Design and testing of a special seeder for small hilly areas

Siyang Zhang *, Chengxing Fu, Siyuan He

College of Machinery and Automation Zhixing College of Hubei University WuHan China

* Corresponding Author Email: zhangsiyangredsun@163.com

Abstract. Hilly areas rugged terrain, the overall terrain is relatively steep, soil erosion is serious resulting in sticky soil, the manual seeding method is not only inefficient and the cost will be greatly increased. In view of the problem of hilly areas in China and the low degree of mechanization of the blogger, based on Creo software designed a set of small hill areas specializing in the integration of ditching, sowing, mulching in one of the maize seeders. This seeder is mainly composed of drive mechanism, furrow opening device, seed transfer device, elevated double-layer disc mulching device, spoon type precision seeding device, and control system module. This seeder can efficiently travel in hilly areas through the driving structure, open the furrow by the furrow opening device structure, then through the seed transfer device, the seeding device will spread the seed, and finally through the elevated double-layer disc mulching device will bury the seed. It realizes the automated seeding process in hilly areas.

Keywords: Small and medium-sized agricultural machinery, precision seeding, slope field seeder, structural design.

1. Introduction

According to the "14th Five-Year" National Agricultural Mechanization Development Plan "clearly requires to speed up to make up for the short board of agricultural mechanization in hilly and mountainous areas. In all the hilly and mountainous counties in China, the total area of arable land is about 700 million mu. However, in the endless hilly slopes, the proportion of machinery instead of manpower is only half, and the comprehensive mechanization rate of hilly areas is only 50.05% by 2024, which is 20 percentage points lower than the national average. And then further understand by consulting related information, China's southern hilly mountainous areas, field roads are narrow, rugged, poor passability, increasing the farmers' input costs. Therefore, it is particularly important to design a seeding machine suitable for hilly areas. The purpose of this paper is to propose and validate a seeder program designed specifically for hilly areas.

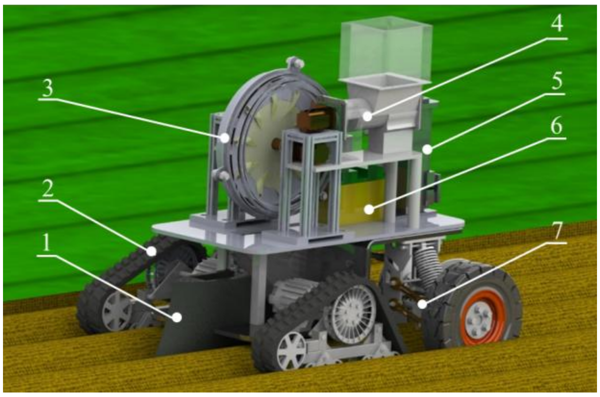
For seeding equipment in hilly terrain, many scholars have carried out a great deal of investigation. Heilongjiang Province Agricultural Machinery Engineering Research Institute of Sun Tao and others developed a 2BY-2 type hilly mountain corn no-till fertilizer seeding machine [1]. The machine can be realized on slopes and hills, mechanical no-till precision seeding, the unit down to the ground once can be completed stubble broken straw, furrowing, fertilizer, seeding, mulching, suppression and other complex operations, reducing the number of units down to the ground, improve operational efficiency, ensure the quality of the operation, reduce the operating costs, and protect the soil environment. However, the mechanical work still needs the supporting power unit, so the degree of automation is low. The 2BYF-6 oilseed rape direct seeding machine developed by Hunan Agricultural University has been widely used in the middle and lower reaches of the Yangtze River.

Currently on the market for the majority of hand-held seeders with a large amount of labor inputs, part of the traction, suspended and semi-suspended seeders need to be tractor and other power equipment to provide kinetic energy and large size.

In this paper, a small hilly seeding machine is proposed and designed, which is not only smaller in size, but also has a triangular track wheel with a cushion wheel mechanism as the driving device. It is favorable for the equipment to work in hilly field terrain. Automated seeding is realized through control system module.

2. Overall design

Design concept: Combining with the terrain characteristics of hilly areas, the design objectives of the seeder are determined, as shown in Fig.1 Structural Schematic Diagram of Small Hilly Area Specialized Seeder Stability, flexibility, adaptability and so on. Multi-stage variable speed mechanism is adopted to adapt to different terrain conditions; adjustable sowing depth control device is designed to ensure that the seeds can be evenly and accurately buried in the soil; and an efficient power transmission system is equipped to ensure that the machine operates smoothly and saves energy.



Notes: 1 Core share furrow opener; 2 Drive unit; 3 Spoon precision planter structure; 4 Spiral horizontal displacement seed conveyor; 5 Automatic lifting and lowering double-disc mulching device; 6 Control system module; 8 Vibration dampening device.

Figure 1. Schematic diagram of the structure of a small hilly area specialized seeder

EXPERIMENTAL DESIGN: Field tests were conducted on different types of hilly fields to evaluate the performance indicators of the planter.

The test results show that the seeder performs well in hilly areas, can effectively complete the seeding task, and also meets the expected goals in terms of seeding depth control. Details of the parameters of this machine can be found in Table1 Main Performance Indicators.

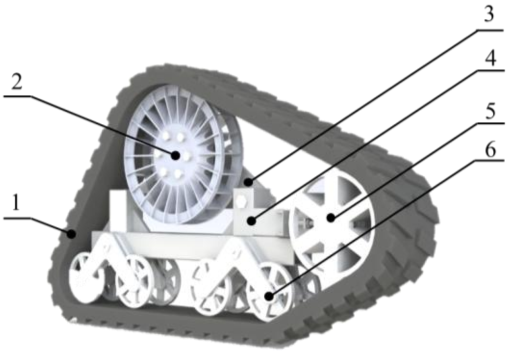
Table 1. Key Performance Indicators

Indicator name	norm
Chassis length× width× height mm× mm× mm	1540× 980× 1150
Track width / mm	480
Climbing gradient/degree	38
Minimum turning radius / m	2 - 3
Rollover stabilizing angle/degree	20
Seed box capacity range/L	15
Power/kw	8
Sowing efficiency/(mu/hour)	5
Overall mass/kg	47.6
Duration/h	4.5

3. Machine components and their main functions

3.1. Drive unit

As shown in Fig.2, for complex terrain, such as mountains, hills, plateaus, etc., it is difficult for ordinary wheels to travel and inconvenient for planting, for which we use triangular track wheel [2] type structure.

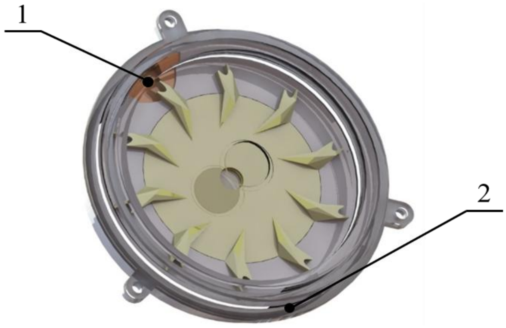


Note: 1 Rubber tracks; 2 Drive wheels; 3 Internal suspensions; 4 Base frame; 5 Guide wheels; 6 Support wheels.

Figure 2. Structure of the drive unit

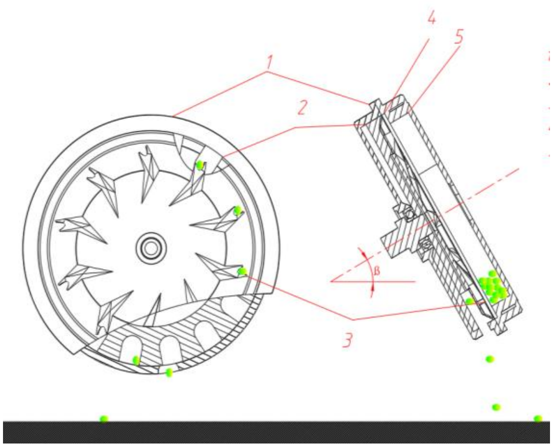
3.2. Spoon Precision Seeding Mechanisms

As shown in Fig.3, the spoon type precision seeding machine [3] mainly consists of a seed discharger housing, a seed casting wheel, a seed distributing spoon disk, a spacer plate, and a seed box. As shown in Fig.4, seed pickup is carried out by means of a seed pickup spoon mounted around the circumference of the spoon wheel, and the seed will enter into the seed pickup spoon type holes along the tangential direction of the spoon wheel, and the seed pickup spoon has a forward tilt angle in the radial mounting direction, which improves the seed pickup capacity of the seed pickup spoon.



Note: 1 Seed pickup scoop notch; 2 Side position plate notch.

Figure 3. Physical drawing of the spoon precision planter



Note: 1 Seed Displacer Housing; 2 Seed Throwing Wheel; 3 Seed Splitting Scoop Tray; 4 Spacer; 5 Seed Box.

Figure 4. Spoon Precision Planter Structure

When the unit operating speed and hole spacing is certain, due to the spoon wheel installed on the circumference of the larger the number of seeding spoon, the slower the rotational speed of the spoon wheel, seeding spoon type hole in the center of the line speed is lower, a single seeding spoon filling time is longer, more conducive to seeding, in the case of not affecting the operation of the seeding spoon, you can increase the number of seeding spoon. Set the spoon wheel installed on the circumference of the seed picking spoon number N, unit operation, spoon wheel rotation week, compartment surface seeding M holes, there are formula

$$N = \frac{\Pi D_d V_m}{sv_d(1\text{-}c)} \tag{1}$$

$$Vd = \frac{\pi D_d n}{60} \tag{2}$$

Vm - unit operating speed, m / s
S - distance between holes, m
C - Ground wheel slip coefficient
n---spoon wheel speed, r/min
vd --- Linear velocity at the center of the seed picking spoon type hole, m/s
Dd - 110 mm diameter at the center of the seed scoop.
From the above equation we get

$$N = \frac{60V_m}{sc(1\text{-}c)} \tag{3}$$

The distribution of seed hole distance is related to the operating speed of the unit Vm, the rotational speed of the spoon wheel n, and the number of seed picking spoon N. When the hole spacing and unit operating speed is certain, the number of seed picking spoons N is inversely proportional to the rotational speed of the spoon wheel. When the unit operating speed of 0.6m / s, hole distance of 0.15m, speed of 20r / min, the ground wheel slip coefficient c for 5% to 12%, take 8%, the calculation can be obtained for the number of seed spoon 10, at this time adjacent to the seed picking spoon type holes corresponding to the center of the angle of 36°.

As shown in Fig.5 , the deformation distribution of the scoop disk is analyzed by ANSYS as shown in Fig. The maximum deformation of the scoop disk is distributed at the outermost side of the part, and the deformation gradually decreases inward, and the maximum deformation is 2.6892×10^{-4} mm.

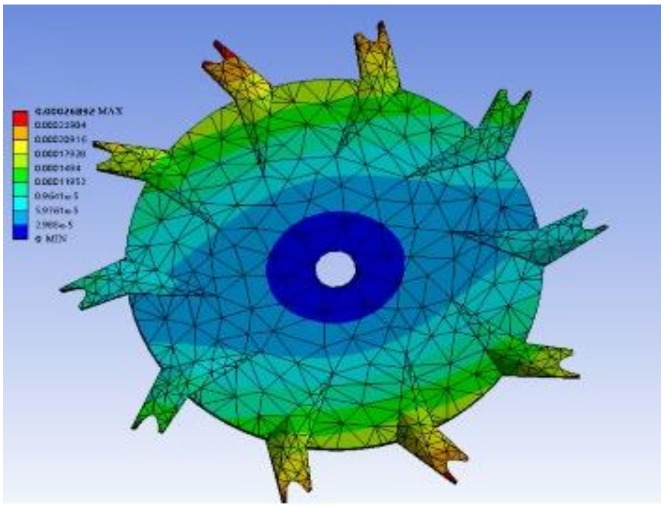


Figure 5. Spoon Precision Seeder Displacement Deformation Diagram

As shown in Fig.6 , the stress distribution of the spoon dish is analyzed by ANSYS as shown in Fig. , the maximum stress is distributed in the position of the spoon dish and the force couple with the external force exerted, and the spoon dish is connected with the rod, and the maximum stress of the spoon dish is 1.284×10^{-1} MPa, so it meets the requirements of the part.

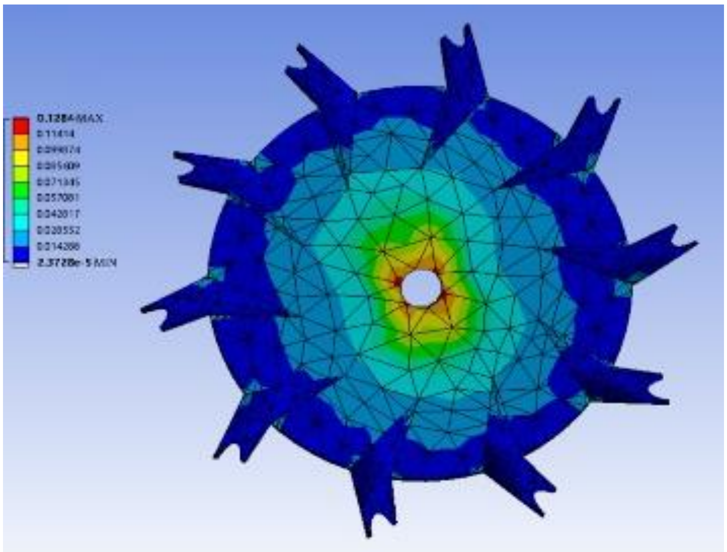
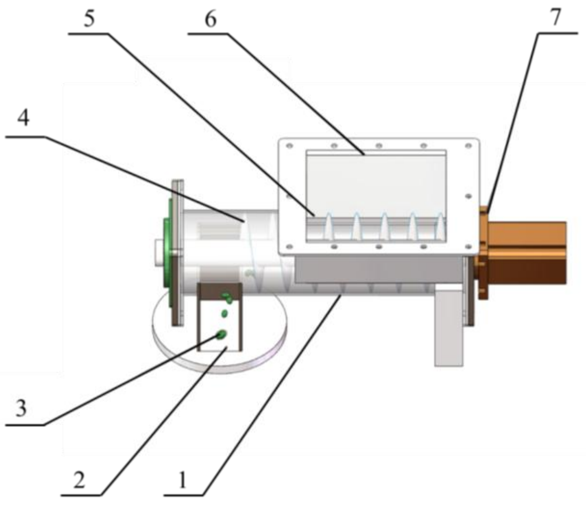


Figure 6. Spoon Precision Planter Stress Map

3.3. Screw type horizontal displacement seed conveyor

The device mainly adopts the principle of spiral motion to horizontal motion, semi-circular input port, model TB-15451 motor, and spiral stopper rod concentrically matched with the outer cylindrical storage, constituting 8 storage positions as shown in Fig.7.

Utilizing a motor to drive a spiral stopper rod to compensate for the output seed rate of the seed sowing machine, the spiral stopper carries out a spiral rotational movement driven by the motor to move the seed horizontally and replenish the seed to the sowing machine.

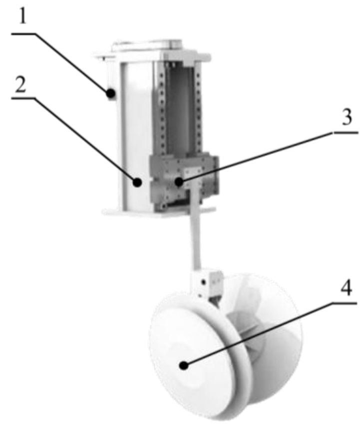


Note: 1 Outer cylindrical reservoir; 2 Outlet; 3 Green beans; 4 Spiral stopper bars; 5 Inlet; 6 Motor.

Figure 7. Physical drawing of spiral horizontal displacement seed conveyor mechanism

3.4. Automatic lift Double-deck disc type Mulching device

As shown in the figure 8 , the lifting device can be moved in a vertical direction and therefore takes up relatively little space. Especially in a limited space, the lifting device can be extremely useful. The machine utilizes the lifting device to enable the mulcher [4] to have a place to be placed when not in use, and to be lowered when in use, and the lifting device also has a self-locking effect, which enables it to secure the mulching machine well.



Note: 1 motor; 2 lifting device; 3 connecting table; 4 double-disc type mulching device.

Figure 8. Physical drawing of the automatic lifting double-disc mulching device

Steel 304 selected, permissible pressure [p] = 7.5~ 13

$$p=\frac{F}{A}=\frac{F}{\pi d_2 hu}=\frac{FP}{\pi d_2 Hh}\le[p] \tag{4}$$

For rectangular thread, h=0.5P, then

$$p=\frac{F}{A}=\frac{200\times 6}{\pi\times 27\times 100\times 3}\approx 0.047\le[p] \tag{5}$$

∅Value generally take 1.2 ~ 3.5. For the whole nut, due to wear and tear can not be adjusted clearance, in order to make the distribution of force is more uniform, the number of thread working circle should not be too much, so take∅ = 1.2 ~ 2.5; for the split nut and also as a support for the nut, can be taken to∅ = 2.5 ~ 3.5; only higher transmission accuracy, load, longer life requirements, it is allowed to take∅ = 4.

According to the formula to calculate the thread diameterd_1, should be in accordance with national standards to select the corresponding nominal diameter d and pitch P thread working circle should not exceed 10 turns.

Check whether the helical pair satisfies the self-locking condition, i.e.

$$\phi\le\varphi_v \arctan\frac{f}{\cos\beta}=\arctan f_v \tag{6}$$

$$\phi\le\varphi_v=\arctan\frac{0.14}{\cos 15°}=\arctan f_v\approx 7.96969 \tag{7}$$

ϕ--Thread angle of rise; --Thread angle of rise; --Thread angle of rise; --Thread angle of rise

φ_v- - Equivalent friction angle;

f_v--equivalent friction factor of the helical pair.

f--Friction factor

As shown in Fig.9 , the axial thrust of external load is applied to the screw with constraint. The maximum displacement distribution is 7.974×10^{-2} mm at the contact between the screw and the nut, and the size of the overall deformation displacement distribution of the screw decreases from the contact to both sides.

Figure 9. Elevator and lowering screw displacement deformation diagrams

As shown in Fig.10 , the stress distribution of the sub-screw, the maximum stress of the screw is 2.068 MPa, the maximum stress of the figure is 4.165×10^2 MPa, much smaller than the maximum stress of the screw, in line with the requirements of the part.

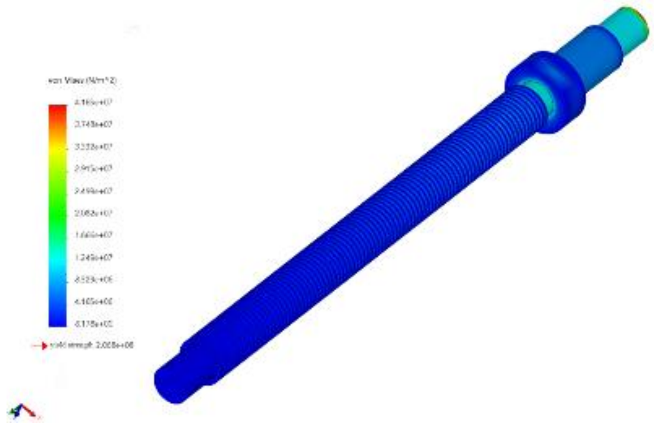


Figure 10. Lift Screw Stress Diagram

3.5. Control system modules

This machine is an engineering machine with highly integrated functions, compact structure and high coordination requirements, many and complex components, and high coordination and timing requirements of major motion mechanisms; when any component of the motion mechanism fails, the whole system needs to react in time to adjust the torque and speed of the drive device to ensure the machine to carry out normal seeding operations, as shown in Figure11 for MCU program part. The drive code is. As shown in Fig.12, it is the main control circuit board.

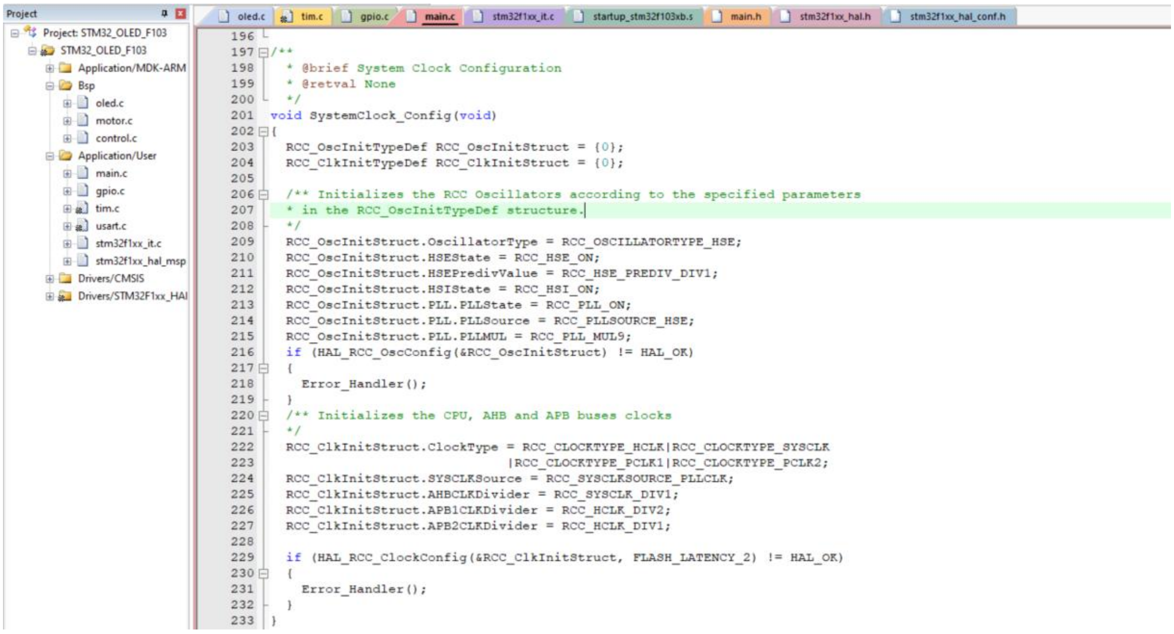


Figure 11. Microcontroller Program Partial Driver Code Fig.

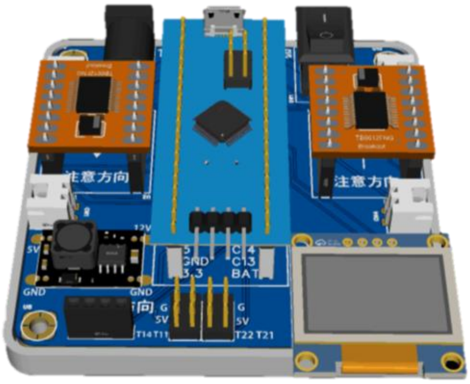
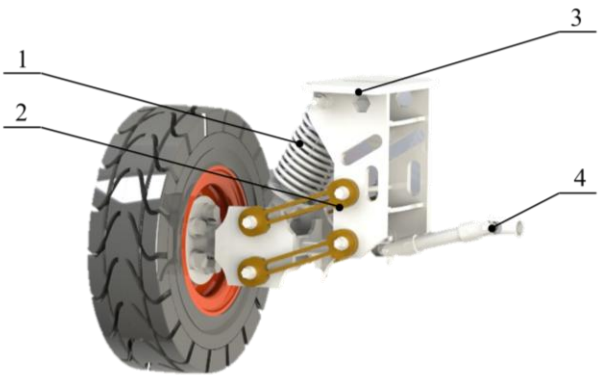


Figure 12. Main Control Board Diagram

3.6. shock absorber

As shown in Fig.13 , the universal joint [5] is made of flexible material, which can withstand and transmit torque within a certain range and ensure the power transmission efficiency. Through its unique structure and material, the driveshaft can have a certain degree of stiffness and flexibility at the same time, thus realizing effective adaptation to the turning movement.



Note: 1 Coil Spring; 2 Connector; 3 Upper mounting assembly; 4 Universal joint.

Figure 13. Diagram of cushioning device

4. Concluding remarks

The low degree of mechanization and automation greatly restricts the modernization of agriculture in hilly and mountainous areas. This seeder can efficiently travel in hilly areas through the driving structure, open furrows by the furrowing device structure, then through the seed transfer device, seeding device will be scattered, and finally through the lifting double-layer disc mulching device will be buried in the seed. It realizes the automated seeding process in hilly areas.

However, the performance of the planter still needs to be further optimized. Future research directions may include a more in-depth exploration of how to further improve the adaptability and efficiency of the planter.

References

[1] SUN Tao, SUN Yi, LI Huirong, et al. Design of 2BY-2 no-tillage fertilizer planter for corn in hilly and mountainous areas [J]. Agricultural Machinery Use and Maintenance, 2023, (03): 20 - 23.

[2] DONG Aixi, YANG Wei, WAN Ruxin, et al. Design of a new triangular rubber track wheel for agricultural vehicles [J]. Agricultural Machinery Use and Maintenance, 2020, (06): 25 - 26.

[3] CHEN Ye, DONG Xin. Experimental research on hemispherical cavity-shaped air suction precision planter [J]. Journal of Northeast Agricultural University, 2016, 47 (11): 100 - 108.

[4] LIU Xuanwei, JIN Liang, ZHAO Yaxiang, et al. Experimental study on double-layer disk mulcher based on uniform design [J]. Chinese Journal of Agricultural Mechanical Chemistry, 2016, 37 (02): 26 - 28.

[5] Wu Sihang. Discussion on the load characteristics of agricultural universal joint drive shafts and the rapid simulation test method [J]. Journal of Agricultural Machinery, 1984, (04): 55 - 63.