DESIGN AND TEST OF NEGATIVE PRESSURE CHAMBER ROTARY BUCKWHEAT SEED METERING DEVICE

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气室旋转式荞麦精密排种器的设计与试验

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ABSTRACT

A negative pressure chamber rotary precision seed metering device was designed to achieve the buckwheat precision sowing goal, solving the problems of traditional negative pressure chamber poor sealing and air suction seed metering device high power consumption. The planting plate of the device was fixedly connected with the shell of the air chamber forming a negative pressure chamber, which rotates around an axis. A planting plate suitable for buckwheat seed metering was designed. Single factor test and response surface test were carried out on the seed metering device. Results showed that the buckwheat precision seed metering achieved best performance when the negative pressure, suction hole diameter and rotation speed was 2.4 kPa, 2.0 mm and 25 r/min respectively. The qualified index, multiples index and miss-seeding index were respectively 88.32%, 7.35%, and 4.33%, which met the technical requirements of buckwheat precision sowing. The results of the study provided references for the design and application of buckwheat precision seed metering device.

摘 要

为实现荞麦精量化播种，解决传统气吸式排种器负压气室密封差、功耗较高等问题。设计一种气室旋转式精量排种器，该排种器排种盘与气室后壳固定连接形成负压气室，工作时负压气室绕排种轴旋转，具有转动能耗小、气密性好等特点，并设计了适合于荞麦排种的排种盘。利用该排种器进行台架试验，以合格指数、重播指数、漏播指数为评价指标，气室真空度、排种孔孔径、排种盘转速为试验因素进行单因素试验和响应面试验。结果表明，在排种器气室负压值 2.4kPa、排种盘孔径 2.0mm、排种盘转速 25r/min 的组合下，荞麦精量排种效果较好，单粒精密排种合格指数 88.32%，重播指数 7.35%，漏播指数 4.33%，满足荞麦精量化播种技术要求。本研究可以为荞麦精量化排种器的设计和应用提供参考。

INTRODUCTION

Buckwheat belongs to *Polygonaceae* family, with high nutritional value *(Gim é Nez Bastida, 2015)*, which is widely cultivated all over the world *(Zhou M., 2018).* Buckwheat seeds are small in size, irregular in geometry, difficult to sow, and lack suitable sowing equipment, which seriously restricts the development of buckwheat. At present, buckwheat is still sown manually in most areas of China, which is inefficient. In some areas, the existing bulk crop sowing machines are used for sowing buckwheat, most of which are mechanical seed metering devices. There are some shortcomings such as low precision, easy damage, poor stability and unsuitable for high-speed operation *(Bu Y. et al, 2016; Du W.W. et al, 2016)*. Therefore, it is of great significance to develop a precision seed metering device suitable for buckwheat characteristics to improve the development of buckwheat industry.

Air suction seed metering device is a relatively advanced seed metering device due to its loose requirements on seed size, small seed damage, strong adaptability and high sowing speed *(Weirich N. P. H. et al, 2012; Han D. D. et al, 2018)*. *Nal I. et al* described the mechanism of seed adsorption according to the basic principles of hydrodynamics and seed Aerodynamics *(Nal I. et al, 2014)*. *Yazgi A.* and *Degirmencioglu A.* studied the effect of different number of holes on seed spacing uniformity of air suction metering device *(Yazgi A. and Degirmencioglu A., 2014)*. *Zhang Kaixing et al.* designed a double disk air suction seed metering device with variable particle size. Through the rotary combination of the two disks, the metering plates with different apertures were transformed, which improved the versatility of the metering device

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(*Zhang K. X. et al, 2020*). Kverneland Company has developed a kind of air suction seed metering plate, which is connected with the shell of the chamber to form a negative pressure chamber. While working, the negative pressure chamber rotates synchronously with the seed metering shaft, which can effectively solve the problems of sealing gasket prone to be worn out and the high energy consumption of the seeder.

In the study, the design is further improved on the basis of Kverneland's seed metering device. The planting plate and the shell of air chamber are fixed and connected, and the annular sealing gasket is installed between the planting plate and the negative pressure chamber to further improve the gas tightness of the negative pressure chamber; some other structures and working parameters are also optimized. Meanwhile, a planting plate suitable for buckwheat seed is designed. Finally, bench test was made to find the best working parameters of the buckwheat seed metering device. The study may provide theoretical basis for the design and application of buckwheat precision seed metering device.

MATERIALS AND METHODS

Structure and working principle of seed metering device

- **Structure of seed metering device**

The negative pressure chamber rotary buckwheat seed metering device mainly consists of rear shell, shell of air chamber, air chamber gasket, planting plate, seed-stirring plate, front shell and other parts, as shown in Fig.1. There is a hollow shaft on rear shell used as an air inlet, and the bearing is installed on the shaft. The left side of the planting plate is fixedly connected with the outer ring of the air chamber shell to form a negative pressure chamber. The inner ring of the air chamber shell is fixedly connected with the sprocket wheel, the bearing outer ring is installed in the sprocket and the inner ring is installed on the shaft on the rear shell. The negative pressure chamber is in clearance fit with rear shell and front shell, so that the negative pressure chamber can rotate around the shaft on rear shell. The annular sealing gasket is installed between the planting plate and the annular groove on the air chamber shell to enhance the sealing performance of the negative pressure chamber. The right side of the planting plate is installed with a seed-stirring plate. The front shell includes a feed port and a seed metering port. The front shell, the isolation seed board and the planting plate form a seed chamber.

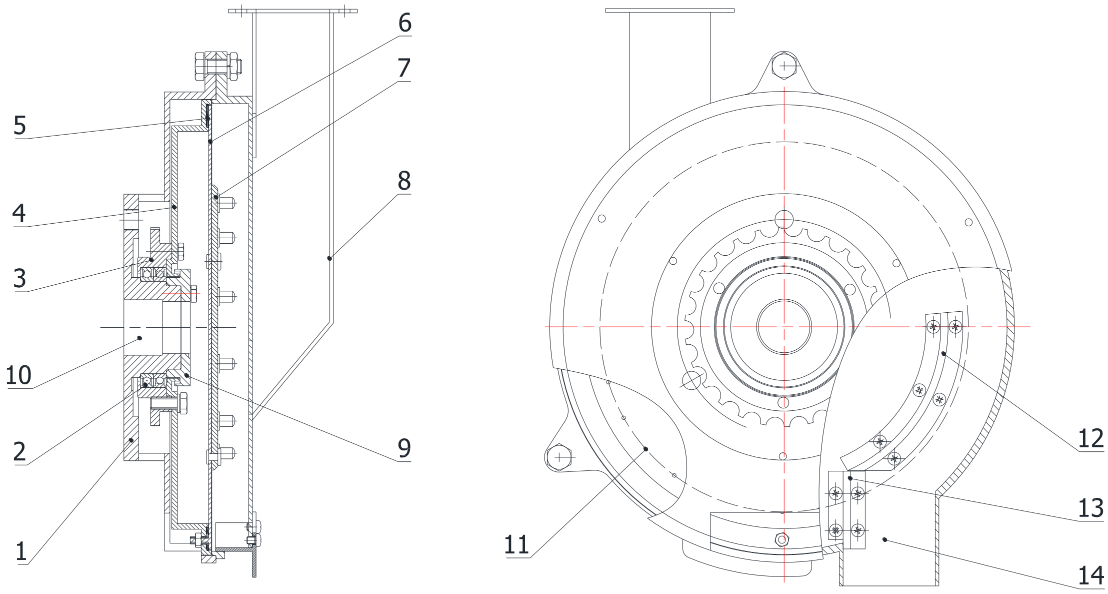


Fig. 1 - Structure diagram of air chamber rotary precision seed metering device

1: Rear shell; 2: Bearing; 3: Sprocket; 4: Air chamber shell; 5: Air chamber gasket; 6: Planting plate; 7: Seed-stirring plate
8: Front shell; 9: End cap; 10: Air inlet; 11: Suction hole; 12 Isolation seed board; 13: Seed unloading board; 14: Seed metering port

- **Working principle of the seed metering device**

When the metering device works, the seeds in the seed box fill the seed chamber through the feeding port. The sprocket drives the negative pressure chamber to rotate and the seeds in the seed chamber are in a discrete state affected by the seed-stirring plate. The negative pressure chamber is connected with the fan through a pipe installed on the air inlet, and a negative pressure is formed in negative pressure chamber under the action of the fan. The seeds are absorbed on the planting plate under the action of negative pressure air flow in the suction hole to complete the seed filling process.

The negative pressure chamber continues to rotate, and the seeds continue to be adsorbed on the planting plate under the action of the negative pressure air flow. When the seed is rotated to the position of seed unloading board, the seed is separated from the planting plate under the action of the seed unloading board, and the seed drops in the seed metering port by its own gravity.

Seed metering device main structure parameters design

- **Design of the buckwheat planting plate**

Planting plate is the core component of seed metering device *(St. Jack D. et al, 2013)*. The parameters of planting pate directly affect the working performance of seed metering device. The main performance parameters include the diameter of planting plate, the number of suction holes, and the diameter of suction holes *(Jia H. L. et al, 2018).*

The larger the diameter of planting plate, more suction holes can be set, which can reduce the linear speed of the planting plate and facilitate the seed adsorption, but the larger the diameter, the larger the overall size and energy consumption of the seed metering device. Considering the working performance and overall size of buckwheat seed metering device, the diameter of planting plate is 200 mm, the thickness is 1.5 mm, and the number of suction holes is 50.

The speed of planting plate directly affects the seeding efficiency and the linear speed of planting plate *(Zeliha Bereket Barut and Aziz Özmerzi, 2004)*. If the rotation speed of the planting plate is too high, the linear speed at the suction hole is large, and it is too short for the suction holes to pass through the seed filling area, or the seeds that have been adsorbed fall due to large collision force, which is easy to cause missing sowing phenomenon. The linear speed of the suction hole on planting plate should not exceed 0.35 m/s.

The rotation speed n_p and the linear speed v_p of planting plate are calculated as follows:

$$n_p = \frac{60 v_m}{SZ} \quad \text{[r/min]} \tag{1}$$

$$v_p = \frac{\pi d_p v_m}{SZ} \quad \text{[m/s]} \tag{2}$$

where: v_m is the operating speed of the seeder (m/s); S is the plant spacing (hole spacing) (m); Z is the number of suction holes on the planting plate; d_p is the diameter of the planting plate (m).

The relevant research shows that, the different planting methods and planting density of buckwheat have no significant difference on the performance value of buckwheat agronomic traits *(Li C.H. et al, 2019)*. At present, there is no specific standard for buckwheat precise planting. According to the planting density of about 700,000 buckwheat plants per hectare, the row spacing is 30 cm and the plant spacing is 4-6 cm. When the forward speed of the seeder is 3.6 km/h, the displacement formula can be used to calculate the row line speed v_p of 0.16 m/s, and the rotation speed of planting plate n_p is 20~30 r/min.

The seed suction hole diameter d is determined by the size of seed.

The empirical formula is as follows:

$$d = (0.64...0.66)b \quad \text{[mm]} \tag{3}$$

where: *b* is the average width of seeds (mm).

Due to the small sphericity of buckwheat seed, the difference of length, width and thickness in triaxial dimension is large. In order to avoid blockage of seed suction hole, the average width is calculated according to the average value of seed thickness. The minimum thickness range of buckwheat seeds of different varieties is about 2.93 ~ 4.32 mm *(Sun J.X. et al, 2018)*.

The diameter of seed suction hole is 1.38 ~ 2.38 mm calculated by the formula (3).

- **Negative pressure chamber design**

The design of negative pressure chamber mainly considers the consistency of vacuum degree and air tightness. The negative pressure chamber is an annular structure, so the negative pressure is uniform and consistent. When the traditional air suction seed metering device works, the air chamber shell is fixed and the planting plate rotates. The continuous friction between the planting plate and the air chamber shell causes high energy consumption and poor working stability. When the designed seed metering device works, the planting plate rotates synchronously with the air chamber shell. The design has the advantages of low energy consumption and low negative pressure requirements.

As shown in Fig.2, the right end face of the air chamber shell is provided with an annular groove, which is used to install the sealing gasket. The planting plate and the air chamber shell are closely matched. A negative pressure chamber with good sealing is formed, which can effectively reduce the Eddy current loss caused by the negative pressure airflow and reduce the negative pressure requirements during the operation of the seed metering device.

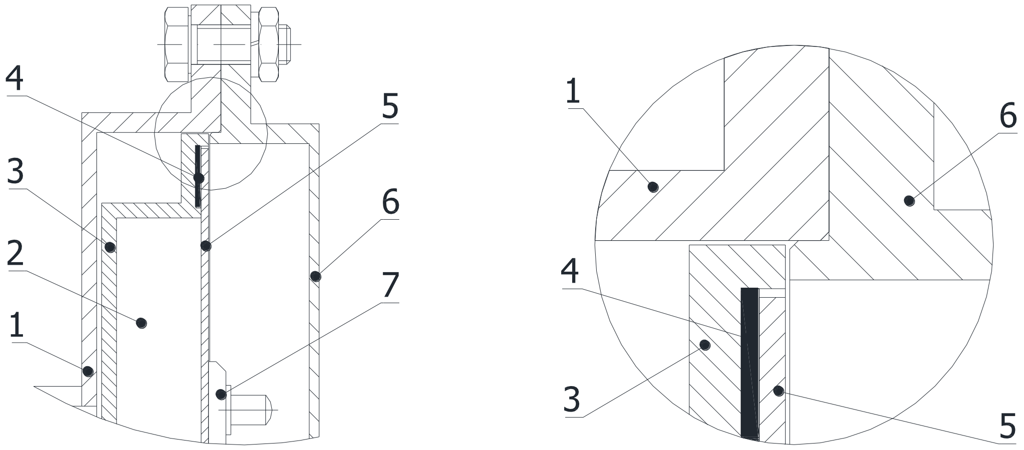


Fig. 2 - Diagram of shell positioning

1-Rear shell; 2- Negative pressure chamber; 3- Air chamber shell; 4- Air chamber gasket; 5- Planting plate; 6- Front shell; 7- Seed-stirring plate

- **Positioning structure design of seed metering device shell**

The position of the seed metering device shell directly affects the stability of the seed metering device. The front shell and the planting plate form the seed chamber through the clearance. Due to the small size of buckwheat seeds, it is particularly important to design the shell positioning reasonably.

As shown in Fig.2, an annular positioning boss is set on the inner wall of the front shell. The front shell positioning boss is closely matched with the right end face and inner surface of the rear shell, so that the positioning of the seed metering device shell is accurate during installation. In addition, there is a 0.5mm gap between the left end face of the front shell boss and the right end face of the air chamber shell, a 0.5mm gap between the inner surface of the rear shell and the outer surface of the air chamber shell, which ensures the chamber shell has no friction with the front and back shells during rotation, and at the same time, the buckwheat seeds cannot be jammed into the gap and damaged.

- **Vacuum degree design of air chamber**

On the air suction seed metering disk rotating in the vertical plane, the stress of the adsorbed seeds is shown in Fig.3. At least the following conditions should be met when a seed is adsorbed by a suction hole:

$$P_0 d / 2 \geq GC \tag{4}$$

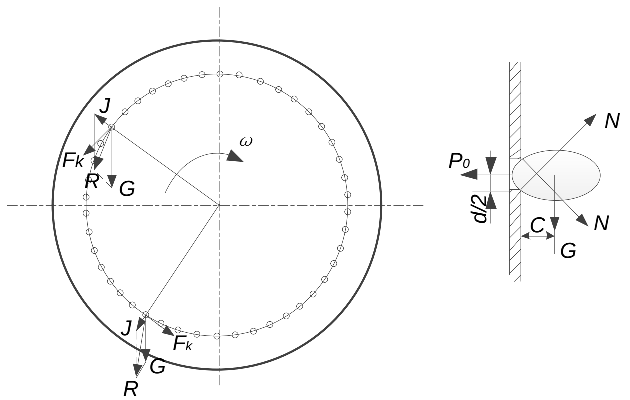


Fig. 3 - Force analysis of seed on suction hole

P_0 – Suction; G - Seed gravity; F_k - Air resistance; J - Centrifugal inertia force; d -Diameter of suction holes; C - The distance between seed barycentre and planting plate

Considering the distribution of seeds in the seed suction area, the collision between seeds, the external environment and the working stability reliability coefficient K_2, the maximum vacuum degree

H_{cmax} required by the negative pressure chamber can be calculated under the maximum limit condition according to the following formula.

$$H_{c\max} = \frac{80K_1K_2mgC}{\pi d^3}\left(1+\frac{v^2}{gr}+\lambda\right) \tag{5}$$

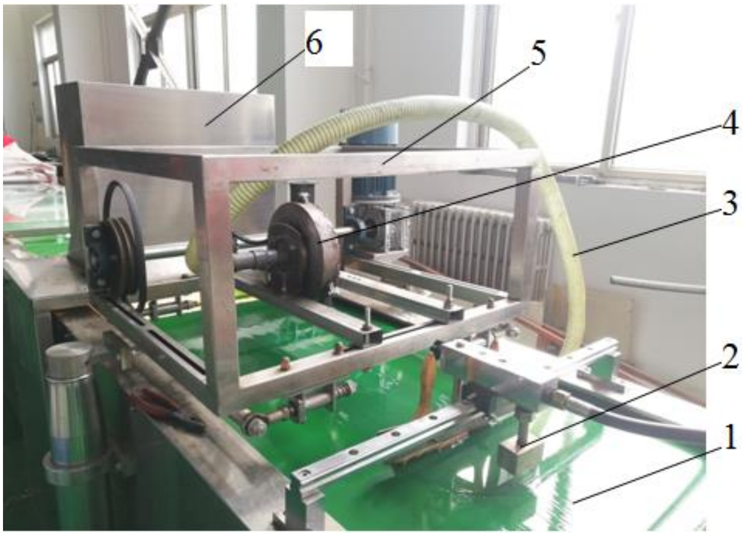
where: m is the mass of a seed (kg); v is the linear velocity at the centre of the suction hole (m/s); r is the rotation radius (m); g is the acceleration of gravity (m/s^2); λ is the comprehensive coefficient of friction resistance of seeds, λ = (6…10) tan θ, θ are the natural repose angle of seeds; K_1 is the reliability coefficient of seed suction, taking 1.8; K_2 is the external condition coefficient, taking 1.8.

Substituting the corresponding data, it can be calculated that the maximum vacuum degree H_{cmax} required by the air suction buckwheat seed metering device is about 3.6 kPa *(Sun J.X. et al, 2018).*

Test and result analysis

- **Test preparation**

Heifeng No.1 Tartary buckwheat seed was selected as the research object. The seed metering device was a designed negative pressure chamber rotary seed metering device. The test equipment was JPS-12 type seed metering device performance test bench developed by Heilongjiang Agricultural Machinery Engineering Research Institute. As shown in Fig.4, during the test, the seed metering device is fixed on the test bench, the sprocket wheel of the seed metering device and the driving shaft of the test bed are driven by chain, and the air inlet is connected with the negative pressure ventilation pipe of the test bench.



(a) Performance test bench of seed metering device

(b) Seeds distribution on seed bed belt

Fig. 4 - Bench test

1-Seed bed belt; 2-Oil nozzle; 3-Suction pipe; 4-Seed metering device; 5-Bench; 6-Camera box

The seed characteristic parameters of Heifeng No.1 Tartary buckwheat were measured as shown in Table 1.

Table 1

Seed characteristic parameters of Tartary buckwheat Heifeng No.1

Variety	Length / mm	Width / mm	Height / mm	1000-grain weight / g
Heifeng No.1 Tartary buckwheat	4.98	3.27	3.21	21

- **Test method**

In the process of bench test, the seed bed belt moves forward at the speed of 3.6km/h to simulate the field moving of the seeder. At the same time, oil is sprayed on the seed bed belt to avoid the jumping of the falling buckwheat seeds *(Karayel D et al, 2006)*. The seeds are discharged from the seed metering device and fall on the advancing seed bed belt. When passing through the camera box, the seed distribution is recorded, and finally the data is processed on the computer. Each experiment was repeated three times, and the distribution of seeds on 30 m seed bed belt was counted.

The qualified index, multiple index and miss-seeding index were taken as the detection indexes, and the diameter of suction hole, the negative pressure of air chamber and the speed of planting plate were taken as the test factors to carry out the seed metering device performance test. The calculation formula of qualified index, multiples index and miss-seeding index is as follows:

$$\begin{cases} R1 = \dfrac{n_1}{N} \times 100 \\ R2 = \dfrac{n_2}{N} \times 100 \\ R3 = \dfrac{n_0}{N} \times 100 \end{cases} \tag{6}$$

In the formula, $R1$ is the qualified index; n_1 is the number of single seed holes; N is the number of theoretical seed rows; $R2$ is multiples index; n_2 is the number of multiple seed holes; $R3$ is the miss-seeding index; n_0 is the number of zero seed holes.

- **Design of single factor test**

In the single factor test of seed suction hole diameter, the rotation speed of planting plate was set at 20 r/min, the negative pressure of air chamber was 2.4kPa, the diameter of suction hole was 1.5, 2.0 and 2.5mm as the experimental factor level. In the single factor test of the speed of planting plate, the planting plate with 1.5mm diameter of suction hole was selected, the negative pressure value of air chamber was set at 2.4kPa, and the rotating speed levels were 16, 18, 20, 22, 24, 26 and 28 r/min. In the single factor experiment of negative pressure, the diameter of seed suction hole was 2 mm, the rotation speed of planting plate was set at 24 r/min, and the horizontal values of negative pressure factors were 2.0, 2.2, 2.4, 2.6, 2.8 and 3.0 kPa, respectively.

- **Design of response surface test**

In order to further research the influence of various factors and their interaction on the buckwheat seed metering device performance, and determine its reasonable working parameters, the *BBD* (*Box Behnken design*) response surface test was carried out. The *BBD* response surface was carried out with the speed of seed metering plate, the diameter of suction hole and negative pressure as the test factors, and the qualified index, multiples index and miss-seeding index were used as evaluation indexes. According to the theoretical analysis results and the optimal range of single factor test, the coding values of BBD response surface test factors are shown in Table 2.

Table 2

Factor level table of the BBD response surface test

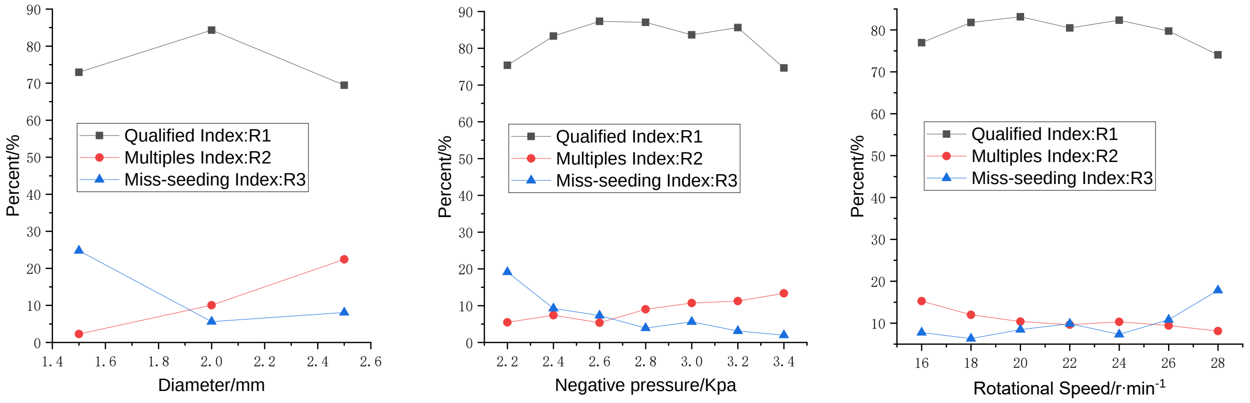
code	**Diameter: A / mm**	**Rotational speed: B / （r·min^{-1}）**	**Negative pressure: C / kPa**
1	1.5	18	2.4
0	2.0	22	2.8
-1	2.5	26	3.2

RESULTS

Results and analysis of the single factor test

The effect of suction holes diameter on the performance of seed metering device is shown in Fig.5 (a). When the diameter of seed suction hole is 2.0 mm, the performance of seed metering device is the best. When the diameter of the suction hole is 1.5mm, the miss-seeding index is higher. Because of the suction hole is small, the negative pressure air flow through the suction hole is insufficient, causing the decrease of seed adsorption. When the diameter of suction hole was 2.5mm, the qualified index was lower, and the replaying index was higher, which indicated that the number of seeds adsorbed by suction hole increased when the diameter was larger.

As shown in Fig.5 (b), with the increase of the speed of the seed metering plate, the qualified index of the metering device first stabilized and then decreased. The multiples index fluctuated up and down within a smaller range, and the miss-seeding index showed a gradual increase trend. When the rotation speed of planting plate is lower than 26 km/h, the performance of seed metering performance is better. The results showed that with the increase of rotating speed, when the linear velocity at the suction hole was too high, the time for the suction hole to pass through the seed filling area was short, and the suction hole was too late to absorb seeds, or the adsorbed seeds were easy to drop after being impacted by other seeds, thus resulting in missed sowing. However, considering the factors such as seeding efficiency and seed spacing, the rotation speed should not be too low.



(a) (b) (c)

Fig. 5 - Effect of single factor on seeding performance

Fig.5 (c) showed that with the increase of negative pressure, the qualified index of seeding performance increased at first and then decreased, the multiples index increased continuously, and the miss-seeding index decreased gradually. When the negative pressure was 2.4…3.2 kPa, the adsorption effect of suction hole on buckwheat seed was better. The qualified index reached the maximum when the negative pressure was 2.4 kPa. Considering that the missing sowing index should not be too high, the vacuum degree of air chamber required by seed metering device should be greater than 2.4 kPa, less than the maximum vacuum degree of H_{cmax} of 3.6 kPa.

Results and analysis of response surface test

According to the requirements of *BBD* response surface with three factors and three levels, a total of 17 groups of tests were conducted. The test scheme and statistical results are shown in Table 3.

Table 3

Scheme and results of the test

Group	A	B	C	Qualified Index: R1 / %	Multiples Index: R2/%	Miss-seeding Index: R3 / %
1	1	0	-1	75.63	12.16	11.21
2	-1	1	0	73.80	2.83	23.37
3	0	-1	1	84.75	10.87	4.38
4	1	-1	0	68.31	24.71	6.98
5	0	1	-1	72.91	9.25	17.84
6	0	0	0	85.26	9.41	5.33
7	0	1	1	81.76	9.32	8.92
8	-1	0	1	83.47	4.17	12.36
9	0	0	0	87.48	7.87	4.65
10	1	0	1	64.21	30.18	5.61
11	0	0	0	88.69	6.82	4.49
12	0	0	0	86.32	9.75	3.93

Table 3
(continuation)

Group	A	B	C	Qualified Index: R1 / %	Multiples Index: R2 / %	Miss-seeding Index: R3 / %
13	-1	0	-1	70.93	3.53	25.54
14	1	1	0	70.35	19.57	10.08
15	0	0	0	88.15	4.22	7.63
16	-1	-1	0	79.18	4.10	16.72
17	0	-1	-1	77.93	14.48	7.59

Regression analysis was carried out on the test results. The influence of each factor and its interaction on the qualified index, multiples index and miss-seeding index of the metering device is shown in table 4. The three regression models of qualified index *R1*, multiples index *R2* and miss-seeding index *R3* were significant, among which the regression model of miss-seeding index was highly significant (P < 0.0001), and the R-squared values of *R1*, *R2* and *R3* were 0.9612, 0.9190 and 0.9757, respectively, indicating that the fitting regression model has high reliability. The lack of fit was not significant (P > 0.05). The response surface equation is obtained as follows:

$$\begin{cases} R1 = 87.18\text{-}3.61A\text{-}1.42B\text{+}2.1C\text{+}1.85AB\text{-}5.99AC\text{+}0.51BC\text{+}10.02A^2 - 4.25B^2 - 3.60C^2 \\ R2 = 7.61\text{+}9A\text{-}1.65B\text{+}1.77C\text{-}0.97AB\text{+}4.1AC\text{+}0.92BC\text{+}3.48A^2 + 1.7B^2 + 1.66C^2 \\ R3 = 5.21\text{-}5.51A\text{+}3.07B\text{-}3.86C\text{-}0.89AB\text{+}1.9AC\text{-}1.43BC\text{+}6.54A^2 + 2.54B^2 + 1.93C^2 \end{cases} \quad (7)$$

Table 4

Significance analysis of different factors on performance indices

source	Qualified Index: *R1*				Multiples Index: *R2*				Miss-seeding Index: *R3*			
	SS	DF	F-Value	P-Value	SS	DF	F-Value	P-Value	SS	DF	F-Value	P-Value
Model	914.78	9	19.26	**0.0004**	869.08	9	8.83	**0.0045**	704.01	9	31.25	**<0.0001**
A	104.26	1	19.76	0.0030	665.94	1	60.88	0.0001	243.21	1	97.18	<0.0001
B	16.10	1	3.05	0.1241	21.75	1	1.99	0.2014	75.28	1	30.08	0.0009
C	35.24	1	6.68	0.0362	24.92	1	2.28	0.1749	119.43	1	47.72	0.0002
AB	13.76	1	2.61	0.1503	3.74	1	0.34	0.5769	3.15	1	1.26	0.2989
AC	143.52	1	27.20	0.0012	67.08	1	6.13	0.0424	14.36	1	8.74	0.0478
BC	1.03	1	0.20	0.6719	3.39	1	0.31	0.5953	8.15	1	3.26	0.1141
A^2	423.06	1	80.18	<0.0001	51.12	1	4.67	0.0674	180.06	1	71.95	<0.0001
B^2	75.92	1	14.39	0.0068	12.23	1	1.12	0.3255	27.21	1	10.87	0.0132
C^2	54.45	1	10.32	0.0148	11.63	1	1.06	0.3368	15.76	1	6.30	0.0404
Lack of fit	29.20	3	5.03	**0.0763**	18.85	3	3.77	**0.1162**	9.18	3	1.47	**0.3500**

According to the factor effect test of each response surface, the significant influence of test factors on qualified index *R1*, multiples index *R2* and miss-seeding index *R3* from large to small is seed suction hole diameter *A*, negative pressure *C* and rotation speed of planting plate *B*. The factors *A* and *C* had significant effects on qualified index *R1*, multiples index *R2* and miss-seeding index *R3*, while factor *B* had no significant effect on pass index *R1* and multiples index *R2* (*P < 0.05*), but had significant effect on missed seeding index *R3*.

The *P* values of *AC* in the three regression models were all less than 0.05, indicating that the interaction between the diameter of suction hole *A* and the negative pressure *C* had significant influence on the qualified index *R1*, multiples index *R2* and miss-seeding index *R3*. As shown in Fig.6, when the rotational speed is 22 r/min, the interaction of factor *A* and factor *C* affects the qualified index *R1*, multiples index *R2* and miss-seeding index *R3*, respectively. It can be seen from the figure that with the increase of suction hole diameter a and negative pressure *B* of air chamber, the qualified index *R1* increases at first and then decreases, and the repeat index *R2* and miss seeding index *R3* show a trend of small first and then increase. The main reason is that the diameter of seed suction hole a and negative pressure *B* of air chamber directly affect the strength of negative pressure air flow through the suction hole, thus affecting the seed adsorption capacity of the suction hole. When the diameter of seed suction hole is selected properly and the negative pressure value of air chamber is moderate, the seed adsorption performance is the best and the working performance of seed metering device is good.

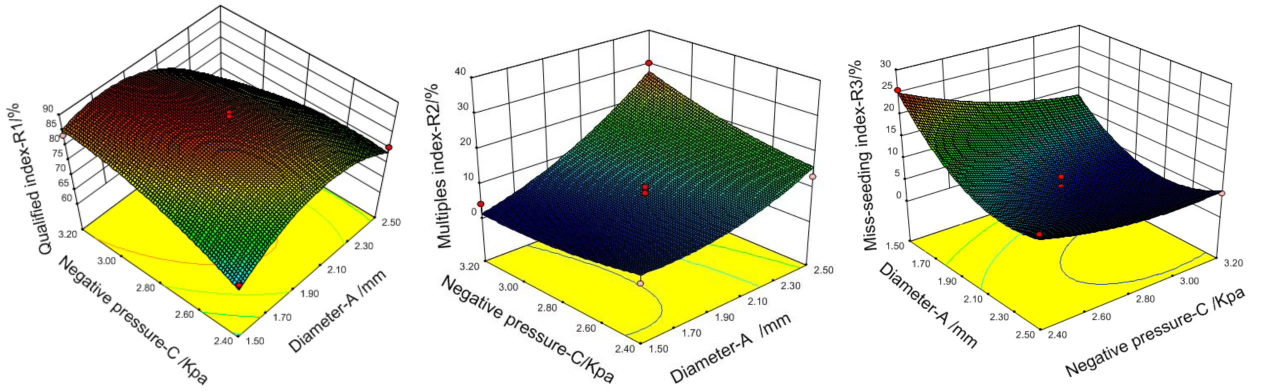


Fig. 6 -The influence of experimental factors on performance of seed metering device

Optimization of working parameters

When the seed metering device works, it is necessary to meet the requirements of high qualified index, low multiples index and low miss-seeding index. In addition, the appropriate multiples index can ensure the survival rate of buckwheat seedlings. The comprehensive indexes of qualified index *R1*, multiples index *R2* and miss-seeding index *R3* are used to establish the optimization function. The qualified index *R1* should be greater than 80%, the multiples index should be less than 15%, the miss-seeding index should be less than 8%, and the diameter of suction hole was set to 2.0 mm. Using the numerical optimization module of Design Expert, the optimal solution is as follows: the diameter of suction hole is 2.0mm, the rotation speed of planting plate is 21.40 r/min, and the negative pressure is 2.91 kPa, the qualified index *R1* is 87.58%, the multiples index *R2* is 8.49%, and the miss-seeding index R3 is 3.93%. Based on the optimal combination of working parameters, the verification test was repeated for 5 times, and the approximate test results were obtained. The qualified index was 88.32%, the multiples index was 7.35%, and the miss-seeding index was 4.33%, which met the technical requirements of precision sowing.

CONCLUSIONS

(1) The structure of Kverneland air suction seed metering device was improved. A kind of negative pressure chamber rotary precision seed metering device was designed. The planting plate rotated synchronously with the air chamber shell forming a negative pressure chamber. An annular sealing gasket was installed between the air chamber shell and the planting plate to further improve the air tightness of the negative pressure chamber. Buckwheat planting plate was designed according to buckwheat seeds physical and mechanical characteristics. The main parameters of the metering device were analysed.

(2) The results of single factor test showed that the seed metering performance was better when the diameter of suction hole was 2 mm, the miss-seeding index increased obviously when the rotation speed of planting plate was higher than 26 r/min, and the suction hole had better seed adsorption effect when the negative pressure was greater than 2.4 kPa. The results of response surface test showed that

the order of significant influence of each factor on qualified index, multiples index and miss-seeding index was the diameter of suction hole, negative pressure and rotation speed of planting plate. The interaction between diameter of suction hole and negative pressure had significant influence on the performance of seed metering device. The results showed that the optimal combination of the factors was: the diameter of suction hole was 2 mm, the negative pressure was 2.91kPa, and the rotation speed was 21.4 r/min. Under the combination, the qualified index was 88.32%, the multiples index was 7.35%, and the miss-seeding index was 4.33%, which met the technical requirements of buckwheat precision sowing.

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