Analysis of Short-Term High-Efficiency Cultivation (Two Harvests Per Year) Technology for Sugarcane

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Abstract. To address issues such as limited yield increase, rising production costs, and growing import dependence in China's sugarcane industry, this paper proposes a short-term high-efficiency cultivation technology for sugarcane (two harvests per year). Compared with the existing intensive cultivation of sugarcane (such as conventional annual ripening or "double high" base cultivation), the fundamental innovation of this technology lies in: ① Through the rapid fermentation of agricultural waste, the integration of water and fertilizer, manual regulation and ripening, and digital precision management, for the first time, sugarcane can achieve two technological maturities within one year; ② Replace over 70% of chemical fertilizers with organic fertilizers, breaking through the high dependence of traditional high-yield cultivation on chemical fertilizers; ③ Integrating a closed-loop management model of "soil fertilization, seedling regulation, pest prevention, and machine adaptation" significantly improves the efficiency of water and fertilizer resource utilization. The annual sugarcane yield reaches 184.8 t/ha (total of two harvests), with an annual theoretical sugar output of 31.81 t/ha, breaking the yield bottleneck of traditional single-season cultivation. This technology effectively reduces production costs, improves resource utilization efficiency, and provides an innovative pathway for the green transformation of the sugarcane industry and "sugar security", offering broad prospects for promotion.

Keywords: Short-term high-efficiency cultivation of sugarcane (two harvests per year), Water and fertilizer integration using agricultural waste, Digital agriculture.

1 Introduction

In recent years, China has issued a series of policies to encourage the improvement of agricultural production, management, and service levels, and to enhance agricultural modernization [1]. Since the 13th Five-Year Plan, China, as a major sugar-producing country, has adopted various policies and measures to ensure the security of sugar sup-

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ply and has achieved remarkable results. In recent years, the national annual sugar production has averaged over 10 million tons, mainly cane sugar. In the 2021/2022 crushing season, national sugar production was 9.56 million tons, a decrease of 10.37% from the previous season, ranking fifth in the world. Among this, cane sugar production was 8.70 million tons, accounting for 91% of national sugar production, a decrease of 4.75% from the previous season. Guangxi, as the core production area, produced 6.1194 million tons of sugar, accounting for 64.01% of national sugar production, a decrease of 2.68% from the previous season [1, 2]. However, rising production costs have reduced farmers' profits, and production relies on policy support [3]. The government reduces farmers' risks and improves planting efficiency through subsidies for improved varieties (e.g., subsidies for the promotion of improved sugarcane varieties and good cultivation methods), mechanization promotion (e.g., Guangxi's "Double High" base construction), and insurance schemes. In some areas of Guangxi, subsidies reach as high as 23,550 RMB/ha. It can be seen that traditional sugarcane cultivation methods not only struggle to increase yield but also face rising production costs, hindering the healthy development of the sugarcane industry. Furthermore, domestic sugar consumption remains stable (national sugar consumption reached 15.5 million tons in the 2021/2022 crushing season), but insufficient production has led to a surge in sugarcane imports, with national sugar imports reaching 5.27 million tons in the 2021/2022 season [1]. This gap provides market impetus for high-yield technologies, and it is necessary to reduce import dependence by increasing yield per unit area. Therefore, there is an urgent market need for more economical and efficient sugarcane cultivation technologies compared to traditional methods.

The short-term high-efficiency cultivation technology for sugarcane (two harvests per year) enables sugarcane to reach technological maturity (sucrose content $\geq$ 12.5%, gravity purity of cane juice $\geq$ 85%) twice within a single year. This technology integrates full mechanization, resource utilization of livestock and poultry manure, water and fertilizer integration, big-data smart agricultural management, artificially regulated ripening, and other techniques, achieving a domestically pioneering "two harvests per year" short-term high-efficiency cultivation model for sugarcane, with an annual yield of over 180 t/ha. It can effectively promote the high-quality, information-based, and modernized development of China's sugarcane industry, ensuring national "sugar security".

2 Application of Key Technologies in the Whole Production Process of Short-Term High-Efficiency Cultivation (Two Harvests Per Year) of Sugarcane

To achieve the high-efficiency production goal of "two harvests per year" for sugarcane, multiple core technologies are integrated, including water and fertilizer integration using agricultural waste, artificially regulated ripening, full mechanization, and a digital agricultural cloud platform. These technologies are precisely incorporated into each stage of sugarcane production, forming a management model characterized by

"soil-specific fertilization, seedling-based regulation, targeted pest control, and mechanism-adapted operations". The multiple components integrated in this technology form a closed-loop collaboration through data-driven integration. The core function of agricultural waste water fertilizer integration technology is to rapidly ferment livestock and poultry manure into liquid organic fertilizer, replacing more than 70% of chemical fertilizers and providing stable nutrient supply for sugarcane growth; The role of artificial regulation ripening technology is to accurately apply ripening agents during the ripening period, inhibit nutrient growth, promote sugar accumulation, and ensure that both seasons of sugarcane reach technological maturity; The role of fully mechanized technology is to cover planting, field management (sprinkler irrigation, soil cultivation, plant protection), and harvesting processes, ensuring the compactness and consistency of the annual two crop operation window; The role of the Shuzhi Agriculture Cloud Platform is to integrate multiple sources of data (such as drone patrols, soil sensors, etc.) for dynamic decision-making. The interaction relationship between each component is as follows: soil sensors and drones upload data on soil moisture and growth to the cloud platform, and the cloud platform makes decisions on water and fertilizer ratios, sprinkler timing, and ripening agent application plans based on this; The decision-making instructions are issued to the integrated water and fertilizer system (controlling the output of fermentation broth) and the sprinkler system (controlling sprinkler operations); At the same time, the cloud platform automatically triggers the task scheduling of harvesting machinery based on the phenological period of sugarcane. This forms an intelligent closed loop of "perception (sensors/drones) → decision-making (cloud platform) → execution (water and fertilizer, ripening, mechanized operations)".The specific application of these technologies throughout the production process is detailed below.

2.1 Variety Selection

Variety selection needs to consider multiple factors such as agronomic traits and planting environment. First, varieties suitable for local soil and climatic conditions should be screened to ensure normal growth. Second, varieties with thin stalks, strong tillering ability, good ratooning ability, strong stress resistance, and high yield and sugar content should be selected. In this technical scheme, because the growth period of sugarcane is relatively short, requiring rapid growth and a certain yield, and thick-stalked sugarcane has limited yield improvement over a short period [4], the approach of achieving high yield through a high number of millable stalks is adopted.

2.2 Land Selection

To achieve the goal of two harvests per year for sugarcane, on one hand, sufficient agricultural waste (such as pig and cattle manure) must be available near the planting base to produce organic liquid fertilizer; on the other hand, the planting plots need to be modified for mechanized water and fertilizer application to enable full mechanization of sugarcane planting operations and automatic spraying of water and fertilizer. Therefore, when selecting a plot, first, field surveys and satellite remote sensing images

are used to determine the topography and the location of surrounding livestock farms to plan the subsequent transport method and route for livestock manure. Second, drones equipped with various sensors are used to model the plot, and the data is uploaded to the digital agricultural cloud platform to facilitate subsequent management of data related to farming, crops, machinery, planting, and harvesting, using spatial coordinates and time dimensions, allowing data to be automatically linked to the specific plot.

Drainage and Irrigation Conditions. The planting base has sufficient water sources to meet the peak water demand from March to December, with an average monthly irrigation water requirement of 54 m^3/ha. The planting plots are free from waterlogging, with no standing water within 24 hours after heavy rainstorms.

Road Conditions. The transport roads leading from outside the planting base to the base's warehouse and fermentation tank can support the smooth passage of transport platforms (total weight 25 t, vehicle width 2.5 m). The field operation roads within the planting base can support the smooth passage of a 15 t mobile water and fertilizer spraying platform (total weight 20 t, vehicle width 2.5 m). The mobile water and fertilizer spraying platform is shown in Figure 1.



Fig. 1. Mobile water and fertilizer spraying platform

Basic Fermentation Raw Material Supply Conditions. The water and fertilizer integration technology using agricultural waste is one of the core technologies enabling short-term high-efficiency cultivation of sugarcane. This involves using agricultural waste such as livestock manure, straw, and sugarcane leaves, which undergo aerobic fermentation with microorganisms, rapidly converting them into bio-organic liquid fertilizer within 72 hours (as shown in Figure 2), achieving full resource utilization of agricultural waste. This can replace over 70% of chemical fertilizers with organic fertilizer. Using pig manure liquid as the base fermentation material, the number of pigs (in heads) that need to be raised in the area of the planting base and its surrounding 20-50 km radius is at least: Planting area (ha) × 225 (heads).



Fig. 2. Agricultural waste before and after fermentation

2.3 Land Preparation and Furrowing

The quality of land preparation and furrowing needs to meet the requirements of deep, loose, uniform, level, fine, and clean. Deep: using large-horsepower tractors for deep loosening and ploughing to a depth of 50 cm or more. Loose: the soil in the planting area is loose after land preparation. Uniform: the planting rows are neat and uniform. Level: the planting surface is flat, without obvious ridges or folds. Fine: the soil clods at the bottom of the furrow are fine. Clean: after furrowing, there are no gravel or other debris at the bottom of the furrow. After land preparation, a combined machine for furrowing, soil pulverization, and fertilization is used for operation. The furrow width is 70 cm, depth 45 cm, and the planting row spacing is a narrow-wide row pattern of 0.3-0.4 m + 1.3 m. The basal fertilizer used is fermented organic fertilizer containing filter mud and soil pest control strains (e.g., Paecilomyces lilacinus), with an application rate of 12-18 t/ha.

2.4 Planting of Sugarcane Tissue Culture Seedlings

To reduce the germination and development time of sugarcane, an automatic transplanter for virus-free tissue culture seedlings is used. This ensures ratoon harvesting for 3-5 years. The tissue culture seedlings have a plant height above 20 cm, and the required number of basic seedlings is 75,000 to 90,000 plants per hectare. After transplanting, intelligent analysis of low-altitude drone remote sensing data on the digital agricultural cloud platform is performed to automatically identify missing seedlings and carry out timely replanting.

2.5 Field Management of Sugarcane

The farmland is divided into management units of 16.7 hectares each. Each management unit is equipped with a water storage tank, a livestock manure fermentation tank (capacity ≥ 840 m^3), a liquid fertilizer pump (power ≥ 22.5 kW), a photovoltaic power generation system covering 600-1400 m^2 (to supply electricity for pumps, sprinkler

systems, and some agricultural machinery), 30-35 sprinkler irrigation devices, and an agricultural monitoring and detection system (including soil sensors, drone remote sensing system, etc.). All relevant operational and environmental data will be uploaded to the digital agricultural cloud platform for integrated monitoring and management.
The sprinkler irrigation system is connected to the livestock manure fermentation tank via pipes and a liquid fertilizer pump, and performs irrigation operations using high-pressure sprinklers (equipped with automatic solenoid valves powered by solar energy). The pipes are made of polypropylene random copolymer (PPR) and buried at a depth ≥ 1.8 m. Within the management unit, based on a sprinkler radius of 40 m, it is further divided into 30 water and fertilizer management sub-units. The opening and closing of the sprinkler valves are controlled through the digital agricultural cloud platform, achieving refined water and fertilizer management. It is required that 2-4 high-pressure sprinklers can operate simultaneously, as shown in Figure 3. If conditions for installing a sprinkler irrigation system are not met, a mobile water and fertilizer spraying platform can be used for fertilization operations, as shown in Figure 1.



Fig. 3. Sprinkler system in operation

During sugarcane growth, soil moisture sensors in the agricultural monitoring and detection system are used to monitor soil water content. The interval for applying water and fertilizer is determined based on data from the digital agricultural cloud platform, maintaining soil water content between 65% and 75%. When rainfall is too low or too high, the concentration of the applied water and fertilizer should be adjusted according to the fertilizer requirement at different growth stages and soil moisture content. Additionally, based on data analysis from drone flyovers (once every two days) on the digital agricultural cloud platform, including spectral data, images, and biomass accumulation, information on sugarcane chlorophyll content, growth vigor, and moisture conditions is obtained. The amount and ratio of water and fertilizer are adjusted accordingly, and any localized nutrient deficiency is identified and corrected in a timely manner.

Seedling Stage to Tillering Stage. During the 3-leaf stage, the 5-8 leaf stage, the first joint elongation, and the third joint elongation of sugarcane seedlings, water and fertilizer are sprayed into the field using high-pressure sprinklers of the irrigation system. The fertilizer application rate is 3000-4500 kg/ha of fermented livestock manure liquid, with an EC of 2-2.5 mS/cm. The high nitrogen content in the liquid fertilizer increases the tillering rate and the rate of tillers becoming millable stalks. In addition, during the tillering stage, a solution containing 0.02%-0.03% ethephon and 0.01%-0.02% potassium dihydrogen phosphate is sprayed 1-2 times. Through earthing up and thinning, it is ensured that each sugarcane seedling produces 5-10 tillers.

Elongation Stage to Maturation Stage. After the fourth fertilization, regular fertilization during the elongation stage is carried out based on seedling condition (plant height about 1.5 m). Fertilization is performed by spraying water and fertilizer into the field using high-pressure sprinklers of the irrigation system, with an interval of about 10 days. The fertilizer application rate at this stage is 24-30 t/ha of fermented livestock manure liquid (containing 1%-5% compound seaweed amino acid liquid fertilizer), with an EC of 3-3.5 mS/cm. In addition to livestock manure, 5‰ palm ash and 4‰ mineral-source fulvic acid are added to the fermentation substrate. The nitrogen content in the water and fertilizer is gradually reduced at the end of the elongation stage to avoid affecting sugar accumulation in sugarcane.

Maturation Stage. During the maturation stage, water and fertilizer are also sprayed into the field using high-pressure sprinklers of the irrigation system, with a fertilization interval of about 20 days. The fertilizer application rate at this stage is 15.0-43.2 t/ha of fermented livestock manure liquid (containing 1%-5% compound seaweed amino acid liquid fertilizer), with an EC of 3.5-4 mS/cm. In addition to livestock manure, 1‰ palm ash, 3-8‰ organic chelated calcium, 0.5-1% potassium superphosphate, and 8‰ mineral-source fulvic acid are added to the fermentation substrate. The purpose of increasing the potassium fertilizer application rate during the maturation stage is to promote sugarcane maturation and increase cane sugar content and juice purity. Water and fertilizer application is stopped one month before harvest.

20-30 days before harvest, a ripening agent (containing 0.02%-0.03% glyphosate and 0.01%-0.04% boric acid solution [5]) is sprayed at a rate of 500-750 kg/ha. This inhibits continued sugarcane growth while achieving the effect of accelerating ripening and increasing sugar content, raising sugar content by 1-1.5%.

2.6 Harvesting

The harvesting standard for sugarcane is a sucrose content ≥ 12.5% and gravity purity of cane juice ≥ 80%, meeting the national standard GB/T 10498-2010 "Sugar Cane". For ratooning, it is required that there are more than 75,000 millable stalks per hectare, mechanical harvesting damage rate is below 10%, and there is no large-area disease (smut, rust, etc.). When using stubble shaving and ridge-breaking & root-loosening machinery, it is required that the stubble shaving blade enters the soil by 5 cm, the ridge-breaking and root-loosening tool enters the soil by 40 cm, and earthing up is performed within 10 days afterward. Subsequent management follows the pattern for newly planted sugarcane.

2.7 Yield Measurement Test

This experiment is a field trial, located in Wuming District, Nanning City, Guangxi Province. The total planting area is 100 acres (approximately 6.67 hectares) per treatment, with typical subtropical climate and soil conditions. The experiment was conducted from January 2024 to January 2025. The sugarcane variety was Guitang 44, with a planting amount of 105000 buds per hectare. Two cropping groups and a conventional management group (local conventional cultivation measures) were set up respectively. The two-harvests-per-year group was managed according to the scheme described above, while the conventional management group followed local conventional cultivation practices.

On July 27, 2024, the first harvest of sugarcane (newly planted Guitang 44) was obtained at a planting base in Wuming District, Nanning City, with an average yield of 93.15 t/ha and an average sucrose content of 12.7%. On January 17, 2025, the second harvest of sugarcane (ratoon Guitang 44) was obtained, with a yield of 91.65 t/ha and an average sucrose content of 21.8%. At the same time, the one-harvest-per-year sugarcane (newly planted Guitang 44) was harvested, with a yield of 109.2 t/ha and an average sucrose content of 23.3%.

It is worth noting that the sugarcane harvested on January 17, 2025, had a relatively high sucrose content, which is related to the prolonged drought in Guangxi. From autumn 2024 to April 2025, rainfall in Guangxi showed a sustained decreasing trend. During the most severe drought period in Guangxi, the average precipitation was nearly 70% less than the normal level for the same period. This prolonged drought, on the one hand, limited sugarcane growth, but on the other hand, promoted sugar accumulation. The reduction in water directly increased the concentration of sucrose, resulting in generally high sucrose levels. Thanks to the efficiency of bio-organic liquid fertilizer, ripening technology, and digital precision management, the average stalk length still reached 272.8 cm, maintaining yield under relatively dry conditions.

In summary, with this technology, the annual sugarcane yield reaches 184.8 t/ha, representing a 69.2% increase compared to the yield of the conventional management group. The annual theoretical sugar output is 31.81 t/ha. The effect of increasing yield and improving quality of sugarcane is significant, indicating good application prospects.

3 Conclusion

The short-term high-efficiency cultivation technology for sugarcane (two harvests per year) achieves spatiotemporal coupling and dynamic optimization of multiple technical elements, forming a precision management model characterized by "soil-specific fertilization, seedling-based regulation, targeted pest control, and mechanism-adapted operations". It significantly improves the utilization efficiency of water and fertilizer resources, replaces over 70% of chemical fertilizers with organic fertilizers, effectively breaks the production bottleneck of traditional single-season cultivation, and provides

an innovative solution for the green and sustainable development of the sugarcane industry. Currently, the promotion and planting area of this technology has exceeded 1066 hectares, with an output value of over 200 million RMB.

In the future, digital planting models for sugarcane of different varieties and in different regions can be further refined. For example, improving and optimizing new AI models and applying them to agricultural big data models. In addition, the impurity removal rate and stubble damage rate of sugarcane harvesters still require further optimization to achieve more efficient and high-quality automated sugarcane harvesting.

Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

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