DESIGN AND EXPERIMENT OF PRESSURE-HOLDING PRECISION SEED-METERING DEVICE FOR MAIZE
/
压持式玉米精量排种器的设计与试验

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ABSTRACT
In order to further improve the seeding performance of the maize seed-metering device, a pressure-holding precision seed-metering device for maize was designed. The seed-metering device is made up of several seed rowing modules, which effectively solves the problems of inconvenient disassembly and complex maintenance of the current maize seed-metering device. The working principle of the device was introduced, and the mechanical and kinematic analysis of the maize seeds during the seeding operation was carried out. The orthogonal test was carried out with the installation diameter of seed-metering device's guide plate, torsion spring's wire diameter and seed-metering device's rotational speed as the test factors, the single-seeding rate, missed-seeding rate and multiple-seeding rate as the indexes, and the relationship between different test factors on the performance of seed-metering device was obtained. By optimizing the model, the best performance of the seed-metering device was obtained when the installation diameter of the guide plate was 92.32 mm, the wire diameter of the torsion spring was 1.59 mm, and the rotational speed of the seed-metering device was 0.41 rot/s. At this time, the single-seed rate was 93.08%, the missed-seeding rate was 3%, and the multiple-seeding rate was 3.9%, which met the requirements of the industry standard.

摘要
为了进一步提高玉米排种器的排种性能，设计了一种压持式玉米精量排种器。该排种器由多个排种模块组合而成，有效解决了目前玉米排种器存在的拆装不方便、维修复杂等问题。介绍了排种器的工作原理，对作业过程中的玉米种子进行了力学和运动学分析。以排种器导引板安装直径、扭簧丝径及排种器转速为试验因素，以单粒率、漏播率及多粒率为指标进行正交试验，得到了不同试验因素对排种器性能的影响关系。通过对模型进行优化，得到了当导引板安装直径为 92.32mm、扭簧丝径为 1.59mm、排种器转速为 0.41r/s 时，排种器工作性能最佳，此时的排种单粒率为 93.08%、漏播率为 3%、多粒率 3.9%，满足行业标准要求。

INTRODUCTION

Maize is an important food cash crop and its yield has a profound impact on the development of a country's agricultural economy *(Feng et al., 2022)*. Precision seeding technology is the key technology to realize maize yield increase and reasonable use of soil resources, and it is also an important part of maize mechanized planting *(Ding et al., 2021; Wu, 2020)*. The core component of this technology is the seed-metering device, and its reasonable design directly affects the performance of the whole precision seeder *(Wang et al., 2021; Fang et al., 2022)*. At present, there are two main types of maize seed-metering device, pneumatic and mechanical *(Bai et al., 2021; Li et al., 2021)*, and mechanical maize precision seed-metering device have been widely used in maize agricultural production because of their reliable operation, simple structure, and stable operation *(Wang et al., 2019; Liu et al., 2018)*.

In recent years, scholars in the industry have conducted a lot of research on mechanical maize precision seed-metering device *(Wan, 2021; Ren, 2021)*. *Wang et al*., *(2022)*, designed a maize seed-metering device for sloping land, which improved the degree of adaptation of the device to different operating environments. *Du et al*., *(2019)*, designed a self-disturbing in-fill type maize precision seed-metering device to improve seed filling performance by increasing the activity of the population.

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Wang et al., *(2019)*, designed a clamping type maize precision seed-metering device to complete the process of seed picking and seed dropping by controlling the clamping block to pick and release the seeds at different positions. *Inderpal et al., (2020)*, designed a tilting disc type of maize seed-metering device and determined the optimum operating parameters of the seed-metering device through experiments. *Cortez et al*., *(2020)*, studied the effect of the forward speed of the seed rower and the tractor on the agronomic traits of maize and obtained the optimum operating speed suitable for the seed-metering device. However, the current mechanical corn precision seed-metering device has the disadvantage of having too much structural integrity and not being easy to repair in case of failure.

In order to solve this problem, this paper designs a pressure-holding maize precision seed-metering device with a modular design to facilitate maintenance and replacement in case of failure. The design and analysis of the structural parameters and working process of the seed-metering device were carried out, and the rationality of the mechanism design was verified by the test bench test.

MATERIALS AND METHODS

STRUCTURE OF SEED-METERING DEVICE

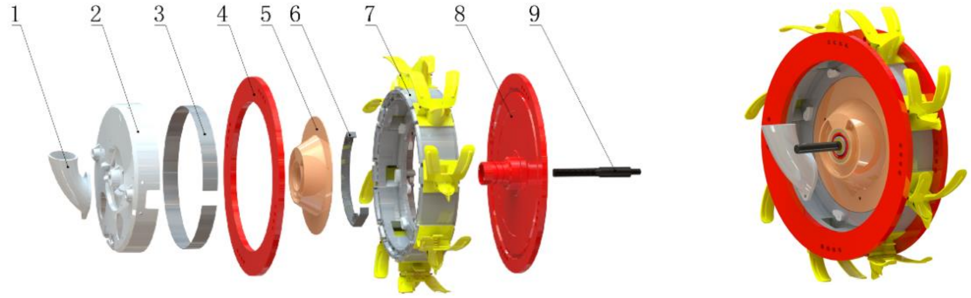


Fig. 1 - Structure diagram of pressure-holding maize precision seed-metering device
1. Seed feeding cylinder; 2. End-cap fixing disc; 3. Steel Belt 4. Fixed Plate; 5. Spaced core tray; 6. Guide plate; 7. Seed displacement module assembly; 8. Motion disc; 9. Shaft

As shown in Figure 1, the pressure-holding maize precision seed-metering device consists of a seed feeding cylinder, end-cap fixing disc, fixed plate, seed core tray, guide plate, seed displacement module assembly (including duckbill, seed picking block, seed storage box, driving arm and torsion spring), motion disc, shaft, etc. In order to facilitate the rapid replacement of damaged parts in case of device failure, the seed releasing module assembly is designed so that each individual seed releasing module is interconnected by means of a slot. Finally, the seeding module is fixed axially by the fixing and motion discs mounted on both ends of the seeding module assembly. The components of the pressure-holding maize precision seed-metering device is fixed by bolts that work together to form the seeder as a whole. Its working parameters are shown in Table 1.

Table 1

Operating parameters of the seed-metering device

Parameters	Value
Diameter [mm]	385
Working width [mm]	90
Quality of the whole machine [kg]	23.5
Working rotational speed [rot/s]	0.3-0.5
Number of seeds per lap	8-10

The seed picking mechanism is the main working part of the seed-metering device, through which the process of seed picking, seed holding and seed dropping can be completed. The structure of seed picking mechanism is shown in Figure 2, which mainly consists of seed picking block, torsion spring, rotary shaft and driving arm.

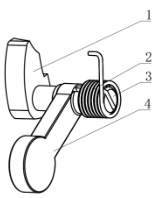
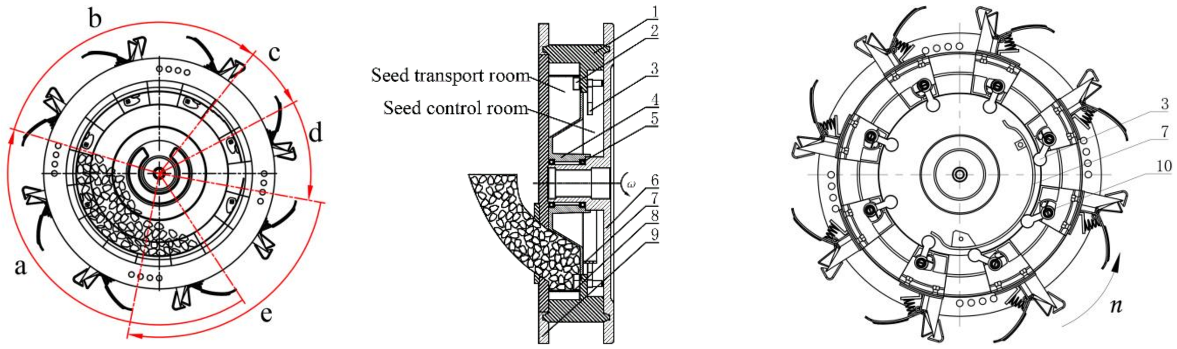


Fig. 2 - Structure diagram of seed picking mechanism
1. Seed picking block; 2. Torsion spring; 3. Rotary shaft; 4. Driving arm

WORKING PRINCIPLE

As shown in Figure 3a, the pressure-holding maize precision seed-metering device can be divided into five working areas. When working, the seeds enter from the seed feeding cylinder, and with the rotation of the seed-metering device, they finish the process of taking, holding, cleaning and dropping seeds in different working areas in turn. A cross-sectional view of the seed-metering device is shown in Fig. 3b, in which it can be seen that the spaced core tray divides the device into a seed transport room and seed control room, with the seed picking block in the transport room and the driving arm in the control room. As shown in Figure 3c, with the rotation of the device, the driving arm in the control room is in constant contact with the guide plate, thus driving the seed picking block to open and close the movement, and then driving the seed to complete a series of processes from seed taking to seed dropping in the seed transport room.



a. Working area division *b. Cutaway view of seed-metering device* *c. Working principle diagram*

Fig. 3 - Working principle of pressure-holding maize precision seed-metering device
a. Seed-taking area; b. Seed-holding area; c. Seed-cleaning area; d. First seed-dropping area; e. Second seed-dropping area
1. Seed storage box; 2. Seed picking block; 3. Driving arm; 4. Spaced core tray; 5. Bearing; 6. Motion disc; 7. Guide plate; 8. Steel Belt; 9. Fixed Plate; 10. Torsion spring;

ANALYSIS OF SEED-TAKING PROCESS

Seed-taking is a relatively complex process in which maize seeds are subject to the combined effects of gravity, friction, centrifugal forces and other seeds' forces, forming a dynamic mechanical system that changes in real time. Since the seed taking process is the first step in the whole seeding cycle, it is particularly important to analyse the movement of the maize during the seed taking process.

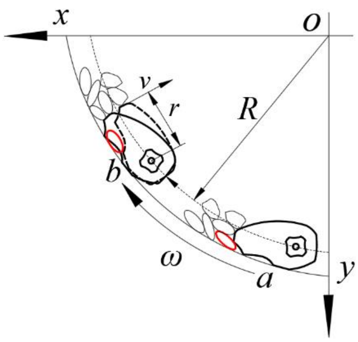


Fig. 4 - Diagram of seed-taking process

As shown in Figure 4, the maize seeds enter the seed-metering device and forms a self-flowing seed cluster under the action of the rotation of the device. For the kinematic analysis of the seed-picking block at this time, a is the start of the seed-taking block opening movement and b is the end in the figure.

In order to reduce the rigid impact of the seed picking block on the maize during the opening and closing process, the motion of the seed picking block is set as a flexible transition, i.e., the seed picking is considered as a simple harmonic motion during the opening and closing process, and the equation of its motion trajectory is:

$$S = A\sin\left(\frac{2\pi}{T}t + \psi_0\right) \tag{1}$$

$$T = \frac{2\pi}{\omega} \tag{2}$$

where:

S - The displacement of the simple harmonic motion of the seed picking block, mm;
A - Movement amplitude of seed picking block, mm;
T - Twice the value of the time taken for the seed picking block from a to b, min;
Ω - Rotation Speed of seed metering device, r/min;
ψ_0 - Initial phase angle of seed picking block, °;
t - Movement time of the seed picking block, min.

Taking the first order derivative of both ends of equation (1) with respect to t yields the equation for the velocity of motion of the seed picking block as:

$$v = A\omega\cos(\omega t) \tag{3}$$

The actual velocity v_1 of the seed picking block is the vector sum of its simple harmonic velocity and the velocity v_0 of the circular motion with the seed picking block, i.e.;

$$v_0 = \omega R = 2\pi nR \tag{4}$$

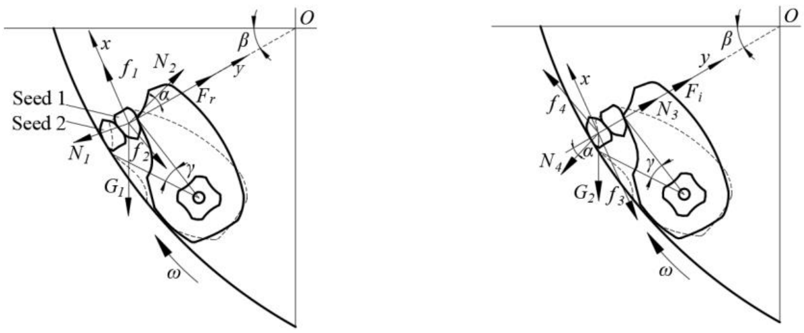
$$v_1 = \sqrt{v^2 + {v_0}^2} = \sqrt{A^2\omega^2\cos(\omega t)^2 + 4\pi^2 n^2 R^2} \tag{5}$$

where:
R - Turning radius of seed picking block, mm;
n - Rotational speed of seed metering device, r/min.

It is clear from the analysis that the opening and closing of the seed picking block and its rotation during the seed taking process will have a disturbing effect on the flow movement of the seed cluster itself, which in turn will affect the seed-taking effect of maize seeds. When the seed picking block has a certain radius of rotation, the rotational speed of the seed-metering device is the main factor affecting the movement of the seed picking block, so setting a better value will increase the probability of taking the maize kernels and prevent the phenomenon of missed seeding.

FORCE ANALYSIS OF SEED GRABBING

Because of the large differences in maize seed size parameters, there is a possibility of seeds grabbing each other's position during seed-picking process, resulting in maize seeds not entering the seed filling space effectively and causing missed seeding. The maize seeds that grabbed each other's position during seed taking are now studied and mechanically analysed separately, as shown in Figure 5.



a. Force analysis of seed 1 *b. Force analysis of seed 2*

Fig. 5 – Force analysis of seed grabbing

In Figure 5a, with the centre of mass of seed 1 as the coordinate origin, the direction of the tangent to the velocity of the seed-metering device as the *x*-axis and the normal direction as the *y*-axis to establish a right-angle coordinate system, the force on seed 1 can be decomposed as:

$$\begin{cases} f_1 + N_2\sin\alpha + N_1\sin\gamma = G_1\sin\beta + f_2\cos\alpha \\ F_r + N_2\cos\alpha + f_2\sin\alpha = N_1\cos\gamma + G_1\cos\beta \end{cases} \tag{6}$$

The force on seed 2 can be decomposed as:

$$\begin{cases} f_4\cos\alpha = N_3\sin\alpha + G_2\sin\beta + f_3 \\ F_i + N_4 = f_4\sin\alpha + N_3\cos\alpha + G_2\cos\beta \end{cases} \tag{7}$$

Of which:

$$\begin{cases} F_r = \omega^2 R_1 \\ F_i = \omega^2 R_2 \\ f_1 = N_1 \mu_1 \\ f_2 = N_2 \mu \\ f_3 = N_3 \mu_3 \\ f_4 = N_4 \mu \end{cases} \tag{8}$$

where:

μ - Friction coefficient between seed 1 and seed 2;
μ_1 - Friction coefficient between the seed picking block and the seed 1;
μ_3 - Friction coefficient between steel belt and seed 2.

From the above equation, it can be seen that when the opening angle γ of the seed picking block changes, the force equilibrium between the maize seeds that grab each other's position will be disrupted, i.e., the support force on seed 1 and seed 2 will change. Since the sliding friction f_3 of the steel belt on seed 2 points in the direction of seed filling, an acceleration along the negative direction of the x-axis can be obtained. At this point, seed 2 is successfully grabbed and seed 1 falls back to the seed filling area. Therefore, by setting the seed picking block to open its own motion while passing the seed group in the seed-filling area, it can make it easier for the picked up seeds to obtain acceleration towards the seed filling space, effectively improving the seed filling rate and avoiding missed seeding.

DESIGN OF GUIDE PLATE'S PROFILE

To enable the seed picking block to open and close precisely and smoothly in the seed-filling area, the profile contour of the guide plate is designed in the shape of a swing follower cam. The swing angle of the driving arm is controlled through calculation of the cam profile parameters to control the opening and closing of the seed-picking block. To prevent damage to the seeds caused by the impact of the seed-picking block's movement, the opening and closing process of the seed-picking block is set as a flexible transition, and the follower motion method uses simple harmonic motion. Focus on the design of the push section entering the seed-filling area and the return section entering the seed-holding area.

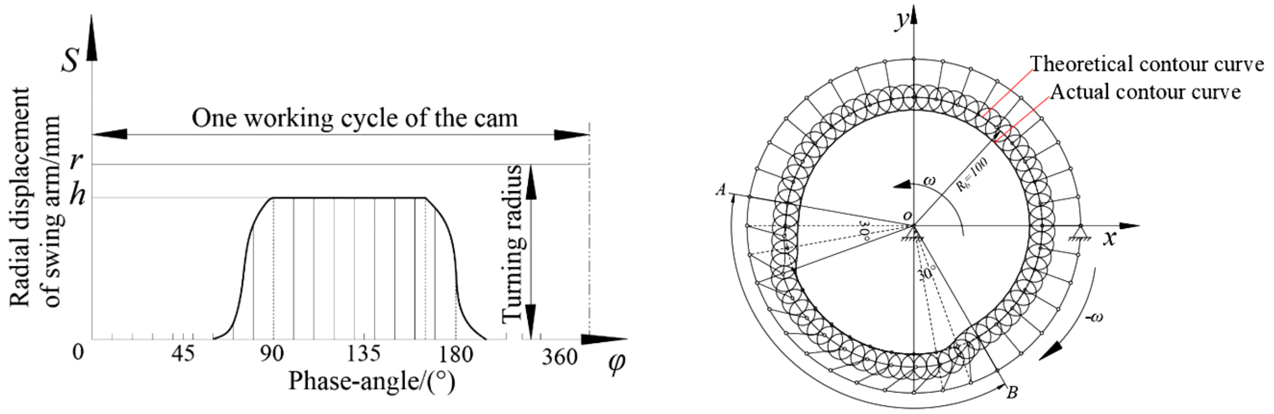
The phase curve equation is:

$$\begin{cases} S_1 = \dfrac{h}{2}\left(1 - \cos\dfrac{\pi\varphi}{\varphi_1}\right) & \left(\dfrac{\pi}{3} \le \varphi \le \dfrac{\pi}{2}\right) \\ S_2 = h\left(1 - \dfrac{\varphi}{\varphi_2} + \dfrac{1}{2\pi}\sin\dfrac{2\pi\varphi}{\varphi_2}\right) & \left(\dfrac{8}{9}\pi \le \varphi \le \dfrac{19}{18}\pi\right) \end{cases} \tag{9}$$

where:

S_1 - length of the pushing displacement into the seed-filling area, mm;
S_2 - length of the return displacement into the seed-holding area, mm;
h - length of the far resting stroke of the driving arm in the seed-clearing area, mm;
φ – phase angle, (°);
φ_1 - angle of the pushing motion, (°);
φ_2 - angle of the return motion, (°).

The resulting phase angle curve is shown in Figure 6a. The driving arm in the seed extraction mechanism is used in conjunction with the torsion spring to form a force locking cam mechanism. Furthermore, the theoretical and actual contours of the cam are plotted according to the phase curve diagram using the inverse rotation method, as shown in Figure 6b.



a. Phase relationship diagram b. Cam profile curves

Fig. 6 – Design drawing of guide plate profile

The *AB* section of the actual contour curve is the outer profile curve of the guide plate. The value of the base circle's radius (noted as R_b) is 100 mm. To make the arms open and close smoothly, the angle of thrust movement (noted as φ_1) into the seed-filling area is set to 30°. The angle of return movement of the seed-filling area into the seed-holding area (noted as φ_2) has a value of 30°. The seed-filling process is the initial step in the seeding process. The seed-filling area's operating range and the seed-picking block's opening angle are the keys to the seed-filling effect. Too large an opening angle of the seed-picking block can easily trap too many seeds, resulting in difficulties in clearing the seeds and causing multiple seeding. Too small an opening angle makes it difficult to fill the seed-filling area, resulting in missed seeds. The length of pushing displacement of the seed-filling area determines the size of the opening and closing angle of the seed-picking block. The value of the length of the pushing displacement is set to 10-15 mm, taking into account the parameters of the mechanism and the size of the opening and closing angles of the seed-picking blocks required for the different sizes of maize kernels. The guide plate's installation radius has a value of 90 to 96 mm, where the exact value is to be obtained through subsequent bench tests. The cam profile curve can be found by bringing the above values into Equation (9).

BENCH TESTING

A pressure-holding maize precision seed-metering device was built for bench testing. The test seeds were selected from Denghai 8883 maize seeds, which are widely grown in China. The device was mounted on the test bench, and the single-seeding rate, multiple-seeding rate and missed-seeding rate of the seeding process were counted by recording the number of seeds discharged from each seed row port, as shown in Figure 7, and was calculated according to the following equation:

$$\theta = \frac{g}{G} \times 100\% \tag{10}$$

where:

θ - the single grain rate, multiple grain rate and missed seeding rate, %;
g - the number of single grains, the number of multiple seeds and the number of missed seeds;
G - the total number of holes measured.

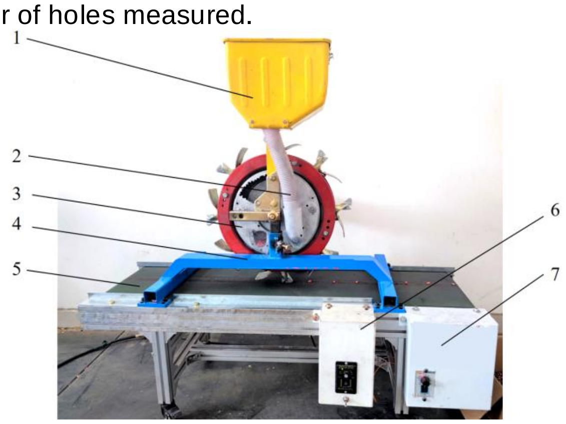


Fig. 7 - Bench test of seed-metering device
1. Seed box; 2. Feeding tube; 3. Seed-metering device; 4. Bracket; 5. Conveyor belt; 6. Control box; 7. Voltage stabilizer

RESULTS

According to the theoretical analysis and pre-experiments, the main factors are the rotational speed of the seed-metering device, the installation diameter of the guide plate and the spring force of the torsion spring. The torsion spring force can be adjusted by changing the wire diameter of the torsion spring. Therefore, a three-factor, five-level orthogonal test was conducted with the rotational speed of seed-metering device, installation diameter of guide plate and wire diameter of torsion spring as the test factors, and the single seeding rate, multiple seeding rate and missed seeding rate as the evaluation index. The values of each factor are shown in Table 2, and the test results are shown in Table 3.

Table 2

Factor and levels of experiment

Level	Installation diameter of guide plate / X_1	Wire diameter of torsion spring / X_2	Rotational speed of seed-metering device / X_3
	[mm]	[mm]	[rot/s]
-1.682	88	1.43	0.23
-1	90	1.5	0.3
0	93	1.6	0.4
1	96	1.7	0.5
1.682	98	1.77	0.56

Table 3

Experiment results

No.	Experimental factors			Experimental index		
	Installation diameter of guide plate / X_1	Wire diameter of torsion spring / X_2	Rotational speed of seed-metering device / X_3	Single seeding rate Y_1 / %	Missed seeding rate Y_2 / %	Multiple seeding rate Y_3 / %
1	-1	-1	-1	92.62	3.18	4.2
2	1	-1	-1	92.2	3.37	4.43
3	-1	1	-1	92.46	3.22	4.32
4	1	1	-1	92.12	3.41	4.47
5	-1	-1	1	92.52	3.11	4.37
6	1	-1	1	92.54	3.26	4.2
7	-1	1	1	92.38	3.36	4.26
8	1	1	1	92.46	3.24	4.3
9	-1.682	0	0	92.63	3.22	4.15
10	1.682	0	0	92	3.55	4.45
11	0	-1.682	0	92.71	3.11	4.18
12	0	1.682	0	92.38	3.26	4.36
13	0	0	-1.682	92.38	3.34	4.28
14	0	0	1.682	92.62	3.22	4.16
15	0	0	0	92.97	3.07	3.96
16	0	0	0	93.04	3.03	3.93
17	0	0	0	93.17	2.95	3.88
18	0	0	0	93.05	3.05	3.9
19	0	0	0	93.07	2.98	3.95
20	0	0	0	93.07	3.05	3.88
21	0	0	0	93.13	3.03	3.84
22	0	0	0	92.99	3.07	3.94
23	0	0	0	93.04	2.99	3.97

As can be seen from Table 3, the single seed filling rate of the pressure-holding maize precision seed-metering device is greater than 92%, and the missed and multiple seeding rates are less than 5%, meeting the industry requirements. The regression models of single seeding rate, missed seeding rate, multiple seeding rate and guide plate's installation diameter, torsion spring wire's diameter and seed metering-device's rotational speed were obtained by analysing the test results.

Analysis of variance was performed on the model and the results are shown in Table 4.

Table 4

Factor and levels of experiment

Source	Single seeding rate /Y_1				Missed seeding rate /Y_2				Multiple seeding rate /Y_3			
	Sum of squares	Degree of freedom	*F*	*P*	Sum of squares	Degree of freedom	*F*	*P*	Sum of squares	Degree of freedom	*F*	*P*
Model	2.68	9	52.77	< 0.0001	0.5127	9	21.81	< 0.0001	0.9101	9	29.33	< 0.0001
X_1	0.2165	1	38.39	< 0.0001	0.0682	1	26.11	0.0002	0.0417	1	12.09	0.0041
X_2	0.0754	1	13.38	0.0029	0.0231	1	8.86	0.0107	0.0150	1	4.35	0.0572
X_3	0.0598	1	10.60	0.0063	0.0124	1	4.76	0.0482	0.0177	1	5.14	0.0411
X_1X_2	0.0025	1	0.4344	0.5213	0.0091	1	3.49	0.0845	0.0021	1	0.6127	0.4478
X_1X_3	0.0925	1	16.39	0.0014	0.0153	1	5.86	0.0308	0.0325	1	9.43	0.0089
X_2X_3	0.0001	1	0.0089	0.9264	0.0028	1	1.08	0.3183	0.0036	1	1.05	0.3247
X_1^2	1.11	1	196.16	< 0.0001	0.2334	1	89.37	< 0.0001	0.3234	1	93.79	< 0.0001
X_2^2	0.5294	1	93.88	< 0.0001	0.0405	1	15.51	0.0017	0.2771	1	80.36	< 0.0001
X_3^2	0.6257	1	110.96	< 0.0001	0.1123	1	43.00	< 0.0001	0.2079	1	60.29	< 0.0001
Residual	0.0733	13			0.0340	13			0.0448	13		
Lack of fit	0.0422	5	2.17	0.1574	0.0197	5	2.22	0.1512	0.0294	5	3.06	0.0778
Error	0.0311	8			0.0142	8			0.0154	8		
Total	2.75	22			0.5467	22			0.9549	22		

Note: P<0.01 is highly significant; P<0.05 is significant

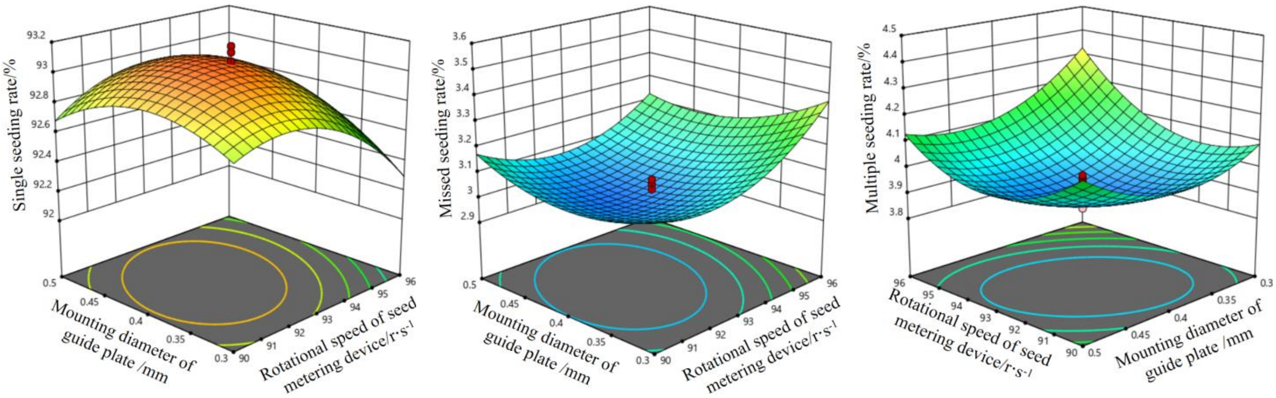
As can be seen from Table 5, the regression model for the single seeding rate Y_1 was significant, where X_1, X_2, X_3, X_1X_3, X_1^2, X_2^2, X_3^2 had a highly significant effect on Y_1. The regression model for the missed seeding rate Y_2 was significant, with X_1, X_1^2, X_2^2, X_3^2 having a highly significant effect on Y_2 and X_2, X_3, X_1X_3 having a significant effect on Y_2. The regression model of multiple seeding rate Y_3 was significant, where the effects of X_1, X_1X_3, X_1^2, X_2^2, X_3^2 on Y_3 were highly significant and X_2, X_3 on Y_3 were significant. After removing the insignificant term, the regression equations of the installation diameter of the guide plate, the wire diameter of the torsion spring and the rotational speed of the seed-metering device on the single seeding rate Y_1, the missed seeding rate Y_2 and the multiple seeding rate Y_3 were obtained as:

$$Y_1 = 93.06 - 0.12X_1 - 0.07X_2 + 0.06X_3 + 0.1X_1X_3 - 0.26X_1{}^2 - 0.18X_2{}^2 - 0.19X_3{}^2 \tag{11}$$

$$Y_2 = 3.03 + 0.07X_1 + 0.04X_2 - 0.03X_3 - 0.4X_1X_3 + 0.12X_1{}^2 + 0.05X_2{}^2 + 0.08X_3{}^2 \tag{12}$$

$$Y_3 = 3.92 + 0.05X_1 - 0.04X_3 - 0.06X_1X_3 + 0.142X_1{}^2 + 0.132X_2{}^2 + 0.114X_3{}^2 \tag{13}$$

In order to visually analyse the influence of the interaction of the influencing factors on each evaluation index, the response surface is plotted by Design-Expert 12.0 software, as shown in Figure 8.



a. $Y_1=f(X_1,1.6,X_3)$ *b.* $Y_2=f(X_1,1.6,X_3)$ *c.* $Y_3=f(X_1,1.6,X_3)$

Fig. 8 - Response surface curves

From Fig. 8, it can be seen that when the seed-metering device rotates at a certain speed, the single seeding rate increases and then decreases as the diameter of the guide plate installation increases. This is due to the fact that when the diameter of the guide plate is too small, the opening and closing angle of the seed picking block is too small, which is not conducive to the entry of seeds with larger characteristic sizes into the seed filling space, resulting in missed seeding. When the diameter of the guide plate is too large, the opening and closing angle of the seed picking block is too large, and the seeds with small characteristic size cannot be effectively pressed and held, so that the seeds fall off in the process of seed filling, resulting in increased missed seeding rate.

When the installation diameter of the guide plate is fixed, the single seeding rate increases and then decreases with the increase of the seed-metering device's rotational speed. The reason is that when the rotational speed of the seed-metering device is too low, the self-rotating flow rate of the seed population is slow, so that the seeds do not have enough speed to enter the seed filling space, resulting in missed seeding. When the speed is too high, the time for the seed picking block to pass through the seed population is reduced, and the contact time between the picking block and the seeds is lowered, so that the seeds cannot enter the seed filling space in a limited time, resulting in missed seeding.

In order to obtain the best combination of parameters affecting the performance of the pressure-holding maize precision seed-metering device, the multi-objective optimization analysis of the guide plate's installation diameter, torsion spring's wire diameter and device's rotational speed was carried out with the objectives of improving the single seeding rate and reducing the missed seeding rate and multiple seeding rate, and the optimization model was obtained as:

$$\begin{cases} \max Y_1(x_1,x_2,x_3) \\ \min Y_2(x_1,x_2,x_3) \\ \min Y_3(x_1,x_2,x_3) \\ 88\,mm \le x_1 \le 98\,mm \\ 1.43\,mm \le x_2 \le 1.77\,mm \\ 0.23\,rot/s \le x_3 \le 0.56\,rot/s \end{cases} \tag{14}$$

Through analysis and calculation, the optimal combination of parameters was obtained as follows: 92.32 mm diameter of guide plate installation, 1.59 mm diameter of torsion spring wire, and 0.41 rot/s rotational speed of seed-metering device, and the single seeding rate in this case was 93.08%, 3% missed seeding rate, and 3.9% multiple seeding rate, which meets the operational requirements.

CONCLUSIONS

(1) This paper designed a pressure-holding type maize precision seed-metering device, and introduced its structure and working principle. The shape of the guide plate profile was designed, a mechanical model of the seeds in the seeding operation was developed, and mechanical and kinematic analyses were conducted to derive the influence of the device's rotational speed on the operational performance. The mechanical analysis of the robbed seeds obtained that when the opening and closing angle of the seed picking block changed, it was beneficial for the seeds to enter the seed filling space and improve the seed filling rate.

(2) A three-factor, five-level orthogonal test was carried out with the single seeding rate, missed seeding rate and multiple seeding rate as the test indexes, and the installation diameter of guide plate, wire diameter of torsion spring wire diameter and rotational speed of seed-metering device as the test factors to obtain the influence parameters of each influencing factor on the operational performance of the seed-metering device.

(3) By analysing the test results and optimizing the regression model, the optimum working parameters of the pressure-holding maize precision seed-metering device were 92.32 mm installation diameter of the guide plate, 1.59 mm diameter of the torsion spring, and 0.41 rot/s rotational speed of the device, at which the single seeding rate was 93.08%, 3% missed seeding rate, and 3.9% multiple seeding rate, meeting the industry regulations and usage requirements.

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