Optimization test of the 2BSL-320 vegetable seeders with air-suction drum type

B Tang[1,3], Y S Wang[1] and S Z Ji[2]

[1] Yancheng Vocational Institute of Industry Technology, Yancheng, 224005, China
[2] Jiangsu Cloud Horse Agricultural Machinery Manufacturing Co., Ltd., Yancheng, 224100, China

E-mail: bright9004@126.com

Abstract. The seeding raising technology of the hole tray assembly line is an important part of modern agriculture. The 2BSL-320 vegetable seeders with air-suction drum type are implements that are used to fill nutritional soil and press a hole in a float tray to sow seeds precisely. It can complete the whole process of putting down the tray, bedding the soil, scraping the soil, pressing a hole, sowing the seeds, compacting the soil, watering and putting away the tray by one time. Based on the introduction of the structure and working principle of the implement's critical components, in order to improve the seeding efficiency and the seeding accuracy of the seeders, the response surface tests and the group experiments were carried out in this paper. And the MATLAB tool box was used to conduct fitting and optimization analysis of the test results, also the rationality of the optimization results was validated by experiments, which had provided a theoretical basis for the design of operation parameters in the vegetable seeders and had improved the seeding efficiency and quality.
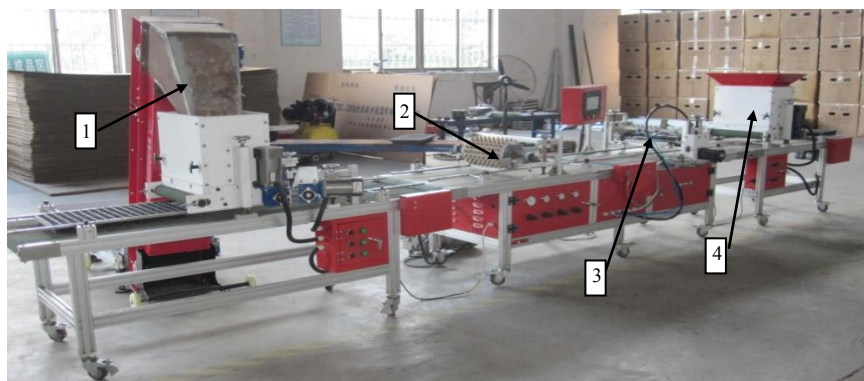
1. Introduction

With the improvement of agricultural mechanization level, mechanized application of seeding technology has been greatly promoted. As an important part of modern agriculture, the seeding raising technology of the hole tray assembly line has the advantages of high mechanization degree, more crop yield, high seedling survival rate, fewer pests and good crop growth, therefore, it has been applied to the planting and cultivation of some important economic crops such as vegetables and flowers at present.

The structure of seeders used mostly is air-suction type. Due to the characteristics of low seed throwing point, flat soil bed, homogeneous seed distribution, high seeding precision, consistent seed depth and neat emergence etc, which are in line with agronomic requirements, the seeders of air-suction type is becoming more and more popular [1, 2]. Air-suction seeders can be divided into needle type, disc type and drum type, among which the drum type has better seeding speed, precision and efficiency, causing it has a wide range of applications. For the drum seeders, the seeding efficiency is affected by many factors, and how to optimize the design of the relevant factors is the key to improve the efficiency of the drum seeders [3]. This paper introduces the structure and working principle of the 2BSL-320 vegetable seeders with air-suction drum type, and the response surface tests were carried out, after which the test results were fitted and optimized to get the optimal combination of parameters, providing a theoretical basis for the parameters design of the vegetable seeders, improving the seeding efficiency and quality.

2. The structure and working principle

The 2BSL-320 vegetable seeders with air-suction drum type are implements that are used to fill nutritional soil and press a hole in a float tray to sow seeds precisely, which have automatic and manual operation modes. This implement can sow coated and non-coated seeds of tobacco, flowers, vegetables, medicinal herbs in the hole trays, and can not only operate in single line, but also can be used in the standard tray of 50 points, 72 points, 98 points and 128 points which are now widely used at home and abroad. By replacing different drums in the seeder, it can sow many kinds of crops. The overall structure of the implement is shown in figure 1, which is mainly composed of the delivering part, the soil bedding part, the hole pressing part, the sowing part, the soil compacting and fertilization part, the sprinkling part and the electrical control parts, etc. The seeders has different stations, each station can work independently. The complete working process of the seeder is composed of putting down the tray, bedding the soil, scraping the soil, pressing a hole, sowing the seeds, compacting the soil, watering and putting away the tray, in which the rotary power and transmission power are provided by a motor, the power source for the drum absorbing the seeds is from a vacuum pump.

Figure 1. Layout of the seeder.

1-soil bedding part; 2- hole pressing part; 3- sowing part; 4- soil compacting and fertilization part.

2.1. Conveyor

The conveyor is composed of motor, driving sprocket, driving roller shaft, driven roller shaft and conveyor belt etc. Its function is to carry the seed tray according to the designed velocity. In order to monitor the position of the tray on the conveyor belt, the photoelectric reflex zones, as shown in figure 2, are equipped on the delivery path, which use photoelectric principles and can feedback signals when the tray passes the reflection area.

Figure 2. Photo-reflect zone of the conveyor.

Figure 3. Graph of the seeding parts.

2.2. Seeding parts

Seeding part, as shown in figure 3, is the core of the machine, composed of cylinder, vibrator, seed

box, blowing mouth and so on. The tray with well-pressed holes is delivered to the seeding part by the conveyor belt. There are three main working processes of the seeding part: seeds absorption process, seeds carrying process and seeds dropping process. In the process of absorption, the sucking holes of the cylinder are used to suck the seeds in the seed box due to the vacuum pressure in the cylinder. In the process of carrying, the cylinder rotates carrying the seeds in the sucking hole to the right dropping position. In the process of dropping, a scraping board is used to cut off the vacuum pressure, and then the seeds drop to the tray below due to the effect of the scraping board and self-weight. To facilitate the adsorption of seeds, a vibrator is adopted to make seeds in a state of floating up and down automatically [4].

The effect of seeding was mainly evaluated by the single grain rate, the replay rate and the cavity rate, and the main influencing factors are vacuum pressure, shape of sucking hole, diameter of sucking hole and tangential velocity of cylinder etc. [5, 6].

3. Performance test

3.1. Test condition
The tests are carried out in the 2BSL-320 vegetable seeder with air-suction drum type. The main technical parameters of the machine are shown in table 1.

Table 1. Main technical parameters of the implement.

Model	2BSL-320	Seeding efficiency/reel·hour^{-1}	600
Matched power/W	1080	Seeders type	air-suction
Working breadth/ mm	320	Depth of soil bed/ mm	30~50
Capacity of soil bed/ L	50	Depth of cover soil/ mm	20~35
Capacity of cover soil/ L	50	Compacting depth/ mm	20~25
Irrigation amount / L·reel^{-1}	06-08		

In order to optimize the hole geometry size and the negative pressure parameter of the designed 2BSL-320 vegetable seeder, the hole diameter and the cylinder pressure are chosen as the main optimization parameters, and the single grain rate and the cavity rate are set as the evaluation indexes.

The test subjects are Nanjing cabbage seeds whose diameters are 1.1 ~ 1.5 mm. Because the seed absorption performance of the taper hole is better than that of the straight hole, the shape of the suction hole is tapered. For the two factors of the hole aperture (A) and the cylinder pressure (B), the response surface analysis of the two factors and three levels are carried out. The test factors and levels are shown in table 2.

Table 2. Experiment table of 2 factors and 3 levels.

Levels	Factors	
	Hole diameters (A)/mm	drum pressure(B)/(kPa)
1	1.3	1.5
2	1.6	2
3	2	4

3.2. Test results

The operation process of the seeder tests are: (1) check the condition of the power, water source, gas source and so on (2) sowing the seeds in the seed box (3) power on (4) adjust the compaction height (5) set the operate interface by the manual button (6) put the seeding tray, begin the seeding work by touching the automatic button (7) test over, press the stop key, and then do the clean-up (8) shut off the power, water source and gas source. The group tests are carried out according to the test conditions in table 2, and each test repeats three times, then take down the seed number and cavity number in the tray, and obtain the single grain rate (Y_1) and the cavity rate (Y_2) by calculation. The results of the response surface tests are shown in table 3. It can be seen from table 3 that the values of Y_1 rise firstly and then decrease with the increase of A when B values are the same, and when A values are the same, the change situation of Y_1 is similar. As for the values of Y_2, higher Y_2 values comes up with lower A when B values are the same, while when A values are the same, Y_2 values decrease firstly and then rise with the increase of B.

Table 3. Experiment results of response surface analysis.

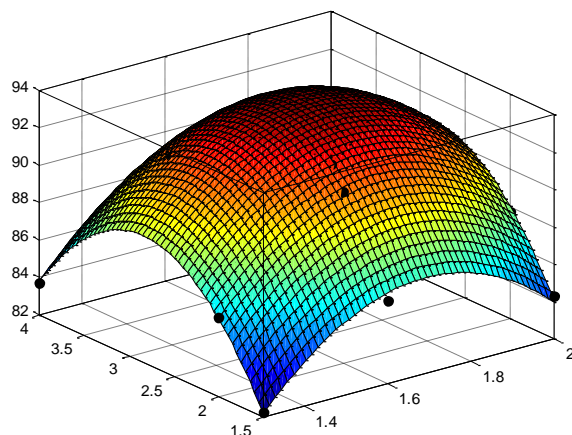| Test number	A	B	Y_1/%	Y_2/%	Test number	A	B	Y_1/%	Y_2/%
1	1.3	1.5	82.29	8.14	6	1.6	4	88.76	6.53
2	1.3	2	86.24	6.59	7	2	1.5	84.32	5.08
3	1.3	4	83.69	7.84	8	2	2	87.67	3.37
4	1.6	1.5	86.43	7.45	9	2	4	85.81	4.65
5	1.6	2	91.21	5.23					

4. Test results analysis

The cftool (Curve Fitting Tool) of the MATLAB is powerful and easy to use, and it can implement various types of linear, nonlinear curve fitting. The multivariate regression fitting on the test results in table 2 is carried out by cftool: import the groups of test results in table 2, choose the polynomial fitting, 2 order of fitting. The regression equations of the single grain rate (Y_1) and the cavity rate (Y_2) are obtained respectively as:
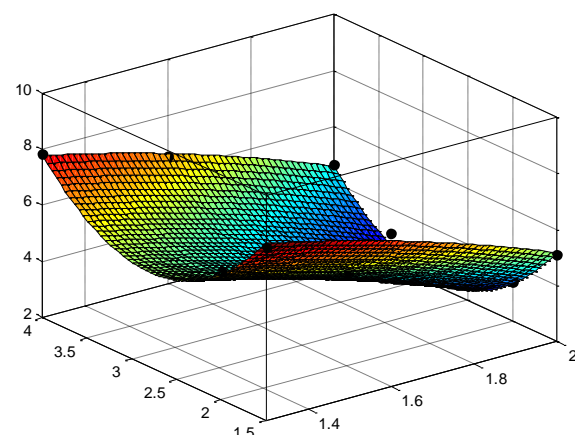
$$Y_1 = -28.96 + 110.4A + 20.69B - 32.75A^2 + 0.1469AB - 3.679B^2$$

$$Y_2 = 19.66 + 1.959A - 9.619B - 1.94A^2 - 0.02587AB + 1.717B^2$$

The response surface curves of Y_1 and Y_2 with A and B can be seen in figures 4 and 5, respectively.

Figure 4. The response surface figure of Y_1 (A, B).

Figure 5. The response surface figure of Y_2 (A, B).

The fitting analysis is taken on the fitting function of the two evaluation index Y1 (A, B) and Y2 (A, B), getting the relevant analysis parameters of fitting are shown in table 4. It can be found from the table 4 that of the two fitting functions, the fitting correlation coefficient (R-square) and adjusted correlation coefficient (Adjust R-square) are close to 1, the variance (SSE) and the root mean square (RMSE) are small, so the correlation of the resulting fitting functions are very good.

Table 4. Parameter list of the fitting analysis.

Data	R-sq	DFE	SSE	RMSE	Adj R-sq
Y_1	0.9916	3	0.4140	0.3715	0.9775
Y_2	0.9951	3	0.0031	0.0323	0.9870

5. Parameters optimization and experimental validation

Optimization problems exist widely in life and many working fields, which are used to discuss the best choice of the decision problem, construct the calculation method in seeking optimal solution. The optimization toolbox in MATLAB can solve many problems of the linear programming, nonlinear programming and multi-objective programming problems and so on [7]. For this reason, optimization toolbox of MATLAB is used to optimize the fitting curve functions obtained, and the ultimate expectation result is maximal single grain rate and minimal cavity rate. The mathematical model is:

- Objective functions: max Y1 (A, B) min Y2 (A, B)
- Constraint conditions: $0.8 \leq A \leq 2.3$, $1.2 \leq B \leq 4$

The fgoalattain solver of multi-objective planning is adopted in the optimization process: establish the objective function of m file, make calls of the m file in the fitting toolbox and input the constraints. The resulting optimization results are:

$$A=1.983, B=2.816, Y_1=91.0901, Y_2=2.3001$$

The actual tests are taken in the 2BSL-320 vegetable seeder with the result of $Y_1 = 89.42$, $Y_2 = 2.93$ through calculation processing to validate the above optimization results, which is in accordance with the theory results. It indicates that the optimization results can provide certain theoretical basis for the design of the operation parameters in the vegetable seeder.

6. Conclusions

The main job of this paper includes:

- Introduce the structure, and working principle about the 2BSL-320 vegetable seeder with air-suction drum type in details, and carry out the seeder tests based on a response surface analysis of the two factors and three levels with the two factors of the aperture (A) and the cylinder pressure (B), the single grain rate and the cavity rate as the evaluation indexes.
- Implement a multivariate regression fitting on the test results by cftool of the MATLAB, and obtain the regression equations of the single grain rate and the cavity rate, on which the multi-objective optimization is based through the optimization toolbox. The resulting optimization results are: $A=1.983$, $B=2.816$, $Y_1=91.0901$, $Y_2=2.3001$.
- Accomplish the actual tests in the 2BSL-320 vegetable seeder with the parameters of $A=1.983$, $B=2.816$ to validate the optimization results, in which the final results is $Y_1 = 89.42$, $Y_2 = 2.93$ that is in accordance with the theory results.

This paper can provide certain theoretical basis for the design of the operation parameters about the 2BSL-320 vegetable seeder.

References

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