DESIGN AND EXPERIMENT OF AUTOMATIC FILM AND TAPE CUTTING SYSTEM FOR COTTON PRECISION FILM-LAYING HOLE SEEDER
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棉花精量铺膜穴播机自动断膜带系统设计与试验

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ABSTRACT
To achieve the process of automatic film cutting for cotton and improve the efficiency of cotton precision film hole seeding machine operation, this paper proposes a wireless handle button control method and designs an automatic film and tape cutting system for cotton precision film-laying hole seeder. The system includes electromagnetic integrated valve group, hole opener lifting hydraulic cylinder, membrane pressing hydraulic cylinder, multifunctional hydraulic cylinder for cutting film, strapping support hydraulic cylinder, hydraulic limit sensor, arc-shaped film cutting shovel reset sensor, wireless control handle for film cutting and film cutting controller. The system is based on the VisualTFT platform, equipped with a multi-functional touch screen. By integrating functions such as obtaining the forward distance of the machine, hydraulic control principles, and wireless control models for film cutting and burying, it achieves automatic cutting and burying of ground film and drip tape processes. The experiment verified the working performance of the automatic film cutting and feeding system of the cotton seed precision film mulching hole seeder and the results showed that the average monitoring accuracy of the machine's forward distance was 98.16%; the response time for controlling the film cutting belt and burying film belt was ≤0.78 s, and the execution time was ≤2.68 s; the success rate of cutting film strips was 100.00% and the success rate of burying film strips was above 98.33%, which met the operational requirements of automatic film strip cutting for precise cotton seeding film hole planting machines.

摘 要
为实现棉花自动断膜带作业过程，提高棉花精量铺膜穴播机作业效率，提出无线手柄按键控制方式，设计了棉花精量铺膜穴播机自动断膜带系统，包括电磁一体化阀组、穴播器提升液压缸、压膜带液压缸、断膜带多功能液压缸、扎带支撑液压缸、液压限位传感器、弧形断膜带铲复位传感器、断膜带无线控制手柄及断膜带测控器等部分。基于 VisualTFT 平台，搭载多功能触模屏，通过对机器前进距离获取、液压控制原理、断膜带无线控制模型等终端功能整体设计，实现了自动切断和填埋地膜、滴灌带过程。试验验证了棉花精量铺膜穴播机自动断膜带系统工作性能，结果表明：机器前进距离平均监测精度为 98.16%；断膜带及填埋膜带控制响应时间≤0.78s，执行时间≤2.68s；切断膜带成功率为 100.00%，填埋膜带成功率为 98.33%以上，符合实际棉花精量铺膜穴播机自动断膜带作业要求。

INTRODUCTION [1]
Cotton is an important strategic commodity and economic crop in the country, with its planting area and output ranking among the top in the world (*Liu W.J. et al., 2020*). Xinjiang is the largest cotton-producing region in China, belonging to a typical arid and semi-arid area.

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The planting system adopts the precision hole seeding model with plastic film covering, which saves labor, reduces planting density, and improves efficiency. It is widely used because of its characteristics such as warming, moisturizing, and improving quality effects. It is an important way to realize the mechanized planting of cotton, which is of great significance for improving the quality and efficiency of cotton production (*Yuan B.S. et al., 2023; Zhang X.J. et al., 2021; Zhang X.J. et al., 2022*). Therefore, the appropriate seeder is crucial for the precision hole seeding planting method with plastic film covering in Xinjiang agricultural areas.

Domestic and foreign scholars have conducted a large amount of research on precision hole seeding technology with plastic film mulching. In terms of cotton precision film mulching and hole seeding machine, it can be divided into pneumatic type and mechanical type according to the working principle. *Yazgi et al., (2014),* studied the effect of different numbers of suction holes and operating speeds of the cotton vertical disc air-assisted planter on planting performance. *Singh G. et al., (2005),* investigated the effects of seeding disc speed, vacuum level, and seed hole shape on cotton seeding quality. Academician Chen Xuegeng's team (*Chen X.G. et al., 2010; Lu Y.T. et al., 2012*) developed a precision cotton seed planter with air suction technology. It could achieve precise seed selection, cleaning, accurate sowing, and precise point seeding, solving the problems of air-suction precision hole seeder such as air leakage and high energy consumption. *Zhang X.J. et al., (2021),* combined with the agronomic requirements of cotton seedling transplantation, designed a double-chamber rotary vertical round disc hole seeding planter for cotton. It solved the problems of poor sowing performance and high damage rate of the vertical round disc cotton planter. *Wang J.K. et al., (2006), Wang J.K., (2006), Wang J.K. et al., (2011)*, designed a self-locking cotton seed precision planter with clamping mechanism. It added a protective device to reduce the problem of seed shedding caused by ground vibration and improved the overall stability of the seeding machine. Research on intelligent technology for mechanized cotton planting focused on automatic navigation and real-time monitoring of planting operation parameters (*Chen H.Y. et al., 2020; Zhang F. 2021; Zhao Y. et al., 2018. Kaivosoja R. et al., (2015),* a GNSS error simulator being developed to improve tractor navigation and positioning accuracy. *Erkan K. et al., (2014),* used distributed nonlinear predictive control method to solve the tractor trajectory tracking problem, which could improve control accuracy and robustness to environmental disturbances. *Zhang X.J. et al., (2022),* developed a cotton precision dibbler seedling status monitoring system based on laser through-beam and Hall sensors; *Cao Y. et al., (2022), Cao Y. (2022),* developed an automatic monitoring system for the seeding performance of cotton hole seeders using a high-speed CCD camera. *Zhou Liming, (2014),* developed a spiral capacitive seed sensor, which achieved the detection of seeding amount in precision cotton planters. In conclusion, the above research has laid a foundation for improving the performance of cotton seed metering and film mulching hole seeding machine, and has achieved good results. However, there are few reports on the research of cotton film cutting belts, and currently it mainly relies on manual operation, which affects the efficiency of machine operation and seriously hinders the rapid development of cotton precision film hole seeding machines.

To address the above issues, this article proposes a wireless remote control method using buttons for the cotton precision film mulch planting machine as the research platform. This article uses the STM32 microcontroller to build and develop an automatic film cutting system for cotton precision seeding and mulch punching machine and field performance verification tests are conducted to improve the quality of automatic film cutting and laying operation of cotton precision film hole seeding machine.

MATERIALS AND METHODS

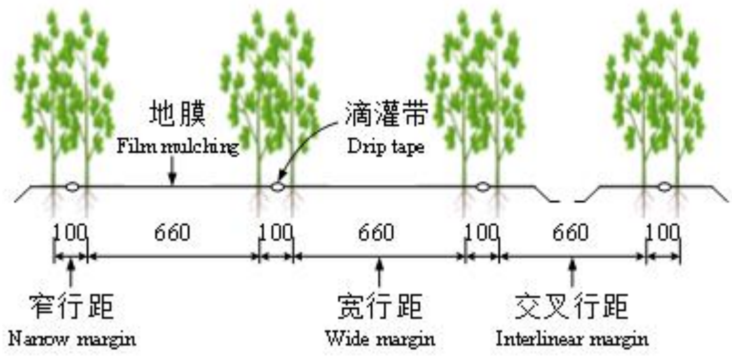
Overall design of cotton precision film mulching and hole seeding machine with film cutting and conveying unit

The cotton precision film laying and hole seeding machine with film cutting belt unit is mainly composed of two parts: mechanical structure and control system, which can be installed at the front or rear position of the hole seeder.

- **Mechanical structure**

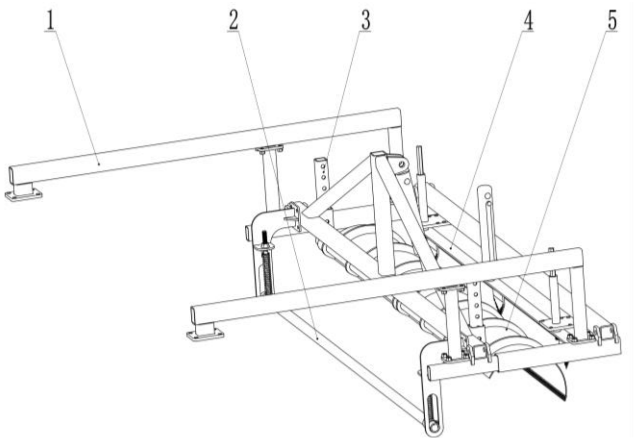
The mechanical structure of the cotton precision mulch seed drill machine's breakage belt unit, located at the end of the cotton precision mulch seed drill machine, was selected as the research object. The narrow-wide spacing planting pattern is shown in Figure 1a. The unit position is shown in Figure 1b. This unit is composed of a frame, limit rods, curved breakaway strips, adjustable curved blades, and a fixed strap assembly, amongst other components (Figure 1b). This module can complete the separation and burial of drip irrigation film and plastic mulch in one go, thereby enhancing the efficiency of cotton seed drillers.

During operations, the machine is connected to a cotton precision-fertilizer-seeding machine via a setup. In this unit, the arc-shaped cutting blade is adjusted in depth by means of the adjustable arc-shaped shovel device prior to its insertion into the soil. The fixed tie assembly is first moved downward to ensure that the ground cover film and drip irrigation tape, which have already been laid out, do not shift during the breakage of the membrane. Subsequently, the curved breakaway strip is flipped down, completing the severance of the plastic film and drip irrigation strips connected to the machine. And then, a certain amount of soil is shoveled in, together with the limit rod, to firmly secure the plastic film and drip irrigation strip connected to the cotton precision seed drill machine, enabling the machine to shift its position for subsequent placement. The retaining strap assembly is repositioned in place. As the machinery is prepared for another round of mulching and drip irrigation, the curved breakaway strip is reset, and its interior soil is emptied out. It is ensured that it can hold down the newly laid plastic film and drip irrigation strips, completing the process of burying the plastic film and drip irrigation strips.



（a）Wide and narrow row planting pattern

（b）Installation position of unit mechanical structure



（c）Unit mechanical structure

Fig. 1 - Mechanical structure diagram of cotton precision film-laying hole seeder with film and tape cutting unit mechanical structure

1. Frame 2. Limit rods 3. Adjustable height mechanism for the curved blade 4. Fixed strap assembly 5. Curved ripper blade

- **Control system**

The overall structure of the cotton precision film hole seeding machine with automatic film cutting and control system is shown in Figure 2. The system mainly consists of an electromagnetic integrated valve group, a lift hydraulic cylinder for hole punching, a membrane pressing hydraulic cylinder, a multifunctional hydraulic cylinder for membrane cutting, a strap support hydraulic cylinder, hydraulic limit sensors, arc-shaped membrane cutting shovel reset sensors, wireless control handle for membrane cutting, and a measuring and control device for membrane cutting.

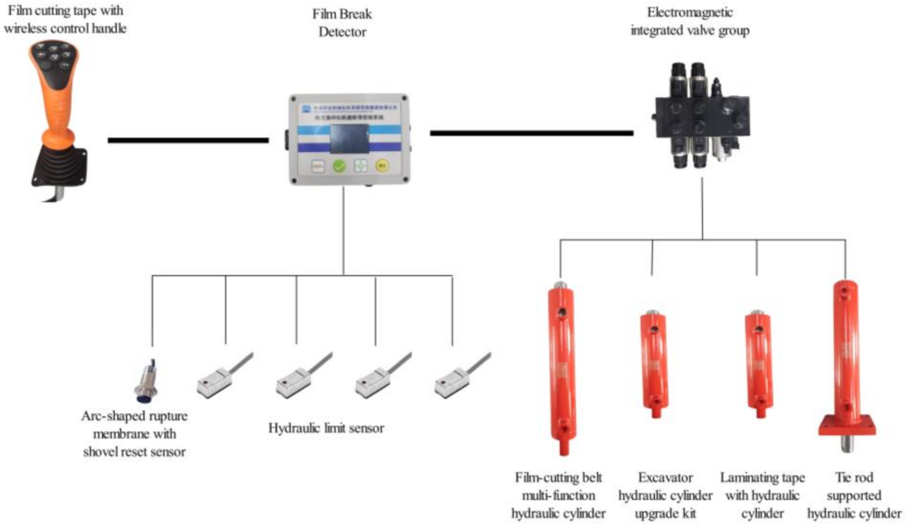


Fig. 2 - Overall Control System composition diagram of automatic film and tape cutting for cotton precision film-laying hole seeder

When the system starts working, first install the film cutting control terminal on the cotton precision film hole seeder frame through operation. It sets the distance parameter for the machine to move forward, and then initiates the reset operation of the arc-shaped film cutting shovel. This system completes the single-point 4-key action (① the hole opener raises the hydraulic cylinder and the zip tie support hydraulic cylinder extends out; ② the film pressing belt hydraulic cylinder and the film cutting belt multi-functional hydraulic cylinder extend; ③ the hole opener raises the hydraulic cylinder and the tie-down support hydraulic cylinder retracts; ④ the film pressing belt retracts with the hydraulic cylinder and the film cutting belt with the multi-function hydraulic cylinder) or single-point 2-key action (① the hole opener lifting hydraulic cylinder extends and the tie support hydraulic cylinder extends, the film pressing hydraulic cylinder extends, and the film cutting hydraulic cylinder extends; ② the hole puncher lifting hydraulic cylinder retracts, the tie support hydraulic cylinder retracts, the film pressing hydraulic cylinder retracts, and the film cutting multi-function hydraulic cylinder retracts) of the film cutting belt through the wireless control handle of the film cutting belt. The film cutting controller receives the wireless control handle button signal of the film cutting belt, and the received instructions correspond to the various oil circuit control signals mapped internally in the controller, analyzing whether it is a single-point 4-key action or a single-point 2-key action. If it is a single point 4-health action, the control valve group of the corresponding hydraulic cylinder control action is completed by combining the light-coupled output switch signal with the measuring controller. It controls the extension length of the hydraulic cylinder by detecting the signal from the hydraulic limit sensor. If the single-point 2-key action is completed after the first key is pressed to achieve automatic film cutting action, the arc film cutting belt shovel reset sensor signal needs to be waited for. It starts the next action when it reaches the set distance parameter for the machine to move forward, thus automatically completing the process of burying the plastic film and drip tape.

System hardware design

- **Film Break Detector**

The film tension controller is the core of the control system, consisting of a display control touch screen, controller, and membrane keyboard. It needs to receive and process signals from hydraulic limit sensors, arc-shaped film cutting shovel reset sensors, film cutting wireless control handles, etc. in real time.

It generates instructions in real time to control the switching of the oil circuit of the electromagnetic integrated valve group, thereby controlling the extension and retraction distances of each hydraulic cylinder. It sets the machine's forward distance parameters through manual key membrane keyboard or touch control touch screen. The controller uses the STM32F103RCT6 microcontroller produced by STMicroelectronics. It adopts the high-performance ARM® Cortex®-M3 core architecture, with 32-bit computing capability and interrupt masking feature. The display screen with touch control uses the serial display screen model DC24320M024 produced by Guangzhou Dacai. It has the advantages of good handling of workpiece movement and vibration, meeting the actual requirements of automatic film cutting with cotton precision film laying and hole seeding machine. The installation location is shown in Figure 3, and the performance parameters are shown in Table 1.

Fig. 3 - Installation diagram of film and tape cutting monitoring controller

Table 1

Display control touch screen performance parameters

Parameter	Performance
Product Series	M Series
Central Processing Unit	400MSOC processor
Size	2.4 inches
Voltage	5 V
Supporting PC software	VisualTFT®
Working frequency	315 MHz

- **Hydraulic limit sensor**

The extension distance of the hydraulic cylinder is an important detection parameter for automatic film cutting. The hydraulic limit sensors are installed on the multifunctional hydraulic cylinder with film breaking belt and the hydraulic cylinder with strapping support, located at the upper and lower limit positions of each hydraulic cylinder. It senses the extension position of the hydraulic cylinder through magnetic signal induction. This article features the contactless magnetic switch hydraulic limit position sensor produced by Zhiding Pneumatics. It has strong anti-interference ability and high cost performance. The installation location is shown in Figure 4, and the performance parameters are shown in Table 2.

Fig. 4 - Installation diagram of Hydraulic limit sensor

Table 2

Hydraulic limit sensor performance parameters

Parameter	Performance
Operating Voltage	12-24 V wide voltage
Operating current	2.5-100 mA
Temperature	-10-70℃
Action time	≤1 ms
Protection circuit	Power Polarity Protection
Service life	Semi-permanent
Impact resistance	1000 m/s^2

- **Arc-shaped rupture membrane with shovel reset sensor**

The arc-shaped film strip shovel reset sensor uses a proximity switch sensor produced by Jingjiake. It features accurate detection and fast response speed. It detects metal from a distance, generates counting pulse signals, transmits them to the film strip controller, and calculates the distance the machine has traveled. The installation location is shown in Figure 5, and the performance parameters are shown in Table 3.

Fig. 5 - Installation diagram of Arcuate rupture membrane with shovel reset sensor

Table 3

Arcuate rupture membrane with shovel reset sensor performance parameters

Parameter	Performance
Specifications	M12 non-embedded
Switching frequency	1 KHz
Response Time	＜0.5 ms
Delayed switch	＜15%（Sr）
Repetitive accuracy	＜3.0%（Sr）
Protection level	IP67
Operating temperature	-25°C to +70°C
Connection method	D4 3*0.15 PVC 2M

- **Electromagnetic integrated valve group**

The electromagnetic integrated valve group uses the electromagnetic multi-way valve produced by Hefei XieLi Hydraulic, which consists of one main oil passage and four branch oil passages. It includes directional solenoid valve, main relief valve, and flow divider valve. Each time it moves, the main oil supply must be opened and connected to the hydraulic interface of the tractor. The oil circuit is divided into four separate hydraulic cylinder extension and retraction circuits. It controls the hydraulic cylinder by switching the hydraulic oil circuit. It also adds dual hydraulic locks, main safety valves, and flow division function to prevent cylinder slippage and protect the entire machine system. It ensures that the working flow into the main valve does not exceed the standard, with the remaining flow being unloaded through the return oil, ensuring that there is no overheating on high-horsepower tractors. The installation location is shown in Figure 6, and the performance parameters are shown in Table 4.

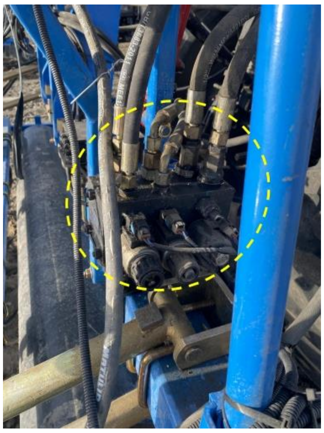


Fig. 6 - Installation diagram of Electromagnetic integrated valve group

Table 4

Electromagnetic integrated valve group performance parameters

Parameter	Performance
Rated flow	50 L/min
Maximum flow rate of the work port	40 L/min
Rated pressure	31.5 MPa
Adjust pressure	18 MPa
Operating Voltage	12-24V wide voltage
Pressure loss	0.7 MPa

- **Hydraulic cylinder**

The hydraulic cylinder is connected to the electromagnetic integrated valve group via hydraulic oil pipes. The pressure film is connected with the hydraulic cylinder and the strap support hydraulic cylinder through the diversion valve, while the multifunctional hydraulic cylinder for film cutting is connected with the hydraulic cylinder for hole punching. Among them, the hydraulic cylinder for the film pressing belt and the multi-functional hydraulic cylinder for the film cutting belt are equipped with stainless steel double-acting hydraulic cylinders with magnetic ring induction produced by Zelco, matched with hydraulic limit sensors to detect the extension position of the hydraulic cylinder. The hydraulic double-acting oil cylinders for the film pressing with liquid hydraulic cylinder and the lifting hydraulic cylinder for the hole seeder are produced by Xingtai Tianjin. The installation location is shown in Figure 7, and the performance parameters are listed in Table 5.

Fig. 7 - Installation diagram of hydraulic cylinder

Table 5

Hydraulic cylinder performance parameters

Name	Parameter	Performance
Film breakage detection multi-function hydraulic cylinder	Bore	50cm
	Thrust	3.9T
	Tension	2.9T
Tie rod supported hydraulic cylinder	Bore	50cm
	Thrust	3.9T
	Tension	2.9T
Laminating with hydraulic cylinder	Bore	40cm
	Thrust	3.12T
	Tension	2.32T
Excavator hydraulic cylinder upgrade kit	Bore	40cm
	Thrust	3.12T
	Tension	2.32T

- **Film cutting tape with wireless control handle**

The wireless control handle for film cutting machine is produced by Henan Pengfei Intelligent Technology. It can complete single-point 4-key or single-point 2-key actions, with features of simple operation, reliable and stable performance, and good scalability. The installation location is shown in Figure 8, and the performance parameters are shown in Table 6.

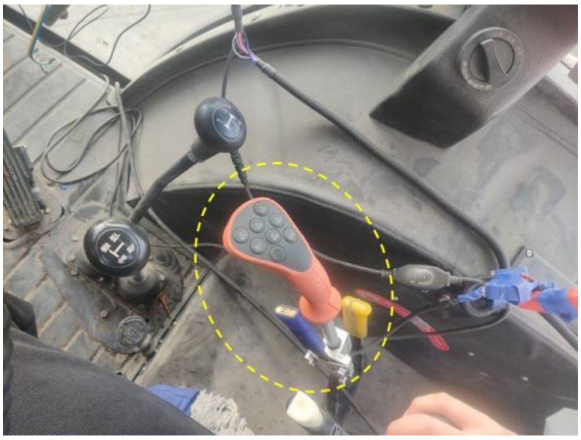


Fig. 8 - Installation diagram of Wireless Control Handle for Film Cutting

Table 6

Wireless Control Handle for Film Cutting performance parameters

Parameter	Performance
Key lifespan	200,000 times
Operating Voltage	12-24V wide voltage
Operating current	50 mA
Working frequency	315 MHz

System Software Design

- **Overall design of terminal functions**

According to the functional requirements of the automatic film cutting control system, this paper designs the system implementation process. The principle of the drive circuit board is shown in Figure 9, and the implementation process is shown in Figure 10. Before starting the system, initialize the configuration, set system parameters, and obtain parameter values by parsing the corresponding protocol. Start the system and cyclically check the working status of each hardware component. After the control system is started, input the distance information of the machine's forward movement through the touch screen. It establishes the serial port connection relationship between the controller and the integrated electromagnetic valve group, hydraulic cylinder, hydraulic limit sensor, arc-shaped film breaker with shovel reset sensor, and the film breaker wireless control handle. The embedded host completes the automatic cutting and burying process of ground film and drip tape by obtaining the extension position of the hydraulic cylinder, the signal of the arc-shaped film cutting belt shovel reset, the signal of the wireless control handle button of the film cutting belt, and combining with the input parameters.

(1) Machine forward distance acquisition

The arc-shaped ruptured membrane belt shovel reset sensor is equipped with a Hall element inside. When the wheel hub passes through the sensor measurement area, a signal is generated due to the Hall effect. However, due to the slipping phenomenon of the ground wheel, the slip coefficient of the ground wheel must be considered.

The formula for calculating the actual distance traveled by the machine is as follows:

$$s = \frac{n\pi d\left(1+\varepsilon\right)}{z} \tag{1}$$

where: *s*—Machine forward distance, m; *n*—Number of pulse signals; *d*—Wheel diameter, m; *z*—Number of wheel revolutions; *ε*—slip ratio, normally taken as 0.05~0.12 (*Zhang J.C. et al., 2021*).

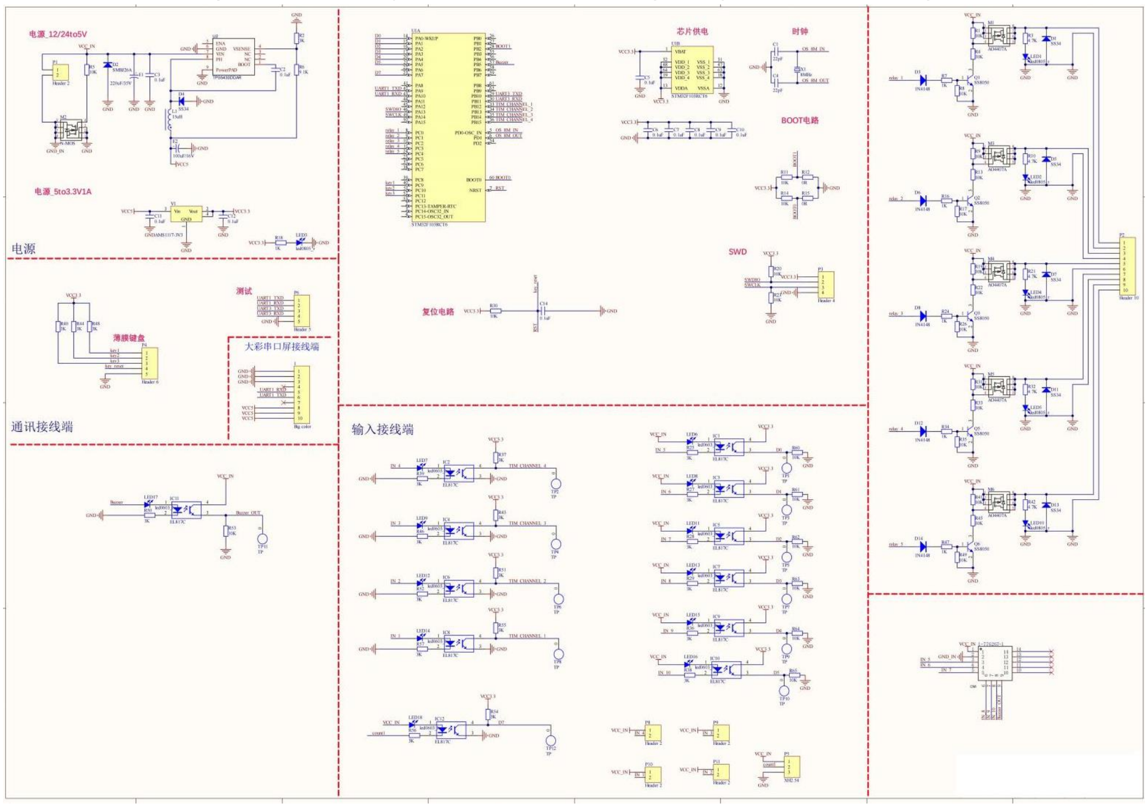


Fig. 9 - Schematic diagram of the driver circuit board

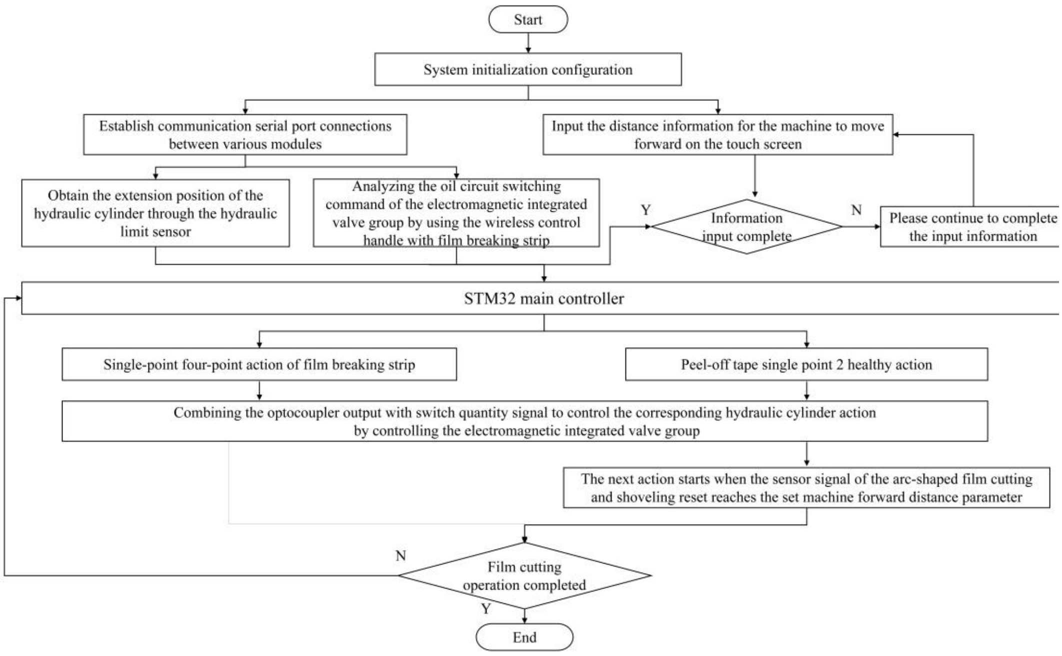


Fig. 10 - Control system implementation flowchart

(2) Hydraulic Control Principles

The hydraulic system is mainly composed of an electromagnetic integrated valve group, hydraulic cylinders, etc. Connect the main oil ports P and T of the integrated valve group to the tractor. The laminating tape hydraulic cylinder and the strapping support hydraulic cylinder are connected to the electromagnetic integrated valve group A1 and B1 for oil distribution. The multi-functional hydraulic cylinder with film cutting device and the lifting hydraulic cylinder with hole opener share the integrated electromagnetic valve group A2 and B2 oil outlets. It achieves the extension and retraction of the hydraulic cylinder through the directional valve. The hydraulic cylinder presses the film and drip tape to prevent rolling when cutting, ensuring the film and drip tape are securely held in place. The strap supports the hydraulic cylinder to tie down the drip tape and mulch film, ensuring that the laid mulch film and drip tape will not shift. Raise the hole opener to prevent the plastic film from wrapping around it. The multi-functional hydraulic cylinder with film cutting function completes the cutting, clamping, and connection of the film and drip tape to the machine, making it easier to re-lay after the machine is moved and then shovel a certain amount of soil to complete the burial process of the film and drip tape. The hydraulic control principle is shown in Figure 11.

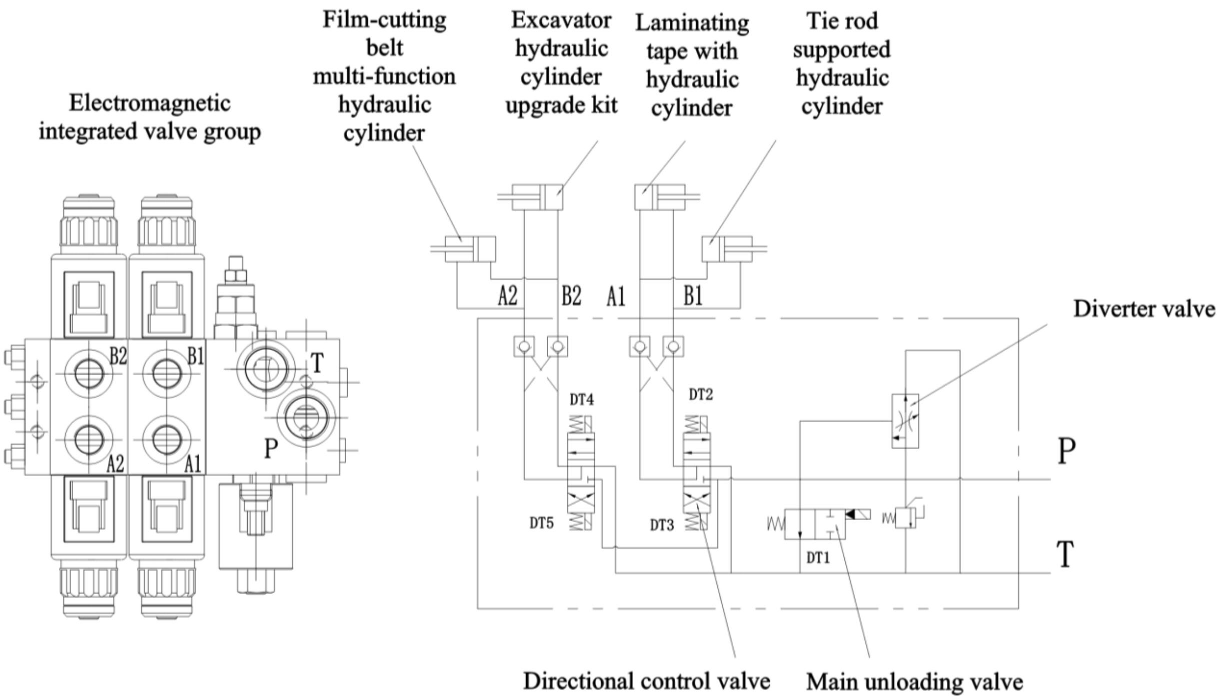


Fig. 11 - Hydraulic control schematic

(3) Film cutting with wireless control

The wireless control of the film cutting tape is achieved by first operating the transmission module through remote control, which controls the relay inside the receiving module of the film cutting tape controller to open or close, thereby enabling remote control of the electromagnetic integrated valve group. The receiving module has 8 input/output ports that can be collected. When the corresponding button on the joystick is pressed, the MCU receives an external interrupt signal indicating a change in the I/O status. After receiving the signal, the MCU triggers the corresponding electromagnetic integrated valve group to actuate, thereby driving the electromagnetic integrated valve group to complete the corresponding hydraulic cylinder extension or retraction process.

The transmission module is a 315M wireless transmission module, with a working frequency of 315 MHz. The transmission head uses SAW oscillation, which provides frequency stability and low temperature drift. When the ambient temperature is between -25-85°C, the frequency drift is only 3 ppm/°C, suitable for multi-point remote control and data transmission systems, operating voltage between DC 3-5 V. The receiving module is a 351 MHz ASK superheterodyne decoding wireless receiving module, with a receiving sensitivity of -112dBm, good selectivity, and suppression of spurious radiation. It operates at a voltage of 3-5 V.

The transmission module uses ASK modulation. When the data signal stops, the transmission current drops to zero. When the button is not pressed, the triode is cut off. The encoding integrated chip PT2262 is in power-off state, not transmitting signals. When the button is pressed, the transistor conducts, and the encoding integrated circuit PT2262 starts to work. According to the level of the data input terminal, the coding is performed, and a complete code word is composed of address code, data code, and synchronization code. The encoded signal is modulated through the 315M wireless data transmission module and transmitted to the surrounding space through the antenna. If the button is held down continuously, the transmitter module will continuously send out wireless signals.

It uses a 315M receiving module and decoding integrated chip PT2272-M4 in conjunction with D flip-flop 4013 and relay to form the receiving part circuit corresponding to the above-mentioned transmission module. When the wireless receiving module does not receive the 315 MHz signal in the space, it only outputs interference signals, all of which are low level. When the receiving module receives a 315 MHz signal, it processes it through amplification, frequency conversion, filtering, etc., and outputs a control signal. Only when the address pin of the PT2262 in the transmitting part matches, a high-level output is generated at the corresponding data pin. When the signal sent by the launch section is received, a rising edge of the level will be generated at the corresponding high level, and the controller will execute the action of the corresponding button's electro-magnetic integrated valve group.

- **Display Interface**

Based on the automatic film cutting control algorithm and flowchart, the system interface of the automatic film cutting control system for the precision cotton film laying and hole seeding machine is planned and designed on the VisualTFT platform. It is mainly used for displaying distance parameters, button single point interface, as shown in Figure 12. The execution distance parameter display interface allows the user to input the forward distance of the machine through touch operation. Automatically complete the process of burying the plastic film and drip tape when the set machine forward distance parameter is reached. The + and - buttons on the button single-point interface are used to increment or decrement the set forward distance of the machine. The √ button confirms the set distance for the machine to move forward, which will be maintained the next time the machine is turned on. The reset button resets the set forward distance of the machine and allows for reconfiguration.

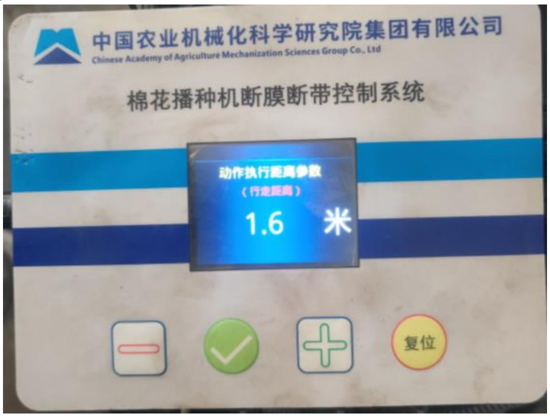


Fig. 12 - System Settings Interface

Performance test design of monitoring system

- **Experimental conditions**

To verify the operation effect of the automatic film cutting control system for cotton precision seed furrow mulching machine, a cotton automatic film cutting control test was conducted on April 18, 2024 in Tiemenguan, Xinjiang. The supporting power is provided by the Dongfanghong 1504 tractor, using a cotton precision film hole seeder equipped with this system for automatic film cutting belt testing.

- **Machine forward distance monitoring test**

The field test sets the test distance at 10 meters, with manual measurement as the actual forward distance of the machine, and the value displayed on the human-machine interaction interface is the machine-measured forward distance. Five test distance points were selected from the test distance stage of 10 m, and each repeated test was conducted for 3 times. The average value was taken as the monitoring test result of the machine advance distance. Calculate the monitoring accuracy by comparing the distance traveled by the machine with the actual value.

- **Control test of membrane strip and buried membrane strip**

To explore the accuracy and dynamic performance indicators of the automatic film cutting control of the cotton precision mulch hole seeder, automatic control performance tests and response tests were conducted. According to the national machinery industry standard JB/T7732-2006 "Film Mulching Seeder" (National Agricultural Machinery Standardization Technical Committee. 2006) and the national agricultural industry standard NY/T987-2006 "Quality of Film Mulching Hole Seeder Operation" (National Agricultural Machinery Standardization Technical Committee. 2006), the experimental process starts by powering on the system and resetting the data. Then start the machine to move forward, with distances of 200 m, 300 m, 400 m, 500 m, and 600 m respectively. The experiment was carried out in 5 groups, and the automatic film-breaking tape control system of cotton precision film-laying burrowing planter was started every 5 m. The repeatability test was carried out 3 times for each group, and the actual values of the successful times of film-breaking tape and the successful times of filling film tape were recorded.

During the automatic control response process of the film cutting tape and burial film tape, the response time and execution time both affect the performance of the test system. Therefore, the automatic control response test of the film cutting tape and burial film tape is set to be conducted 3 times, and the average value is taken as the result of the automatic control response test of the film cutting tape and burial film tape. The adjustment response time and execution time of the hydraulic cylinders for film pressing tape, tying tape support, multi-function hydraulic cylinder for film cutting tape, and hydraulic cylinder for hole opener lifting are recorded.

RESULTS AND ANALYSIS

Test results of machine forward distance monitoring

The test results of different machines' forward distance monitoring are shown in Table 7. The results indicate that the monitoring range of machine's forward distance was 96.53% to 99.60%, with an average monitoring accuracy of 98.16%.

The reasons for the error are: in the actual operation of the machine, due to the uneven surface of the cotton field, the machine is easily disturbed when the speed is slow; as the operating speed gradually increases, the impact of the uneven surface decreases.

Table 7

Test results of machine forward distance monitoring

Actual distance traveled by the machine/m	Monitoring the distance traveled by the machine/m	Monitoring Accuracy/%	Average monitoring accuracy/%
2.02	2.09	96.53	98.16
4.15	4.05	97.59	
6.20	6.08	98.06	
8.10	8.18	99.01	
9.95	9.99	99.60	

Results of Control Tests for Geomembrane and Landfill Liner

The automatic control response test results of the film cutting tape and the burial film tape are shown in Table 8. Test results proves that the module meets the requirements of field operations.

Table 8

Response Test Results of Membrane Strips and Buried Membrane Strips

Hydraulic cylinder	Stretch out		Retract	
	Response Time/s	Execution time/s	Response Time/s	Execution time/s
Laminating with Hydraulic Cylinder	0.65	1.16	0.63	1.20
Tie rod supported hydraulic cylinder	0.72	2.44	0.78	2.36
Film-cutting tape multi-function hydraulic cylinder	0.76	2.55	0.70	2.68
Excavator hydraulic cylinder upgrade kit	0.70	1.24	0.76	1.09

The field trial site was shown in Figure 13, the operation situation was shown in Figure 14, and the results were shown in Table 9. The test results show that the success rate of cutting film strips was 100.00%, and the success rate of burying film strips was above 98.33%, which meets the requirements for automatic cutting of film strips by the cotton seed precision film hole seeding machine. However, there is still room for improvement in the success rate and accuracy of the prototype film filling, and further research is needed on its working principle, hydraulic system, and control module to improve the accuracy of film cutting control.

Fig. 13 - Field test site

（a）Cutting film strip operation effect

（b）Effectiveness of landfill liner installation

Fig. 14 - Effectiveness of film cutting operation

Table 9

Test Results of Automatic Control Performance of Membrane Strips and Buried Membrane Strips

Distance traveled by the machine/m	Total number	Number of successful membrane cutting operations	Number of successful landfill liner installations	Success rate of film breaking/%	Success rate of landfill liner/%
200	40	40	40	100	100
300	60	60	60	100	100
400	80	80	79	100	98.75
500	100	100	99	100	99.00
600	120	120	118	100	98.33

CONCLUSIONS

This article described an automatic film cutting belt control system designed for a precision film laying and hole seeding machine for cotton. Field tests were conducted to verify the reliability of the system operation.

(1) This article proposed a wireless joystick button control method, designed with the STM32 microcontroller as the core to control the cotton precision film laying hole opener system, which consisted of an electromagnetic integrated valve group, a hydraulic cylinder for lifting the seedling plate, a hydraulic cylinder for pressing the film, a multifunctional hydraulic cylinder for film cutting, a hydraulic cylinder for tying support, a hydraulic limit sensor, an arc-shaped film cutting shovel reset sensor, a wireless control joystick for film cutting, and a film cutting controller, aiming to improve the efficiency of cotton planting machines.

(2) Based on the VisualTFT platform, the software system developed for the automatic film cutting tape control system could complete the cutting and burying of drip tape and mulch film in one step through the wireless control module of the film cutting tape, achieving single-point 4-key action or single-point 2-key action.

(3) Field tests of the cotton precision film mulching and hole seeding machine with automatic film cutting and feeding system showed that the system worked stably and reliably. The average monitoring accuracy of the advance distance of the machine was 98.16%. The control response time of broken film belt and landfill film belt was ≤0.78 s, and the execution time was ≤2.68s. The success rate of broken film tape was 100.00%, and the success rate of landfill film tape was more than 98.33%. The success rate of cutting film tape was 100.00%, and the success rate of landfill film tape was more than 98.33%, which was in line with the requirement of automatic cutting film tape of actual cotton precision film laying burrowing planter.

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REFERENCES

[1] Cao Y., Guo W.S., Zhao P.F., Wang X.F., Wang L., Yang Q.N., (2022), Design of automatic detection system for cotton drill seed metering performance based on LabVIEW[J]. *Journal of Agricultural Mechanization Research*, 44(11): 135-141, Beijing / P.R.C.;

[2] Cao Y., (2022), Design of Performance Testing System for Seed Metering of Dibbler Based on Machine Vision[D]. *Tarim University*, Xinjiang / P.R.C.;

[3] Chen H.X., Han Y.C., Ma L., Yang B.F., LEI Y.P., Wang Z.P., Li Y.B., (2020), Application of smart agriculture in cotton production management[J]. *Cotton Science*, 32(03): 269-278, Henan / P.R.C.;

[4] Chen X.G., Lu Y.T., (2010), Sowing performance of air-suction cylindrical cotton precision dibbler[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, 41(08): 35-38, Beijing / P.R.C.;

[5] Erkan K., Erdal K., Herman R., Wouter S., (2014), Distributed nonlinear model predictive control of an autonomous tractor-trailer system[J]. *Mechatronics*, 24: 926-933, Oxford / UK.;

[6] Kaivosoja J., Linkolehto R., (2015), GNSS error simulator for farm machinery navigation development[J]. *Computers and Electronics in Agriculture*, 119: 166-177, London / UK.;

[7] Liu W.J., Fan Y.S., Dong Y.Q., Qu T., Zhu K., Liu Y.C., Wei F., (2020), Analysis and Suggestions on the Current Situation of Cotton Production in China[J]. *China Seed Industry*, (1): 21-25, Beijing / P.R.C.;

[8] Lu Y.T., Li Y.X., Chen X.G., (2012), Design and experiment on air-suction cotton precision dibbler[J]. *Journal of Gansu Agricultural University*, 47(03): 129-133. Gansu / P.R.C.;

[9] Singh R.C., Singh G., Saraswat D.C., (2005), Optimization of Design and Operational Parameters of a Pneumatic Seed Metering Device for Planting Cottonseeds[J]. *Biosystems Engineering*, 92(4): 429-438, San Diego, California / USA.;

[10] Wang J.K. (2006), Study on Clamping and Self-Locking Cotton Precision Dibbler[D]. *Shihezi University,* Shihezi / P.R.C.;

[11] Wang J.K., Kan Z., Wu J., Cha H.S., (2006), Design and experiment on clamping and self-locking cotton precision dibbler[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, (05): 54-56, 82. Beijing / P.R.C.;

[12] Wang J.K., Guo K.Q., Lv X.M., Fu W., Qi C.S., (2011), Experiment and Improvement on Clamping Cotton Precision Seeding Dibbler[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, 42(04): 43-47, Beijing / P.R.C.;

[13] Yazgla A., Degirmencioglu A., (2014), Measurement of seed spacing uniformity performance of a precision metering unit as function of the number of holes on vacuum plate[J]. *Measurement*, 56(10): 128-135, London / UK.;

[14] Yuan B.S., Bai S.H., Niu K., Zhou L.M., Zhao B., Wei L.G., Liu L.J., (2023), Analysis on research progress of key technology and equipment of cotton planting mechanization[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, 39(06): 1-11, Beijing / P.R.C.;

[15] Zhang X.J., Chen Y., Shi Z.L., Jin W., Zhang H.T., Fu H., Wang D.J., (2021), Design and experiment of double-storage turntable cotton vertical disc hole seeding and metering device[J]. *Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE)*, 37(19): 27-36, Beijing / P.R.C.;

[16] Zhang X.J., Zhang H.T., Shi Z.L., Jin W., Chen Y., Yu Y.L., (2022), Design and experiments of seed pickup status monitoring system for cotton precision dibblers[J]. *Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE)*, 38(05): 9-19, Beijing / P.R.C.;

[17] Zhang F., (2021), Analysis of the Application of Smart Agriculture in Cotton Production Management[J]. *Agricultural Engineering Technology*, 41(24): 33, 36, Henan / P.R.C.;

[18] Zhang J.C., Yan S.C., Ji W.Y., Zhu B.G., Zheng P., (2021), Precision Fertilization Control System Research for Solid Fertilizers Based on Incremental PID Control Algorithm[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, 52(03): 99-106, Beijing / P.R.C.;

[19] Zhao Y., Chen X.G., Wen H.J., (2018), Application of the development of precision agriculture and the China's Beidou satellite navigation System in agricultural production in The Xinjiang Production and Construction Corps[J]. *Journal of Shihezi University (Natural Science)*, 36(04): 397-404, Shihezi / P.R.C.;

[20] Zhou L.M., (2014), Research on detection of yield and seeding rate of cotton based on capacitive method[J]. *China Agricultural University*, Beijing / P.R.C.;

[21] Zhou L.M., Li S.J., Zhang X.C., Wang S.M., Yuan Y.W., Dong X., (2014), Detection of seed cotton mass flow based on capacitance approach[J]. *Transactions of the Chinese Society for Agricultural Machinery (Transactions of the CSAM)*, 45(06): 47-52, Beijing / P.R.C.;

[22] ***National Agricultural Machinery Standardization Technical Committee., (2006), JB/T 7732-2006 Film planter[S]. *China Agriculture Press*, Beijing / P.R.C.;

[23] ***National Agricultural Machinery Standardization Technical Committee., (2006), NY/T 987-2006 Quality of Film Mulching Seeder Operation[S]. *China Agriculture Press*, Beijing / P.R.C.;