Design and Test Analysis of 1GYF-240 Sugarcane Straw Crushing and Returning Machine

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Abstract. Sugarcane is one of the largest economic crops in China. However, the current domestic sugarcane straw crushing and returning machines have limitations such as short service life, poor crushing effect, and low operating efficiency. In order to solve these problems, a 1GYF-240 sugarcane straw crushing and returning machine was developed in this study. First of all, the power is provided by the tractor, and at the same time, it drives the blade in the crushing mechanism to rotate at a high speed. Next, the profiling leaf collector collects the sugarcane stalks that are close to the ground and feeds them into the crushing chamber. Finally, the swinging knife and the fixed knife are used for crushing, and the crushed straw is evenly thrown to the field along the rear baffle under the action of centrifugal force, thereby completing the operation of crushing and returning the sugarcane straw to the field. The results of field experiments show that the qualified rate of sugarcane straw crushing is 93.8%, and the work efficiency is 0.78hm2·h-1, which shows good operation effect. The results of comparative experiments show that this study not only solves the environmental pollution problem of traditional incineration well, but also has the function of heat preservation and water retention. In addition, compared with similar domestic models, the experimental results show that the crushing and returning machine has obvious advantages in picking up rate and crushing rate of sugarcane straw, and has higher reliability in actual operation. This research can provide the foundation and support for the design and popularization of the sugarcane leaf crushing and returning machine.

1 Introduction

Sugarcane is the main sugar crop in China, and more than 90% of the sugar comes from sucrose. The healthy development of the sugarcane industry is an important guarantee for the effective supply of sugar and the national sugar security[1,2,3]. In the sugarcane industry, a large amount of waste (such as cane leaves, straw, etc.) is often piled up on a large scale or burned on site[4,5]. This phenomenon has caused the environment to suffer serious pollution and has caused non-negligible damage to the quality of the environment. Therefore, how to turn these materials, which are regarded as wastes, into treasures has become an issue that the current government departments attach great importance to and arouses widespread concern in the society.

Crushing and returning sugarcane stalks to the field is the most direct, realistic and easy-to-promote technical measure[6,7]. At present, sugarcane straw crushing and returning machines widely used in China, such as 1GYF-150, 4F-1.8, 3SY-140, 1JH-150, etc., all use wheeled tractors as power supporting equipment to complete the operation[8]. However, the above-mentioned implements have disadvantages such as short service life, poor crushing effect, and low operating efficiency in the actual operation process. To solve the above problems, this study designed a 1GYF-240 type sugarcane straw crushing and returning machine based on the characteristics of sugarcane planting in southern hot areas. Possibility of wind and water erosion, while improving soil fertility and drought resistance. The whole machine has the advantages of light weight and stable operation performance.

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2 Machine structure and working principle

2.1. Machine structure

As shown in Figure 1 and Figure 2, the 1GYF-240 sugarcane straw crushing and returning machine is mainly composed of a transmission system, a frame, a front baffle, a throwing knife, a fixed knife, a knife roller, a rear baffle, a limit wheel and a profiler. Composition of leaf collectors, etc. The machine is hung on a wheeled tractor with a power of more than 88 kW through three points. Among them, the profiling leaf collector is mainly composed of inclined rods and connecting plates. The slant bar consists of a bent rod and a culet etc. bolted together, which allows quick and easy replacement of the culet after wear or impact damage.

Fig. 1. 1GYF-240 sugarcane straw crushing and returning machine physical picture

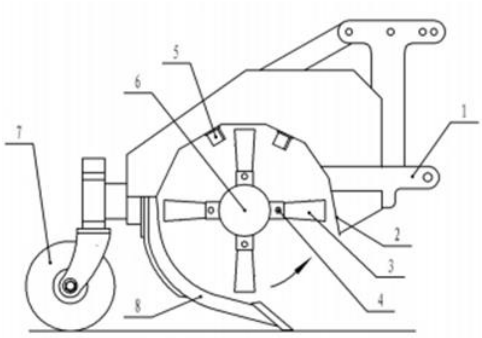


Fig. 2. 1GYF-240 Structural Diagram of Sugarcane Straw Crushing and Returning Machine. 1. Three-point suspension 2. Frame 3. Moving knife 4. Pin shaft 5. Fixed knife 6. Knife shaft 7. Limiting wheel 8. Leaf collector

The 1GYF-240 sugarcane straw crushing and returning to the field has the following characteristics: ① The limit wheel is used as the profiling wheel, and it is rigidly connected with the inclined rod. This makes the oblique bar and the tractor wheel on the same end face, and is arranged in front of the lower flail. ② The design of the machine makes the bottom tip of the inclined rod close to the ground, which can be adjusted adaptively according to the ups and downs of the ground, so as to achieve a roughly profiling effect. ③ Due to the function of the profiling leaf collector, the sugarcane stalks close to the ground can be collected and lifted to a certain height, which facilitates subsequent crushing operations. The main technical parameters of the 1GYF-240 double-roller sugarcane straw crushing and returning machine are shown in Table 1.

2.2 Working principle

In actual operation, the 1GYF-240 sugarcane straw crushing and returning machine is first connected to the tractor through a three-point suspension. Then, the tractor provides power, and the power is transmitted to the gear box through the universal joint shaft, and then to the V-belt pulley through the transmission shaft, and the V-belt variable speed transmission drives the blade in the crushing mechanism to rotate at a high speed. Then, when the tractor is moving forward, the profiling leaf collector collects the sugarcane stalks that are close to the ground and feeds them into the crushing chamber, where the throwing knife and fixed knife are crushed. Finally, under the action of centrifugal force, the crushed straw is evenly thrown into the field along the back baffle, thus completing the operation of crushing and returning sugarcane straw to the field[9,10,11]. Adjusting the height of the limit ground wheel and the frame from the ground can control the working height of the movable knife from the ground and improve the crushing rate of sugarcane straw.

Table 1. Main technical parameters of 1GYF series sugarcane straw crushing and returning machine.

Main parameter unit	Value
Length×width×height/mm	2650×1650×1250
Prototype total mass/kg	750
Supporting power/kW	88.2～117.6
Machine working range/cm	240
Type and number of flails	48 L improved knives
Knife roller speed/r·min-1	1830
Productivity/hm2·h-1	≥0.74
Crushing rate/%	≥93.6
Pick up rate/%	≥93.2

3 Structural Design of Key Components

3.1. Tool selection and design

In general, the blades of the straw crushing and returning machine can be divided into four categories according to the shape, namely, the hammer knife, the straight knife, the T knife, the L-shaped knife and its improved type[12,13]. Among them, the hammer melon crushing effect is good, but the energy consumption is large. The straight knife has a good cutting effect, but it is easy to clog, and the blade needs to be cleaned frequently, which affects the working efficiency. The manufacturing cost and maintenance difficulty of the T-knife are relatively high, and at the same time, it has relatively large vibration and noise during operation, which may affect the stability of the machine and the operating environment. The L-improved knife is mainly used for chopping and cutting, and has the characteristics of good picking effect and not easy to be entangled and blocked by sugarcane leaves. Therefore,

this study chooses the L improved knife as the knife of the sugarcane straw crushing and returning machine. At the same time, the throwing knife and the fixed knife overlap a certain amount in the radial direction, so that the whole machine has a higher picking rate and crushing rate, and the power consumption is small.

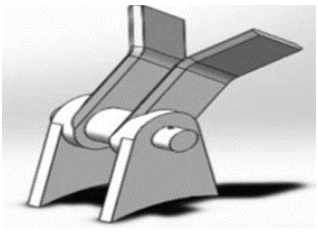


Fig. 3. 1GYF-240 Sugarcane Straw Crushing and Returning Machine

Through the combination, optimization and arrangement of moving and fixed knives, the moving knives adopt two L improved knife structures (Figure 3), the knives are arranged in a double helix arrangement, the number of blades is increased on both sides, and the crushing chamber is enlarged. The cutter effectively overcomes the problem of straw blockage and winding, the crushing rate is increased by 5%, the efficiency is increased by 3%, and it can be adapted to the crushing operation of different crop straws.

3.2. Design of steerable ground wheels

Sugarcane is a ridge planted crop. In actual operation, the sugarcane straw crushing and returning machine usually needs to be equipped with a ground wheel device. The device is generally composed of wheels, wheel shafts, pin shafts, etc., and adjusts the distance between the tool tool and the ground by controlling the up and down movement of the pin shaft. However, due to the high-speed rotation of the tool rolls, the rotational speed of most of the tool rolls is above 1800 revolutions per minute, which makes the entire machine tool prone to relatively large vibrations. Especially when making headland turns or lifting, this vibration can become more severe. In severe cases, this vibration may cause damage to important components and parts such as cutter roller bearings, and affect the working reliability and service life of the machine tool.

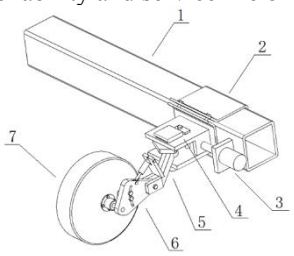


Fig. 4. Limit Wheel Connection

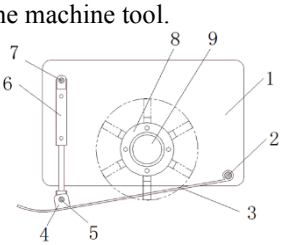


Fig. 5. Automatic adjustment limit device

To solve the above problems, this study designed a steerable profiled ground wheel instead of a fixed ground wheel, and designed a high-standard tire vibration damping configuration. The device effectively solves the problem of vibration caused by jumping or displacement when the machine tool is lifted, and improves the working efficiency and reliability of the machine tool, with a reliability of 92.7%. In addition, the limit wheel connection device (Figure 4) and the automatic adjustment limit device (Figure 5) of the sugarcane straw crushing and returning machine were designed to improve the crushing efficiency of the machine and ensure the reliability of the machine.

3.3. Rack design

In this study, according to the growth characteristics of sugarcane planting, the frame and rear cover of the crushing and returning machine are optimized, and the transmission gearbox is reversed and reversed to adapt to the working environment with many stones and uneven surfaces.

In this study, an adjustable offset sugarcane straw crushing and returning machine connection mechanism is designed. Through the lateral movement of the front beam, the sugarcane leaf crushing and returning machine can still continue to work normally during the horizontal movement of the sugarcane straw crushing and returning machine , which improves the quality and work efficiency of the sugarcane straw crushing and returning machine.

4 Field experiments

In order to verify the effectiveness of the proposed 1GYF-240 sugarcane straw crushing and returning machine, this study designed sugarcane straw crushing and returning experiments and comparative experiments.

4.1. Evaluation index

During the test, the tractor speed was set to the slow second gear of 1 m/s, and 10 1×1 (m) measurement areas were randomly selected in the test area where the sugarcane straw crushing and returning machine passed, and all the crushed particles in the measurement area were picked up. For sugarcane straw, use a balance to weigh out the mass m1, then pick out the sugarcane straw with a length > 20 cm and weigh out its mass m2, and calculate the pass rate of crushing sugarcane straw in each measurement area according to the formula (1) [14], namely:

$$P = \left(\frac{m_1 - m_2}{m_1} \right) \times 100\% \quad (1)$$

In the formula, P is the pass rate of sugarcane straw crushing in each measurement area; m1 is the total mass of sugarcane straw (g) in each measurement area; m2 is the total mass (g) of sugarcane straw with a length > 20 cm in each measurement area.

The working efficiency of the sugarcane straw crushing and returning machine refers to the working area of the machine per unit time. Use a stopwatch to measure and record the time it takes for the machine to complete a sampling test unit in the field, and its work efficiency is calculated according to formula (2). The average value of

the recorded 10 sets of values is the working efficiency of the sugarcane straw crushing and returning machine[15].

$$\omega = \frac{3.6LB}{10000q} \quad (2)$$

In the formula, ω is the working efficiency of the machine (hm2/h); L is the length of the sampling unit (m); B is the working width (mm); q is the time spent on one sampling test unit (s).

4.2. The experiment of crushing and returning to the field

The test of sugarcane straw crushing and returning to the field was carried out at the sugarcane straw crushing and returning demonstration base of the Institute of Agricultural Machinery, Chinese Academy of Tropical Agricultural Sciences, Jinxing Farm, Zhanjiang Nongken, Guangdong, with an area of 2 hm2. Before the test, 5 small experimental areas of 10×10 (m) were randomly selected in the test area, and the sugarcane leaf coverage rate and sugarcane leaf coverage thickness were measured. The field operation scene diagram of the 1GYF-240 sugarcane straw crushing and returning machine is shown in Figure 6.

Fig. 6. 1GYF-240 sugarcane straw crushing and returning machine physical picture

Table 2. Coverage rate of sugarcane straw in experimental plot.

Serial number	1	2	3	4	5	Ave rage
Coverage/ %	95.4 5	97.2 4	92.6 8	99.3 6	98.8 2	96.7 1

Table 3. Covering thickness of sugarcane straw in the experimental plot.

Serial number	1	2	3	4	5	Average
Covering thickness/cm	10.2	9.7	11.6	13.8	11.5	11.36

Table 2 and Table 3 are the calculation results of sugarcane leaf coverage and sugarcane leaf coverage thickness in randomly selected experimental areas, from which it can be seen that the average coverage rate and average straw coverage thickness of sugarcane straw in the experimental area are 96.71% and 11.36cm, respectively. The calculation results show that the coverage rate of sugarcane straw in the field is high, and a crushing and returning machine is needed for efficient crushing and returning to the field. At the same time, the sugarcane straw covering thickness is within the operating range of the 1GYF-240 sugarcane straw crushing and returning machine.

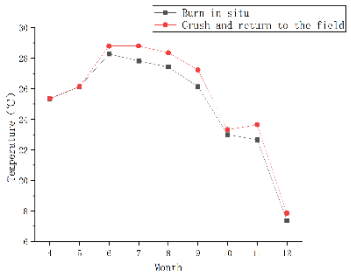
Table 4. Coverage rate of sugarcane straw in experimental plot.

Crushing pass rate/%	Working efficiency/$hm^2 \cdot h^{-1}$
93.8	0.78

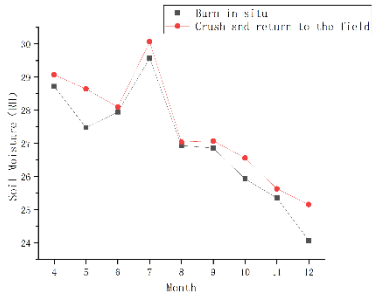
It can be seen from Table 4 that in the actual operation process, the pass rate of sugarcane straw crushing is 93.8%, and the working efficiency is 0.78 $hm^2 \cdot h^{-1}$. The field test results are shown in Figure 6. The 1GYF-240 sugarcane straw crushing and returning machine works well, and the crushing pass rate and machine performance are relatively stable.

4.3. Contrast test of crushing and returning to field and burning

In order to further prove the impact of the 1GYF-240 sugarcane straw crushing and returning machine on the field after operation, this section designs a group of comparison experiments between the sugarcane straw crushing and returning method and the traditional incineration returning method. The test was carried out at the sugarcane straw crushing and returning demonstration base of the Institute of Agricultural Machinery, Chinese Academy of Tropical Agricultural Sciences, located in Zhanjiang Nongken Jinxing Farm, Guangdong Province (20.65° north latitude, 110.15° east longitude). The trial will run from April 2022 to December 2022. The soil is red loam, and the sugarcane variety is 'Yuetang 7929', which will be newly planted in 2021.



(a) Temperature



(b) Humidity

Fig. 7. The temperature and humidity change curves of the field under the method of returning to the field by crushing and returning to the field by burning

The comparative experiment included two treatment methods of crushing sugarcane straw and returning it to the field by burning it. Among them, each treatment group includes 5 experimental plots with an area of about 0.26 hm2, and each experimental plot has 5 random temperature and humidity measurement nodes.

Fig. 7 is a graph showing the change of temperature and humidity in the field with time after the sugarcane stalks were crushed and returned to the field and incinerated and returned to the field. As for the soil temperature, it can be seen from Figure 7(a) that the temperature of the test plot using the method of crushing and returning to the field is higher than that of the test plot using the method of burning and returning to the field from April to December. In terms of soil moisture, it can be seen from Figure 7(b) that the humidity of the test plots using the method of crushing and returning to the field was higher than that of the test plots using the method of burning and returning to the field from April to December.

The test results show that the use of crushing and field returning machines not only solves the problems of air pollution caused by traditional incineration, endangering the environment and human health, but also has the function of heat preservation and water retention, which helps to protect the health of the soil ecosystem and provides Good growth environment, thereby increasing sugarcane yield.

Based on the analysis of this conclusion, the main reasons are as follows:

Insulation phenomenon: ①Straw mulch can form a physical barrier to protect the soil surface from direct sunlight and high temperature. This helps to slow down the rate of evaporation of the soil, thereby reducing the loss of soil moisture. ②Straw mulching can slow down the change of soil temperature, especially at night, and help maintain a relatively stable soil temperature.

Water retention phenomenon: ①Straw mulching can reduce the evaporation rate of the soil surface, reduce the loss of water evaporation from the soil to the air, and help to maintain soil moisture. ②The decomposition of straw will release organic matter, which can improve the water retention capacity of the soil. They absorb water and form stable water stores in the soil, making the soil more water-retaining. ③Straw mulching can slow down the erosion and runoff speed of rainwater, help to retain water in the soil and reduce water loss.

4.4. Compared with the domestic sugarcane straw crushing and returning machine

In order to further reflect the superiority of the 1GYF-240 sugarcane straw crushing and returning machine proposed in this study, this section designs a group of comparative experiments between this model and the existing domestic sugarcane straw crushing and returning machine.

Table 5. Comparison of 1GYF-240 sugarcane straw crushing and returning machine with similar domestic models.

Type	1GYF-240	1GYF-150	3SY-140	FZ-100	4F-1.8
Productivity (hm2/h-1)	≥0.74	≥0.15	≥0.133	≥0.2	≥0.8
Workpiece width (㎝)	240	150	140	100	180
Pick up rate (%)	≥93.2	≥91	≥90	≥90	≥90
Crushing rate (%)	≥93.6	≥91	≥80	≥80	≥80
Crushing length (㎝)	≤20	≤20	≤30	≤25	≤10
Supporting power (kW)	88.2～117.6	36～58	36～58	36～58	58～66
Working reliability (%)	92.7	91.3	89.5	91.4	90.8

It can be seen from Table 5 that, compared with similar crushing models at home and abroad, the 1GYF-240 sugarcane straw crushing and returning machine has higher productivity and operating width, and the sugarcane straw picking rate and crushing rate have obvious advantages. In addition, in this study, the performance of the crushing and returning machine body is more stable, the service life of the V-belt is at least doubled, and the sugarcane head is not damaged, and the reliability is higher in actual operation.

5 Field experiments

1) A 1GYF-240 sugarcane straw crushing and returning machine was developed, which saves energy and has good crushing rate and working efficiency. First of all, the power is provided by the tractor, and at the same time, it drives the blade in the crushing mechanism to rotate at a high speed. Next, the profiling leaf collector collects the sugarcane stalks that are close to the ground and feeds them into the crushing chamber. Finally, the swinging knife and the fixed knife are used for crushing, and the crushed straw is evenly thrown to the field along the rear baffle under the action of centrifugal force, thereby completing the operation of crushing and returning the sugarcane straw to the field.

2) The results of field experiments show that the pass rate of 1GYF-240 sugarcane straw crushing and returning machine is 93.8%, and the working efficiency is 0.78hm2 • h-1. The crushing pass rate of the whole machine and the performance of the equipment are relatively stable, which meets the agronomic requirements of sugarcane leaf crushing.

3) The results of comparative experiments show that this study not only solves the environmental pollution problem of traditional incineration well, but also has the function of heat preservation and water retention.

4) Finally, compared with similar domestic models, the experimental results show that the crushing and

returning machine has obvious advantages in picking up rate and crushing rate of sugarcane straw, and has higher reliability in actual operation.

Acknowledgments

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