signals from ultrasonic sensors, such as IR sensors, about the presence of sugarcane and it transmits signals to relays to control the belt conveyor operations. Microcontroller unit and user-friendly interface for writing, compiling and uploading code.
Ultrasonic Sensor	:	It detects the presence of sugarcane when it passes through the conveyor and responds to the Arduino Board for further relay mechanism.
Infra-red Sensor	:	It detects the infrared radiation emitted by the cutter blade handle and transmits the signal to the Arduino board.
Relay	:	It acts as an electromechanical switch. It operates a vertical conveyor, horizontal conveyor and cam with desired delay timing.
Web Camera	:	Capture the bud image when it passes through the horizontal conveyor. 1080p resolution and Ultra-wide 95° lens.
Power source	:	The battery gives the Raspberry Pi board power to activate the Arduino Board.
DC motors (4 No)	:	12 volt and 12 rpm for operating the horizontal belt, 12 volt and 38 rpm for operating the vertical belt, 12 volt and 51 rpm for operating the cam and 12 volt and 10000 rpm for operating the cutting unit.

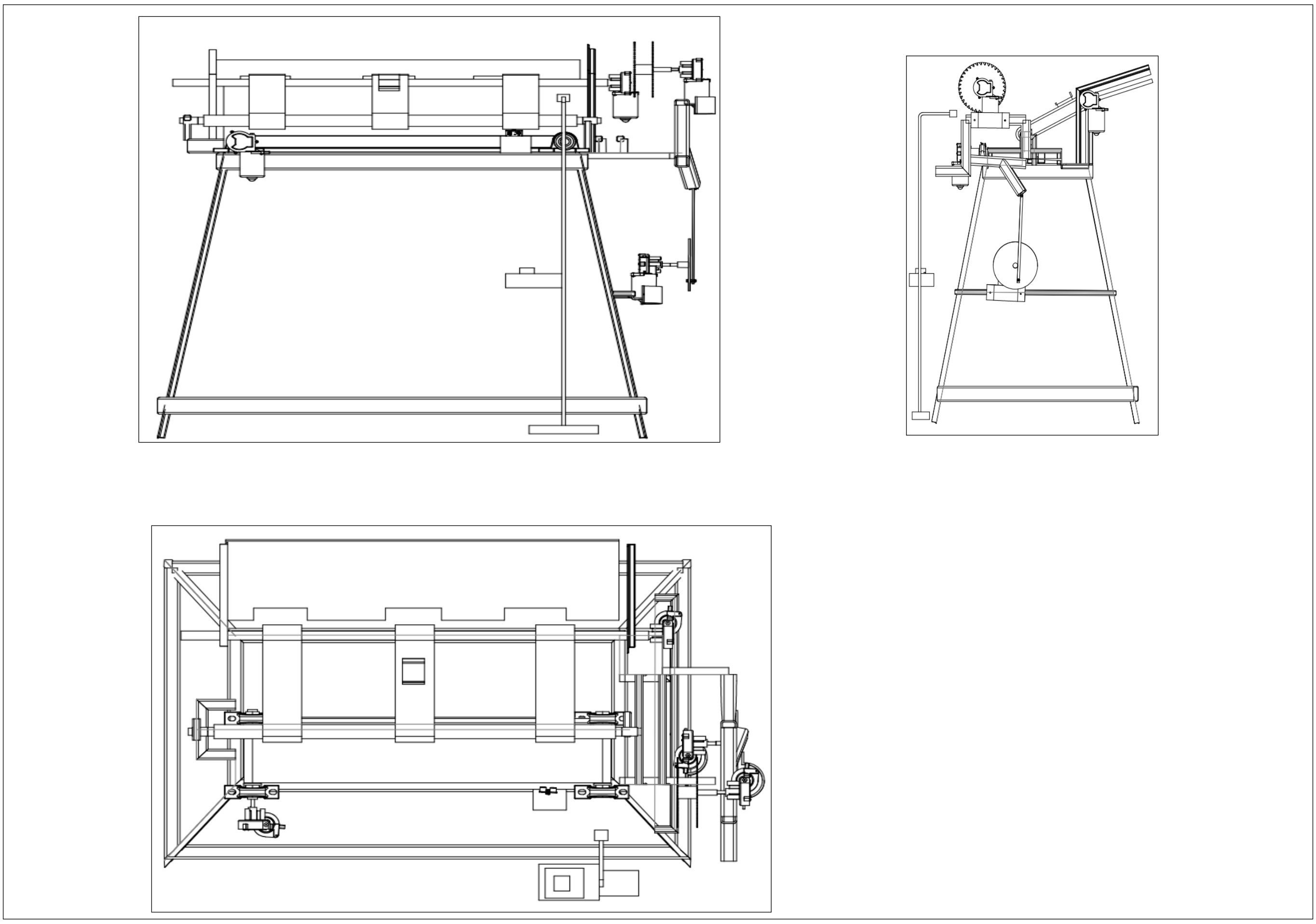

Fig. 1. Battery-operated automated sugarcane single bud sett cutter (front, side and top view).

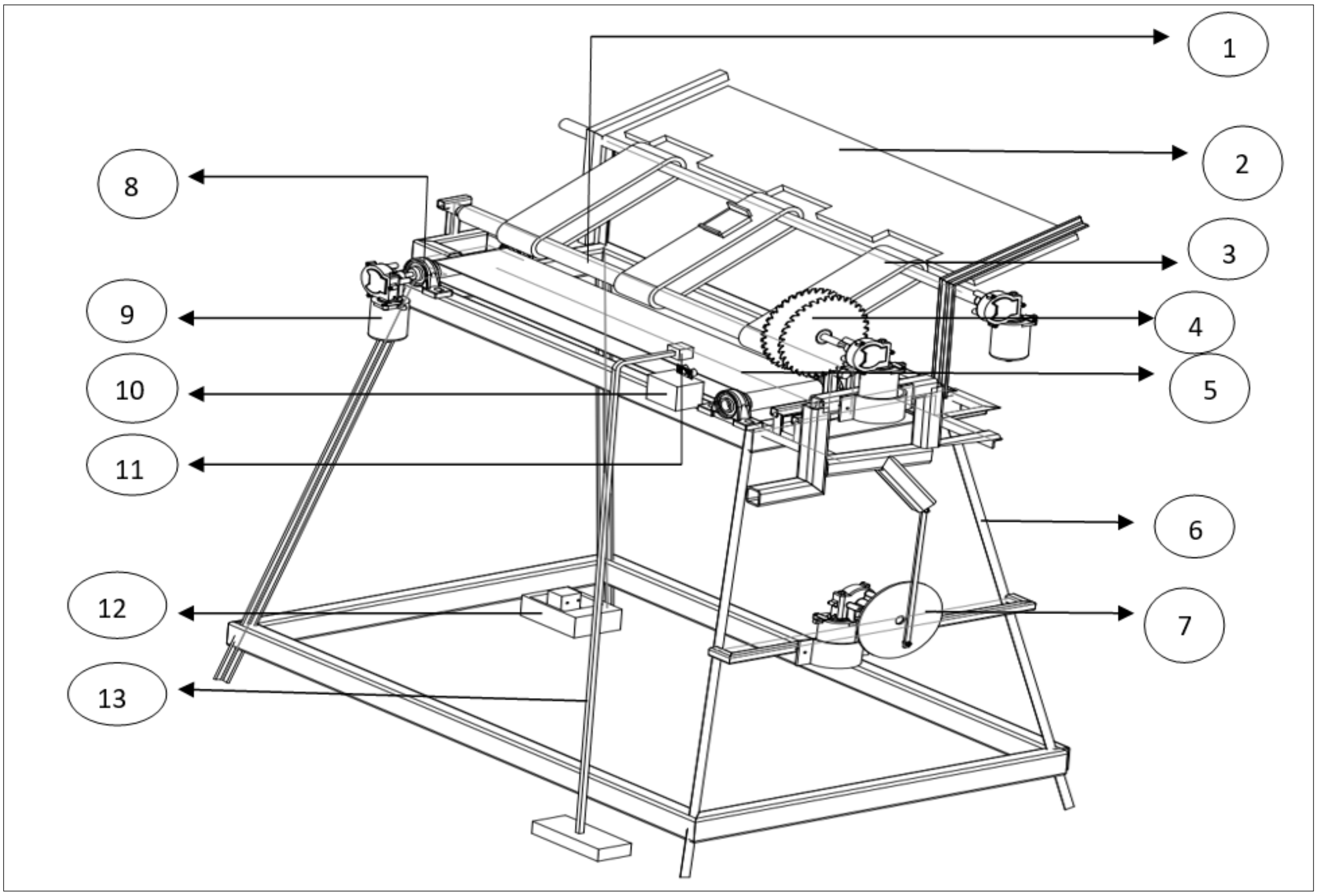

Fig. 2. Isometric view of battery-operated automated sugarcane single bud sett cutter. 1. Shaft 2. Stacker 3. Vertical conveyor 4. Serrated Disc 5.Vertical conveyor 6. Mainframe 7. Cam 8. Pillow block bearing 9. Motor 10. Ultrasonic sensor 11. Web camera 12. Electronic components box (Arduino Board, Raspberry PI 5, relay) 13. Stand.

Construction of the machine

The main frame of this machine was fabricated with 32 × 32 × 6 mm mild steel 'L' angle. All other components are mounted in this main frame to make the machine operate quickly and conveniently. On the rear side, at the top of the main frame, a stacker has been provided to hold whole sugarcane for continuous cutting operation. The size of the stacker was 980 × 430 × 300 mm with 1 mm thickness. Three rexine flat belts were used at the desired distance, 990 × 100 × 2 mm, for conveying the sugarcane from the stalker to the horizontal conveying belt. A DC motor of 12 volts and 38 rpm was used to drive the conveyor belt with suitable arrangements of rollers. On the front side of the main frame, a horizontal conveyor, PVC flat belt, was attached with a dimension of 1900 × 150 × 3 mm. A DC motor of 12 volts and 12 rpm was used to drive the conveyor belt with suitable arrangements. Pillow block bearings serve as a base to support shafts, to which conveyor belts are attached using various accessories. The housing material for a pillow block is typically made of cast iron. Four bearings with a 20 mm bore are mounted on the main frame.

At the right side of the main frame, two serrated discs of 160 mm diameter were provided with adjustable spacers to perform the sett-cutting operation in the desired sizes. A DC motor of 12 volts and 10000 rpm was used to rotate the serrated disc. A cam is a rotating piece in the middle of the right side frame. It was used primarily to transform rotary motion into reciprocating motion. For cam action, a 160 mm diameter, 4 mm thickness mild steel plate was used and the connecting rod was fitted 50 mm from the centre of the plate. A DC motor of 12 volts and 50 rpm was used to drive the cam arrangements.

Cutting the single bud setts in the sugarcane is exceptionally tedious and includes a ton of time and work. Hence, an utterly automatic sugarcane sett cutter that uses DC motors for a programmed sugarcane cutting system with image processing technology, which is detailed in module 1 and module 2. The framework utilizes an automated machine with a strong mechanized game plan to push the whole sugarcane into the cutting part of the machine. When a sugarcane stick is used, the bud is captured by the image processing concept and fed to the cutting part of the machine for single bud sett cutting.

Sugarcane bud image processing using Rasberry Pi (Module -1)

The image processing system uses the Raspberry Pi board as the central controller, running the latest version of Raspbian Wheezy. After installing the operating system onto the board, connect all the necessary hardware components and power up the system. The board will begin booting and logging into the Raspberry Pi using the username and password. The system operates on the Linux Debian OS and uses Python for programming code. Python environment and software are checked for updates using network settings with terminal commands.

The installation and setup commands are executed for image processing: Matplotlib, numpy, scipy and imaging. Camera settings are enabled on board for image capturing and storage. Python code is tested for image noise. The implemented method and the schematic diagram of Module 1 are shown in Fig. 3 and 4.

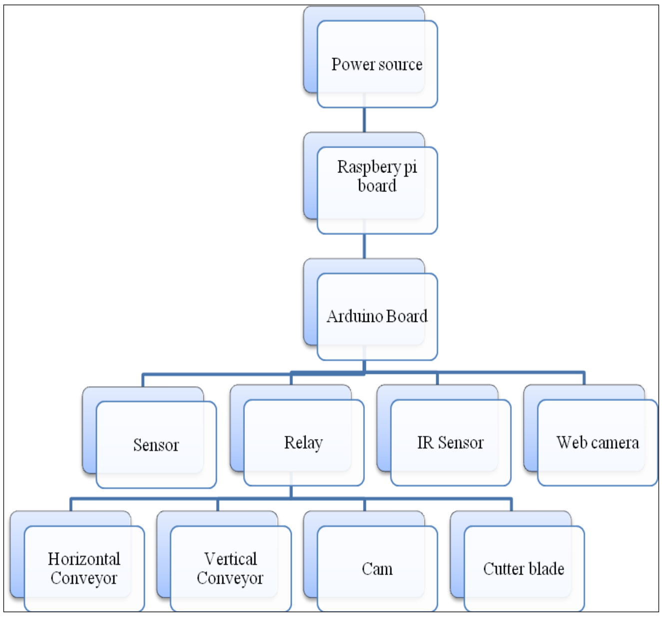

Fig. 3. Flow diagram of working of automatic sugarcane single bud sett cutter.

Automation control system using Arduino (Module-2)

The automation control system comprises an Arduino board with an ultrasonic sensor. It is empowered with ultrasonic sensors that constantly track the sugarcanes' place. Once an Arduino board controls horizontal and vertical conveyor actions, parcels are halted and handled by the drive framework connected to another ultrasonic sensor that estimates the level of the sugarcane. Programmed control of the conveyor belt process is significant. So, carrying out such a framework utilizing the Arduino stage is feasible. The schematic diagram of Module 2 is shown in Fig. 5.

Methodology of testing

During the machines' operation, the Raspberry Pi detects the sugarcane bud image (Fig. 4) and compares the target image with the reference image, which is fully automated and applied to the entire image. Due to barometrical conditions, noise in the images makes noise removal significant to improve image quality. For this, the Rudin-Osher-Fatemi (ROF) denoising model is used. The total variation of a grayscale image I is the sum of the gradient norms for a smooth representation. This model uniquely produces a softer version of the image while preserving edges and structures. Image comparison is performed on Raspberry Pi to properly cut a bud from sugarcane. An Arduino board controls the horizontal and vertical movements of the conveyor belt carrying sugarcane. The integration of Module 1 and Module 2 ensures efficient coordination. To ensure the most accurate performance testing of the battery-operated automated sugarcane sett cutter, temperature, humidity and cane variety are controlled by conducting tests in controlled environmental conditions or carefully selecting cane samples with uniform size and measuring the relevant environmental factors. The image processing technology is adjusted to work in these

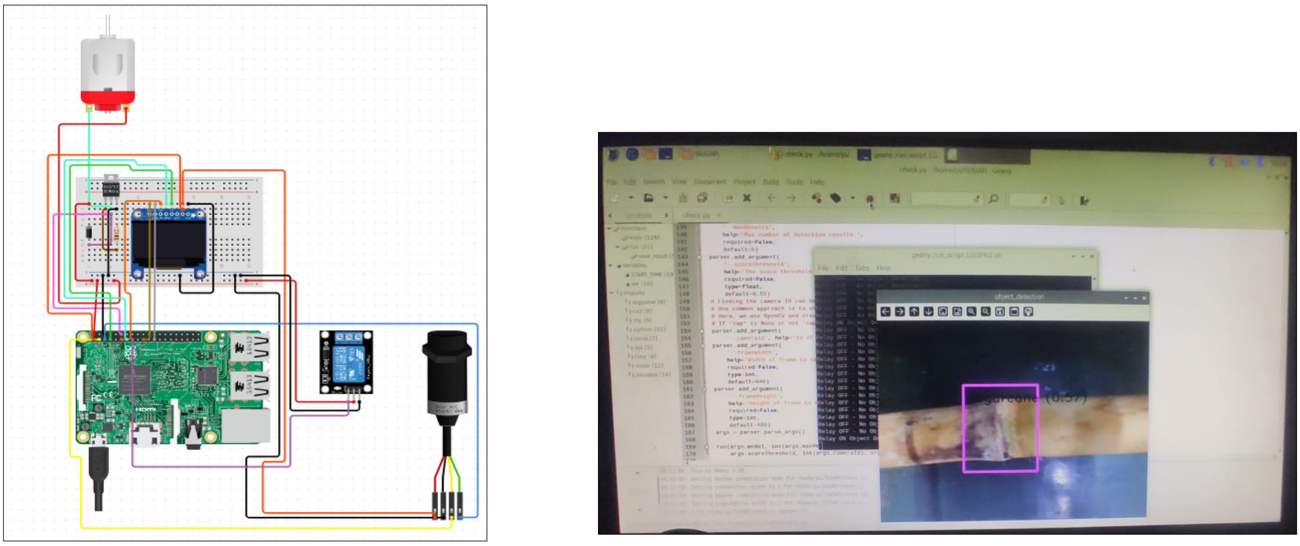

Fig. 4. Schematic diagram for sugarcane bud image processing using Rasberry Pi.

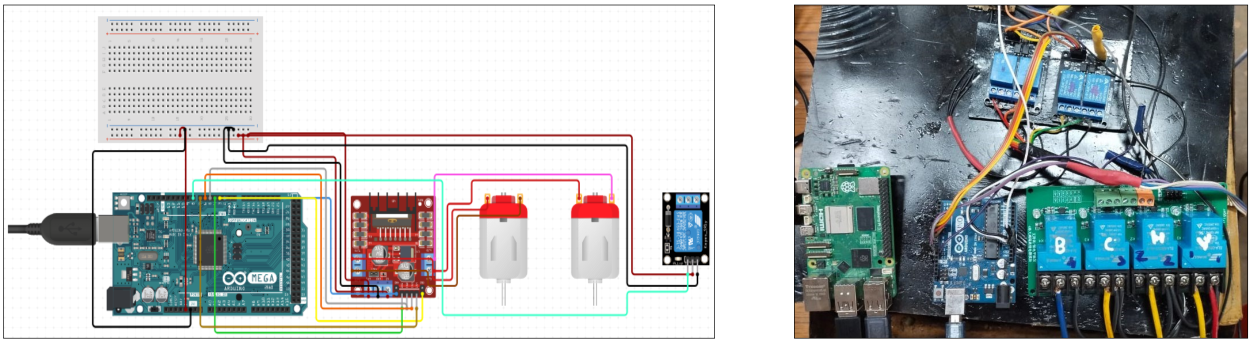

Fig. 5. Schematic diagram of an automation control system using Arduino.

conditions, using calibrated sensors and lighting to ensure precise bud detection and accurate cutting.

Results and Discussion

The battery-operated automated sugarcane bud sett cutting machine was developed (Fig. 6) at the Department of Farm Machinery and Power Engineering (FM and PE), Agricultural Engineering College and Research Institute in Trichy district, Tamil Nadu, with the following specifications given in Table 1.

- Image processing technology enables accurate detection of sugarcane buds, improving cutting precision, reducing wastage and enhancing germination rates.
- Compared to other speeds, the machines' cutting speed at 7000 rpm achieved the highest output (2670 setts/h) with smooth cuts and minimal damage.
- The cost of cutting setts using the automated machine is ₹115/1000 setts, lower than the ₹150/1000 setts cost of manual cutting.
- The machine costs ₹42000, including fabrication labour and profit, with a battery life of 3 years and an overall machine lifespan of 7 years.

A 12-volt battery was used as a power source, providing power to the Raspberry Pi board, Arduino Board and all the DC motors. Raspberry Pi board is used to activate the Arduino Board, which acts as a memory source that transmits signals to sensors, relays, IR sensors and

Fig. 6. Prototype of the battery-operated automated sugarcane bud sett cutting machine.

webcams. The sensor and webcam detect the sugarcane bud and capture the bud image, respectively. Using image processing technologies, the sugarcane sett cutter can detect the sugarcane node accurately while filtering out irrelevant data that could hinder precise detection and cutting. This improves cutting accuracy, reduces wastage and enhances germination rates. It ensures the system operates efficiently and effectively across different controlled conditions and sugarcane varieties. When it passes through the conveyor and responds to the Arduino Board for further relay mechanism. Relay acts as an electromechanical switch that operates the vertical

Table 1. Components and their details of battery-operated automated sugarcane single bud sett cutter

S.No	Components	Specifications
1	**Overall dimensions (L×B×H), mm**	1400 × 870× 900
2	**Sugarcane stacker, mm**	980 × 430 × 300
3	**Vertical conveyor belt**	
i	Material	Rexine Flat Belt
ii	Width, mm	100
iii	Length, mm	990
iv	Thickness, mm	2
v	DC motor	12 V, 38 rpm
	Type	Centre shaft DC geared motor
4	**Horizontal conveyor belt**	
i	Material	PVC Flat belt
ii	Width, mm	150
iii	Length, mm	1900
iv	Thickness, mm	3
v	DC Motor	12 V, 12 rpm
	Type	Centre shaft DC geared motor
5	**Serrated disc**	
i	Diameter, mm	125
ii	Thickness, mm	1
iii	Number of teeth	100
iv	DC Motor	12 V, 10000 rpm
v	Type	Centre shaft DC geared motor
6	**Cam**	
i.	Material	Mild steel
ii.	Diameter, mm	160
iii.	Thickness, mm	4
iv	DC Motor	12 V, 51 rpm
v	Type	Centre shaft DC geared motor

conveyor, horizontal conveyor and cam with desired delay timing. IR Sensor detects the infrared radiation emitted by the cutter blade handle and transmits the signal to the Arduino board. The working and performance of the battery-operated automated sugarcane single bud sett cutter (Fig. 7) was evaluated using the leading varieties CoC24 and CoSi (Sc) 6 in the Trichy district. The tests were conducted at three cutting disc speeds (6000, 6500 and 7000 rpm) and the smoothness of the cut and the minimum fissures in the setts were evaluated, as shown in Table 2.

From Table 2, it is evident that the number of setts per hour increased with the rotational speeds from 6000 to 7000 rpm of cutting disc, but then almost no significant change from 7000 to 7500 rpm, but damage the setts. The machine output is two times increased without fissures. Hence, the cutting disc at 7000 rpm achieved the highest output capacity, the best smooth cutting and the best without fissures in the setts compared to the other speeds. The output of the machine was found to be 2670 setts/h. The cost of cutting the whole cane into setts for planting purposes using the automatic single bud sugarcane sett cutter was calculated as Rs. 115/1000 setts compared to Rs. 150/1000 setts manual setts cutting using chopper knives.

Table 2. Performance evaluation of battery-operated automated sugarcane single bud sett cutter

Parameters	**Speed of the sett cutting blade (rpm)**			
	6000	6500	7000	7500
No of setts/ hour	1210	1642	2670	2540
Smoothness of cut	No smoothness	Good	Very Good	Good
Fissures in setts	More fissures	Minimum fissures	No fissures	No fissures but damage the setts

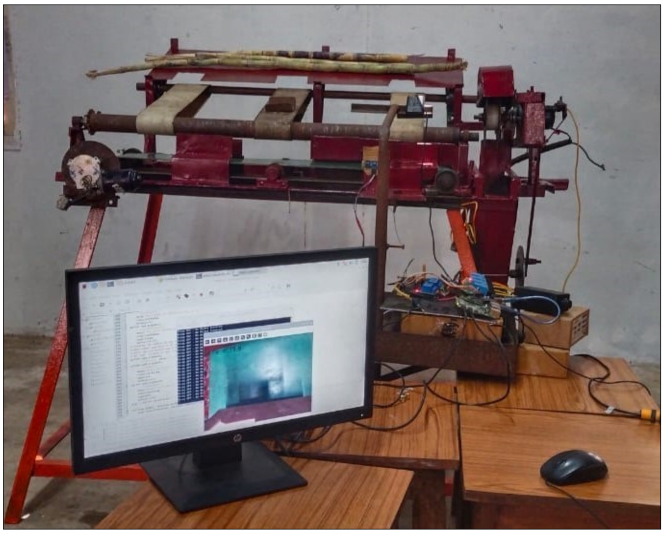

Fig. 7. Working of automated sugarcane single bud sett cutter with image processing.

The machine costs ₹42000/-, including fabrication labour charges and a 20 % profit margin. The 12-volt battery has a durability of 3 yr, while the overall lifespan of the machine is approximately 7 yr.

Conclusion

The machine was evaluated with leading CoC24 and CoSi (Sc) 6 varieties of Trichy district, Tamil Nadu, India. The cutting disc speed of 7000 rpm was optimal for the more significant number of setts with minimum fissures and more germination percentage. The machine cut setts to variable sizes using different spacers between cutting discs, making it suitable for various sugarcane varieties. The machines' output was 2670 setts per h. Germination rates reached 94 % in the portrayed nursery. The battery-operated automated sugarcane sett cutter with image processing technology shows great potential for improving efficiency and reducing labour costs. However, for large-scale adoption:

- Farmers need financial support and training.
- Policymakers provide subsidies for research and development
- Manufacturers must focus on producing affordable and customizable machines

Conducting further trials in diverse climates and with different sugarcane varieties is essential to fine-tune the machines' performance and ensure it can adapt effectively to Indias' varied agricultural conditions. These efforts will ensure that this technology reaches the right hands and proves its effectiveness in improving the efficiency and sustainability of sugarcane farming.

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Authors' contributions

KP conceived, developed, and drafted the manuscript. KB contributed by integrating image processing technology, while RT was involved in the sequence alignment.

Compliance with ethical standards

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

Ethical issues: None

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