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THE DESIGN AND EXPERIMENTAL STUDY OF A TESTING STAND FOR PNEUMATIC SEED METERING DEVICE

ZHAO MANQUAN[1], LIU WENZHONG[1], WANG WENMING[1], ZHAO LINA[1]

[1] Z. MANQUAN, Professor, Inner Mongolia Agricultural University/Huhhot, China, nmgzmq@yahoo.com.
[1] L. WENZHONG, Lecturer, lwz1997@126.com.
[1] W.WENMING, Lecturer, wenming - wang @126.com.
[1] Z. LINA, Assistant, zhaolina007@163.com.

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ABSTRACT A testing stand for seed metering device was designed in accordance with the seed metering theory of pneumatic seed metering device, the feature of its achieved the goal of minimizing pollution and saving seed, and the testing effectiveness is confirmed to be favourable and able to satisfy the requirement of experiment. Taking the rotation speed of seed metering disk and the vacuum degree in suction chamber as experimental factors, a single factor experiment with the influence of these factors on seed metering performance of soybean was conducted and the result shows that: □ The rotation speed of seed metering disk is suited to the vacuum degree in suction chamber obtained by theoretical calculation. However ,when the rotation speed of seed metering disk exceeds the one of seed metering disk suited to the vacuum degree obtained theoretical calculation, the seeding quality will get worse and the miss seeding rate increases prominently and comes up to the maximum value of 29.63%.□ When the vacuum degree in suction chamber is 2.5 kPa, the miss seeding rate will go up and the seeding rate up to standard tends to decrease with the rotation speed of seed metering disk enhances.□ When the rotation speed of seed metering disk is fixed at 54 rpm, the seeding rate up to standard varies in a range from 76.11% to 80.65% under the condition of the vacuum degree being 1.5 kPa in suction chamber, when the vacuum degree in suction chamber being lower than 1.5 kPa, the seeding rate up to standard will decrease evidently ,and when the vacuum degree in suction chamber is 1.0 kPa ,the seeding rate up to standard merely reaches to 52.07%,and the miss seeding rate, however, goes up to 40.83%.

Keywords: Test bed of Air-suction Seed metering device, Working parameter, Sowing performance experiment.

INTRODUCTION The testing stand for seed metering device is a testing facilities indispensable to attaining high quality seeding machine and an important means by which the renewed seeding machine can be developed [1].With the precision seed metering device having been developed towards the one of high speed and high efficiency, the means and method of research work and experiment have also been unceasingly renewed. At present, the main testing means employed at home are naked eye direct inspection,

inspection with grease smeared belt, high-speed photographing, inspection with micro-computer, inspection system with fictitious instrument and the inspection with image processing etc [2,3]. But the seed catching method of the testing stand for seed metering device is mainly by use of canvas belt smeared with grease or some other viscous substance at present. Besides, there is also a moveable testing stand for seed metering device by making use of sand pit or fixed sand tray as a seed catching bed.

The several seed catching method mentioned above are all processed of certain shortcomings among which, the canvas belt testing stand is of following imperfections, such as the high running cost, the seed being so badly contaminated as cannot to be retrieved for reuse, causing unnecessary waste and the running condition of the testing is so relatively poor as to be inconvenient for direct sampling. And as for the moveable testing stand, since it adopts dynamic testing method, that is, that the seeding unit body is mounted on a small moving cart and makes relative motion over the sand pit or fixed sand tray ,which results in the construction of testing stand being complicated, and cumbersome ,furthermore ,as the length of the sand pit being limited, the number of sampling is restricted and the statistical result will be impaired. To counter those shortcomings, certain improvement has been carried out to the original canvas belt testing stand and a testing stand for seed metering device taking a conveyer belt, on which the sand is evenly spread, as the seed bed has been developed, having overcome the defects such as environmental pollution and seed waste caused by grease smeared belt testing stand as well as the shortcomings of movable testing stand.

1 THE DESIGN OF PRINCIPAL FUCTIONAL PARTS

1.1 Operating principle The seed metering device advances ahead with the tractor when the seed metering performance of a seeding machine is tested in the field. However, the operation procedure of the testing stand is just contrary to the above, it takes the conveyer belt sand being evenly spread on as seed bed and makes the belt move at a speed of imitated seeding machine running in the field. When testing procedure is in progress, the seed metering device keeps motionless and the conveyer belt (seed bed) makes relative motion to the seed metering device, and thus the relative motion of seeding machine over ground is changed into the motion of ground relative to the seeding machine. Judged by the concept of relative motion, which is only a problem, of having changed the reference coordinate system, so the effect is the same. Seed metering device is fixed on the frame, the suction chamber is connected to the blower, as the blower runs, a vacuum produces in the suction chamber, so a pressure difference produces between both sides of seed metering disk and the seeds are adsorbed on the holes of seed metering disk under the effect of pressure difference. The shaft of seed metering device driven by the sprocket activates the seed metering disk to rotate, as the seed metering disk rotates and begins to deviate from suction chamber□ the adsorption effect on the seeds will vanishes, and the seeds will drop onto the conveyer belt sand being evenly spread under the effect of gravitation force of itself, preventing the seeds from rolling and bouncing. The visual system of the testing mechanism carries out the function of taking real time photograph and data processing, determining the spacing between each other of all the scattered seeds and thus attaining the goal of inspecting each target, e.g. seeding evenness etc.

The essential operation principle of this testing stand is in that the sand expeller discharges sand out from sand hopper and spills on the moving conveyer belt, forming a sand strip of certain width, the sand substitutes the grease originally being smeared on the conveyer belt, and then seed metering device expels the seeds onto sand strip to avoid the seed rolling about and bouncing. A separation device is disposed at the end of conveyer belt by which separates the seeds from sand for reuse,

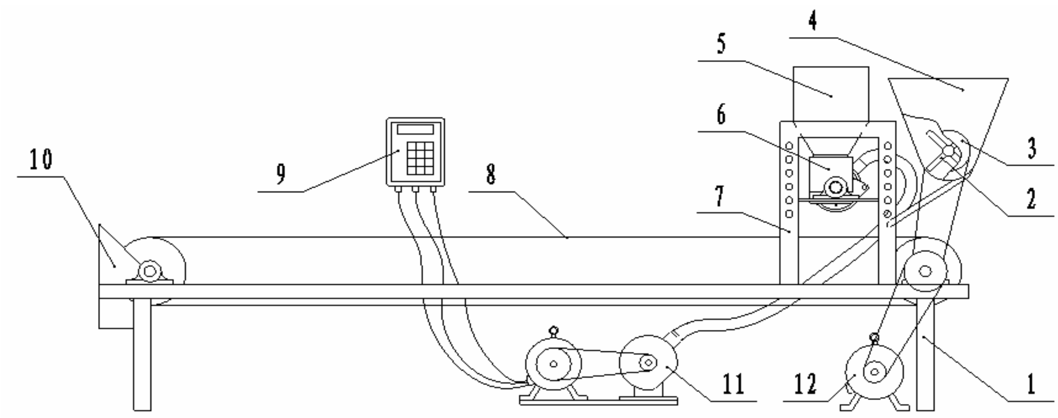


Fig.1 testing stand for seed metering device

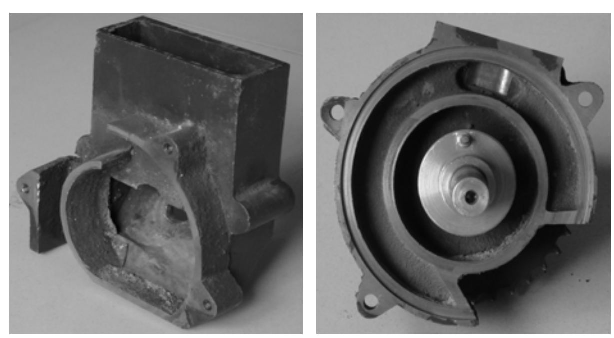
1. frame 2.sand discharger 3. belt pulley 4.sand hopper 5.seed-box 6.seed metering device 7.frame for seed metering device 8.conveyer belt 9.frequency converter 10.sand-seed separator 11.blower-motor drive 12.conveyer belt-motor drive

1.2 Construction The overall construction of the testing stand is illustrated in Fig.1. It is composed of frame, seed bed belt, frame for seed metering device to be mounted, sand discharger, sand-seed separator and motive power drive and governor etc.

1.3 Parameter design of essential functional parts The parameter design of essential function parts consists of the design of the frame, sand discharger and the pneumatic seed metering device.

1.3.1 Design of seed metering device

The pneumatic seed metering device employed in this study is the one improved on the base of the pneumatic seed metering device of 2BQM-2 pneumatic precise plastic film mulch seeding machine [4,5] developed by Inner Mongolian Agricultural University.



a. seed chamber b. suction chamber

Fig.2 the housing of seed metering device

The housing of the seed metering device is divided into two chambers, seed chamber and suction chamber [Fig.2] in which the suction chamber takes a shape of ring-like groove, seed falling angle is 45°; the seed adsorption disk is of 150mm diameter, 2mm thickness and 6 cylindrical seed adsorption holes are evenly distributed on a circle of 124mm diameter on the seed adsorption disk.

1.3.2 The design of sand discharger

The sand discharger (including the parts of sand discharger, belt pulley, sand hopper) is a key part of this testing stand. The sand discharger is placed in the sand hopper, a rectangle sand run-off opening is disposed at the bottom of sand hopper, the sand discharger is driven by the pulley linked up with conveyer belt wheel, sand is expelled through the sand-run-off opening, the flow rate of the expelled sand is controlled by adjusting the rotation speed of sand discharger and the width of the sand-run-off opening. To determine the parameter of sand discharger, the volume of sand hopper and speed of sand discharger are taken into consideration in particular. The volume of sand hopper must be big enough to satisfy the demand on the sand required for in one testing procedure and the rotation speed of sand discharger should ensure a sufficient flow rate of sand expelled.

It is shown in Fig.3 that the testing result obtained by the testing stand for seed metering device employed in the study is much similar to the one acquired by JSP-12 computer-visual testing stand for seed metering device developed by Hei Long Jiang Farm Machinery Engineering Scientific Research Institute, which prove that the performance of the testing stand developed by us is fairly sound and able to satisfy the requirement for testing operation.

a.The illustrated seed metering result of JSP-12 computer visual testing stand for seed metering device

b.The illustrate seed metering result of the testing stand for seed metering device developed by ourselves

Fig.3 The comparison between two seed metering result

1.3.3 The design of testing stand frame

The major consideration in designing the testing stand frame is devoted to the determination of the length and speed of seed bed belt. Since this testing stand for seed metering device may employ mechanical-visual means to determine the spacing between each seeds scattered on seed bed belt, the survey, real time data collection, pattern processing and data storing etc can be conducted without interruption, a section of seed bed belt relatively short may satisfy the requirement for testing operation. At the same time, in order to directly observe the actual seed metering state within a small section of seed bed belt, taking the fact that the seed bed belt can still be able to move forward a certain distance after seed bed belt being braked up into account, it is firmly believed that the dimension of original testing stand frame may be able to meet the requirement for testing operation, that is, the effective length of seed bed belt is fixed to be 9m, width 0.14 m and the circumference 7.32 m. At present, the operation speed of precision seeding machine for intertilled crop is generally about 5□8 $km.h^{-1}$ and the speed of some advanced pneumatic seeder may reach to 10□12 $km.h^{-1}$ abroad and at home. Generally, if the operation speed exceeds 10 km.h^{-1}, the seeding quality will evidently get worse, and the testing criterion demand that the advancing speed of seeder in testing procedure is prescribed within 1.0□3 m.s^{-1}(3.6□10.8 km.h^{-1}). The design of testing stand for seed metering device should try to extend the testing range, and meet the requirement for actual speed of the seeder available nowadays. Judged by the operation speed of advanced seeder for intertilled crop available abroad and at home, the rotation speed of seed metering disk is generally in the range of 20□200 rpm when the operation speed of seeder is 12 km.h^{-1}. Both the advancing speed of seed bed belt and rotation speed of seed metering device can be controlled by frequency converter, which might meet the requirement for properly matching all the different speeds.

2 PERFORMANCE TESTING

2.1. Testing method The seed metering device is mounted on its corresponding frame, the vacuum manometer is connected to the vacuum connection pipe, the advancing speed of seed bed belt is adjusted to the operation speed of imitated seeder. In accordance with the operation speed of seeders generally available being in the range of 2□5 km.h^{-1} and the demand of testing criterion, the seed bed belt speed is fixed upon 1.02 m.s^{-1}, and then the corresponding rotational speed of seed metering disk is determined by calculation on the base of theoretical spacing between each kernel of seeds for various crop. The seed metering device and blower are driven by different electric motor respectively and the speed of them are controlled by frequency converter, the rotation speed of them are measured by DT-2234B digital tachometer. By the time the running is smoothed up, the opening of sand discharger is opened and the sand is expelled onto the conveyer belt along its central part, forming a sand strip with a certain width and thickness. The seed fallen onto the sand strip from seed metering device is measured and counted to calculate the rate of seed spacing up to standard, rate of duplicated seeding and the rate of miss seeding.

A testing procedure is conducted to determine the performance of pneumatic seed metering device in accordance with the state standard,□GB6973-2005 single kernel (precision) seeder's testing method□[6],the seed metering performance is judged by the seed spacing fallen on the seed bed. The testing procedure proceeds for the four different crops, soybean, corn, sunflower and sunflower (small seed) by changing the seed adsorption disk respectively to inspect the adaptability of seed metering device to each variety of crop and the universality of the seed metering device.

The physical-mechanical characteristics of the four varieties of crops are listed in the table 1.

2.2 The single factor experimental design and analysis of result for soybean There are many factors to affect the performance of the pneumatic seed metering device among which the major factors are included the rotational speed of seed metering disk n, the vacuum degree in suction chamber p, number of adsorption holes z, thickness of seed metering disk, shape of adsorption hole and distribution, seed adsorption hole diameter d and the interval between two adjacent adsorption holes δ etc. Taking soybean as an intermediate of study, the influence of the rotational speed of seed metering disk and the air pressure in suction chamber on the seed metering quality is investigated under the circumstances of all the other factors unchanged except for fixing the seed adsorption hole diameter at 5 mm.

Table 1. The physical mechanical characteristics of seed

item	Thousand kernel weight (g)	Unit weight (g/L)	Moisture content (%)	Seed dimensions(mm)		
				length	width	thickness
Soybean(dong nong No.46)	200	875	14.5	6.64	6.43	5.81

2.2.1 The influence of rotational speed of seed metering disk on the seed metering quality

The seed metering characteristics at different rotation speed of seed metering disk is investigated when the vacuum degree in suction chamber kept 2.5 kPa. The testing procedure is carried out when the rotation speed of seed metering disk are kept at five different values, that is, they are 21.7, 39, 54, 70 and 84 rpm respectively. Every one hundred seed spacing measured of in testing procedure (when the running of seed metering disk smoothened) under each operation conditions is taken as statistical sample, then the rate of seed spacing up to standard, rate of duplicated seeding and the rate of miss seeding are calculated, and result of calculation and data processing is listed in table 2, and the analytical result is illustrated in Fig.4.

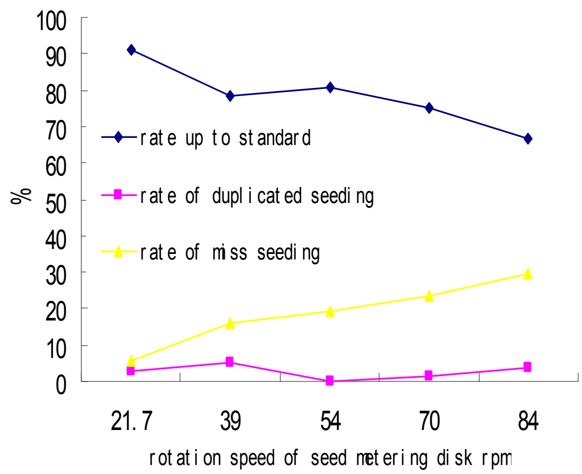


Fig.4 The curve for seed metering performance

Table 2 The influence of different rotation speed of seed metering disk on the seed metering quality

A result is achieved by processing quadratic regression of interrelated parameters on the base of testing result in table 2 as flows[7]:

(1) The regression equation of the rate of seed spacing up to standard y to the rotation speed of seed metering disk x

Testing serial number	Seed adsorption hole diameter (mm)	Vacuum degree in suction chamber (kPa)	Rotation speed of seed metering disk (rpm)	Rate up to standard (%)	Duplicated seeding rate (%)	Miss seeding rate (%)
1	5	2.5	21.7	91.26	2.91	5.82
2	5	2.5	39	78.57	5.36	16.07
3	5	2.5	54	80.65	0	19.35
4	5	2.5	70	75.00	1.56	23.44
5	5	2.5	84	66.67	3.70	29.63

$$y = -1.4542x^3 + 13.158x^2 - 40.018x + 119.18$$
$$R^2 = 0.9661$$

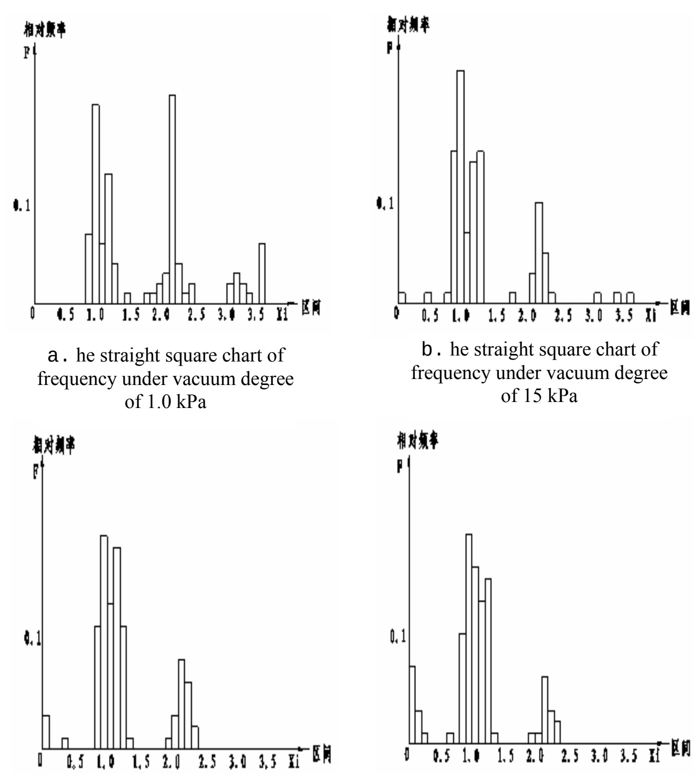
(2) The regression equation of miss seeding rate y to the rotation speed of seed metering disk x

$$y = 0.6992x^3 - 5.8425x^2 + 13.578x - 5.224$$
$$R^2 = 0.6204$$

(3)The regression equation of duplicated seeding rate y to the rotation speed of seed metering disk x

$$y = 0.7558x3 - 7.3246x2 + 26.47x - 13.988$$
$$R2 = 0.9981$$

It is found in Fig.4 that with the increase of rotation speed of seed metering disk, there is a tendency for the rate of seed spacing up to standard and the rate of duplicated seeding to decrease to some extent, but the miss seeding rate rise evidently. The main reason for the result above mentioned is in that, that with the rotation speed of seed metering disk increasing, the linear velocity of seed adsorption hole will go up correspondingly, the time interval of seed adsorption hole passing through the seed charging section is shortened and the probability for the seed adsorption hole to adsorb seed get lowered , at the same time, the collision between the seed adsorbed on the seed adsorption hole and the other seeds get serious and some of them might be bumped down from the adsorption hole. Besides with the rotation speed of seed metering disk being increased and the speed of relative motion of seed adsorption hole enhanced, some seed will drop off owing to the hysteresis of seed in motion. Furthermore, with the rotation speed of seed metering disk being increased, when the centrifugal force acted on the seed exceeds the adsorption force, the seed will break away from the seed adsorption hole.



a. he straight square chart of frequency under vacuum degree of 1.0 kPa

b. he straight square chart of frequency under vacuum degree of 15 kPa

c. he straight square chart of frequency under vacuum degree of 1.0 kPa

d. he straight square chart of frequency under vacuum degree of 1.0 kPa

ïg .5 the straight square chart of frequency at the rotation spee of 54 rpm of seed metering disk

2.2.2 The influence of vacuum degree in suction chamber on seed metering quality

It is acquainted with from the theoretical analysis of pneumatic seed metering device [8, 9] that the influence of vacuum degree in suction chamber on seed metering quality is considerably great. If the vacuum degree is too low, the miss seeding rate of seed metering device will increase and if the vacuum degree is beyond the normal value, then the rate of overlapped adsorption will increase, however, the air pressure in suction chamber fluctuates considerably in practical operation process. Therefore, it is necessitated to study the variation law of seed metering quality with the fluctuation of vacuum degree in suction chamber in order to determine the range of vacuum degree for normal operation. An experimental study into the influence of the air pressure in suction chamber on seed metering performance was carried out under the condition that the rotation speed of seed metering disk is fixed at 54rpm and the vacuum degree in suction chamber adopts a certain value from within the range of optimum vacuum degree between 1.0 to 4.5kPa (the adoption of vacuum degree in following experiments should follow this principle). A one hundred of seed spacing measured of under each operation condition in testing procedure were taken as statistic sample and the rate of seed spacing up to standard, rate of duplicated seeding and the miss seeding rate were calculated and the calculation result is listed in table 3, the histogram of frequency is illustrated in Fig.5 and the analytical result is shown in Fig.6

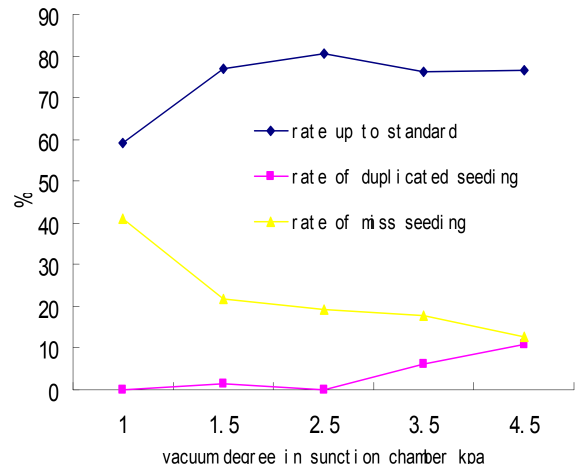


Fig. 6 seed metering performance curve

Table 3 The influence of different vacuum degree in suction chamber On the seed metering quality

Testing serial number	Diameter of seed adsorption hole(mm)	Rotation speed of seed metering disk(rpm)	Vacuum degree (kPa)	Rate up to standard (%)	Duplicated seeding rate(%)	Miss seeding rate(%)
1	5	54	1.0	59.17	0	40.83
2	5	54	1.5	76.80	1.60	21.60
3	5	54	2.5	80.65	0	19.35
4	5	54	3.5	76.11	6.19	17.70
5	5	54	4.5	76.47	10.78	12.75

It is shown in Fig 5 a that the frequency of seed spacing nearby the theoretical seed spacing up to standard is relatively low, that is that the rate of seed spacing up to standard is relatively low, at the same time, the frequency of seed spacing greater than 1.5xr is relatively high that means the phenomenon of miss seeding is more evident when the rotation speed of seed metering disk is 54rpm and the vacuum degree in suction chamber is 1.0kPa, which is indicated that the vacuum degree in suction chamber is not suited to the rotation speed of seed metering disk ,and the vacuum degree is somewhat low, It is found in Fig.5c and 5d that when the rotation speed of seed metering disk is 54rpm and the vacuum degree in suction chamber reaches 2.5kPa, the frequency of seed spacing nearby the theoretical seed spacing up to standard is relatively high, that is, the rate of seed spacing up to standard is considerably high, which shows that the vacuum degree in suction chamber greater than 2.5kPa might be suited to the rotation speed of seed metering disk when the rotation speed of seed metering disk is fixed at this value. It is shown in fig.5c that when the rotation speed of seed metering disk is 54rpm and the vacuum degree in suction chamber is 3.5kPa, the frequency of seed spacing nearby the theoretical seed spacing up to standard is relatively high, but the seed spacing frequency lower than 0.5xr gets high, which indicates that the vacuum degree in suction chamber exceeds the appropriate vacuum degree in suction chamber at this rotation speed of seed metering disk.

A following result is obtained by proceeding quadric regression for interrelated parameters on the base of testing result in table 3 that:

(1) The regression equation of the rate of seed spacing up to standard y to the vacuum degree x in suction chamber

$$y = 1.5567x^3 - 17.076x^2 + 58.527x + 16.05$$

$$R^2 = 0.9968$$

(2) The regression equation of duplicated seeding rate y to the vacuum degree x in suction chamber

$$y = 0.1333x^3 - 0.2164x^2 - 0.1398x + 0.514$$

$$R^2 = 0.9327$$

(3) The regression equation of miss seeding rate y to the vacuum degree x in suction chamber

$$y = -1.69x^3 + 17.293x^2 - 58.387x + 83.436$$

$$R^2 = 0.9952$$

It is found from the curves shown in fig 6 illustrated the variation pattern of the rate of seed spacing up to standard, rate of duplicated seeding and the rate of miss seeding under different vacuum degree in suction chamber, when the rotation speed of seed metering disk is 54 rpm and the speed of seed bed belt is fined at a certain value that: when the vacuum degree in suction chamber is kept high, the rate of seed spacing up to standard gets high and the miss seeding rate decreases.

However, when the vacuum degree in suction chamber exceeds 2.5kPa the rate up to standard has not increased with the increase of vacuum degree in suction chamber of which the reason is that even though the miss seeding rate decreased but the duplicated seeding rate increases with the enhance of vacuum degree in suction chamber. It can also be seen from the histogram for frequency under the condition of different vacuum degree that when the rotation speed of seed metering disk is at 54 rpm and the vacuum degree in suction chamber is 1.0kPa, the seed metering quality gets worst and the phenomenon of miss seeding becomes serious, but with the vacuum degree in suction chamber goes up, the seed metering quality begins to get better.

3 CONCLUSION On the base of consulting the research work on the pneumatic seed metering device achieved by scientists abroad and at home recent years, a testing stand for seed metering device was developed, and a single factor experiment and analysis for the two factors exerting influence on the seed metering performance were conducted and a principal conclusion was reached as follows:

1.the testing stand for seed metering device developed by us not only features of minimizing environmental pollution and saving seed but also having favorable testing effectiveness in contrast with some other testing stand ,being able to satisfy the testing demand

2. A single factor experiment taking the rotation speed of seed metering disk and the vacuum degree in suction chamber as experimental factors exerting influence on the seed metering performance was carried out for the seeding operation of soybean and the result of experiment is as follows:

(1) When the rotation speed of seed metering disk exceeds the one suited to the vacuum degree determined by theoretical calculation, the operation quality gets worse, and the miss seeding rate increases evidently, of which the maximum value comes up to 29.63%
(2) When the vacuum degree is suction chamber is 2.5kPa, the miss seeding rate goes up and the seeding rate up to standard has a tendency of decrease with the rotation speed of seed metering disk speeds up
(3) When the rotation speed of seed metering disk is fixed at 54rpm, the seeding rate up to standard will be in a range from 76.11 to 80.65% in case of vacuum degree in suction chamber being higher than 1.5kPa; the rate up to standard decreases obviously when the vacuum degree in suction chamber is lower than 1.5kPa and the rate up to standard merely reaches to 52.07% and the miss seeding rate rises up to 40.83% when the vacuum degree is 1.0kPa.

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