# Optimization of target detection scheme for single-bud segment sugarcane cutting machine and seed-picking scheme for planter seed meter

Zhaojun Niu[1,2†], Chang Ge[1,2†], Lijiao Wei[1,2], Gang Song[2*], Mingxin Hou[3], Ming Li[1,2], Tao Huang[1*], Zhongqing Ou[1,2], Qinghe Meng[1,2], Jianmin Zhang[4]

(1. *Institute of Agricultural Machinery Research, Chinese Academy of Tropical Agricultural Sciences, Zhanjiang, 524013, Guangdong, China*;
2. *Key Laboratory of Tropical Crop Agricultural Equipment, Ministry of Agriculture and Rural Affairs, Mazhang District, Zhanjiang, 524091, Guangdong, China*;
3. *Guangdong Ocean University, School of Mechanical and Power Engineering, Zhanjiang, 524088, Guangdong, China*;
4. *Guangxi Shuanggao Agricultural Machinery Co., Ltd., Nanning, 530104, Guangxi, China*)

**Abstract:** Sugarcane mechanized planting technology consists of seed preparation and field planting. This study aims at the issues of easy damage to the seeds during the operation of the automatic cutting machine for single-bud segment sugarcane, lack of intelligent seed selection and calibration technology, low recognition accuracy, and the need for manual feeding of the planting machine's seed meter which leads to seed leakage. This study, based on machine vision and deep learning, optimizes the seed calibration method and proposes an improved YoloV5-STD target detection algorithm to improve the recognition accuracy of seed characteristics and optimize the overall engineering structure. For the planting machine, a new type of hopper for the seed meter is designed using natural rubber as the base material mixed with polystyrene, and the flexible automatic seed metering mechanism is analyzed to achieve automatic feeding and seed metering. Test assessment indicators were formulated based on the enterprise standards of the Institute of Agricultural Machinery Research, Chinese Academy of Tropical Agricultural Sciences. Experimental results show that the recognition accuracy of the 2DZ-2 type single-bud segment intelligent cutting machine is ≥95%, the bud injury rate is <1.8%, the qualified rate of cutting is 95.8%, and the single-channel cutting efficiency is 64 buds/min. The 2CZD-2C type single-bud segment planter has a planting qualification rate of 96.6%, a planting efficiency of 208 buds/min, and a seed leakage rate of <2.1%.

**Keywords:** target detection, scheme optimization, automatic seed cutting, flexible seed metering
**DOI:** 10.25165/j.ijabe.20251805.9144

**Citation:** Niu Z J, Ge C, Wei L J, Song G, Hou M X, Li M, et al. Optimization of target detection scheme for single-bud segment sugarcane cutting machine and seed-picking scheme for planter seed meter. Int J Agric & Biol Eng, 2025; 18(5): 165–170.

## 1 Introduction

Sugarcane is a strategic resource and the primary source of sugar and ethanol worldwide[1-3]. In China, sugarcane cultivation covers an area of over 1.3 million $hm^2$ annually, primarily concentrated in major producing regions such as Guangdong, Guangxi, Hainan, and Yunnan, making it one of the country's primary economic crops[4-6]. Sugarcane planting in fields involves the use of seedling sections classified by the number of buds, including single-bud, double-bud, and multi-bud segments. Since sugarcane buds grow on the internodes, a single-bud seedling refers to a seedling section with one effective bud, or internode, typically 5-8 cm long. Mechanized planting equipment for sugarcane is divided into two types based on the function of the seed metering device: solid-cutting and pre-cutting[7-10]. Pre-cutting equipment is designed for single-bud and double-bud seedlings, which can reduce the labor intensity of auxiliary workers and improve the survival rate and effective utilization of seedlings. As is well known, smaller crop seed sizes facilitate mechanized seeding, making single-bud seedling sections a breakthrough in automated seeding technology.

Single-bud planting is a pre-cutting sugarcane cultivation technique that facilitates fully automated mechanized seeding, encompassing two major processes: mechanized seedling preparation and field sowing. Currently, China's sugarcane mechanized planting technology is facing challenges in automation[11,12]. Foreign cutting equipment has a high bud injury rate and lacks bud recognition capabilities, while the agronomic requirements for automated planting technology differ from those in

**Received date:** 2024-06-13 **Accepted date:** 2025-07-17
**Biographies: Zhaojun Niu,** Associate Research Fellow, research interest: agricultural machinery engineering, Email: niuzhaojun0818@163.com; **Chang Ge**, Associate Research Fellow, research interest: agricultural product processing. Email: gechang0831@163.com; **Lijiao Wei**, Associate Research Fellow, research interest: tropical agricultural machinery, Email: 406775423@qq.com; **Mingxin Hou**, PhD, Associate Professor, research interest: artificial intelligent and control algorithms, Email: houmx@gdou.edu.cn; **Ming Li**, Full Research Fellow, research interest: tropical agricultural machinery, Email: 744826527@qq.com; **Zhongqing Ou**, Associate Research Fellow, research interest: tropical agricultural machinery, Email: ouzhq@qq.com; **Qinghe Meng**, Assistant Researcher, research interest: tropical agricultural machinery, Email: 1452768668@qq.com; **Jianmin Zhang**, Engineer, research interest: agricultural machinery engineering, Email: 2105913277@qq.com.
†The authors contributed equally to this work.
***Corresponding author: Gang Song**, Assistant Research Fellow, research interest: design and automation of tropical agricultural machinery, Key Laboratory of Tropical Crop Agricultural Equipment, Ministry of Agriculture and Rural Affairs, No.3, Huxiu Road, Mazhang District, Zhanjiang 524091, Guangdong, China. Tel:+86-13078298737, Email: sg19862006@163.com; **Tao Huang**, Assistant Research Fellow, research interest: agricultural product processing. Institute of Agricultural Machinery Research, Chinese Academy of Tropical Agricultural Sciences, No.5, Shetan Road, Xiashan District, Zhanjiang 524013, Guangdong, China. Tel: +86-15088148196, Email: khuangtao@163.com.

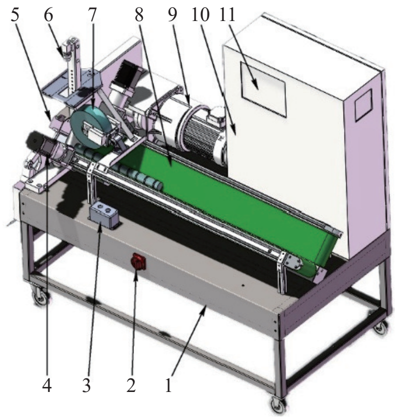
China, making it incompatible with the field conditions of China's main sugarcane producing areas, which are primarily small and medium-sized plots and hilly regions. Domestic intelligent cutting equipment is still in the research and development stage[13], with immature and low-automation planting equipment, primarily relying on knife-roller real-time cutting models[14,15]. These models, though widely used due to their low cost and simplicity, require significant manual labor, and their operational quality and efficiency depend on auxiliary workers. Therefore, precise and intelligent recognition of seedling bud characteristics and automatic and stable seed metering of planting equipment are urgent scientific issues to be addressed. This study focuses on single-bud seedling sections and conducts research on these issues.

For single-bud automatic cutting equipment, the seedling characteristic recognition module and recognition algorithm are the core components. Initially, mechanical sensors were used in the cutting test bench, later optimized with optical sensors[16]. The second-generation prototype employs high-definition industrial cameras, and the control section utilizes PLC and PC control cabinets. This study adopts a PCB high-definition vision module to replace the industrial camera, utilizing a motion control card and vision control card to replace the PLC and PC. Algorithm commands are executed through serial ports, optimizing and streamlining the engineering architecture, significantly reducing costs while improving performance. In terms of software, Labellmg is used for image feature annotation, and PYcharm is employed to optimize the target detection algorithm, enhancing the speed and accuracy of feature recognition[17]. For single-bud automatic planting equipment, the metering device is the core component[18-21], determining the automation level and performance of the planting machine. The metering device's hopper has evolved from an initial rigid plastic type to a first-generation natural rubber trough type, and finally, to the second-generation optimal flexible and lightweight type. This evolution addresses the issue of seed leakage caused by field operation vibrations, improving planting qualification rates and enabling fully automated seeding without manual feeding. This study refers to the enterprise standards of the Agricultural Machinery Research Institute of the Chinese Academy of Tropical Agricultural Sciences regarding sugarcane automatic cutting machines and single-bud planting machines to develop evaluation metrics and test schemes. Through comparative experiments, the main performance parameters of the optimized intelligent cutting and planting equipment are evaluated.

## 2 Optimization of intelligent seed cutting technology

The preparation of sugarcane seedlings is a labor-intensive process in the pre-cutting sugarcane planting operation. Currently, the preparation of sugarcane seedlings is mainly done manually, where the sugarcane is manually cut into sections required by the planting machine. This process involves heavy labor and low work efficiency. In recent years, semi-automatic seedling cutting equipment has emerged in China, which is driven by an electric motor or hydraulic motor. Although it effectively reduces labor intensity, it sacrifices accuracy, resulting in an increase in the breakage rate. To address this issue, the automatic positioning and seedling cutting technology were investigated based on sugarcane feature recognition, and the 2DZ-2 single-bud segment automatic sugarcane seedling cutting machine was designed (as shown in Figure 1).

The key to accurate positioning lies in the performance of the feature detection module and the design of the algorithm. The early control system (as shown in Figure 2) utilized a PLC controller, which processed and visualized the detection part through a PC in the electric control box and sent the processing results to the PLC. The PLC then operated based on the received data, controlling the servo motor to feed the sugarcane and the three-phase motor to drive the cutting mechanism for sectioning. A control system required two sets of software to execute, and the hardware performance, algorithmic efficiency, accuracy, and equipment cost of the detection module were issues to be optimized in the next step. To address the encountered problems, the optimization research was conducted on the target detection scheme and feature recognition algorithm from the inside out.




1. Rack 2. Power switch 3. Emergency stop and manual/automatic switch 4. Private server motor 5. Cutting mechanism 6.Target detection module 7. Pinch roller 8. Sugarcane conveyor belt 9. Three-phase motor 10. Distribution box 11. PC LCD screen

Figure 1 Automatic cutting machine of single-bud sugarcane

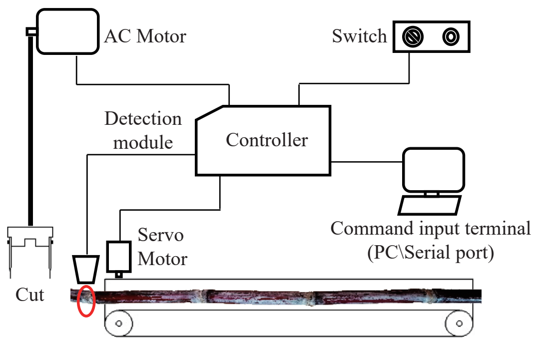



Figure 2 Schematic diagram of control system

### 2.1 Optimization analysis of sugarcane seedling feature detection scheme

The length of the single-bud segment of sugarcane seedling is 5-8 cm, and each segment of the sugarcane seedling should have an effective bud. The buds of sugarcane grow on the sugarcane joints. Therefore, the primary goal of achieving accurate positioning and cutting of the entire sugarcane stalk is to detect and identify the sugarcane joints and buds. In this study, three target detection schemes were tested, as shown in Figure 3. Initially, a mechanical sensor was used with a sliding wheel and rebound mechanism to detect the sugarcane joints. The test results showed that the target detection effect was good when the sugarcane joints were obviously protruding. However, due to the irregular growth of sugarcane, the degree of protrusion and concavity of the joints varies, and some sugarcane even has no obvious protrusion and concavity numbers, making it impossible to guarantee the accuracy of target detection.

To address this issue, an optical sensor was used to replace the mechanical sensor. The target detection principles of the two sensors are the same. When the mechanical wheel or optical ray passes through the sugarcane joints during the feeding process, it generates a significant fluctuation signal, which allows the system to identify the feature part and perform positioning and cutting actions. The test results showed that although the optical sensor has higher detection sensitivity, it is easily affected by factors such as sugarcane skin color and environmental light, resulting in a lower accuracy of target detection compared to the mechanical sensor. Finally, the above issues were solved through machine vision. The main reason is that there are obvious visual differences between sugarcane joints, buds, and segments. By using industrial cameras or even PCB high-definition vision modules to replace human eyes for target detection, the test results showed that machine vision target detection has higher accuracy. Moreover, through the optimization of the target detection algorithm, the detection accuracy of buds with inconspicuous and small features can be further improved.

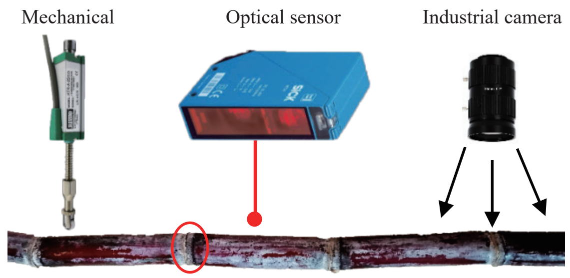


Figure 3 Scheme of target detection

### 2.2 Improved YoloV5-STD target detection algorithm

Currently, there are various algorithms used for object detection, such as SSD, CNN, and Yolo[22,23]. Yolo (You Only Look Once), as an end-to-end training and inference algorithm, transforms the detection task into a mathematical regression problem, predicting bounding boxes and class probabilities in images. Its speed is suitable for real-time detection, and the series has been optimized and upgraded to the 12th generation. Given the algorithm's applicability and compatibility with engineering application software and hardware, this study adopted the YoloV5 algorithm and optimized it with improvements, adding detection boxes for small targets (Small Target Detection-STD) to enhance the accuracy of target recognition. Our team has also applied this improved algorithm, YoloV5-STD, in the identification of foreign objects on the water surface of marine equipment[24] and the target grasping of robotic arms, achieving satisfactory recognition results. In the optimization and comparative tests of sugarcane intelligent cutting technology based on the 2DZ cutting machine, multiple experiments were conducted using the enterprise standard Q/RJ 003-2021 of the Institute of Agricultural Machinery, Chinese Tropical Agricultural Sciences, with the recognition accuracy, bud damage rate, and cutting qualification rate as evaluation indicators. Each set of cutting lasted for 2 min, and the results showed that compared to mechanical sensors and optical sensors, the recognition accuracy of the improved YoloV5-STD visual recognition reached $Z \geq 95\%$ (as shown in Figure 4), with a bud damage rate of $S < 1.8\%$ and a cutting qualification rate of 95.8%.

$$Z(\%) = \frac{N_F}{N_S} \times 100\% \tag{1}$$

$$S(\%) = \frac{C_F}{C_Z} \times 100\% \tag{2}$$

where, $Z$ is seed cane preparation recognition accuracy rate, %; $N_F$ is the number of accurately identified seed cane segments passing through the recognition area within a unit time, expressed in segments; $N_S$ is the total number of seed cane segments actually cut in the cutting area within a unit time, expressed in segments; $S$ is seed cane cutting bud damage rate, expressed in percentage, %; $C_F$ is the number of bud damages that occurred during the transportation and cutting process within a batch, expressed in segments; $C_Z$ is the total number of seed cane segments processed through cutting within a batch, expressed in segments.

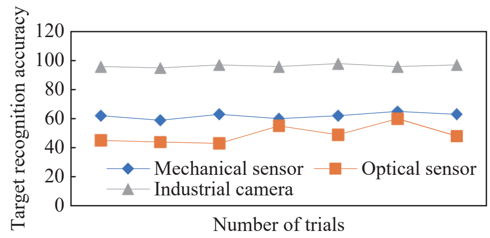


Figure 4 Comparison of recognition accuracy of three schemes

The proposed YoloV5-STD algorithm maintains the same network framework structure as YoloV5, incorporating modules such as convolutional layers (Conv), Focus, BottleneckCSP, and Spatial Pyramid Pooling (SPP). The primary difference lies in the provision of four preset anchor boxes, with an additional set of smaller selection boxes (as indicated by the dashed circle on the left side of Figure 5). These selection boxes are designed to be sensitive to small objects in the image. Additionally, adjustments were made to the PANet structure, with the addition of an STD module (as shown in the shaded section on the right side of Figure 5) in the Neck PANet. The feature pyramid network is utilized as the Neck part for feature extraction. The added shallow layer information utilizes 6×6 pixels or larger to predict the characteristics of small objects. The detection results are then derived through four layers of varying resolutions ranging from 12×12 to 48×48, from shallow to deep, thereby enhancing the accuracy of small target recognition. Using the deep learning server PowerEdge T640, the YoloV5-STD algorithm was trained and tested, demonstrating superior performance and higher accuracy compared to the YoloV5 prototype. The mAP0.5 reached 99.27%, and the training object loss rate was reduced from 1.02% to 0.4%. The precise recognition and efficient operation of the cutting equipment provide a solid foundation for mechanized planting.

## 3 Optimization of flexible seed metering technology for single-bud planting machine

Sugarcane planting is also a labor-intensive operation process. Currently, the mechanized planting of pre-cut sugarcane mainly includes double-bud section and single-bud section modes. Compared to the real-time cutting mode, the survival rate and disease resistance of sugarcane seeds are significantly improved through pre-selection, germination, soaking, and other processes. The mechanized planting of single-bud sugarcane seeds is a more precise planting technique that inherits the advantages of the pre-cut mode while significantly reducing the amount of seeds used per unit area. The flexible seed metering technology for single-bud sections proposed in this study is based on the analysis and experiments conducted on the 2CZD-2C sugarcane planter designed by our team. The planter integrates processes such as anti-vibration soil crushing, ridging and furrowing, soil covering, and irrigation. The seed metering device (as shown in Figure 6) adopts a classic chain

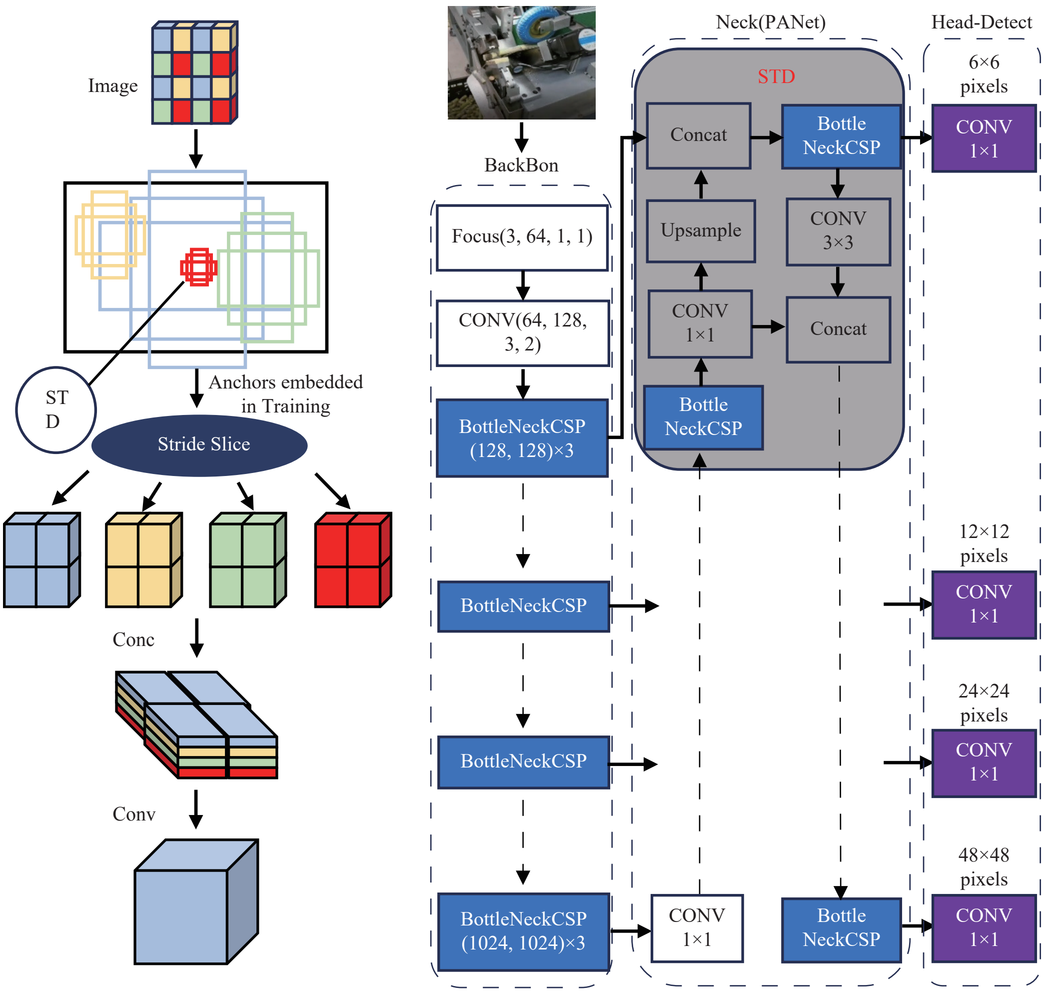
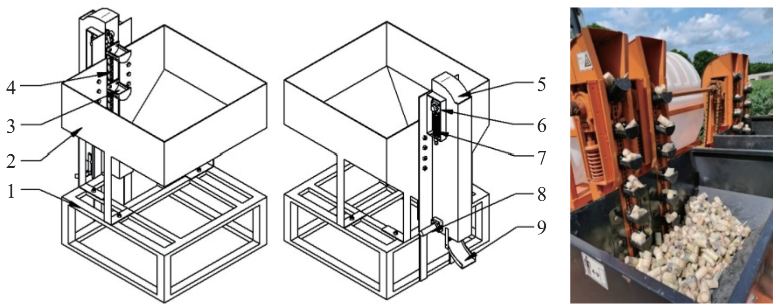



Figure 5 Anchors and PANet framework of YoloV5-STD




1. Rack 2. Seed box 3. Flexible hopper 4. Drive chain 5. Guard board 6. Sliding screw 7. Tensioning spring 8.Transmission shaft 9. Seed guide groove

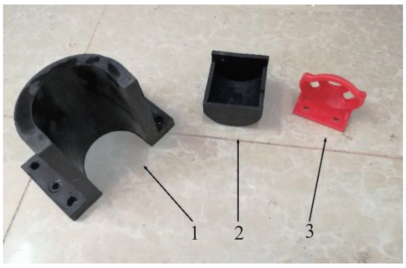
Figure 6 Seeder of single-bud sugarcane planter

transmission mechanism.

The seed metering device is the core component of the sugarcane planter, and its performance determines the degree of automation of the planter's operation. Currently, there are several common types of seed metering devices for sugarcane planters, including knife roller type, slotted type, multi-stage belt type, finger clamp type, and vibration plate type. Most of them require manual assistance to feed and sort the sugarcane seeds, which means manually taking the seeds out of the seed box and feeding them into the seed metering device. Otherwise, issues such as seed leakage, intermittent seeding, and overseeding may occur. In the current situation of labor shortage and rising labor costs, there is an urgent need to further improve the automation level of the seed metering device to reduce labor intensity or reduce the number of auxiliary workers. Therefore, this study has carried out optimization research on the hopper of the seed metering device.

### 3.1 Optimization analysis of the seed hopper design for the seed metering device

Initially, a plastic hopper commonly used in potato planting machines (as shown in Figure 7, Part 3) was adopted. This hopper material is hard and brittle, with a small circular holding space designed for the contact surface of potato spheres. It has poor compatibility with small and lightweight cylindrical sugarcane seeds, resulting in a high rate of empty hoppers when the transmission chain lifts the seeds without manual feeding and supplementation. Additionally, there is a significant phenomenon of sugarcane seeds falling off due to machine vibration. To address these issues, a natural rubber trough-type seed hopper (as shown in Figure 7, Part 1) was specifically designed. This hopper is made from commonly available rubber material through mold casting, significantly reducing the missed seeding rate. However, this hopper holds too many seeds, with 6-8 seeds per hopper, leading to severe overseeding. Additionally, when the seeding speed is too fast, the sugarcane seeds are prone to being thrown off. The material has poor toughness, short lifespan, and is prone to wear and tear. Based on these observations, the following conclusions can be drawn: 1) The rubber hopper has strong adhesion to sugarcane seeds, and the flexible material can effectively address the issue of sugarcane seeds falling off due to vibration; 2) A suitable seed holding space can replace manual feeding and supplementation; 3) Optimizing the straight-angle fracture position of the hopper can extend its service life; 4) Optimizing the material can increase the toughness of the hopper.




1. Rubber hopper 2. Flexible hopper 3. Hard plastic hopper

Figure 7 Material hopper

### 3.2 Optimal flexible and lightweight material hopper

Based on the previous conclusions, in order to increase the toughness of the material hopper, a blend of natural rubber as the base material with a certain proportion of polystyrene was used. The space for planting sugarcane seeds was optimized according to the holding capacity of 2-3 seeds per hopper (as shown in Figure 8). To prevent seeds from being thrown off due to high-speed operation, the structure was modified into a semi-closed trough shape. The positions prone to tearing were optimized with chamfering, resulting in a lighter overall design while still maintaining a certain elastic deformation capability. The flexible hopper is primarily subjected to the force of the sugarcane seeds within a unit volume in the longitudinal direction of the seed box during operation. Through mechanical finite element simulation analysis, it was found that the fracture limit and the overall strength of the material were increased by three times compared with the second-generation rubber material hopper. A new mold was created for casting, and experimental analysis was conducted. The comparison of operational data for three types of material hoppers in the seed metering device of planting machine was conducted in accordance with the enterprise standard Q/RJ 001-2021 of the Agricultural Machinery Research Institute of the Chinese Academy of Tropical Agricultural Sciences. The planting qualification rate ($H$) and seed leakage rate ($L$) were used as evaluation indicators. The single measurement distance was 100 m, and each type of material hopper was measured ten times.

$$L(\%) = \frac{L_M}{L_Z + L_M} \times 100\% \tag{3}$$

$$H(\%) = \frac{g}{20} \times 100\% \tag{4}$$

where, $L$ is seed leakage rate, %; $L_M$ is the number of leakage segments, expressed in segments; $L_Z$ is the total number of planting segments of sugarcane, expressed in segments; $H$ is planting qualification rate of sugarcane, %; $g$ is the number of qualified planting points of sugarcane in the measured area. (In each measuring area, 20 different points of 1-m-long single rows are selected. Points with fewer than nine sections of sugarcane are recorded. Three areas are measured and the average value is calculated.)

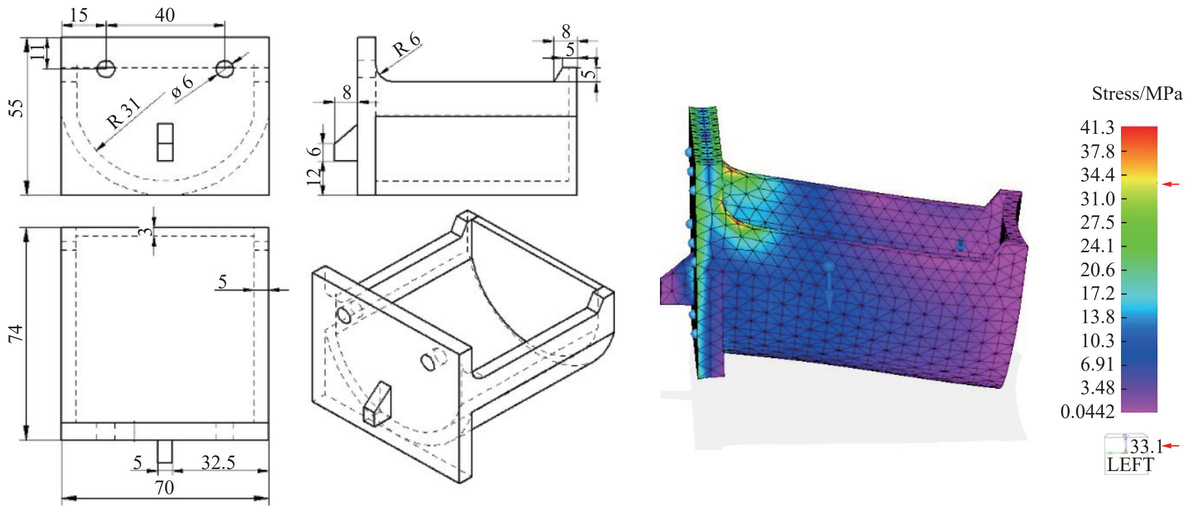



Figure 8 Optimization design and simulation analysis of flexible hopper

From the comparison of experimental results, it can be observed that the planting qualification rate (as shown in Figure 9a) ranks as follows: the second-generation flexible bucket > the first-generation rubber bucket > the plastic bucket. The plastic bucket has a low overall planting qualification rate due to its small seed holding capacity and poor adhesion to sugarcane seeds. Additionally, the unpredictable shaking and vibration caused by terrain result in significant variations in the qualification rate, leading to a high fluctuation in the data line. In comparison, the data lines of the first-generation rubber bucket and the second-generation flexible bucket are relatively stable. The planting qualification rate of the second-generation flexible bucket is significantly higher than that of the plastic bucket, but its qualification rate is still limited by the high replanting rate caused by excessive sowing density.

From the perspective of the leakage rate (as shown in Figure 9b), the first-generation rubber bucket still experiences seed leakage, which may be attributed to low uniformity or the seeds being shaken off from the other end of the hopper. However, the overall data line is relatively consistent compared with the plastic bucket. This suggests that the plastic bucket is more susceptible to external factors that impact the leakage rate during operation. On the other hand, the second-generation flexible bucket hardly misses any planting throughout the entire operation process. The only possible scenarios for seed leakage are when the speed of the entire machine is uneven, leading to uneven seeding, or when the seed box has insufficient seed storage.

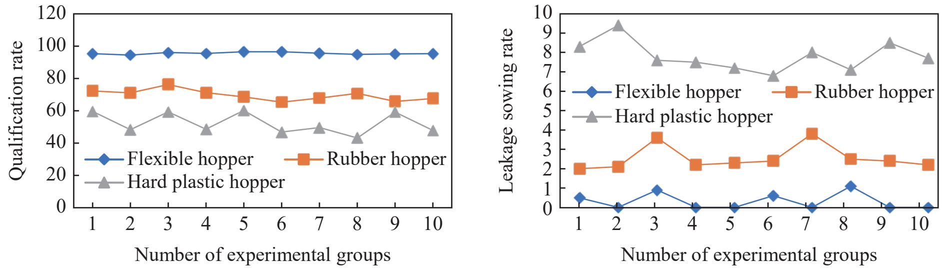



Figure 9 Influence of different feeding hoppers on the qualified rate and leakage sowed rate of planting

## 4 Conclusions

(1) In terms of intelligent seed cutting technology, an improved YoloV5-STD target detection algorithm was proposed, which improved the success rate of small target detection in sugarcane seed characteristics. Experimental results showed that the 2DZ-2 automatic positioning intelligent seed cutting machine adopting the approximate algorithm had a recognition accuracy rate of ≥95%, a seed damage rate of <1.8%, and a qualified seed cutting rate of 95.8%.

(2) In terms of planting technology, a flexible seeding technology was proposed. The application of the first-generation rubber bucket and the second-generation flexible bucket significantly improved the performance of the planter seed metering device. The 2CZD-2C single bud segment planter using flexible buckets achieved fully automatic seeding without manual assistance. Experimental results showed that the planting qualification rate reached 96.6%, the planting efficiency was 208 buds/min, and the seed leakage rate was <2.1%.


## Acknowledgements

This work is supported by the Project of Guangxi Zhuang Autonomous Region Key Technologies R&D Program (Grant No. GK AB23026069 and GN AB241484034), the Basic Scientific Research Expenses of Central Public Welfare Scientific Research Institutes (Grant No. 1630132022001), the Basic Scientific Research Expenses of Chinese Academy of Tropical Agricultural Sciences (Grant No. 1630132024004), and the Zhanjiang Science and Technology Project (Grant No. 2023A01009).


## [References]


[1] Emori E Y, Ravagnani M A S S, Costa C B B. Application of fuzzy control in the evaporation stage of a first- and second-generation sugarcane ethanol biorefinery. Chemical Engineering Communications, 2023; 210(7/9): 1340–1357.

[2] Nguyen Q C, Ngo H Y T, Vu M H T. Advantages of altering cropping schedules in the face of climate variability: A case study of Tan Ky sugarcane cultivation area, Nghe An province. Research on Crops, 2023; 24(1): 132–138.

[3] Aparatana K, Yumika N, Sano M, Watanabe K, Mitsuoka M, Ueno M, et al. Predicting sugarcane quality using a portable visible near infrared spectrometer and a benchtop near infrared spectrometer. Journal of near infrared spectroscopy, 2023; 31(1): 14–23.

[4] Wu Q B, Li Z X, Yang J T, Xu F, Fu X Q, Xu L P, et al. Deciphering the atlas of post-translational modification in sugarcane. Journal of Agricultural and Food Chemistry, 2023; 71(26): 10004–10017.

[5] Mollov D, Filloux D, Grinstead S, Bolus S, Claude L, Fernandez E, et al. Sugarcane mild mosaic virus: The rediscovery of an identified but unrecognized virus. Plant Pathology, 2023; 72(2): 312–321.

[6] Liang Y L, Yu S F, Zhen Z, Zhao Y J, Deng J M, Jiang W G. Climatic change impacts on Chinese sugarcane planting: Benefits and risks. Physics and Chemistry of the Earth, 2020; 116: 1–8.

[7] Liu Q T, Mo J L, Li T H. Technical status and key technical problems of sugarcane planter in China. Sugarcane Industry, 2011; 5: 52–58. (in Chinese)

[8] Naik R, Annmalai S J K, Nair N V, Prasad N R. Studies on mechanization of planting of sugarcane bud chip settings raked in protrays. Sugar Tech, 2013; 15(1): 27–35.

[9] Namjoo M, Razavi J. Development and evaluation of a new double-row sugarcane billet planter with overlap planting pattern. Agricultural Mechanization in Asia, Africa and Latin America: AMA, 2014; 45(2): 57–64.

[10] Cao Y L. Improvement and test of 2CZQ-2 seed cutting sugarcane planter. Guangzhou: South China Agricultural University, 2016. (in Chinese)

[11] Liu X P, Niu Z J, Li M, Hou M X, Wei L J, Zhang Y, Huang L. Design and experimental research on disc-type seeding device for single-bud sugarcane seeds. Int J Agric & Biol Eng, 2023; 16(2): 115–124.

[12] Xu C, Liu P, Meng W G. Design analysis of finger clip seeding device based on precutting sugarcane seeder. Agricultural Development and Equipment, 2016; 5: 55–56. (in Chinese)

[13] Zhou D Q, Fan Y L, Deng G R, He F G, Wang M L. A new design of sugarcane seed cutting systems based on machine vision. Computers and Electronics in Agriculture, 2020; 175: 105611.

[14] He F G, Deng G R, Li M, Niu Z J, You X. Design of electromagnetic vibration-type single-bud sugarcane seed metering device. Sugar Tech, 2019; 6. DOI: 10.1007/s12355-019-00715-y.

[15] Dong X H, Niu Z J, Li M. Design and test of trough wheel sugarcane healthy seedling planter. Mechanical Design and Manufacture, 2017(12): 265–268.

[16] Zhang Y Y, Zhang B, Shen C, Liu H L, Huang J C, Tian K P, et al. Review of the field environmental sensing methods based on multi-sensor information fusion technology. Int J Agric & Biol Eng, 2024; 17(2): 1–13.

[17] Feng J T, Yang Q Y, Tian H, Wang Z P, Tian S J, Xu H R. Promising real-time fruit and vegetable quality detection technologies applicable to manipulator picking process. Int J Agric & Biol Eng, 2024; 17(2): 14–26.

[18] Yang S, Zhai C Y, Gao Y Y, Dou H J, Zhao X G, He Y K, et al. Planting uniformity performance of motor-driven maize precision seeding systems. Int J Agric & Biol Eng, 2022; 15(5): 101–108.

[19] Wu D L, Ding D, Cui B W, Jiang S, Zhao E L, Liu Y Y, et al. Design and experiment of vibration plate type camellia fruit picking machine. Int J Agric & Biol Eng, 2022; 15(4): 130–138.

[20] Zhao X S, Ran W J, Hao J J, Bai W J, Yang X L. Design and experiment of the double-seed hole seeding precision seed metering device for peanuts. Int J Agric & Biol Eng, 2022; 15(3): 107–114.

[21] Ahmad F, Adeel M, Qiu B J, Ma J, Shoaib M, Aamir S, et al. Sowing uniformity of bed-type pneumatic maize planter at various seedbed preparation levels and machine travel speeds. Int J Agric & Biol Eng, 2021; 14(1): 165–171.

[22] Liu M X, Jiang W C, Hou M X, Qi Z H, Li R X, Zhang C. A deep learning approach for object detection of rockfish in challenging underwater environments. Frontiers in Marine Science, 2023; 10: 1242041.

[23] Yu G Y, Cai R L, Luo Y T, Hou M X, Deng R L. A-pruning: a lightweight pineapple flower counting network based on filter pruning. Complex & Intelligent Systems, 2023; 10: 2047–2066.

[24] Hou M X, Liang M H, Yu G Y, Liu M X, Pan X X. Small target detection for fish food image processing based on deep learning. Journal of Imaging Science and Technology, 2024; 68(1): 1–12.