DESIGN AND EXPERIMENT OF AN AIR-SUCTION SEED METERING DEVICE FOR WATERMELON SEEDS BASED ON AIR-BLOWING DISTURBANCE

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In order to meet the demand for precision sowing of watermelon seeds, this article proposes a new type of air-blowing disturbance seed supply air-suction seed metering device, introduces the structure and principle of the seeder, analyzes the posture characteristics of the seeds during filling, and verifies the optimal angle of air-blowing disturbance seeds was 30° . The effects of airflow velocity and airflow angle on the boiling height and number of watermelon seeds were determined through bench tests. The test results showed that the qualified rate, missing rate and reseeding rate were 85.32%, 9.35% and 5.39% under the condition of 12km/h seeding speed, which basically met the requirements of precision seeding.

Keywords: watermelon seeds; air-blowing disturbance; air-suction seed metering device

1. Introduction

Watermelon is a type of seeding watermelon with high food value and is an important cash crop [1]. Watermelon seeds are flat seeds characterized by irregular shapes and significant differences in dimensions, and the same type of seeds also includes corn seeds and sunflower seeds. In the sowing process, flat seeds have problems such as poor mobility of seed groups, poor seed-filling effect, and adsorption stability, which increases the difficulty of mechanized precision sowing.

Precision seeding is the mainstream development direction of agricultural seeding technology; mechanized precision seeding of watermelon seeds can improve seeding efficiency, seize farm time, and save labor costs. The seed metering device is the core device of the planter; according to the working principle, it is divided into two kinds: mechanical and pneumatic. Mechanical seed metering devices mostly use gravity to fill the seed. Gravity seed filling is limited by the

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structure, it is more challenging to adapt to the quantitative seed filling of flat seeds with significant differences in size, and it is easy to injure the seeds. The seed metering device has poor seed-filling performance in a large-scale planting environment [2-3]. Liu Xiguang [4] and others designed a mechanical watermelon seed metering device based on TRIZ theory, and the metal dome of the seed pickup block of this seed metering device led to high mechanical wear in seed metering operation. Pneumatic seed metering devices, especially air-suction seed metering devices, have gradually replaced mechanical seed metering devices with their advantages, such as high working speed, low seed damage, and stable seed metering performance. Karayel D[5] et al. investigated the effect of different, forward speeds on the uniformity of seed spacing of melons and watermelons and showed that the average hole spacing was not affected by the forward speed and seed metering plate, but the number of seeds in the holes was affected. Karayel D et al.proposed an artificial neural network method for the optimal negative pressure of an air suction seeder, which showed that the accuracy and success rate of linear regression and polynomial regression of negative pressure values obtained using the artificial neural network method reached 0.9949. Yazgi A[6] et al. studied flat and round corn seed metering devices and measured the overall angle of inclination and seeding plate speed for optimal seed metering device operation. Celik A [7] et al. compared the operational performance of four seed metering devices to explore the pass rate of sowing sunflower seeds at different speeds, with the no-till planter having the highest consistency in grain spacing and the air-suction seed metering device having the optimum pass rate and consistency in sowing depth. Li Miaomiao [1] and others selected three kinds of watermelon seeds and developed an air-absorption watermelon hole seeder. Still, the reseeding rate was high, and there needed to be better stability of seed discharge performance for different varieties of watermelon seeds. Ding Li [8] and others from China Agricultural University conducted a theoretical analysis of the adsorption attitude of flat corn seeds and the timing of seed casting and proposed that the adsorption of seeds lying flat is conducive to achieving better seed casting timing. Yang Li [9] designed an air-suction corn precision metering device with a mechanical supporting plate to assist in carrying the seed, which utilizes the supporting plate eyelets to assist in holding the seed and realizes the assisting carrying seed air-suction corn precision metering device with a mechanical supporting plate to assist carrying seed. In recent years, the research has focused on the structure of the seed metering device and the impact of operating parameters on the performance of seed metering operations, as well as to improve the operating speed and reduce the wind pressure, the research on watermelon seed air-suction seed metering device is mainly to improve the filling performance, focusing on the structure of the suction holes and assist the improvement of seed filling performance, and less research on seed adsorption attitude regulation.

When the air-suction seed metering device is used for the seed metering operation of watermelon seeds, due to the flat structural characteristics of watermelon seeds, it cannot closely adhere to the seed suction holes, the adsorption stability is poor, and the seed metering performance is low. In this paper, starting from the adsorption attitude of watermelon seeds, it is proposed to utilize air-blowing disturbance of the adsorption attitude of watermelon seeds, and to design a kind of air-suction seed metering device based on air-blowing disturbance of seed supply

2. Materials and methods

2.1 Design of air-blown disturbance seed metering device

The air-blowing disturbance seed supplying air-suction seed metering device consists of seed feeding cover, seed metering plate, air-blocking device, Negative pressure shell, air-blowing interface and sieve plate, and other components, and its structure is shown in Figure 1.

This seed discharging system starts from the control of the flattening characteristics and adsorption attitude of watermelon seeds, and proposes a seed supply method to regulate the adsorption attitude of seeds through positive pressure airflow based on the airflow suspension movement characteristics of watermelon seeds. The seeds inside the seed shell are stacked in the seed supply area due to gravity. The positive pressure airflow at the bottom of the seed supply chamber is used to blow and disturb the seed group, causing it to be in a flowing state. Under the action of the negative pressure shell airflow, the seeds are adsorbed at the suction hole of the Seeding plate and rotate to the seeding area with the Seeding plate. The seeds at the suction hole are isolated from negative pressure by the air blocking device and rely on gravity for seeding. Due to the flat structure characteristics of melon seeds, the suspension posture of the seeds changes under the action of air blowing disturbance. By designing the structure and working parameters of the seeding system reasonably, the seed posture is adjusted to maintain the flat surface of the seeds and the suction hole surface flat at the moment of adsorption, and the relative motion between the seeds and the suction hole in the flat surface is zero, so that the melon seeds are in an ideal adsorption state.

As the core component of the air-suction seed metering device, the size of the seed metering plate affects the overall structure of the seed metering device and the determination of parameters such as air chamber pressure. The diameter of the air-suction seed metering device's seeding plate is generally in the range of 140 to 260 mm, due to the design of this paper's air-blowing disturbance seed supply air-suction metering device is used for the seeding of watermelon seeds of large particle size, under the premise of the suction hole parameter to meet the requirements, this paper selects the diameter of the seeding plate of 245 mm[10]. Suction hole diameter selection on the seed metering device has a greater impact on the performance of seed filling, watermelon seed shape is irregular, the diameter of the suction hole is selected as 5mm, taking into account the airflow perturbation to regulate the adsorption posture of the seed for the seed flattened surface and suction holes to the surface of the paste, and to ensure that the seed metering plate between the two neighboring suction holes need to be greater than the longest size of a seed, the number of suction holes is set at 14[11-12].

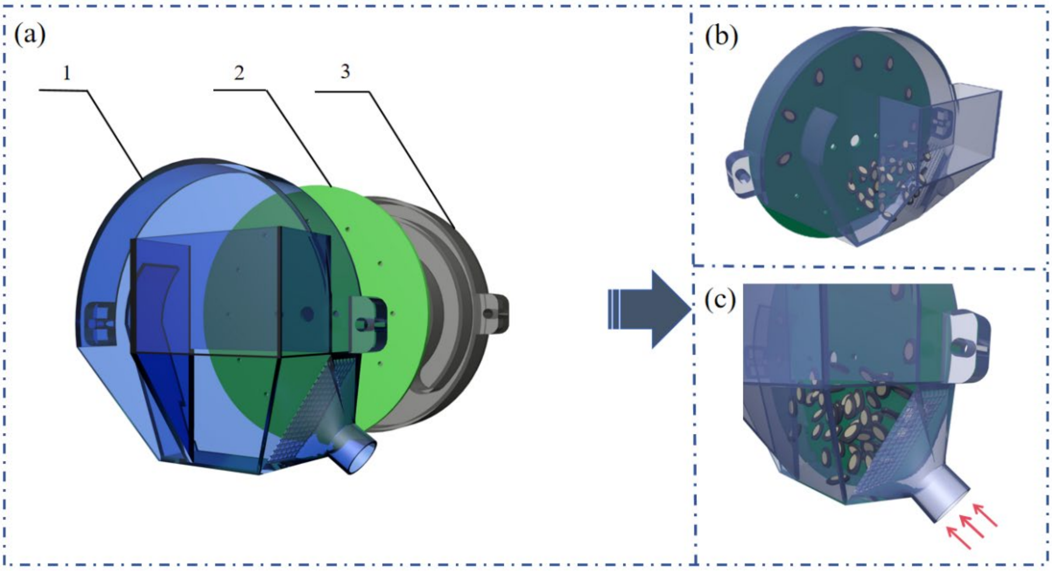


Fig. 1. Schematic diagram of the structure and operating principle of the seed metering device. (a) Exploded view; (b) Schematic diagram of the working status of the air-blowing mechanism; (c) Schematic diagram of airflow disturbance state. 1. Seeding cover, 2. Seeding plate, 3. Negative pressure shell.

2.2 Analysis of posture characteristics of melon seeds

Watermelon seeds are irregularly shaped large-sized seeds with poor mobility, and air-blowing disturbance can improve the flow rate of seeds in the seed supply area. Conduct force analysis on the moment when seeds are adsorbed and detached from the population during the filling process of traditional air suction seeders and air-blowing disturbance seed supply air-suction seed metering device, and elucidate the operational mechanism of airflow regulation on the adsorption posture of melon seeds.

According to the fluid mechanics theory, the seed adsorption condition is that the seed moving toward the suction hole is greater than the combined force in the opposite direction until the suction hole absorbs it. The force at the instant of seed adsorption during the operation of the traditional air-suction seed metering device is as follows:

$$F_d - F_f - (G + F_a - F_n)\sin\theta = ma \quad (1)$$

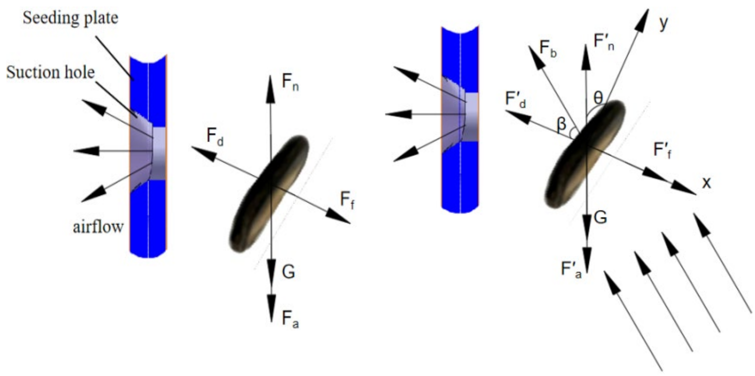
F_d --spoiler drag force, N;F_b--Upper seed pressure, and N;F_N --Lower layer seed support force, N;F_f --Seed movement resistance, and N;G— gravity, N

The stress of the air suction seed trap is as follows:

$$F_b \cos\beta + F_d^{'} - F_f^{'}(G + F_a^{'} - F_n^{'})\sin\theta = ma^{'} \quad (2)$$

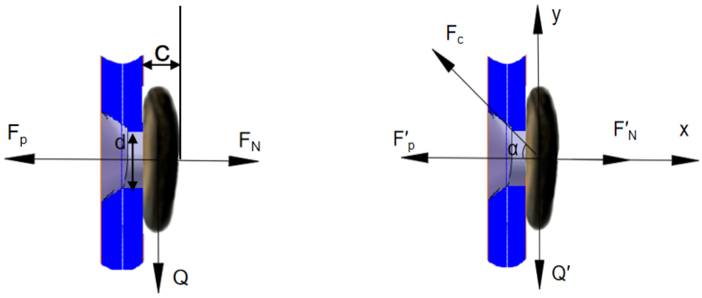
F_b—Airflow buoyancy, N

The moment the seeds are adsorbed during the operation of traditional air suction seeders, the disturbance drag force is the main force that determines the adsorption of melon seeds, and at the moment when the seeds are adsorbed during the operation of the air blown disturbance feeding suction seeder (ASM), in addition to the disturbance drag force, the seeds are also subjected to the buoyancy force F of the airflow[13]. A comparison of Eq. 1 and Eq. 2 shows that the acceleration $a^{'}$ is bigger than a at the moment the seed metering device absorbs seeds under the condition of air-blowing seed supply, the speed of the seed near the suction hole increases, which improves the flow speed of the seed in the seed filling area, and when the seed disk rotates at a higher speed, the seed can have a certain speed, which increases the time of the seed contacting with the suction hole and improves the rate of seed filling[14].



Traditional air suction seed drain | Air blowing disturbance for seed supply air suction type seed trap

a. Instent stress analysis of seed adsorption



Traditional air suction seed drain

Air blowing disturbance for seed supply air suction type seed trap

b. Analysis of force at moments upon seed detachment from the population

Fig. 2. Stress analysis of filling process

The force situation at the moment when the seed leaves the seed group is shown in Figure 2; seeds within a conventional air-suction seed metering device are subjected to suction pore adsorption forces, F_p, support FN, and the combined force Q of gravity and friction within the seed group. The seeds in the air-blowing disturbance seed supplying air-suction seed metering device are also subjected to an air-blowing pressure F_c. Analyzing the moment when the seed is adsorbed in a conventional air-suction seed metering device if it is to be ensured that the seeds do not fall out, the pressure difference P0 between the two sides of the suction hole needs to be satisfied :

$$P_0 \geq \frac{4cQ}{\pi d^3} \tag{1}$$

c—Seed thickness, mm

d—Suction hole diameter, mm

The air-blowing disturbance supply air suction seeder needs to meet the following requirements for instant seed adsorption:

$$P_0 \geq \frac{4cQ - 8F_c \cos\alpha}{\pi d^3} \tag{2}$$

α—Blowing angle,°

The above equation shows that as F_c increases and α decreases, the pressure difference P_0 on both sides of the suction hole decreases, effectively reducing the negative pressure of seed filling [15].

2.3 Experiment on Seed Posture Characteristics

Explore the attitude change law of melon seeds under the condition of air blowing, build the test bench of air blowing seeds as shown in Figure 3, build a rectangular pipe of 100mm long and 55mm high, use a metal screen to separate the connecting parts between the rectangular pipe and the air blowing pipe mouth, and the Angle of air flow is controlled by the inclination Angle of the connector. First, 50 seeds were put into the rectangular pipe, and the seed thickness fell evenly on the metal sieve net. Then, the air flow was blown to the seed layer of the sieve net through the air blowing pipe. The high-speed camera observed the movement state of the seeds, and the attitude change law of the air flow in the boiling process of the seeds was further explored. The selected airflow angle was 30°, and five horizontal factors of 4,6,8,10 and 12 m/s were selected for the single factor test of airflow velocity. The selected airflow velocity was 5 m/s, and the airflow angles of 0°, 15°, 30°, 45° and 60° were selected for the single factor test of airflow angle. The boiling intensity of the population, the movement trajectory of the seeds was used as the test indicators.

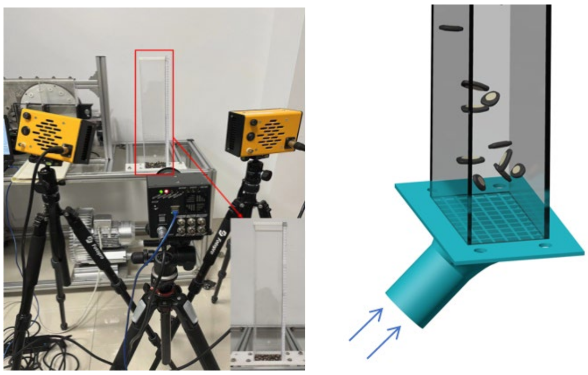


Fig. 3. Air blowing seed test bench

The size of seeds is different, so the adsorption attitude of seeds plays an important role in the drainage process. The charging performance test platform includes seed arrangement, motor, speed and pressure control and detection device, and high-speed camera system. The speed and pressure control and detection devices include positive and negative pressure fan, negative pressure meter, motor controller and tachometer, and the high-speed camera system includes video camera (FASTCAM Mini AX), laptop computer and fill light.

Fig. 4. Air blowing seed test bench

The statistics of 100 seeds adsorbed in parallel and vertically, and the status of the seeds from the adsorption moment to the separation plate were observed. The traditional air suction seed trap used in the test is the grant air suction seed trap, and the high-speed camera collects the adsorption attitude and planting state of the seed extraction and carrying process. Test in the forward speed of 4,6,8,10,12 km/h, to stabilize the adsorption rate (suction hole in the seed adsorption), leakage rate (suction hole in the process of the position of seed adsorption drop in advance) as the test index, explore the parallel adsorption and vertical adsorption at different speed and stable adsorption rate and leakage rate.

2.4 Simulation of the flow field in the seed metering device

Using the pressure difference on both sides of the suction hole from the seed suction and population, the filter both positive pressure airflow and negative pressure airflow, the suction hole air field of the seed distribution performance is very important, through the Fluent software to simulate the pressure distribution of the suction hole analysis, and explore the seed force under the compound action, and determine the flow blowing Angle.

When conducting the airflow field fluid simulation, it is necessary to judge the basic physical properties of the fluid, such as the fluid compressibility and laminar or turbulence problem, which is of great significance to the simulation. In hydrodynamics, the fluid is divided into compressible fluid and incompressible fluid according to whether the fluid density is constant. The compressibility [16-18] of the fluid can be judged by Mach number Ma. When Ma <0.3, the air density does not change with the velocity, which is considered incompressible fluid; when Ma> 0.3, the air density decreases with the velocity increases, which is considered compressible fluid.

The Mach number expression is as follows:

$$Ma = \frac{v_m}{a_m} = \sqrt{\frac{v_m^{\ 2}}{KRT}} \tag{3}$$

v_m is the flow field velocity of the negative pressure chamber, m/s; a_m is the speed of sound, m/s; K is the ratio of the specific heat and the specific heat; R is the gas constant, J (kg · K); T is the absolute temperature, K.

When the negative pressure of the negative pressure chamber of the seed filter is 4 kPa, the flow field velocity is measured by digital anemometer, the ratio of air constant pressure heat to constant volume heat at constant temperature is 1.4, the gas constant is 287J (kg · K), the absolute temperature is 293K, Ma is 0.035 <0.3, which is considered an incompressible fluid[19].

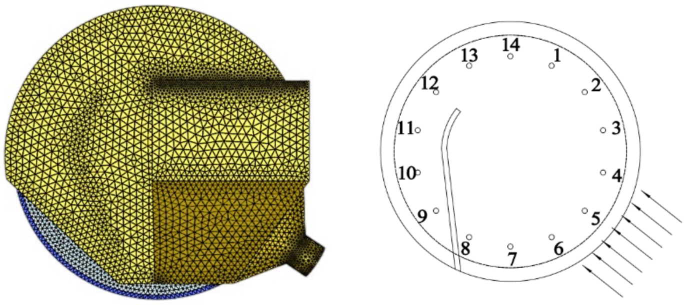
In the calculation process, the Reynolds number Re is generally used to choose the laminar flow or turbulence. The flow field of the filter is an internal flow field simulation, which is usually considered turbulence when Reynolds Re is> 2300; Re <2300[20]. The Reynolds number expression is as follows:

$$\begin{cases} \mathrm{Re} = \dfrac{\rho v_d d}{\mu_0} \\ s_m v_m = s_d v_d \end{cases} \tag{4}$$

Where: ρ is the fluid density, kg/m3; d is the suction hole diameter, m; μ is the fluid viscosity, Pa · s; s_m is the cross-sectional area of the negative pressure chamber inlet, m^2; s_d is the total suction hole cross-sectional area, m^2; v_d is the fluid velocity at the suction hole, m/s.

In the standard condition, the air density is 1.29 kg/m^3, the viscosity is 1.810-5Pa · s, the diameter of the air inlet is 40mm, the suction hole diameter is 5mm, and the formula Re is 19708.33>2300, so the airflow field should be selected as the turbulence model.

The seed arrangement model is simplified to keep only the front shell, type hole and negative pressure shell. Using the method of regional grid division, the inlet boundary condition is defined as velocity inlet, the exit boundary condition is pressure outlet, the interface is set as interface, and the other wall is defined as wall. The .msh file, imported into fluent, the turbulence model adopts RNG k- ε model, defines the outlet pressure as-3 kPa, the inlet speed is 5 m/s, the momentum equation, Rui kinetic energy equation and Rui kinetic energy dissipation rate all adopt the first-order wind difference format, using the SIMPLE algorithm. The maximum number of operational steps was defined as 1000 and the convergence condition was 10-4. The established fluid simulation model is shown in Figure 5. Taking the Angle of the disturbance flow as the factor, five flow angle levels of 0°, 15°, 30°, 45° and 60° were selected for flow field simulation, and the pressure change at the suction hole and the distribution of the flow field under different flow angles were observed.



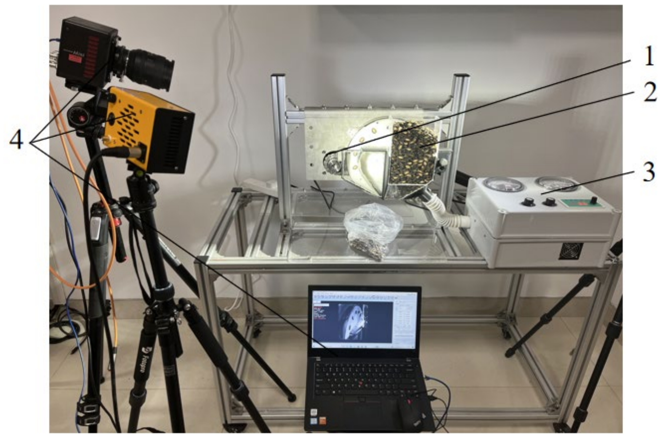
a. Simulation model of the seed arrangement device

b. The suction hole number

Fig. 5. Fluid simulation model

2.5 Prototype performance experiment

The seeding performance test device includes seed metering device, motor, rotational speed and air pressure control and detection device, and high-speed camera system, wherein the rotational speed and air pressure control and detection device includes positive and negative pressure fan, negative pressure meter, motor controller and tachometer, and the high-speed camera system includes video camera (FASTCAM Mini AX), laptop computer, and fill-in light.



1.Drive motor 2.Seed metering device 3.Speed and pressure control and detection device 4.High speed camera system
Fig. 6. Filling performance test device

The test selected "Lanzhou big board" watermelon seeds, using the traditional air-suction seed metering device and air-blowing disturbance seed supply air-suction seed metering device for seed filling performance test, set the negative pressure of 3kPa, the size of the airflow for 5m/s, the airflow angle of 30°.Images of the statistical seed-filling process were captured using a high-speed camera system at five levels of forward speed: 4, 6, 8, 10, and 12 km/s.

In the analysis of seed-taking performance, the high-speed camera is used to align the seed filling position and record the number of seeds on the suction holes at the moment of leaving the seed group, and each group of test records acquires 251 consecutive suction hole images for statistics, and each group repeats three times to take the average value as the test results. Referring to GB/T 6973-2005 Test Methods for Single Grain (Precision) Planter, the single grain adsorption rate, resorption rate, and leakage rate are used as the evaluation indexes of seed filling performance.

$$\begin{cases} S = \dfrac{n_1}{N} \times 100\% \\ M = \dfrac{n_2}{N} \times 100\% \\ D = \dfrac{n_3}{N} \times 100\% \end{cases} \quad (5)$$

S is the single particle adsorption rate,%; M is the reabsorption rate,%; D is the leakage rate,%; n_1 is the number of suction pores for adsorbing a single seed; n_2 is the number of suction pores for adsorbing multiple seeds; n_3 is the number of adsorption pores for unadsorbed seeds; N is the statistical number of suction holes.

To verify the performance of air blown seed adjustment for seed filling posture, a high-speed camera was used to observe a single adsorbed seed and record its filling posture, with parallel adsorption rate as the evaluation indicator[21].

$$H = \frac{n_4}{N_1} \times 100\% \quad (6)$$

H is the parallel adsorption rate,%; n_4 is the number of adsorption pores parallel to the flat surface of the seed at the moment of leaving the population; and N_1 is the statistical number of adsorption pores per particle[22].

3 Results and discussion

3.1 Experimental results and analysis of seed posture characteristics

Stabilized adsorption and leakage rates were used as the test indexes to explore the influence of adsorption posture on the stability of seed discharge results, as shown in Fig. 7.

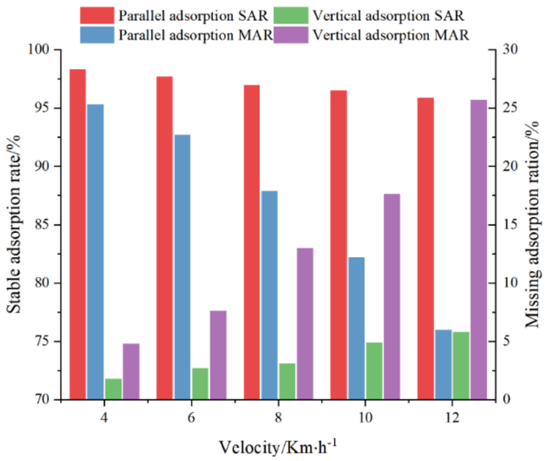
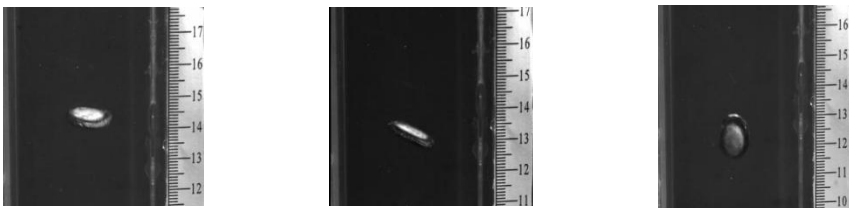


Fig .7. Effect of seed adsorption posture on seeding performance

As can be seen from Fig. 7, the stabilized adsorption rate of watermelon seeds in the parallel adsorption attitude was significantly larger than that in the vertical adsorption, and the stabilized adsorption rate varied less with the increase of the speed, and it always remained above 95%. The stabilized adsorption rate in vertical adsorption was 95.23% at 4 km/h and 75.31% at 12 km/h, which decreased by 19.92 percentage points. The leakage rate and the stable adsorption rate showed opposite trends, and the leakage rate gradually increased with the increase in speed, and the leakage rate at parallel adsorption was always less than 5%. The leakage rate was higher in vertical adsorption, which was 4.77% at 4 km/h and 24.69% at 12 km/h, increasing by 19.92 percentage points. The effect of watermelon seed adsorption attitude on seed discharge performance showed that parallel adsorption of watermelon seeds was preferred. The higher the frequency of parallel adsorption, the higher the stabilized adsorption rate and the lower the leakage rate.

Due to the seeds' flattened morphology characteristics, the seed particles' movement is more violent during the levitation test, with significant upward and downward fluctuations. When the flattened surface of the seed is perpendicular to the direction of the airflow, the seed has a large contact area with the airflow, the buoyancy force of the airflow is greater than the gravitational force, and the seed moves upward rapidly. Due to the irregular shape of watermelon seeds, the seeds rotate during the movement process, the airflow blowing to the flat surface of the seeds decreases, the buoyancy decreases, and the seeds rise slower and begin to fall downward. When the flat surface of the seed and the direction of the airflow are parallel, the seed is subject to the minimum buoyancy; there is a momentary suspended state, then the seed is rotated again, blowing to the flat surface of the seed airflow increases, the buoyancy increased, the seed rises again. The watermelon seeds will make this reciprocal movement in the updraft many times.



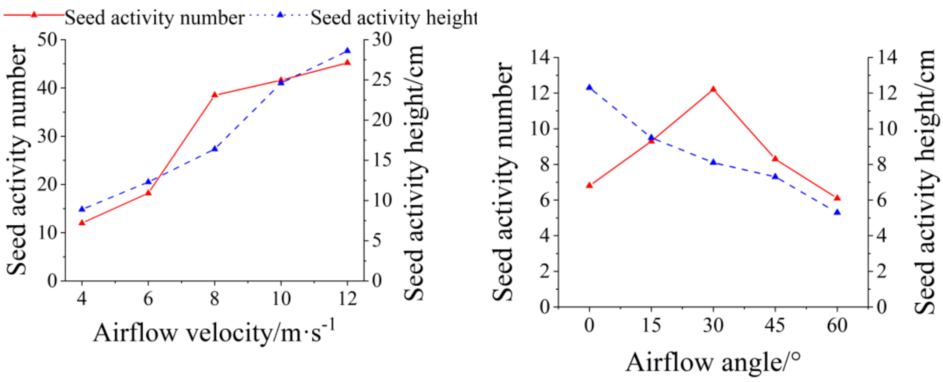
a.Flat surface perpendicular to airflow b.Flat surface incline to airflow c.Flat surface parallel to airflow

Fig. 8. Posture variation of flat seeds in air suspension test

The results of the one-way test for airflow velocity are shown in Fig. 9, where the number and height of boiling seeds showed an increasing trend as the airflow velocity increased. The minimum number of boiling watermelon seeds was 12, and the minimum height was 8.9 cm at an air velocity of 4 m/s. The maximum number of boiling watermelon seeds was 45, and the maximum height was 28.6 cm at an air velocity of 12 m/s. The maximum rise in the number of boiling watermelon seeds was 20 at air velocities of 6-8 m/s. The watermelon seeds had the fastest increase in boiling height of 8.2cm at airflow speeds of 8-10m/s.

Considering that a degree of seed boiling that is too high would affect the seeds adsorbed at the suction holes, an airflow rate of 5 m/s was chosen for the one-way test of airflow angle. With the increase of airflow angle, the number of boiling seeds tended to increase and then decrease; the number of boiling seeds was twelve at the airflow angle of 30°, and the number of boiling seeds was six at the airflow angle of 60°. The boiling height of seeds showed a decreasing trend with the increase of airflow angle; the maximum boiling height of seeds was 12.3cm at the airflow angle of 0°, and the minimum boiling height of seeds was 5.3cm at the airflow angle of 60°.

When the airflow angle is unchanged, with the gradual increase in airflow speed, the watermelon seed boiling number and height of the increasing trend; when the airflow speed reaches the maximum, the highest degree of seed boiling; when the air velocity is unchanged, with the increase of airflow angle, the height value of seed boiling gradually decreased, the number of seed boiling was first increased and then reduced, the reason is that when the airflow angle is greater than 30°, the seeds follow the airflow trajectory deflection angle is more extensive so that the number of seed boiling is reduced.



a.The influence of airflow velocity on seed boiling intensity   b.The influence of airflow angle on seed boiling intensity

Fig. 9. Effect of disturbing airflow on seed boiling intensity

Combined with the experimental observation, because the morphological characteristics of watermelon seeds have apparent differences, the movement trajectory of the seeds and their attitude flip with the increase in the airflow angle changes significantly. When the airflow angle is 0-30°, the watermelon seeds are blown to the inner wall of the pipeline in the process of turning over many times with the pipeline wall; in the process of increasing the airflow angle, the number of times the seeds are blown to the wall in the process of turning over decreased and the number of times the flat surface of the seeds and the wall are attached to the increase, which improves the success of parallel adsorption of the watermelon seeds. When the angle of the airflow is greater than 30°, the number of times that the flat surface of the seed bounces back after being attached to the wall increases, and it cannot maintain a stable state.

3.2 Fluid simulation results and analysis

The pressure change at the center of suction holes is investigated by taking the airflow angle of disturbing species as a factor. The simulation results are shown in Fig. 10, under the condition of different airflow angles, the negative pressure value at each suction hole is different, and the negative pressure value shows a trend of decreasing, then increasing, then decreasing, and finally growing.

Under different factors, the suction hole pressure of numbers 4-8 is greater than that of other numbers, which is because when the airflow is blown to the seed supply chamber, it first passes through the suction holes of numbers 4-8, which obviously improves the negative pressure at the suction holes, then the airflow passes through the suction holes of number 13 and 14, and then passes through the suction holes of number 1-3, and the airflow is constantly dissipated in the process, and the value of the negative pressure at the suction holes is gradually decreasing. No. 9-12 suction hole negative pressure value changes are not significant, maintained at about 1.9kPa; the reason is that the seed blocking plate isolates the direction of movement of the airflow, so that No. 9-12 suction hole air pressure changes are not noticeable.

In order to clarify the impact of airflow angle on the negative pressure of the suction hole in the seed-filling area, an analysis was conducted on the negative pressure value of the 5th suction hole relative to the center position of the air-blowing pipeline mouth. As the airflow angle increases, the negative pressure value at the center of the No. 5 suction hole shows a tendency to increase first and then reduce later; when the angle of the airflow is 30 °, the negative pressure value is the maximum of 2.26kPa, and when the angle of the airflow is 0 °, the negative pressure value is the minimum of 2.11kPa.Compared with no disturbance of the airflow, the negative pressure value is increased by 0.38kPa and 0.23kPa, respectively, and the simulation test proves that the airflow disturbance significantly affects the negative pressure value of the suction holes in the seed filling area.

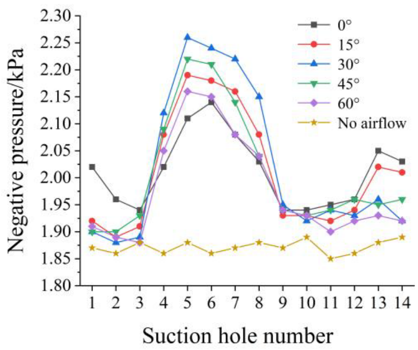


Fig .10. Negative pressure of suction holes in each range of chamber

Observe the distribution of pressure and velocity of the flow field inside the No. 5 suction hole, analyze the reasons for the change of the negative pressure value of the flow field, and make a cross-sectional flow field trace diagram, as shown in Fig. 11, the traditional air-suction seed metering device (Fig. a) suction hole to obtain the source of the airflow is only the seed inlet, the seed supply chamber produces a giant vortex, and the airflow resistance is considerable. When the use of air-blowing disturbance seed supply and seed discharge system for the bottom of the seed supply chamber into the airflow, suction holes to obtain the source of airflow for the seed inlet and air-blowing air inlet, when the angle of the airflow for the 0-30 °, with the increase in the angle of the flow field trajectory, is more and more smooth. When the angle is 30°, the vortex generated inside the seed supply chamber is smaller, and the utilization of airflow is more reasonable. The vortex range gradually increases when the angle is greater than 30 ° and the flow field trajectory is more complex.

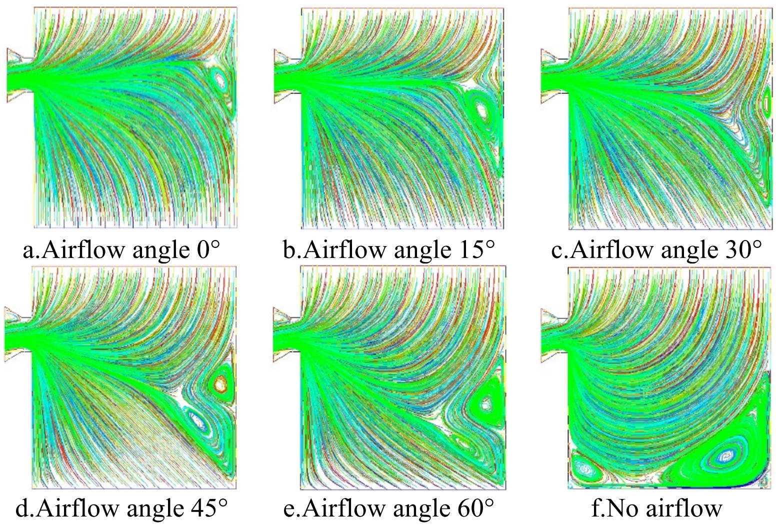


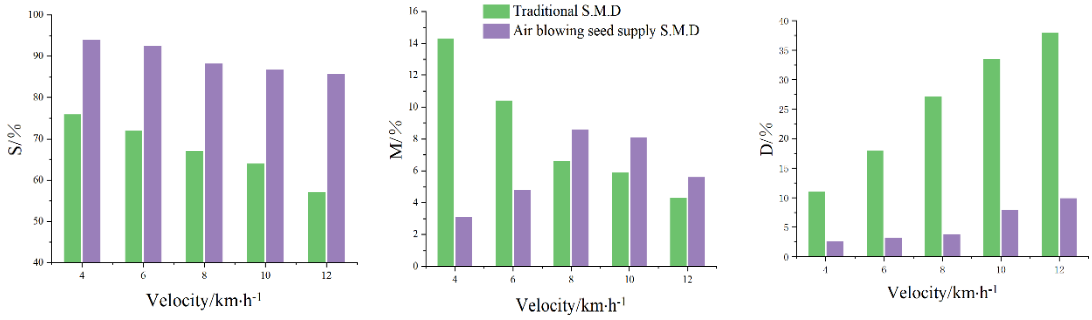
Fig. 11. Effect of airflow angle on the flow field inside the seed supply room and the suction hole

3.3 Analysis of prototype experimental results

The test results are shown in Figure 12. The single-grain adsorption rate of the two seed metering devices decreases gradually with the increase in speed. The single-grain adsorption rate of the air-suction seed metering device for air blowing is significantly better than that of the traditional air-suction seed metering device, and the difference is gradually increasing. At 4km/h, the single-grain adsorption rate of the two kinds of plates was the highest, 75.46% for the traditional air-suction seed metering device and 94.43% for the air-blown seed metering device, and the single-grain adsorption rate of the two kinds of plates was the lowest at 12km/h, 56.61% for the traditional air-suction seed metering device and 85.32% for the air-blown seed metering device. From 4 to 12km/h, the single-grain adsorption rate decreased by 18.85 percentage points for the traditional air-suction seed metering device and 9.11 percentage points for the air-blown seed metering device. The single-grain adsorption rate of the air-suction seed metering device increased by 18.97-28.81 percentage points at each speed level compared with that of the conventional air-suction seed metering device.

The reabsorption rate of traditional air-suction seed metering device decreases gradually with the increase of speed, while the air-suction seed metering device shows a trend of increasing and then reducing; the reason is that when the speed is lower, due to the influence of air-blowing airflow, making the seeds in the vicinity of the suction holes are more discrete, the chances of absorbing the seeds are greatly improved, so that the reabsorption rate is increased; when the speed is higher, the seeds are subjected to the centrifugal force is gradually increased, resulting in the chances of absorbing the seeds are progressively reduced. At 4km/h, the traditional air-suction seed metering device has the highest resorption rate of 14.32%, and at 12km/h, the lowest resorption rate is 4.24%, which reduces the resorption rate from 4 to 12km/h by 10.08 percentage points. The air-suction seed metering device had the highest resorption rate of 8.32% at 8km/h and the lowest resorption rate of 3.12% at 4km/h.

With the increase in speed, the leakage rate of both seed metering devices showed a gradually increasing trend, and the traditional air-suction seed metering device had a significantly higher leakage rate than the air-blown seed metering device at all speed levels. At 4km/h, the leakage rate of the two seed metering devices was the lowest, with 10.22% for the traditional air-suction seed metering device and 2.45% for the air-blown seed metering device; at 12km/h, the leakage rate of the two seed metering devices was the highest, with 39.25% for the traditional air-suction seed metering device and 9.32% for the air-blown seed metering device. From 4 to 12km/h, the leakage rate of the conventional air-suction seed metering device increased by 29.03 percentage points, and the air-suction seed metering device increased by 6.87 percentage points. The leakage rate of the air-suction seed metering device was reduced by 7.77-29.93 percentage points at each speed level compared to the conventional air-suction seed metering device.



a.The influence of speed on single particle adsorption rate

b.The influence of speed on reabsorption rate

c.The influence of speed on leakage rate

Fig. 12. Effect of velocity on seed filling performance of watermelon seeds

Through the watermelon seed filling performance test, the air-blowing seed supply air-suction seed metering device seed filling performance is significantly better than the traditional air-suction seed metering device.

With the increase in speed, the parallel adsorption rate of both the traditional air-suction seed metering device and the air-blown seed supply air-suction seed metering device for sowing watermelon showed a gradual decrease, and the test results are shown in Figure 13.

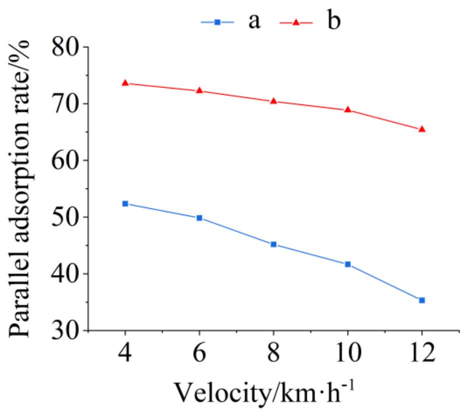


Fig. 13. Adsorption properties of various seeding plate

At 4~12km/h, the parallel adsorption rate of air-blowing disturbance seed supplying air-suction seed metering device (b) was significantly higher than that of traditional air-suction seed metering device (a), and the parallel adsorption rate of all kinds of plates was the highest at 4km/h, which was 52.36% for the traditional air-suction seed metering device and 73.56% for the air-blowing disturbance seed supplying air-suction seed metering device. At 12km/h, the lowest parallel adsorption rate was observed at 35.32% for conventional air-suction seed metering device and 65.41% for air-blown seed supply air-suction seed metering device. At all speeds, the parallel adsorption rate of the air-suction seed metering device increased by 21.20 to 30.09 percentage points compared to the conventional air-suction seed metering device.

4 Conclusions

(1) An air-blowing disturbance seed metering device was designed to improve the air-suction seed metering device for watermelon seed-taking performance. Firstly, the structure of the air-blowing disturbance feeding and suction seeder must be created. The diameter of the seeding plate was determined to be 245mm, the diameter of the suction hole was 5mm, and the number of suction holes was 14.

(2) The influence of the angle of air-blowing disturbance and airflow velocity on the seed adsorption attitude is clarified by analyzing the seed-filling process. Simulate and analyze the positive and negative pressure composite flow field using Fluent software, and conduct seed-filling performance comparison tests between the physical prototype of the air-blowing disturbance feeding and suction seeder and the traditional seeder. Through the simulation of the airflow field, when the airflow speed is 5m/s, and the airflow angle is 30°, the suction hole adsorption force is the largest, and the trajectory of the flow field is the best.

(3) Through the watermelon seed filling performance comparison test, we obtained that the single grain adsorption rate of watermelon seed increased by 18.97~28.81 percentage points at each speed level, and the leakage rate decreased by 7.77~29.93 percentage points. The test shows that the seed-filling performance of air-blown seed supply air-suction seed metering device is better than that of traditional air-suction seed metering device.

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