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Working Process Analysis and Parameter Optimization of Millet Hill-Drop Seed Metering Device

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Abstract: Due to the small size, light weight, and impurities of millet, the existing seeders have poor quality when sowing millet, this study analyzed the working process of the pneumatic-mechanical combined seed metering device, established the equations of seed movement in the seed filling zone, seed cleaning up zone, seed carrying zone and seed dropping zone by dynamic theory. The theoretical factors affecting the sowing quality were clarified in order to improve the sowing effect of the millet hole sower. Vacuum degree, suction hole diameter, and hole wheel rotational speed served as the test factors, and qualifying rate, reseeding rate, and missing rate served as the evaluation indices in a three-factor, three-level orthogonal test. Better parameter combination is obtained through range and variance analysis: Vacuum degree is 2.0 kPa, suction hole diameter is 1.0 mm and rotating speed of hole wheel is 20 r/min. Verification tests were performed to ensure that the pass rate is 93.9%, reseeding rate is 3.1% and the missing rate is 3.0%, meeting the criteria for millet hole sowing. The results of this study can be promoted and applied in the research and development of millet hole sowing seeders.

Keywords: Millet, Seed-Metering Device, Parameter Optimization

Introduction

Broadcast sowing and drill sowing were the two main traditional millet sowing techniques used in China. Both of these techniques had a number of problems, including high sowing rates, heavy fertilizer and water applications that significantly raise input costs (Shujuan *et al*., 2021; Cui *et al*., 2016). Hill-drop technology was a cutting-edge crop planting technique that modifies the traditional drill seeding and accumulation operation mode, precisely regulated seed seeding amount, seed spacing, and uniformity of field distribution, not only lower input cost but also eliminates the need for thinning after seedlings emerge (Zhang *et al*., 2017; Hou *et al*., 2017). However, the existing millet hill seeders were still unable to fully adapt to the hill-drop planting method for millet because the millet seeds were small in size, light in weight and they also contained impurities (Li *et al*., 2021).

Due to the limited millet planting areas abroad, research on millet hill-seeder is scarce (Chen *et al*., 2021; Li *et al*., 2019; Yang *et al*., 2021). For millet, numerous types of hill-drops sowing and seed metering systems had been created in accordance with agronomic needs; these devices can be classified as pneumatic or mechanical in terms of their operating principles (Qinghui *et al*., 2020; Wenqing *et al*., 2019). The mechanical seed metering system has a straightforward design, it has issues with seed damage and limited adaptability to various seeds. The pneumatic seed metering device has a complex structure and is prone to easy hole plugging despite having good adaptability to seeds and minimal seed damage. Wang *et al*. (2017) improved the suction hole structure of the seed metering plate of the air suction millet hole seeder, but the suction hole will still be blocked to a certain extent; (Lv, 2016) added a hole suction air cleaning equipment to the air suction millet hole seeder, the problems of hole obstruction and poor seed uniformity are solved, but single grain rate of millet is high. Wang (2020) designed a slant gravity seed cleaning hole type millet precision metering device, which realized the purpose of relying on gravity seed cleaning without a seed cleaning brush. There is no sliding contact with

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other parts, which not only simplifies the structure but also further reduces the seed crushing rate (Bian *et al*., 2007). Although Hill-drop sowing of millet had improved somewhat as a result of pertinent studies, there were still some issues such as hole plugging, uneven seed distribution, and low seed fill rates when seed trays rotated quickly.

The combination of positive-negative air pressure and hole wheel millet hole sowing seeder is designed by our research team and is used in conjunction with a positive and negative air pressure integrated fan. The negative pressure chamber is connected to the inlet end of the fan and the positive pressure nozzle is connected to the outlet of the fan. The principles of negative pressure-assisted seed filling and positive pressure forced seed feeding are used to effectively solve the above problems. Multiple such seed-sowing devices can be installed on the seed-planting machine at the same time for precise seeding in multiple rows in the millet planting area. However, the influencing factors of seeding performance are not yet clear, affecting the processing of factories and the use of farmers.

In order to determine the theoretical factors that affect seeding performance and the processing and usage parameters of the seeder, this study conducted a theoretical analysis of the working process of the seeder and obtained the optimal parameter combination of the seeder through orthogonal experiments. This study provides guidance for the processing and production of seed metering devices in factories and their use by farmers.

Structure and Working Principle of Seed Metering Device

The structure of the seed metering device is shown in (Fig. 1). It primarily consists of the seed box, shell, negative pressure chamber, hole wheel, seed protection board, seed cleaning up brush, drive shaft, and positive pressure nozzle.

When working, the seeds in the seed box fill into the hole relying on gravity and the suction produced by the negative pressure chamber at the suction hole; the seeds in the hole rotate Counter Clockwise with the hole wheel to get to the seed cleaning up area. The seeds outside the hole are cleaned up by friction produced by clean up brush; In the seed carrying area, the seeds continue to rotate Counter Clockwise with the hole wheel under the protection of the seed protection board and suction to reach the seed dropping area; In the seed dropping area, the seeds break away from the hole and fall into the soil rely on their own gravity and the positive pressure blowing force generated by the positive pressure nozzle.

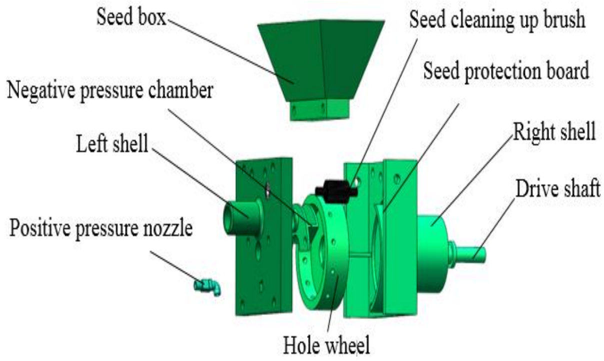

Fig. 1: Structure diagram of seed metering device

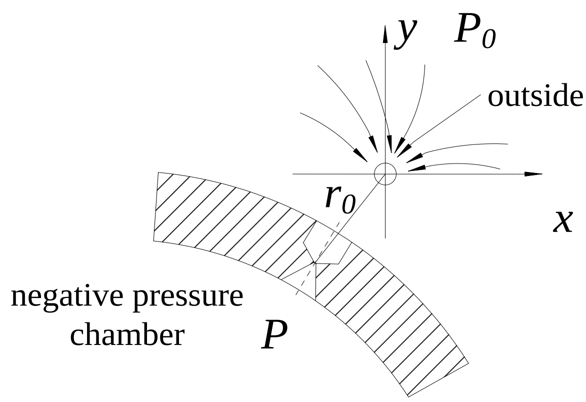

Fig. 2: Diagram of force of seed in fluid

Analysis of the Working Process of Seed Metering Device

Mechanical Analysis of Seed Filling Process

It is possible to separate the seed-filling process into two parts (Bian *et al*., 2007). In the first stage, the seed is propelled by gravity and attracted to the orifice wheel's outer wall. In the second stage, the seed is inserted into the hole and rotates alongside the hole wheel.

Stress Analysis of Seeds in Flow Field

The air in the hole will be completely sucked out during seed filling by the negative pressure chamber located inside the hole wheel in the seed filling area. The specific pressure difference is created close to the molded hole, which disrupts the airflow and results in the presence of a flow field. Determine the elements that affect the airflow forces that seeds are subjected to by using a single grain of millet as the study object and analyzing the force of the airflow on the seed in the flow field. The stress of seeds in the flow field is shown in (Fig. 2).

$$\begin{cases} P_0 - P = \frac{1}{2}v_0^2 \\ v_0^2 = \frac{S}{4}\left[\frac{-6r_0}{(l_0^2+r_0^2)^2} + \frac{8r_0^3}{(l_0^2+r_0^2)^3} + 2(l_0^2+r_0^2)^{-\frac{3}{2}}\right] \\ S = (c_1 - c_2)\frac{2q}{\pi R_a} \end{cases} \quad (1)$$

where, v_0 is the airflow velocity, m/s; r_0 is the distance between the seed center and the suction hole, m; S is the effective adsorption area, m^2; l_0 is the lateral distance of the offset between the seed and the suction hole center, *m*; q is the airflow, m^3/s; *Ra* is the suction hole radius, *m*; C_1 is a constant and decreases with q increasing; C_2 is a constant, taken as 0.2~0.3.

The calculation method of airflow field force is shown in Formula 2:

$$F_P = \iint_s (P_0 - P)ds = \int_0^{2\pi}\int_0^r \frac{1}{2}\rho\frac{S^2}{2} \cdot \left[\frac{-3r_0}{(r^2+r_0^2)^2} + \frac{4r_0^3}{(r^2+r_0^2)^3} + (r^2+r_0^2)^{-\frac{3}{2}}\right] RdRdq \quad (2)$$

where, r is the radius of millet seed, mm; R is the radius of the section where the seeds are subjected to the airflow force; ρ Is the air density, kg/m^3.

The calculation formula of airflow through a single hole is shown in Formula 3.

$$q = \frac{\pi d_0^2}{4}\sqrt{\frac{2\Delta P}{\rho\xi}} \quad (3)$$

where, d_0 is the diameter of the suction hole, mm; ΔP is the vacuum degree in the hole, *Pa*; ξ is the drag coefficient of the hole.

The force acting on the millet seeds is integrated into the plane and the projection of millet seeds onto the plane is simplified as a sphere. Formula 4 shows how Formula 3 is used to determine the force F_P on the seed in the flow field.

$$F_P = (c_1 - c_2)^2\frac{\pi d_0{}^2 \Delta P}{8\xi} \cdot \left[\frac{3r_0}{r^2+r_0^2} - \frac{2r_0^3}{(r^2+r_0^2)^2} - \frac{1}{\sqrt{r^2+r_0^2}} + \frac{1}{r_0}\right] \quad (4)$$

The filling effect is influenced by the airflow force of the seeds in the flow field. According to formula 4, the suction hole diameter d_0, the vacuum degree in the hole ΔP and the distance from the seed center to the hole length r_0 all have an influence on the airflow force F_P of seeds in the flow field. The primary parameters affecting the air force on seeds are the diameter of the hole and the vacuum degree in the hole because the seeds in the seed box are close to the outer wall of the hole wheel.

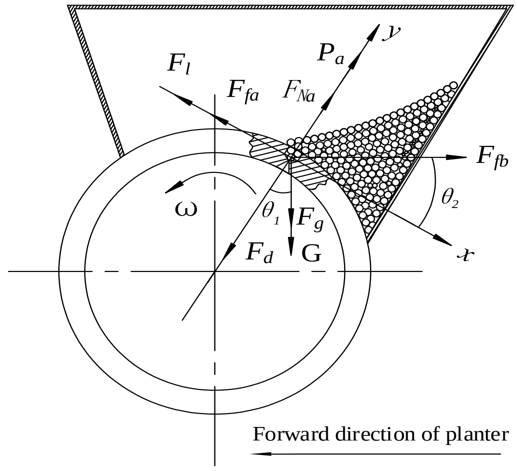

Fig. 3: Stress diagram of the seed adsorption stage

Mechanical Analysis of Seed Adsorption Process

The resultant force acting on the seed acts on the seed centroid and a consistent flow of air is provided in the negative pressure chamber. The action of gravity and suction makes the seed rotate with the hole wheel during the seed-filling stage. Creating a plane rectangular coordinate system, using the tangent line as the X-axis and the radial direction of the special-shaped hole wheel as the Y-axis, and then assessing the force acting on the seed throughout the adsorption process. The force and movement of seeds in this process are shown in (Fig. 3).

$$\begin{cases} F_d + mg\cos\theta_1 - F_{Na} - P_a - F_{fb}\sin\theta_2 = 0 \\ F_l + F_{fa} - mg\sin\theta_1 - F_{fb}\cos\theta_2 = 0 \\ F_{fa} = F_{Na}\tan\varphi_1 \\ F_{fb} = F_g\tan\varphi_2 \\ p_a = m\omega^2 R \\ \omega = \frac{\pi n_p}{30} \end{cases} \quad (5)$$

where, F_d is the resistance of airflow at the suction hole to flow around millet seed, *N*; F_l is the lift force of airflow around the suction hole on millet seeds, *N*; F_{fa} is the friction force of shaped hole wheel on seed, *N*; F_{fb} is the friction between seeds, *N*; F_{Na} is the supporting force of hole wheel on seed, *N*; F_g is seed group pressure, *N*; φ_1 is the friction Angle between millet seed and shaped hole wheel, (°); φ_2 is the internal friction Angle of millet seed, (°); θ_1 is the Angle between gravity and Y-axis direction, (°); θ_2 is the Angle between F_{fb} and X-axis direction, (°); m is the mass of millet seed, kg; R is the radius of the hole wheel, *m*; P_a is the centrifugal force, *N*; ω is the angular velocity of shaped hole wheel, rad/s; n_p is the rotational speed of hole wheel, r/min:

$$\begin{cases} F_l = \dfrac{1}{2} C_l \rho v_a^2 S_D \\ F_d = \dfrac{1}{2} C_d \rho v_a^2 S_D \\ S_D = \dfrac{\pi d_1^2}{4} \\ \xi = \dfrac{2\Delta P}{\rho v_a^2} \end{cases} \tag{6}$$

$$\Delta P = \frac{4\xi}{\pi d_1^2 (C_d - C_l)} \cdot \left[\frac{m_0 \pi^2 n_p^2 R}{900} - \frac{F_{Na} \sin(\varphi_2 - \theta_1 - \varphi_1)}{\cos\varphi_1 \sin(\varphi_2 - \theta_2)} + \frac{m_0 g \sin(\theta_1 + \theta_2 - \varphi_1)}{\sin(\varphi_2 - \theta_1)} \right] \tag{7}$$

Formula 7 shows that during the seed adsorption process, the vacuum degree is influenced by the speed of the hole wheel, angles of internal friction, the mass of seeds, and angle of filling under the condition that the seed is adsorbed successfully, the higher the rotary speed of the hole wheel, the greater the vacuum degree required. The set forward speed of the seeder is 2-6 km/h, which means the angular velocity of the hole wheel is 2.1-6.3 rad/s, The One thousand grains mass of millet seed is 2.5 g, φ_1 is 25.3°, φ_2 is 21.1°, Set θ_1 is 30°, θ_2 is 40°. The vacuum degree needed for the seed metering device is 1.13-3.21 kPa, according to the calculation. The vacuum degree ranges from 1.5-3.5 kPa in the performance test of the seed metering apparatus due to the complexity of the conditions of the seeding device in actual sowing processes.

Analysis of Seed Cleaning Up Process

The seed cleaning up brush applies external force to the seeds during this stage. It is important to ensure that the seeds inside the formed hole are not removed by the brush during contact with the brush and that the seeds' gravity is ignored. The force of seeds in the seed-clearing stage is shown in (Fig. 4).

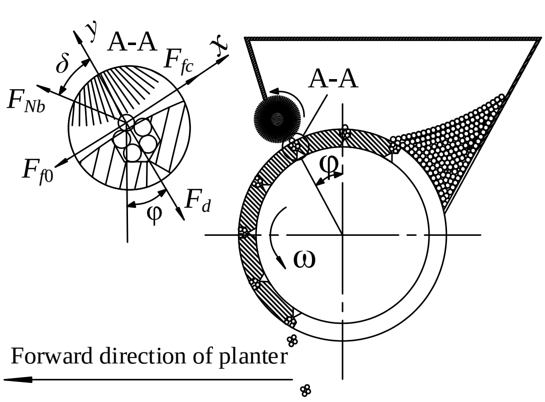

Fig. 4: Seed force diagram in seed clearing up the stage

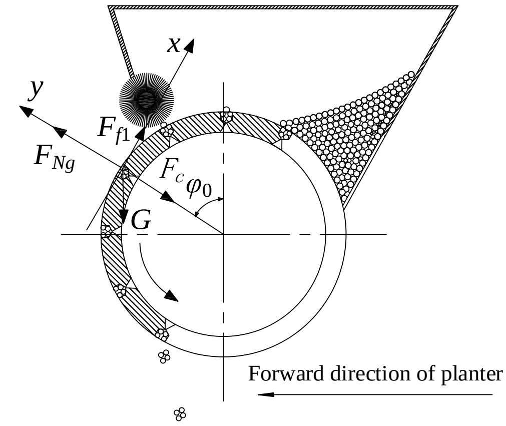

Fig. 5: Seed force diagram at carrying process

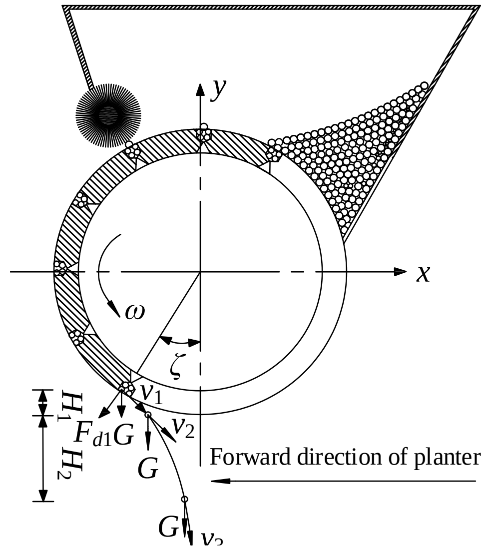

Fig. 6: Movement analysis diagram of millet seed at seed dropping stage

$$\begin{cases} \sum F_x = F_{fc} - F_{f0} - F_{Nb} \sin\delta = 0 \\ \sum F_y = F_d - F_{Nb} \cos\delta = 0 \end{cases} \tag{8}$$

According to the formula:

$$F_d = (F_{fc} - F_{f0}) \cot\delta \tag{9}$$

where, F_{fc} is the friction force between the seed cleaning brush and the seed, *N*; F_{Nb} is the support force of the hole to the seed in the seed cleaning up stage, *N*; δ is the angle between F_{Nb} and y-axis, (°).

According to Formula 9, in the seed cleaning up stage, the adsorption force F_d of the hole on the seed is inversely proportional to Angle δ, so Angle δ can be increased by increasing the diameter of the outer edge of the typed hole to reduce the adsorption force F_d required in this stage.

Analysis of Seed Carrying Process

In the stage of seed carrying, seeds move with the hole wheel, and the air resistance is ignored. The force of seeds in this stage is shown in (Fig. 5).

The force equation of the seed is as follows:

$$\begin{cases} \sum F_x = mg\,sin\,\varphi_0 - F_{f0} = 0 \\ \sum F_y = F_c + mg\,cos\,\varphi_0 - F_{Ng} = m\omega^2 R \\ v = \omega R \end{cases} \tag{10}$$

where, φ_0 is the adsorption angle, (°); F_{f0} is the friction force between the type hole wheel and the seed in the seed carrying stage, *N*; *Fc* is the adsorption capacity of pores on seeds at seed protection stage, *N*; F_{Ng} is the supporting force of the hole on the seed in the seed carrying stage.

The following equation can be obtained through calculation:

$$F_c = m\frac{v^2}{R} + F_{Ng} - F_{f1}\,cot\,\varphi_0 \tag{11}$$

Eq. 11 shows that the adsorption force F_c of the suction hole for seeds has a negative correlation with the radius of the shaped hole wheel and has a positive correlation with the linear velocity on the surface of the hole wheel at the seed-carrying stage.

Analysis of Seed Dropping Process

The final stage in the process of the seed metering device is seed dropping, which includes taking the seeds from the seed metering device and separating them from the hole to the soil. The consistent and constant separation of seeds from the hole during seed dropping is essential, as it slows down the initial speed at which seeds leave the seed metering device. When the beginning speed is too high, seed metering and hole formation are less likely to be uniform. As a result, it's important to establish the seed's motion equation when it is dropped. During the seed-dropping stage, the seed is subject to the dual actions of its own gravity and the positive pressure-blowing force of the seed-dropping nozzle. The force on the seed during this process is shown in (Fig. 6).

There are two different periods in the stage of seed dropping: When seeds leave the hole wheels in the first period (t_1), they fall to a height of *H*, where they are affected by gravity and a positive pressure blowing force; In the second period (t_2) when seeds fall to a height of H_2, they are only affected by their own gravity. For analysis, the force process should be made simpler. Assuming that t_1 is a fixed value and the positive pressure blowing force F_{d1} of seeds is constant. The air resistance of the seed is negligible.

The equation can be obtained by analyzing the force on the seeds at time t_1 and t_2:

$$\begin{cases} \sum F_{x1} = F_d \cos\zeta \\ \sum F_{x2} = G + F_d \sin\zeta \end{cases} \tag{12}$$

$$\begin{cases} \sum F_{x2} = 0 \\ \sum F_{y2} = G \end{cases} \tag{13}$$

The movement of seeds at time t_1 and t_2 is analyzed and equations are obtained:

$$\begin{cases} v_{2x} = v_p \sin\zeta - \dfrac{t_1 \sum F_{x1}}{m} \\ v_{2y} = v_p \cos\zeta + \dfrac{t_1 \sum F_{y1}}{m} \end{cases} \tag{14}$$

$$\begin{cases} v_{3x} = v_{2x} \\ v_{3y}^2 - v_{2y}^2 = \dfrac{2H_2 \sum F_{y2}}{m} \end{cases} \tag{15}$$

It can be known from Eqs. 14-15:

$$\begin{cases} v_{2x} = v_p \sin\zeta - \dfrac{t_1 F_d \cos\zeta}{m} \\ v_{2y} = v_p \cos\zeta + \dfrac{G t_1 + t_1 F_d \sin\zeta}{m} \end{cases} \tag{16}$$

$$\begin{cases} v_{3x} = v_p \sin\zeta - \dfrac{t_1 F_d \cos\zeta}{m} \\ v_{3y} = \sqrt{2gH_2 + (v_p \cos\zeta + \dfrac{G t_1 + t_1 F_d \sin\zeta}{m})^2} \end{cases} \tag{17}$$

where, F_{d1} is the positive pressure blowing force of seeding air nozzle on millet seed, *N*; v_{2x} is the horizontal fractional velocity of millet seeds in t_1 period, m/s; ζ is casting angle, take 60°; v_{2y} is the vertical fractional velocity of millet seeds in t_1 period, m/s; v_{3x} is the horizontal fractional velocity of millet seeds in t_2 period, m/s; v_{3y} is the vertical fractional velocity of millet seeds in t_2 period, m/s.

Equation 17 shows that the linear velocity v_p on the surface of the hole wheel is proportional to the values of v_{3x} and v_{3y}. The surface linear velocity v_p of the hole wheel should not be too fast in order to slow down the contact speed of the seeds as they fall. It should not be too slow to ensure that the horizontal fractional velocity v_{3x} of the seed is positive.

Materials and Methods

Test Plan

Vacuum level, suction hole diameter, and shaped hole wheel rotation speed are used as test variables. Do the orthogonal test of three factors and three levels. The test's factor levels are shown in (Table 1). The test is designed using the L_9 (3^4) orthogonal table and it requires nine sets of tests, with each set being run three times. The average is calculated to determine the test's final result.

Test Results

The test results are shown in (Table 2). To determine the impact of each experimental element on the evaluation index, range and variance analysis is used. The results of variance analysis are shown in (Table 3) and the results of range analysis are shown in (Table 4).

According to the results of variance analysis, vacuum degree has a significant effect on the reseeding rate, it has a very significant effect on qualified rate and missing rate.

The diameter of the suction hole has a significant influence on the qualified rate and reseeding rate. It has no significant effect on the missing rate. The rotation speed of the hole wheel has a very significant effect on the reseeding rate, it has a significant effect on the qualified rate and missing rate The findings of the range analysis show that the larger the range value, the more effect experimental elements have on the evaluation index. The influence of factors on the qualified rate and missing rate is in the order of A, C, and B. That means the diameter of the hole and vacuum degree have the biggest effects on the qualified rate and missing rate, while the rotation speed of the hole wheel has the littlest effect. For the reseeding rate, the influence of factors on it is in the order of C, A and B. That is, the rotation speed of the hole wheel has the greatest influence on the replay rate, followed by the vacuum degree and the diameter of the hole has the least influence on the reseeding rate. The optimal parameter combination of the qualified rate and missing rate is $A_3B_2C_2$ and the optimal parameter combination of reseeding rate is $A_1B_1C_2$. To ensure the emergence rate of millet, the qualified rate and missing seeding rate should be considered first, to keep the higher qualified rate and lower missing seeding rate. In conclusion, $A_3B_2C_2$ is the greatest combination of parameters for this seed metering device. that means the vacuum degree is 2.0 kPa, the suction hole diameter is 1.0 mm and the rotation speed of the hole wheel is 20 r·min^{-1}.

Table 1: Levels of test factors

Test number	Factors Vacuum degree A/kPa	Suction hole diameter B/mm	Hole wheel speed C/r·min^{-1}
1	1.0	0.8	15
2	1.5	1.0	20
3	2.0	1.2	25

Table 2: Test results

Test number	A	B	Error	C	Qualified rate/%	Reseedin rate/%	Missing rate/%
1	1	1	1	1	82.7	3.5	13.8
2	1	2	2	2	86.5	2.9	10.6
3	1	3	3	3	79.6	3.8	16.6
4	2	1	2	3	87.7	2.7	9.6
5	2	2	3	1	89.6	4.4	6.0
6	2	3	1	2	90.8	3.6	5.6
7	3	1	3	2	93.7	3.0	3.3
8	3	2	1	3	88.2	4.5	7.3
9	3	3	2	1	87.1	5.7	7.2

Table: 3: Results of variance analysis

Evaluation index	Variation	Sum of squares	Freedom	Mean square	F-value	significant
Qualified rate	A	86.816	2	43.408	187.822	**
	B	9.982	2	4.991	21.596	*
	Error	0.462	2	0.231		
	C	9.982	2	21.669	93.755	*
	Entirety	140.596	8			
Reseeding rate	A	1.722	2	0.861	59.615	*
	B	2.629	2	1.314	91.000	*
	Error	0.029	2	0.014		
	C	2.629	2	1.434	99.308	**
	Entirety	7.249	8			
Missing rate	A	104.649	2	52.324	278.651	**
	B	5.042	2	2.521	13.426	
	Error	0.376	2	0.188		
	C	5.042	2	16.361	87.130	*
	Entirety	142.789	8			

Note: $F_{0.05}$ (2,2) =19, $F_{0.01}$(2,2) =99, Fa=(2,2)>$F_{0.01}$(2,2), indicating a very significant effect, represented by "**"; If $F_{0.05}$(2,2) < F_a (2,2) <$F_{0.01}$(2,2), it indicates that there is a significant influence and is represented by"*"

Table 4: Range analysis results

Evaluation index		Vacuum	Suction hole diameter	Error	Hole wheel speed
Qualified rate	K_1	248.8	264.1	261.7	259.4
	K_2	268.1	264.3	261.3	271.0
	K_3	269.0	257.5	262.9	255.5
	Range	20.20	6.8	1.6	15.5
	Primary and secondary order	A>C>B			
	Optimal order combination	$A_3B_2C_2$			
Reseeding rate	K_1	10.2	10.7	11.6	13.6
	K_2	10.7	11.8	11.3	9.5
	K_3	13.2	13.1	11.2	11.0
	Range	3	2.4	0.4	4.1
	Primary and secondary order	C>A>B			
	Optimal order combination	$A_1B_1C_2$			
Missing rate	K_1	41	26.7	26.7	27.0
	K_2	21.2	23.9	27.4	19.5
	K_3	17.8	29.4	25.9	33.5
	Range	23.2	5.5	1.5	14.0
	Primary and secondary order	A>C>B			
	Optimal order combination	$A_3B_2C_2$			

Table 5: Verification test results

Test number	Qualified rate/%	Replay rate/%	Missing rate/%
1	94.3	3.1	2.6
2	94.1	3.0	2.9
3	93.5	3.3	3.2
Average	93.9	3.1	3.0

Test Verification

To verify the reliability of better parameter combinations. Set the vacuum level to 2.0 kPa, the hole wheel's rotating speed to 20 r·min^{-1}, and the hole's diameter to 1.0 mm on the test bench to do the verification test. Repeat the test three times and calculate the average value as the final result. The test results are shown in (Table 5). The average qualification rate is 93.9, the average reseeding rate is 3.1% and the average missing rate is 3.0%, which can meet the requirements of millet hill-drop planting.

Discussion

By analyzing the force and motion of the seed in the working process of the seed metering device, it can be concluded: In the flow field and the seed filling area, the main factors affecting the airflow force of seeds in the flow field are the diameter of hole and the vacuum degree in the mold holes; In the seed cleaning up area, the absorption force of the hole on the seed is determined to be inversely proportional to the angle of seed cleaning up in order to lower the required absorption force at this stage, the angle of seed cleaning up can be raised by increasing the diameter of the hole. In the seed-carrying area, the adsorption force of the hole on the seed is negatively correlated with the radius of the hole wheel and positively correlated with the linear velocity of the hole wheel surface during the seed-carrying stage; In the dropping area, it is concluded that the horizontal and vertical partial velocities during the seed dropping process are proportional to the surface linear velocity of the hole wheel. In order to reduce the contact velocity during the seed falling process, the surface linear velocity of the hole wheel should not be too large; In order to ensure that the seed horizontal velocity is positive, the surface linear velocity of the hole wheel should not be too small.

A three-factor, three-level orthogonal test with vacuum degree, hole diameter, and hole wheel rotational speed as the test factors and qualified rate, reseeding rate, and missing rate as the evaluation indexes are used to determine the performance of the seed metering device and its parameters. According to the findings, the primary factors influencing the qualified and missing rates were vacuum degree, suction hole diameter, and hole wheel rotational speed, while the main factors influencing the reseeding rate were vacuum degree, suction hole diameter, and hole wheel rotational speed. The optimized pneumatic-mechanical combination cereal hole sowing seeder's technical specifications are as follows: Vacuum degree 2.0 kPa, suction hole diameter 1.0 mm, and hole wheel speed 20 r/min. Under these circumstances, the pass rate is 93.9%, the reseeding rate is 3.1%, and the missing rate is 3.0%, all of which are within the agronomic-ally acceptable range for millet hole sowing.

Conclusion

According to theoretical analysis and experimental results, it can be seen that the diameter of the hole, vacuum degree, and the hole wheel speed have important effects on the working performance of the millet hole sowing and metering device. When factories process the seed metering device, the diameter of the hole should be close to 1.0 mm. When farmers use the seed metering device, the vacuum degree should be close to 2.0 kPa and the hole wheel speed should be close to 20 r/min, which can achieve better seeding quality.

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Author's Contributions

Tao Chen: Conceived or designed the study and performed data acquisition and analysis.

Shujuan Yi: Conducted theoretical analysis and experimental design for the study.

Yifei Li: Collected and analyzed data for the study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and that no ethical issues are involved.

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