SEED DISCHARGE PERFORMANCE TEST OF AIR SUCTION SEED DISCHARGER FOR SMALL VEGETABLE SEEDS

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面向小粒蔬菜种子的气吸排种器排种性能试验

Yanjun LI [1,2], Yichao NING*[2],Fuxiang XIE*[1], Yang Bai[1]
[1]School of Machinery and Automation, Weifang University, Weifang/China;
[2] State Key Laboratory of Agricultural Equipment Technology, Beijing/China
Tel: 15584399067; E-mail: nyc9603@sina.com
Correspondent author: Yichao NING, Fuxiang XIE
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ABSTRACT

Vegetable precision planting agronomy is suitable for my country's current vegetable planting system, and the air-suction vegetable precision planter is currently the most important work tool in my country. This paper designs a kind of air-absorbing vegetable precision sower for the problems of small vegetable seeds with small grains, poor mobility and high difficulty in achieving uniform sowing of small seeds. First, Fluent software is used to simulate and analyze the flow field of the air chamber in the seed metering device, and the pressure and velocity of the fluid in the air chamber are analyzed. Through the comparison of the pressure distribution cloud chart and the velocity distribution cloud chart, the influence of different apertures, holes, vacuum degree, and gas chamber depth on the flow field of the gas chamber is analyzed. The air suction seed discharger test bench was set up and orthogonal test was carried out, and the test results showed that the optimal parameter combination was 3.5 kPa vacuum degree of the air chamber, 2.4 mm diameter of the type hole, and 18 r/min rotational speed of the seed discharging disk. The high-speed photographic test was carried out under the optimal parameter combination, and the results showed that leakage of suction, adsorption of 1 seed, and adsorption of multiple seeds appeared in the process of suction, and it is important for the development of the air suction precision machine for small seeded vegetables with better performance. The results showed that the phenomenon of leakage, adsorption of 1 seed and adsorption of multiple seeds occurred in the process of seed suction, which provided a reference basis for the development of a better performance of the air-absorption precision planter for small seeds.

摘要

针对蔬菜播种存在播种劳动强度大、良种消耗多、播种质量有待提高等实际问题，结合我国蔬菜精量播种农艺要求及种植体系，本文设计了一种气吸式蔬菜精量排种器，利用 Fluent 软件对排种器内气室流场进行模拟分析，分析了气室内流体的压力和速度，通过压力分布云图与速度分布云图的对比，得出了真空度和排种盘型孔直径对气室流场的影响。搭建气吸排种器试验台进行正交试验，试验结果表明，最佳参数组合是气室真空度为 3.5kPa、型孔直径为 2.4mm、排种盘转速为 18r/min。在最佳参数组合下进行高速摄影试验，结果表明，在吸种过程中出现了漏吸、吸附 1 粒种子、吸附多粒种子的现象，为研制出性能更优良的小粒种子蔬菜气吸精量播种机提供参考依据.

INTRODUCTION

With the continuous strengthening of China's science and technology, the overall level of agricultural mechanization technology in China has significantly improved. However, the mechanized planting technology of some small-seeded vegetable crops still needs to be improved *(Tian et al., 2023)*. Vegetable seeders mainly have two types: mechanical and pneumatic. Mechanical seeders can generate static electricity, causing seeds to stick together and making precise sowing difficult *(Qi et al., 2020)*. Moreover, improper structural design of the seeder may increase the seed breakage rate when considering mechanical seeding of small-seeded vegetables such as Chinese cabbage *(Chen et al., 2019; Andrii et al., 2018).* Although pneumatic seeders require complex maintenance and high cost, they can effectively reduce seed breakage rates and achieve higher seeding efficiency than mechanical seeders *(Guan et al., 2018; Yazgi et al., 2007)*. This is why pneumatic seeders are becoming more and more deeply researched and widely applied in China *(Jia, 2022; Huang et al., 2022; Zhang et al., 2022)*. *Zhang et al., (2020),* conducted Adams simulation analysis on the pneumatic single-pan double-row seeding device.

The simulation showed that the seed cannot fall when the honeycomb structure hole inclination angle is 2°. When the honeycomb structure hole inclination angle is 18°, the performance meets agronomic requirements and provides theoretical basis for the machining and manufacturing of the whole machine. *Liu et al., (2010),* conducted experimental research on the influence of rotating speed and vacuum degree of the soybean pneumatic seeder on the seeding performance. *Liao Yitao et al., (2024),* designed a positive-negative pressure combination seeder with 2 seeding discs that can simultaneously plant 8 rows of small cabbage and conducted a bench test, achieving an average qualified index of 91.32%, an average replanting index of 6.19%, and an average missed planting index of 2.49% when the seeding disc rotating speed was 30 r/min, the negative pressure was -3000 Pa, and the positive pressure was 300 Pa, meeting the agronomic requirements for small cabbage planting.

This article addresses the difficulties of achieving uniform homogeneous sowing of small vegetable seeds due to their small size and poor fluidity using ordinary seeders. Additionally, those seeders cannot meet the requirements of precise seeding operations for small vegetable seeds. For this reason, a seeder for small vegetable seeds with precise seeding capabilities is designed, and theoretical analysis of the overall structure of the pneumatic seeder is conducted. An ADAMS software is used for sowing trajectory simulation while a Fluent software is used for simulating the gas chamber airflow to analyze the changes of the gas chamber airflow under different vacuum degrees and apertures. A vegetable seed planter unit is built and seeding performance testing research is carried out to provide a reference for the development of new type seeders and precise seeding machines for vegetables.

MATERIALS AND METHODS

Analysis of Suction Process of Pneumatic Seeder

The structure of the seed discharger is shown in Fig. 1. During the suction process of the seeding machine, the force acting on the seed is quite complex. The frictional force acting on the seed in the filling zone is much greater than the weight of the seed itself. In order to ensure that the seed can be smoothly adsorbed onto the seeding plate, a force analysis is performed on the seed to calculate the minimum required air pressure *(Xu et al., 2022)*.

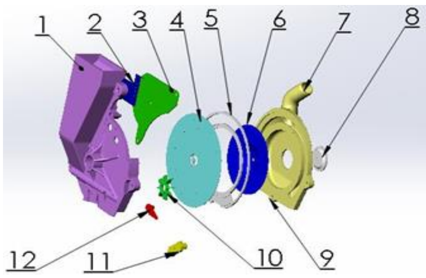


Fig. 1 – Assembly model seeding device

1.Seed box; 2.Seed stopper; 3.Seed scraper; 4.Seed discharge disc; 5.Sealing ring; 6.Sealing disc; 7.Negative pressure inlet; 8.Gasket; 9.Positive pressure hole; 10.Seed churn; 11.Seed paddle; 12.Seed churn holder

A three-dimensional Cartesian coordinate system is established with the center of mass of the seed as the origin. The i-axis represents the direction of the line velocity of the seeding plate rotation, the j-axis represents the direction of the centrifugal force acting on the seed, and the k-axis represents the direction perpendicular to the seeding hole of the seeding plate *(Zhang et al., 2021)*.

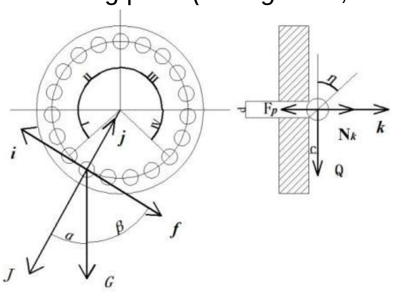


Fig. 2 – Force analysis of seed aspiration

Ⅰ is the process of sucking seeds from the seed tray; Ⅱ is clearing seeds from the seed tray; Ⅲ is carrying seeds from the seed tray; Ⅳ is the process of casting seeds from the seed tray.

The force analysis of the seeding plate during the suction process is as follows:

$$\begin{cases} \sum F_i = 0,\ N_i - f - G\cos\theta = 0 \\ \sum F_j = 0,\ N_j - J - G\sin\theta = 0 \\ \sum F_k = 0,\ N_k - F_p = 0 \\ \sum M = 0,\ F_p \dfrac{d}{2} - QC = 0 \end{cases} \tag{1}$$

G -the weight of the seed [N];

J - the centrifugal force acting on the seed [N];

F - the combined frictional force and air resistance acting on the seed [N];

Q - the total force acting on the seed resulting from the combination of G, J and f [N];

N_i, N_j, N_k - the components of force acting on the seed from each seeding hole in the i, j, and k directions [N];

F_p - the force of adhesion acting on the seed [N];

C - the distance between the point of action of the seeding hole on the seed and the center of mass of the seed [m].

The force acting on the seed from each seeding hole on the seeding plate in the i-j plane N_{ij} can be calculated as follows:

$$N_{ij} = \sqrt{N_i^2 + N_j^2} = \sqrt{J^2 + G^2 + f^2 + 2G\sqrt{f^2 + J^2}\sin(\alpha + \beta)} \tag{2}$$

α - the angle between the direction of the weight of the seed and the direction of the centrifugal force acting on the seed [°];

β - the angle between the direction of the weight of the seed and the i-axis [°]

The force equilibrium at the suction hole yields:

$$\begin{aligned} F_p &= Q\frac{d}{2C} = Q\tan\eta = N_{ij}\tan\eta \\ &= \sqrt{J^2 + G^2 + f^2 + 2G\sqrt{f^2 + J^2}\sin(\alpha + \beta)}\tan\eta \end{aligned} \tag{3}$$

η - the angle between Q and the point on the seed where the seeding hole provides support to the seed [°];

d - the diameter of the seeding hole on the seeding plate [m].

The theoretical negative pressure value is:

$$P = \frac{F_p}{S} = \frac{4 * \sqrt{J^2 + G^2 + f^2 + 2G\sqrt{f^2 + J^2}\sin(\alpha + \beta)}\tan\eta}{\pi d^2} \tag{4}$$

P - the theoretical minimum negative pressure [kPa];

S - the area of the cylindrical seeding hole [m²].

In actual working conditions, irregularities in machinery vibrations and the shape of seeds may cause uncertainty. To ensure successful seed suction, the actual minimum negative pressure P_{min} should be:

$$P_{\min} = K_1 K_2 K_3 P = \frac{4 * \sqrt{J^2 + G^2 + f^2 + 2G\sqrt{f^2 + J^2}\sin(\alpha + \beta)}\tan\eta}{\pi d^2} \tag{5}$$

K_1 - the reliability coefficient of seed suction [1.8-2.0];

K_2 - the stability coefficient of the seeding machine operation [1.6-2.0];

K_3 - the coefficient of influence of seed moisture content [1.1-1.2].

Analysis of the process by which the seeding plate carries seed

During the seed carrying stage, the entire seed planter operates smoothly without interference from other forces, and the negative pressure fluctuation is also small. When the seed carrying rotator rotates, the seed is only affected by air resistance without other forces interfering. The force situation is much smaller than that of the seed suction process. Since the fan is a constant pressure, the pressure inside does not change all the time.

At the same time, the negative pressure required for the seed-carrying process is much lower than that of the seed suction process, so it is not necessary to calculate the external force acting on the seed during the seed-carrying process, thus obtaining the required negative pressure *(Li et al., 2023)*.

Due to the existence of uncertain factors during the seed suction process, the actual air pressure value is much larger than the theoretical air pressure value, which may cause one type of hole in the seed plate to simultaneously adsorb multiple seeds *(Liao et al., 2018)*. Therefore, a seed clearing area is set between the seed suction area and the seed carrying area, and excess seeds are scraped off by the scraping plate when the seed adsorption becomes stable. The angle of the scraping plate can be adjusted at any time, and it can be adjusted according to different seeds and different models of seed discs to achieve the best sowing effect.

Fluent flow analysis of the seeder

The internal flow field of the air-suction seed planter was analyzed using Fluent software. The mesh model for the fluid simulation of the seed planter was established, and input and output boundary conditions were set *(Chen et al., 2018)*. By comparing and analyzing different vacuum degrees and different aperture sizes inside the planter, the internal pressure, velocity, and flow field were analyzed to discover the influence of different conditions on the internal pressure and flow velocity and achieve precision seeding *(Tang et al., 2022; Zang et al., 2015)*.

The seed plate and vacuum chamber are key components of the seed planter and are shown in Fig 3. The hole design of the seed plate is circular, and the number of holes is 20, with an angle of 18º between every two holes. The size of the vacuum chamber is designed according to the size of the seed plate, and the diameter of the connecting suction tube is approximately 25 mm *(Gong et al., 2014)*. Due to the complexity of the internal structure of the seed planter, the internal model was simplified into three parts: the seed plate holes, seed chamber, and vacuum chamber, for the simulation analysis of the gas chamber flow field.

Fig. 3 – Structure of seed plate and vacuum chamber

Bench experiments

Yellow Sword 1 pelletized carrot seeds of Shouhe Company with water content less than 8% were used as test materials in the experiment *(GB/T 6973-2005)*. The test equipment mainly consisted of conveyor belt, speed regulator, pneumatic device, and seed discharger as shown in Fig. 4. Other test auxiliary pieces of equipment are, rotational speed tester (3402, TACHO Hi Tester, Japan), wind pressure tester, camera, stopwatch, meter scale, and so on. High-speed photographic equipment used in Japan PHOTRON company produced FASTCAM-MiNi WX50 type675KM-16 high-speed camera, recording speed up to 67,500 frames per second (FPS), recording capacity of 16 G, the test was selected for the recording speed of 125 FPS.

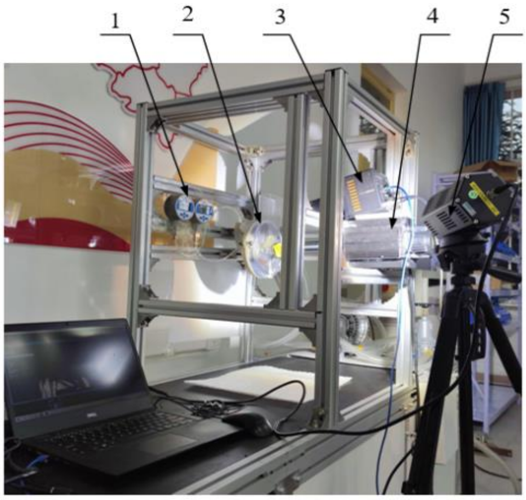


Fig. 4 – Test bench and test seeds

1.Digital display precision pressure gauge; 2.Pneumatic precision seed discharger;
3.High speed camera; 4.Servo motor; 5.LED flash light

Experiments indicators and experiments methods

The precision seed planter adopts the international standard ISO 7256/1-2004 "Seeders-Testing methods-Part 1: Single Seed Drills (Precision Seeders)," and combines it with the actual situation in China to select test indicators. The use of this standard can make the test results of different types of single seed (precision) seeders comparable *(Biocca M. et al., 2019)*. In this standard, the three main performance indicators of the precision seed planter are the qualified planting rate, missed planting rate, and replanting rate.

Orthogonal experiments

Due to the influence of vacuum degree, hole diameter of tray and rotation speed of tray on the working performance of the seeder, the orthogonal test method was adopted to analyze the working performance of the seeder. Based on the results of single-factor tests, the rotational speed of the tray, vacuum degree of the chamber and hole diameter of the tray, which have significant effects on the test indicators, were selected for orthogonal tests. The range and variance analysis of the orthogonal test results were conducted to obtain the primary and secondary priority orders affecting the operating parameters of the test indicators, thus finding the optimal combination of operating parameters for the seeder and providing theoretical support for obtaining the optimal working state of the seeder *(Kumar et al., 2012).* Based on the single-factor test, the orthogonal test was conducted on three factors: the rotational speed of the tray A, the vacuum degree B, and the hole diameter C. The qualifying rate, re-broadcast rate, and leak broadcast rate of the seed were used as test indicators, with each level repeated 10 times and the results averaged. The level table of the orthogonal test factors is shown in table 1.

Table 1

Factors and level of orthogonal test

Level	Factors		
	A. Seed reel speed r/min	B. Vacuum Level /kPa	C. Hole diameter /mm
1	12	2.5	2.2
2	18	3	2.4
3	24	3.5	2.6

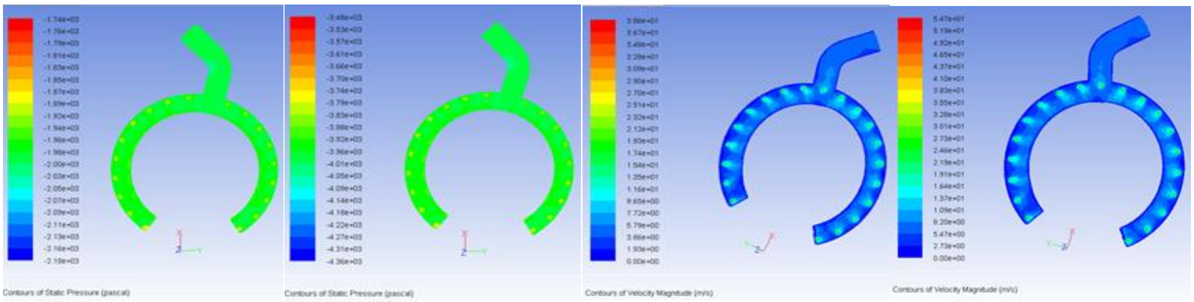
High-speed photography experiments

To observe the situation of seeds during the entire sowing process, a high-speed camera was used to record the seed suction process of the seeder, as the holes in the seeder rotate at a high speed and the human eye cannot see the situation of the holes adsorbing seeds *(Elnesr et al., 2016)*.

RESULTS

Changes in flow field at different vacuities

Vacuum degree is an important factor affecting the flow field of the seed planter. Analyzing the changes of the internal flow field of the planter under different vacuum conditions and selecting the pressure of 2000 Pa and 4000 Pa as the two working conditions for comparative analysis, as shown in Fig 5.



(a) Pressure distribution cloud map (b) Velocity distribution cloud map

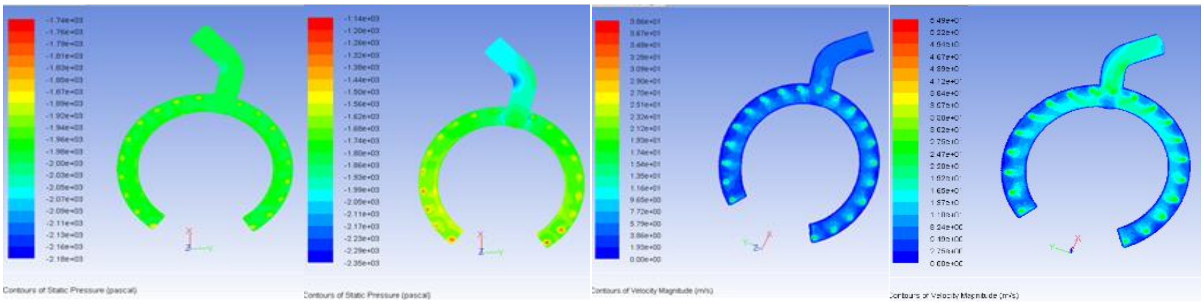
Fig. 5 – Variation of flow field at different vacuum degrees

When the negative pressure inside the planter changes, there is no significant change in the internal pressure, and the overall trend is consistent, with relatively high pressure at each suction hole. Therefore, it can be judged that the pressure of the fan only affects the pressure of the flow field inside the planter, and has almost no effect on the flow field in the vacuum chamber.

In operation, only enough pressure is needed to provide stable negative pressure to ensure that the seeds are easily adsorbed. The gas velocity is related to the shape of the type hole on the planter, and the velocity is distributed circularly, and the velocity gradually decreases along the hole center. When the negative pressure inside the planter changes, the velocity distribution inside the planter near the hole is significantly higher, and the speed becomes smaller as it gets farther away from the hole position. There is gas flow at the type hole, and the velocity at various inner walls is basically close to zero. It can be concluded that the size of the pressure only affects the size of the velocity, and the velocity is proportional to the pressure. When the pressure value increases, the velocity value increases significantly. The figure shows the pressure distribution at different hole positions, where the pressure near the hole on the right side of the planter is relatively high, and the pressure near the bottom hole is relatively low. The reason for this phenomenon is that the type hole on the right side of the planter is closer to the pipeline of the fan, while the type hole near the bottom is farther away from the pipeline of the fan.

Changes in flow field at different aperture sizes

Comparative analysis was carried out between the 2 mm and 4 mm diameter type holes under the same simulation conditions when the pressure was set to 2000 Pa on the planter, as shown in Fig 6. The observation was made on the internal pressure and velocity distribution of the planter.



(a) Pressure distribution cloud map (b) Velocity distribution cloud map

Fig. 6 – Changes of flow field at different apertures

When the diameter of the type hole on the planter changes, the pressure distribution inside the planter will also change. When the diameter of the type hole increases, the pressure at the type hole also increases. This phenomenon is particularly evident at the bottom type hole of the planter, and there is a phenomenon of lower negative pressure at the bend of the upper pipe. The pressure distribution at other positions is relatively uniform. The larger the diameter of the type hole, the more obvious the influence on the internal pressure situation. Therefore, the diameter of the type hole affects the pressure, and the larger the diameter, the greater the pressure in the vacuum chamber. The gas velocity inside the planter is related to the diameter of the type hole on the planter. The larger the diameter of the type hole, the faster the internal gas velocity inside the planter. However, the gas velocities among the phases inside the planter are relatively consistent. For the same diameter, especially for larger diameters, the gas velocities at different positions are slightly different. The closer to the pipeline above, the faster the gas velocity. For different type holes, the larger the diameter, the faster the gas velocity in the upper pipe. The larger the diameter of the type hole, the greater the pressure at the hole.

In summary, when the diameter of the type hole on the planter is too large, gas leakage will occur and the pressure value will not continue to increase with the diameter. In addition, when the diameter of the type hole on the planter increases, the power required for the fan will also increase. Therefore, it is not recommended to choose too large type holes under the premise of meeting the sowing requirements. In this experiment, the vacuum degree of the planter is 2000 Pa, and the diameter of the type hole is 2 mm.

Orthogonal experiments

The orthogonal experimental design and the experimental results are shown in Table 2.

According to the data in Table 3, it can be concluded from the range analysis of the qualified rate of the experimental indicators that $k_{A2}>k_{A3}>k_{A1}$, so it can be judged that A2 is the optimal level of factor A; $k_{B3}>k_{B2}>k_{B1}$, it can be judged that B3 is the optimal level of factor B; $k_{C1}>k_{C3}>k_{C2}$, it can be judged that C1 is the optimal level of factor C. Since the larger the qualified suction rate, the better the working performance of the pneumatic sowing mechanism, the optimal combination of the qualified suction rate is A2B3C1. Moreover, 2.86>1.41>1.19, indicating that the factor that has the greatest impact on the qualified suction rate is the rotation speed of the pneumatic sowing plate, followed by the vacuum degree of the chamber, and finally the diameter of the holes.

Table 2

Orthogonal test scheme and test results

A	B	C	Suction seed qualification rate/%	Resorption rate/%	Leakage rate/%
1	1	1	87.19	6.99	5.82
1	2	2	86.61	7.81	5.58
1	3	3	88.36	5.47	6.17
2	1	2	89.52	4.99	5.49
2	2	3	89.6	4.2	6.2
2	3	1	91.63	3.14	5.23
3	1	3	87.55	6.87	5.58
3	2	1	89.39	4.86	5.75
3	3	2	88.50	5.81	5.69

According to the range analysis of the missed suction rate of the experimental indicators, $k_{A1}>k_{A3}>k_{A2}$, it can be judged that A2 is the optimal level of factor A; $k_{B2}>k_{B3}>k_{B1}$, it can be judged that B1 is the optimal level of factor B; $k_{C3}>k_{C1}>k_{C2}$, it can be judged that C2 is the optimal level of factor C. Since the smaller the missed suction rate, the better the working performance of the pneumatic sowing mechanism, the optimal combination of the missed suction rate is A2B1C2, and 0.40>0.22>0.21, indicating that the diameter of the holes has the greatest impact on the missed suction rate, followed by the rotation speed of the pneumatic sowing plate, and finally the vacuum degree of the chamber.

According to the range analysis of the repeated suction rate of the experimental indicators, $k_{A1}>k_{A3}>k_{A2}$, it can be judged that A2 is the optimal level of factor A; kB1>kB2>kB3, it can be judged that B3 is the optimal level of factor B; $k_{C2}>k_{C3}>k_{C1}$, it can be judged that C1 is the optimal level of factor C. Since the smaller the repeated suction rate, the better the working performance of the pneumatic sowing mechanism, the optimal combination of the repeated suction rate is A2B3C1, and 2.65>1.48>1.21, indicating that the rotation speed of the pneumatic sowing plate is the most important factor affecting the repeated suction rate, followed by the vacuum degree of the chamber, and finally the diameter of the holes.

Table 3

Range analysis of orthogonal test results

	η1			η2			η3		
	A	B	C	A	B	C	A	B	C
K1	262.16	264.26	268.21	17.57	16.89	16.80	20.27	18.85	14.99
K2	270.75	265.60	264.63	16.92	17.53	16.76	12.33	16.87	18.61
K3	265.44	268.49	265.51	17.02	17.09	17.95	17.54	14.42	16.54
k1	87.39	88.09	89.40	5.86	5.63	5.60	6.76	6.28	5.00
k2	90.25	88.53	88.21	5.64	5.84	5.59	4.11	5.62	6.20
k3	88.48	89.50	88.50	5.67	5.70	5.98	5.85	4.81	5.51
R	2.86	1.41	1.19	0.22	0.21	0.40	2.65	1.48	1.21

The results of the orthogonal experiment analysis are shown in Table 4. According to the variance analysis of the qualified absorption rate, it can be found that $F_{0.1}(2,6)=3.46$ is obtained after consulting the F-table. Compared with the F value in Table 4, it can be concluded that the three factors have a certain impact on the qualified absorption rate. The rotational speed of the pneumatic seeding plate has a significant influence on the qualified absorption rate, while the vacuum degree of the air chamber and the diameter of the mold hole have an insignificant effect on the qualified absorption rate. According to the variance analysis of the leak suction rate, after consulting the F-table, it can be found that $F_{0.1}(2,6)=3.46$. Compared with the F value in Table 4, the three factors have a certain impact on the leak suction rate, but the vacuum degree of the air chamber, the rotational speed of the pneumatic seeding plate, and the diameter of the mold hole have an insignificant effect on the leak suction rate.

According to the variance analysis of the re-absorption rate, after consulting the F table, it can be found that $F_{0.1}$ (2,6)=3.46. Compared with the F value in Table 4, the three factors have a certain impact on the re-absorption rate. The rotational speed of the pneumatic seeding plate has a significant influence on the re-absorption rate, while the vacuum degree of the air chamber and the diameter of the mold hole have an insignificant effect on the re-absorption rate.

In the single-factor experiment of the seedling planter, the effects of vacuum degree of the air chamber, diameter of the mold hole, and rotational speed of the pneumatic seeding plate on the working performance of the seedling planter were mainly analyzed. The range and variance analysis of the orthogonal experiment results were conducted, and the primary and secondary orders and the significant influence of the test indicators were obtained. Due to the requirements of the experiment, a higher qualified absorption rate needs to be obtained while reducing the leak suction rate and the re-absorption rate as much as possible. Based on the range analysis of the primary and secondary orders and the variance analysis of the significant impact, the optimal combination was finally determined as A2B3C1, that is, the rotational speed of the pneumatic seeding plate is 18 r/min, the vacuum degree of the air chamber is 3.5 kPa, and the diameter of the mold hole is 2.4 mm.

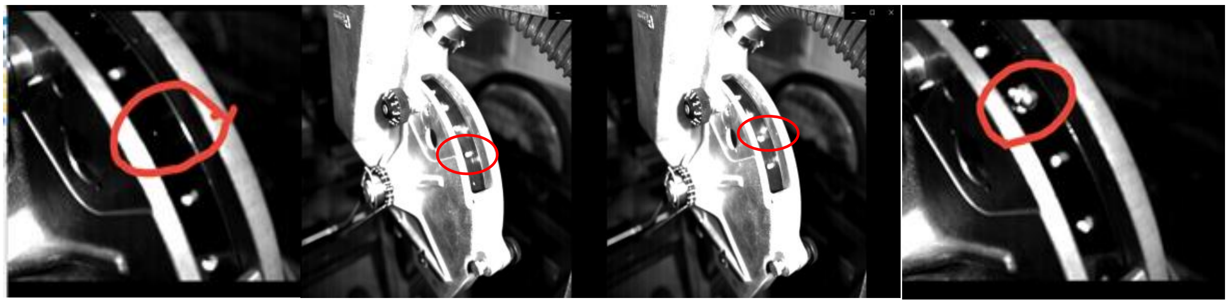
Table 4

Analysis of variance of orthogonal experiment results

Source of variation	SS			df			MS			F		
	η_1	η_2	η_3	η_1	η_2	η_3	η_1	η_2	η_3	η_1	η_2	η_3
A	12.52	0.08	10.84	2	2	2	6.26	0.04	5.42	6.11	0.35	4.95
B	3.11	0.07	3.28	2	2	2	1.55	0.03	1.64	0.60	0.30	0.69
C	2.32	0.30	2.19	2	2	2	1.16	0.153	0.09	0.42	1.93	0.43

High-speed photography experiments

Under the optimal combination parameters obtained from the orthogonal experiment, the rotational speed of the pneumatic seeding plate was selected as 18 r/min, the vacuum degree of the air chamber was 3.5 kPa, and the diameter of the mold hole was 2.4 mm for high-speed photography experiments to observe the grainy vegetable seeds' absorption situation in the seed planter and summarize the absorption characteristics of the seed planter.



(a) leakage (b) single seed (c) two seeds (d) multi-seeded

Fig. 7 – High-speed photography test results

The results of the high-speed photography experiments are shown in Fig 7. During the experiment, phenomena such as leak suction, adsorption of one seed, adsorption of two seeds, and adsorption of multiple seeds appeared. Through analysis, it was found that the leak suction phenomenon was caused by the unstable air chamber pressure. Adsorption of one seed is the main performance indicator of this type of seed planter, which can be achieved by adjusting parameters such as the rotational speed of the pneumatic seeding plate, the vacuum degree of the air chamber, and the diameter of the mold hole to achieve stability. The phenomenon of adsorption of multiple seeds is caused by uneven air chamber pressure, and later, the air chamber structure and the design of the sub-seeding needle need to be optimized to reduce the number of adsorbed seeds and achieve precision seeding.

CONCLUSIONS

（1）In this study, a kind of air-absorbing vegetable precision seed discharger was designed, the working principle of the seed discharger was clarified and its working process was analyzed theoretically, and the factors affecting the seed suction and seed carrying process of the seed discharger were obtained, as well as the size of the minimum negative pressure value of the air chamber required for the type of holes to be able to stably adsorb the seeds.

（2）Using Fluent software to theoretically analyze the flow field of the gas, establish a grid model for the simulation of the fluid inside the seeder, and obtain the pressure and velocity distribution cloud diagrams of different vacuum degrees and different aperture sizes inside the seeder, analyze the pressure, velocity and flow field inside the seeder, and provide a reference guide for the design of a better seeder.

（3）Using qualified rate, re-sowing rate, and missed rate as test indicators, orthogonal test and high-speed photography test were carried out, and the test results yielded the optimal parameter combinations, and the comprehensive balance of the test indexes, the seed discharge disk rotational speed of 18 r/min, the vacuum degree of the air chamber of 3.5 kPa, and the diameter of the type hole of 2.4 mm, the best effect of seed discharge. High-speed photography test showed that in the process of seed suction, there were leakage, adsorption of 1 seed, adsorption of 2 seeds and adsorption of more than 2 seeds.

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