DESIGN AND EXPERIMENT OF AIR-SUCTION PRECISION SEED-METERING DEVICE FOR GARLIC

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大蒜气吸式精量排种器的设计与试验

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ABSTRACT

To address the challenges associated with garlic single-seed extraction, including seed damage, blockages, and the inefficiency of directional placement for irregularly shaped garlic seeds, an air-suction seed metering device, integrated with image recognition and orientation technology, was developed. The working principle of the product is expounded, and comprehensive analysis and design of key components—such as the seed dispenser, directional needle, and combined suction block—are presented. A test bench was constructed using Jinxiang hybrid garlic as the experimental material, with the negative pressure in the air chamber, the rotation speed of the seed dispenser, and seed quantity in the seed chamber as the primary experimental factors. The performance indicators included the single seed rate, cavitation rate, and double grain rate. A three-factor, five-level orthogonal design was employed to assess the effects of each factor and their interactions on the single seed rate. The optimal operating parameters for garlic species A, B, and C were identified as follows: the negative pressure in the air chamber was 11.85 kPa, 12.03 kPa, and 13.21 kPa, respectively; the rotation speed of the seed dispenser was 7.13 r/min, 6.85 r/min, and 7.25 r/min, respectively; and the seed quantity in the seed chamber was 138.97 mm, 140.90 mm, and 141.24 mm, respectively. The corresponding single seed rates were 95.98%, 96.50%, and 96.23%, respectively. Under these optimal operating conditions, the study further explored the effects of the positional parameters of garlic seeds of different grades, as well as the positional parameters of the directional needle, on the preliminary directional performance. The optimal positional parameters were subsequently determined. The results of this study offer critical insights and establish conditions for the intelligent orientation of garlic planting machines.

摘要

针对目前大蒜单粒取种技术易损伤且易堵塞，及定向技术对形状不规则蒜种效果不佳问题，设计了一种结合图像识别定向技术的气吸式精量定向排种器。阐述了其工作原理并分析设计了排种盘、定向针和组合吸块等部件。通过搭建试验台，选用金乡杂交蒜为试验材料，以气室负压、排种转速、种室内种子量为试验因素，以单粒率、空穴率、双粒率为试验指标，进行三因素五水平旋转正交试验，分析了各因素及其交互作用对单粒率的影响，得出A、B、C三级蒜种的最佳工作参数：气室负压分别为：11.85 kpa、12.03kpa、13.21 kpa，排种盘转速分别为7.13r/min、6.85r/min、7.25r/min，种室内种子量分别为138.97 mm、140.90mm、141.24mm，对应单粒率分别为95.98%、96.50%、96.23%。在最佳工作参数下，探究不同等级蒜种，定向针的位置参数对初步定向性能的影响，确定了最佳位置参数。研究结果可为大蒜种植机的智能化定向提供条件。

INTRODUCTION

As the world's largest producer and exporter of garlic (*Binbin et al., 2019*), China is facing an increasing demand for mechanized planting solutions (*Xiaoxin et al., 2023*). In garlic cultivation, positioning the bud tip upwards during planting has been shown to significantly improve seedling emergence and enhance plant quality (*Tao et al., 2021*).

Extensive research, both domestically and internationally, has focused on mechanized single-seed extraction and bud tip orientation technologies for garlic. Common single-seed extraction methods include

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chain spoon (*Ruichuan et al., 2013*), rotary spoon (*Maheswarr et al., 2007*), clamping (*Hiroki et al., 2008*), rotary cylinder (*Yuzhen et al., 2017*), and rotary mechanisms (*Shichun et al., 2009*), among others. However, these methods are often plagued by issues such as seed skin damage, clogging, and seed leakage, which significantly reduce planting efficiency. Garlic seed bud tip orientation technologies typically include techniques such as the three-stage directional bucket (*Aijun et al., 2018*) and double duckbill (*Jialin et al., 2018*), among others. Despite their widespread use, these methods show limited effectiveness in orienting hybrid garlic seeds, which account for nearly two-thirds of the garlic planted in China. Machine vision technology has emerged as a promising solution for improving the mechanized orientation of hybrid garlic seeds (*Zhen et al., 2023*). In recent years, researchers such as Fang Chun (*Chun et al., 2019*), Gao Chi (*Chi et al., 2010*), Yang Qingming (*Qingming et al., 2010*), Robles (*Robles et al., 2016*), and Paul (*Paul, 2015*) have conducted significant studies on image recognition methods for garlic seed bud tip identification and orientation.

This study aims to leverage machine vision technology for the mechanized orientation of garlic seeds by designing an air-suction seed metering device. This device will incorporate image recognition technology to enable the precise placement of single garlic seeds. The ultimate goal is to establish a mechanical foundation for integrating image recognition orientation technology into garlic planting machinery, thereby improving seeding accuracy and efficiency.

MATERIALS AND METHODS

The structure and working principle

As illustrated in Figure 1, the air-suction seed metering device for garlic primarily consists of several key components, including a seed dispenser, directional needles, an image acquisition and recognition device, a directional adjusting device, combined suction blocks, and other associated elements (*Jingling et al., 2021*). Multiple evenly spaced circular holes are arranged along the circumference of the seed dispenser, with corresponding combined suction blocks installed at these locations. Each suction block features a central suction hole. The combined suction block interacts with the directional adjusting device to achieve precise orientation of the seeds.

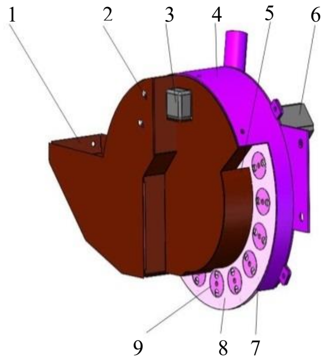


Fig. 1 - Structure diagram of garlic air suction precision directional seed dispenser

1. Seed chamber shell; 2. Directional needles; 3. Image acquisition and recognition device; 4. Air chamber shell; 5. Seed stirrer; 6. Directional adjusting device; 7. Sealing rubber strip; 8. Seed dispenser; 9. Combined suction block

As illustrated in Figure 2, the seed dispenser is divided into four distinct zones. When the seed-metering device is working, the initial air pressure in the air chamber is low, and a small amount of garlic seeds are taken out under the action of negative pressure. The suction holes are gradually filled with garlic seeds, and the final negative pressure of the air chamber reaches a basically stable state. As the seed dispenser rotates, the excess garlic seeds are removed under the action of the directional needles, leaving only one seed. Its length direction is adjusted to be tangential to the distribution circle at the center of the suction hole. The image acquisition and recognition device works at workstation 1 to determine the direction of the bud tip (forward or backward). The recognition result is sent to the directional adjusting device using the control method of the delayed queue. Considering the recognition time of the image acquisition and recognition device, the orientation adjusting device is arranged at workstation 2 to function. If the bud tip is facing backward, the directional adjusting device remains stationary. If the bud tip is facing forward, the directional adjusting device rotates the working surface of the combined suction block 180° to complete the orientation of the garlic seeds. When the garlic seeds leave the air chamber, they lose the adsorption effect of the negative pressure and fall into the lower device by the gravity of the seeds themselves.

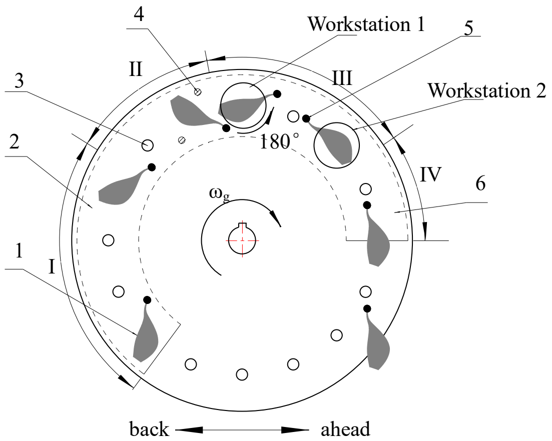


Fig. 2 - Diagram of the division of seed dispenser and the movement of garlic seeds
I. Seed suction zone; II. Preliminary orientation zone; III. Secondary orientation zone; IV. Seeding zone
1. Garlic seed; 2.Seed dispenser; 3.Suction hole; 4. Directional needle; 5. The bud tip of garlic seeds; 6. Air chamber

Design and analysis of key components

Design of seed dispenser

The number of suction holes

The number of suction holes plays a crucial role in determining the seeding effectiveness within the seed suction zone (*Ziheng et al.,2024*). Therefore, it is essential to select an appropriate number of suction holes. The total number of suction holes on the seed dispenser should comply with the following formula (1).

$$z=\frac{60v_m}{sn_p(1-p_0)} \tag{1}$$

Where:

v_m is the operating speed of the planter,（m/s）;

s is the plant spacing,（m）;

n_p is the speed of the seed dispenser,（r/min）;

p_0 is the slip coefficient of the ground wheel, which is 8.5% in this paper.

Considering that the operating speed of the seeder exceeds 0.22 m/s and the plant spacing ranges from 0.08 to 0.12 m, the speed of the seed dispenser was set at 7 r/min. Based on these parameters, the number of suction holes was determined to be 16. Consequently, the central angle between adjacent suction holes was calculated to be 22.5°.

The diameter of the suction hole

Due to the irregular shape and significant size variation of garlic seeds, the selection of the suction hole diameter is critical. This diameter must be determined based on the size of the garlic seeds (*Principles of Design of Seeding Machinery, 1982*).

$$\begin{cases} d_c = (0.64\sim0.66)\, b_1 \\ (k_{min}+h_{min})/2 \le b_1 \le (k_{max}+h_{max})/2 \end{cases} \tag{2}$$

where:

d_c is the diameter of the suction hole,（mm）;

b_1 is the average value of garlic seed width and thickness,（mm）;

k_{min} is the minimum value of garlic seed width,（mm）;

h_{min} is the minimum value of garlic seed thickness,（mm）;

k_{max} is the maximum value of garlic seed width,（mm）;

h_{max} is the maximum value of garlic seed thickness,（mm）;

The size of Jinxiang hybrid garlic (*Tao et al.2018)* can be inserted into the formula (2) and the value range of the diameter of the suction hole should be 8.1~14.2 mm.

The radius of the distribution circle at the center of the suction hole

As illustrated in Figure 3, to prevent interference between two adjacent garlic seeds, the distance between the centers, O_1 and O_2, of the two adjacent suction holes must satisfy the following condition:

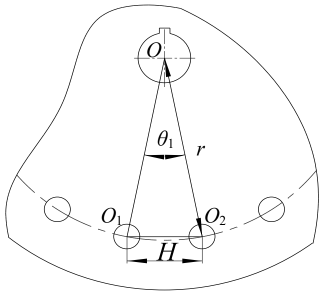
$$H \geq 2L_{max} - d_{cmin} \tag{3}$$

where: L_{max} is the maximum length of the garlic seeds, (mm);

d_{cmin} is the minimum value of suction holes, (mm);

Jinxiang hybrid garlic: L_{max} is 31.90 mm (*Tao et al., 2018*), then H is larger than 55.70 mm. In the isosceles triangle $O\ O_1\ O_2$, the radius of the distribution circle of the center of the suction hole is larger than 142.31 mm, so 145 mm are taken in this paper.

Fig. 3 - Local schematic diagram of seed dispenser



O is the center of the seed dispenser; O_1 is the center of the suction hole circle; O_2 is the center of the adjacent suction hole circle.

Determination of directional needle positional parameters

The diversity of garlic adsorption states

Due to the irregular shape and size of garlic seeds, and the large gaps between adjacent garlic seeds, garlic seeds will randomly appear in a variety of adsorption states, as shown in Figure 4. In order to adapt to the diversity of garlic seed adsorption states, the number of directional needles is designed to be two, distributed on both sides of the center circle of the suction hole.

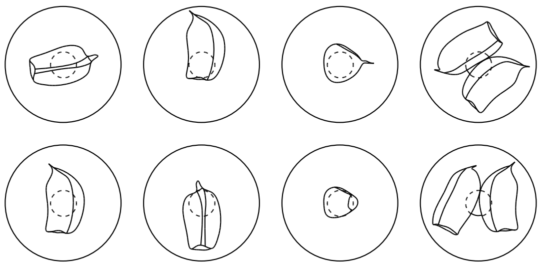


Fig. 4 - Different adsorption states of garlic species

Normal position parameters

The normal positional distance between the internal and external directional needles significantly influences the effectiveness of the preliminary orientation and seed-clearing process. As shown in Figure 5, garlic seeds pass through the internal and external directional needles in the direction of their thickness or width. Since the maximum width is greater than the maximum thickness, only the width dimension needs to be considered. The normal distance (E) between the internal and external directional needles, the radius (p) of the internal directional needle distribution circle, and the radius (q) of the external directional needle distribution circle must satisfy the following formula (4).

$$\begin{cases} \frac{k_{max}}{2} + \frac{d_d}{2} \leq r - p \leq L_{min} - \frac{d_{cmax}}{2} + \frac{d_d}{2} \\ \frac{k_{max}}{2} + \frac{d_d}{2} \leq q - r \leq L_{min} - \frac{d_{cmax}}{2} + \frac{d_d}{2} \\ E = q - p \end{cases} \tag{4}$$

where: k_{max} is the maximum value of the width of the garlic seed, mm;

L_{min} is the minimum length of the garlic seed, mm;

d_{cmax} is the maximum value of the suction holes, mm;

d_d is the diameter of the inner and outer directional needles, and it is taken 3 mm in this paper;

The size of Jinxiang hybrid garlic (*Tao et al.2018)* and the radius of the distribution circle of the center of the suction hole (r) can be inserted into the formula (4) and the value range of the normal distance E should be 25.14~38.32 mm.

Tangential position parameters

To prevent the garlic seeds from simultaneously contacting both the internal and external directional needles and being displaced, it is necessary to maintain a specific relative position between the internal and external directional needles in the tangential direction, which should be satisfied with F being larger than L_{max}, taking F=50 mm.

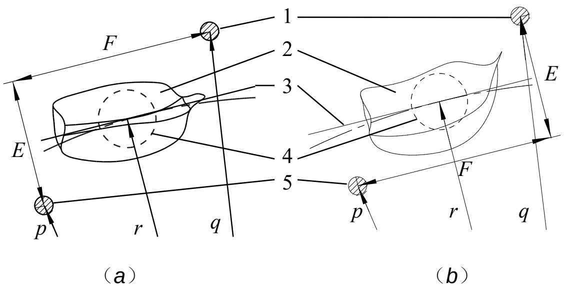


Fig. 5 - Garlic seeds passed through the directional needle smoothly

1. External directional needle; 2.Garlic seed; 3.The tangential direction of the suction hole; 4. Suction hole; 5.Internal directional needle

Combined suction block

Analysis of the motion process

In the secondary orientation process, the two levers of the directional adjusting device are mounted on the air chamber side of the seed dispenser. The initial positions of the levers and the two working edges of the combined suction block are aligned along the tangent direction of the suction hole distribution circle. These components must satisfy two key conditions: 1) The levers must be able to rotate 180°, and during this rotation, the garlic seeds should also rotate approximately 180° to ensure effective directional adjustment; 2) Upon completion of the lever rotation, the combined suction block must return to its initial position relative to the seed dispenser (namely, reset), and ensure that no interference occurs between the combined suction block and the levers when the system reaches the direction-adjusting station in the subsequent cycle, thereby maintaining the continuity of the directional adjustment process.

The seed dispenser rotates clockwise with an angular velocity ω_g, while the lever rotates counterclockwise around point O' with an angular velocity ω_z when the garlic seed requires adjustment. Each action involves a 180° rotation, which drives the combined suction block to rotate synchronously, as depicted in Figure 6.

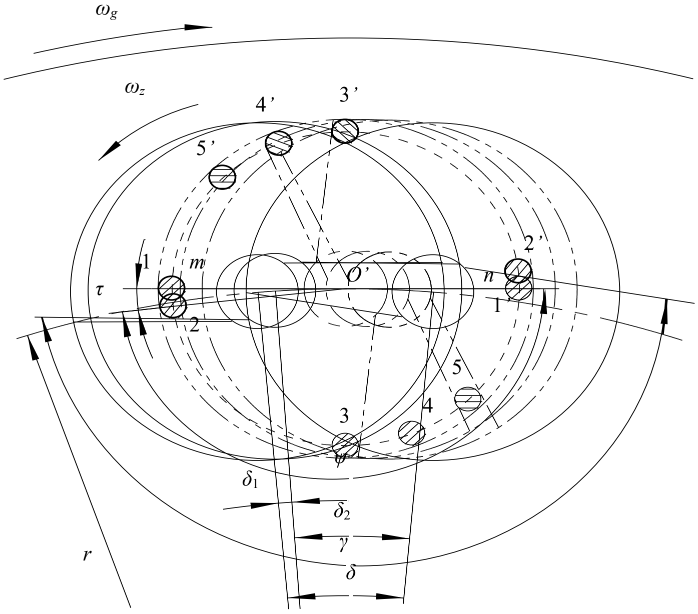


Fig. 6 - Movement process of the combined suction block

Position of the working edge of the combined suction block

Initially, the positions of lever m and lever n are at positions 1 and 1', respectively. As the lever begins to rotate counterclockwise, lever m first contacts the working edge of the corresponding combined suction block at position 2, initiating its rotation. When lever m reaches position 3, it disengages from the working side, and lever n continues to rotate the combined suction block. Upon lever n rotation to position 4', both levers are in the idle state. When lever m reaches position 5, it again engages the working edge before lever n, continuing to drive the combined suction block's rotation. At the end of the rotation cycle, lever m returns to position 1', and lever n returns to position 1. At this point, both levers have completed a full working cycle.

The 180° rotation of the lever is divided into two phases: idling time τ and effective rotation time ψ, with the corresponding rotation angles of the seed dispenser being δ_1 and δ_2, respectively. The combined suction block undergoes a 180° rotation in synchrony with the rotation of δ_2 in the seed dispenser, during which the garlic seed is adjusted accordingly. For the garlic seed to be properly oriented, the idling time of the lever and the corresponding revolution time of the seed dispenser must be carefully coordinated.

As illustrated in Figure 7, a right-angle coordinate system is established with the center of the combined suction block, O_c as the origin, the x-axis tangential, and the y-axis normal to the system. The end of the lever's rotation is tangent to the working edge of the combined suction block during detachment. Therefore, the initial position of the working edge of the combined suction block must be tangent to the lever. The coordinates of the tangent point (G) are given by:

$$\begin{cases} x = r_2 \tan\beta_2 \cos\beta_2 \\ y = r_2 \cos\beta_2 - r \end{cases} \tag{5}$$

included among these:

$$\begin{cases} r_1 = \sqrt{r^2 + (d_a/2)^2} \\ r_2 = r_1 + d_b/2 \\ \beta_1 = \arctan\frac{d_a/2}{r} \\ \beta_2 = \beta_1 - \frac{\delta}{2} \end{cases} \tag{6}$$

where:

r_1 is the radius of the distribution circle at the center of the lever, (mm) ;

r_2 - the radius of the distribution circle at the tangent point G (mm) ;

d_a - the lever installation diameter (mm) ;

d_b - the diameter of the lever (mm) ;

β_1 - the angle between the center O' of the lever mounting and the center of the lever circle on the seed dispenser (°);

β_2 - the angle between the center O_c of the combined suction block and the center of the lever circle on the seed dispenser (°) .

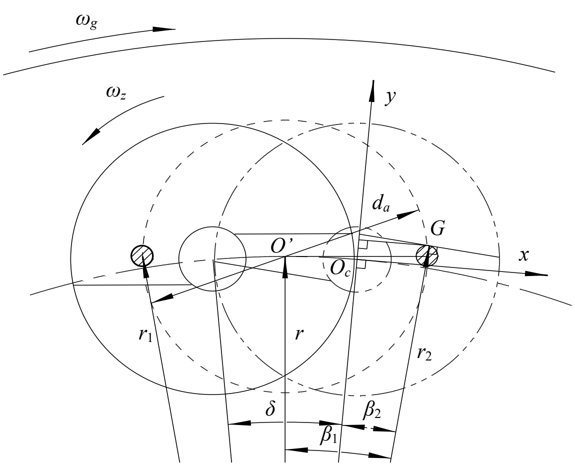


Fig. 7 - Analysis of the working state at the end of the lever rotation

Requirements for lever rotation

Due to the rotation of the seed dispenser, the lever may interfere with the subsequent arrival of the combined suction block's working edge as the lever nears the end of its rotation. The critical state of interference occurs when the outer circumference of the combined suction block becomes tangent to the motion trajectory of the outermost point of the lever, as illustrated in Figure 8. In this scenario, the combined suction block being adjusted begins to move toward the end of the lever's rotation, with the rotation angle of the combined suction block denoted as ε. Therefore, it is necessary for the time T required for the lever to complete one full working cycle to be less than the time t required for the seed dispenser to rotate by the angle ε. The calculation formula for t is given by:

$$\begin{cases} t = \varepsilon / \omega_g \\ \theta = \arccos \dfrac{2r^2 - (d_z/2 + d_a/2 + d_b/2)^2}{2r^2} \\ \varepsilon = 22.5° - (\theta - \delta/2) \end{cases} \tag{7}$$

where:

θ is the central angle corresponding to the center of the combined suction block and the center of the lever installation on the seed dispenser under the interference critical state (°);

d_z is the diameter of the combined suction block (mm);

According to equation (7):

$$T < \frac{1}{\omega_g}\left[22.5° - \arccos \frac{2r^2 - (d_z/2 + d_a/2 + d_b/2)^2}{2r^2} + \frac{\delta}{2}\right] \tag{8}$$

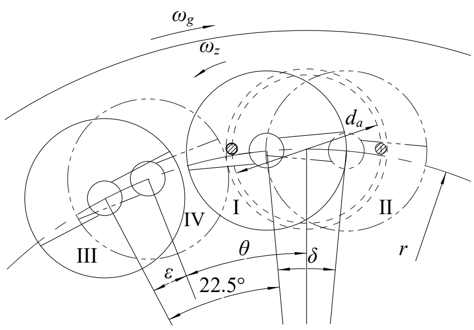


Fig. 8 - Analysis of the interference state of the lever

I is the initial position of the combined suction block; II is the end position of the rotation of the combined suction block; III is the initial position of the next combined suction block; IV is the interference position that the next combined suction block and the lever rotation

RESULTS AND ANALYSIS

The experimental apparatus and materials

The test was conducted using the JPS-12 seed dispenser performance test bench. The pneumatic system of the original test bench was upgraded to accommodate the specific air pressure requirements of the seed dispenser, as illustrated in Figure 9.

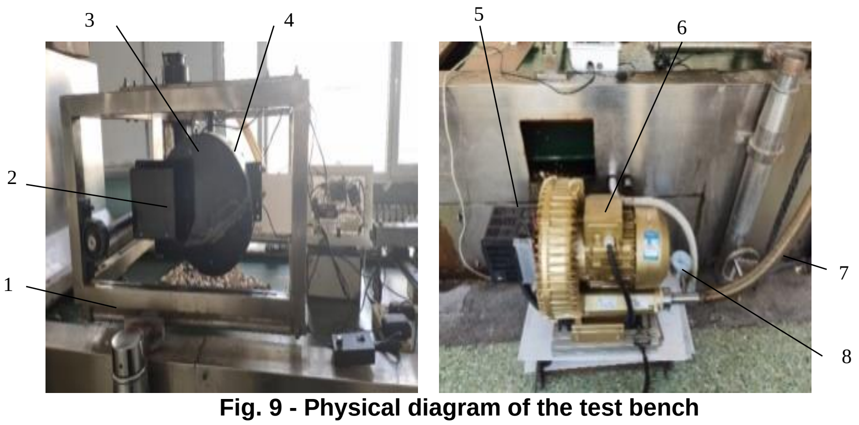


Fig. 9 - Physical diagram of the test bench

1. test benches; 2. seed dispenser; 3. image acquisition and recognition device; 4. directional adjusting device; 5. 7.5 kW Panasonic-MK30 inverter; 6.6. 3 kW GBHB-7D5-36-1R8 fan; 7. air pipe; 8. pressure gauge

Jinxiang hybrid garlic was selected as the test material, with seed thickness used as the basis for grading (*Tao et al., 2018*). The garlic seeds were categorized into three size classes: *A* (12–15 mm), *B* (15–18 mm), and *C* (18–21 mm). This grading process is designed to enhance the operational performance and efficiency of the garlic planting machine.

Single seed performance test

The experimental design

The diameters of the suction holes for garlic seeds in size classes *A*, *B*, and *C* were determined to be 10 mm, 11 mm, and 12 mm, respectively, based on preliminary pre-tests. To optimize the operating parameters of the seed dispenser, a three-factor, five-level rotary orthogonal experimental design was conducted using Design Expert software, in accordance with the GB/T 6973-2005 standard for Single-Grain (Precision) Seed Sowers (*GB/T 6973-2005, 2005*). The test factors selected were the negative pressure of the air chamber, the rotational speed of the seed dispenser, and the quantity of seeds in the seed chamber, while the test indices included the single grain rate, cavitation rate, and double grain rate. Upon analyzing the effects of these three factors on garlic seeds of different grades, it was found that the results were consistent across grades. As an example, the analysis focuses on *B*-size garlic seeds, which correspond to a suction hole diameter of 11 mm. The test factors and their corresponding codes are summarized in Table 1.

Table 1

Test factor coding table

Code	Factors		
	X_1 / kPa	X_2 / (r/min)	X_3 /mm
-1.682	10.3	5.3	90
-1	11.0	6.0	110
0	12.0	7.0	140
1	13.0	8.0	170
1.682	13.7	8.7	190

Note: X_1, X_2, and X_3 are the negative pressure of the air chamber, the rotation speed of the seed dispenser, and the quantity of seeds in the seed chamber, respectively. The quantity of seeds in the seed chamber is measured by the height from the bottom of the air chamber to the surface of the seeds. And the scale is marked inside the seed chamber for easy reading of the experiment.

The experimental results and analysis

A total of 23 experimental runs were conducted. The study included 14 sets of analysis points and 9 sets of zero points. Each set of experiments was repeated 3 times, and the average value was taken as the experimental result.

The experimental data were then input into the Design-Expert software for statistical analysis and regression fitting (*Chao*, 2022). Through analysis of variance (ANOVA) for the single grain rate, cavitation rate, and double grain rate, non-significant factors were identified and eliminated. The resulting regression equations for each index and factor are as follows:

$$\begin{cases} Y_1 = 96.31 + 1.91X_1 - 1.19X_2 + 0.59X_3 + 1.76X_1X_2 + 0.78X_2X_3 - 4.50{X_1}^2 - 1.86{X_2}^2 - 2.24{X_3}^2 \\ Y_2 = 2.41 - 5.28X_1 + 2.48X_2 - 1.40X_3 - 0.79X_1X_2 + 2.90{X_1}^2 + 1.28{X_2}^2 + 2.18{X_3}^2 \\ Y_3 = 1.32 + 3.37X_1 - 1.29X_2 + 0.81X_3 - 0.97X_1X_2 + 0.68X_1X_3 - 0.53X_2X_3 + 1.60{X_1}^2 + 0.59{X_2}^2 \end{cases} \quad (9)$$

In the equation, Y_1, Y_2, and Y_3 are the single-grain rate, cavitation rate, and double-grain rate, respectively.

By using the dimensionality reduction method, one of the parameters of the negative pressure in the air chamber, the rotational speed of the seed dispenser, and the seed quantity in the seed chamber were adjusted to zero. A response surface graph was drawn to show the interaction between the other two factors on each indicator. Through response surface analysis, it was found that within the range of the air chamber pressure of 11~13 kPa, the seed dispenser speed of 6~8 r/min, and the seed quantity in the chamber of 110~170 mm, optimization solution is carried out under the condition of maximizing single seed rate and minimizing cavitation rate and double grain rate. The optimal parameter combination of the seed-metering device is obtained as follows: the negative pressure in the air chamber is 12.03 kPa, the rotational speed of the seed dispenser is 6.85 r/min, and the seed quantity in the seed chamber is 140.90 mm. At this time, the single seed rate is 96.50%, the cavitation rate is 1.87%, and the double grain rate is 1.63%.

Using the same method as above. For Grade *A* garlic, it was found that the negative pressure in the air chamber is 11.85 kPa, the rotational speed of the seed dispenser is 7.13 r/min, and the seed quantity in the seed chamber is 138.97 mm. At this time, the single seed rate is 95.98%, the cavitation rate is 2.13%, and the double grain rate is 1.89%. For Grade *C* garlic, it was found that the negative pressure in the air chamber is 13.21 kPa, the rotational speed of the seed dispenser is 7.25 r/min, and the seed quantity in the seed chamber is 141.24 mm. At this time, the single seed rate is 96.23%, the cavitation rate is 2.59%, and the double grain rate is 1.18%.

Preliminary orientation performance tests

Preliminary directional seed discharge performance indicators

In garlic planting, after individual grain orientation, the garlic seeds are first dropped into the receiving hopper, from which a vertical planting device then inserts them into the soil. To assess the orientation performance, garlic seeds were dropped into the hopper at various angles. The results showed that when the angle between the longitudinal axis of the garlic seeds and the normal line of the center distribution circle of the suction holes ranged from 40° to 90°, the upward rate of the bud tip exceeded 95%. Consequently, this range was established as the preliminary directional qualification standard. The preliminary orientation rate is calculated as follows:

$$M = \frac{N}{Q} \times 100\% \tag{10}$$

where: M is the preliminary orientation rate;

N is the number of garlic seeds qualified for preliminary orientation;

Q is the number of test garlic seeds.

Table 2

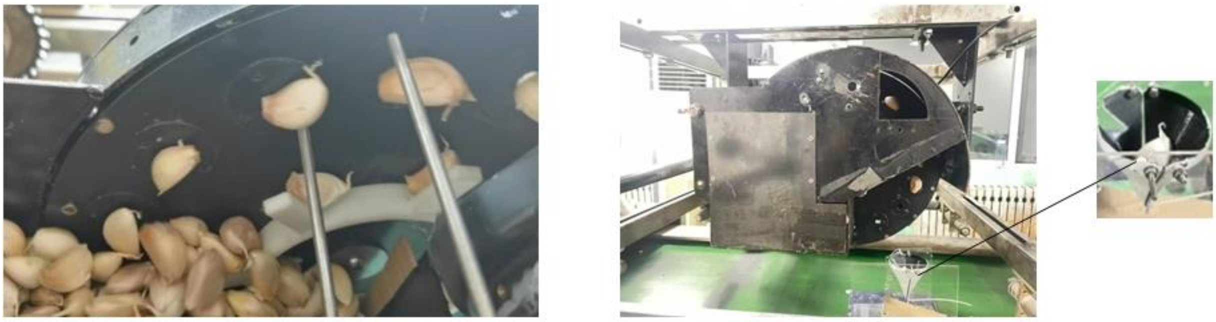
Percentage of bud tips facing up under different erection degrees of garlic species

Uprightness / °	Bud tip upward rate / %
0～20	85.66
20～40	91.16
40～60	95.61
60～80	96.33
80～90	98.75

Effects of directional needle position parameters on preliminary directional performance

Under the optimal working parameters, experimental studies were conducted on different grades of garlic. After the garlic varieties were classified according to thickness, it was observed that both the width and length of each grade increased with thickness. Consequently, the actual value of the distance *E* should be adjusted accordingly, compared to the theoretical analysis value. The experimental process is shown in Figure 10.

Fig. 10 - Diagram of the operation of the seed metering device



The positional parameters and test results for the directional needle are presented in Table 3.

Table 3

Statistical table of orientation effect of different grades of garlic seeds

Garlic seed level	*E* / mm	*r-p*, *q-r* / mm	Initial orientation rate / %
A	30	20.10	90.45
		17.13	95.33
		14.17	88.64
		11.19	53.20

Garlic seed level	*E* / mm	*r-p*, *q-r* / mm	Initial orientation rate / %
B	35	22.13	75.64
		19.16	88.75
		16.19	96.04
		13.22	68.41
C	40	24.16	86.15
		21.19	92.62
		18.22	95.31
		15.25	57.21

The experimental results indicated that when the distances *r-p* and *q-r* are too small, the garlic seeds are prone to either falling prematurely or experiencing excessive angular deviation, leading to orientation failure. Additionally, since most garlic seeds are adsorbed below the center of the suction hole, the internal directional needle is more likely to cause the garlic seeds to be dislodged compared to the external directional needle.

CONCLUSIONS

（1）This study designed an air-suction seed metering device, incorporating a seed dispenser, directional needles, and combined suction blocks. This dispenser is equipped with the capabilities for single-seed extraction and preliminary orientation. Combined with image recognition and orientation technology, it can achieve continuous single-grain discharge of garlic seeds with the bud tip facing upward.

（2）A three-factor, five-level experimental design was employed, with the negative pressure in the air chamber, the rotational speed of the seed dispenser, and the number of seeds in the seed chamber as the test variables. The results indicated that, under the optimal operating parameters, the single-seed rate for garlic species *A*, *B*, and *C* were 95.98%, 96.50%, and 96.23%, respectively. The corresponding cavitation rates were 2.13%, 1.87%, and 2.59%, while the double-seed rates were 1.89%, 1.63%, and 1.18%, respectively. These results demonstrate that the performance of the system meets the requirements for the mechanization of garlic sowing.

（3）Through preliminary directional performance testing, the positional parameters of the directional needles for different grades of garlic seeds were determined. The radii of the distribution circles for the internal and external directional needles for garlic species *A*, *B*, and *C* were found to be 128 mm and 158 mm, 129 mm and 164 mm, and 124 mm and 164 mm, respectively.

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