Optimization and test for spraying parameters of cotton defoliant sprayer

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Abstract: Boom sprayer is widely used in large farm crops because of its high working efficiency and favorable spraying effect. But there are still some problems in cotton defoliant spraying in Xinjiang, China. Cotton is planted in a high density in Xinjiang, the row space is (10+66) cm, leaves in two adjacent rows are seriously overlapped, the lower leavers are poorly sprayed, so the defoliation effect is poor, and the cotton quality is degraded. To solve this problem and improve the defoliant droplets coverage on the cotton canopy, the original boom spraying was modified, and the spraying pardameters was optimized by the central combination test and design concept of Box-Behnken based on a single-factor test. A quadratic polynomial model of droplets coverage was created by using working parameters including horizontal spraying boom height, hang boom height and nozzles angle as the influential factors and the mean droplets coverage on cotton canopy as the target function, and the effectiveness of mode and interaction of factors were analyzed. The model was optimized and analyzed using the regression analysis method and response surface analysis method of software Design-Expert 7.0.0, and the optimal combination of spraying parameters was obtained. The results showed that the droplets coverage on cotton canopy were influenced by boom height, sprayer height and angled nozzles sequentially from large to small, and the optimal combination of spraying parameters was under horizontal spraying boom height of 134 cm, hang spraying boom height of 27.5 cm and nozzles angle of 21°. The mean droplets coverage of experimental value and predicted value on cotton canopy were 19.6% and 20.43% respectively in such conditions, and the relative error to the estimated value on the model was –4.25%. The research result can provide a reference for further optimizing the spraying parameters of cotton defoliant sprayer.

Keywords: pesticide sprayer, cotton, spraying parameter, optimization, mathematical model, response surface
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1 Introduction

Defoliant spraying is a key link in the mechanized cotton harvest, as sufficient and uniform spraying can improve the defoliation quality and decrease the cotton trash content, and it is significant to solve defects of the cotton quality[1]. But in practice, the anticipated effect are hardly to realize as the defoliant is influenced by weather and the spraying way[2]. Xinjiang is the major cotton producing area in China, where cotton is planted in a high density and cotton leaves are overlapped densely, and it was found in the production and test that the general low defoliation rate and high trash content are caused by the reason that lower leaves cannot be defoliated timely[3]. The key to improve the defoliation effect is to manually improve the droplets coverage on leaves in the middle and lower layers, and spraying the defoliant sufficiently and uniformly on the leaves. Distribution of droplets is influenced by many factors

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including crop density, defoliant composition, ambient temperature and spraying time[4], and also the working parameters of defoliant sprayer which influence the droplets coverage on the cotton canopy[5,6].

Many scholars have made a lot of exploration based on the original large sprayer[7-11]. Some studies described that angling the nozzles was an efficient, easily adjustable, and inexpensive way to improve the deposition or penetration in the canopy of the crop[12,13]. A boom sprayer was designed by Heilongjiang Institute of Agricultural Mechanical Engineering Science. The core part of this sprayer was integrated with domestic and overseas advanced techniques, the nozzle spraying pressure was enlarged to improve the defoliant atomization and penetrability, and the defoliation effect and working efficiency. However, the horizontal boom height was not optimized, most of the defoliant was attached to the upper leaves by lowly spraying, droplets are distributed in a poorly penetrating and seriously shifting effect, and thus a lot of defoliant was wasted[14-16]. Xinjiang Farm redesigned the boom sprayer with nozzles mounted to the vertically downwards boom based on the original cotton sprayer to solve the defect that the defoliant can be hardly sprayed on middle and lower leaves, as a result, it breaks through the bottleneck that the nozzles of a common sprayer spray vertically downwards from the cotton top. The deposition of defoliant on lower leaves and the spraying effect are improved by laterally spraying in cotton rows. But the defoliant droplets coverage on upper and lower leaves is not maximized because the boom height and angled nozzles are designed only by experience.

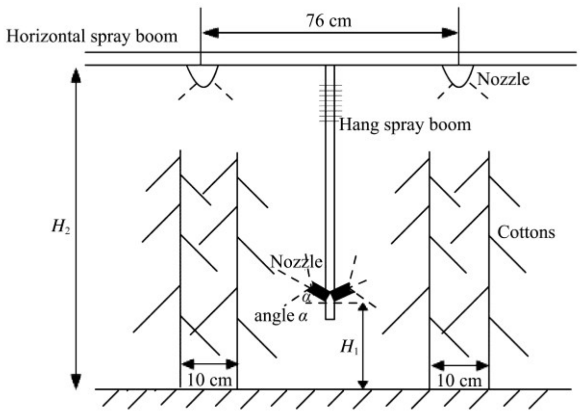
Relatively few studies have explored the effects of nozzles height and angled nozzles and cereal canopy penetration for vertical spray boom applications[17,18], this research took the common boom sprayer as the research target, modifies the horizontal boom height, hang boom height and nozzles' angle, and analyzed the key factors influencing the cotton canopy droplets coverage by a central combination test[19] to obtain the optimized parameters for the working of boom sprayer, and provided references and bases for further improving the cotton defoliant spraying technique

2 Material and method

2.1 Test devices and environmental conditions

The pesticide sprayer was a trailer boom sprayer, the boom was made up of a horizontal boom and a hang boom, several parallel booms were vertically hung under the horizontal boom, nozzles on the horizontal boom were spaced by 76 cm, hung booms were spaced by 76 cm, each hung boom had two bilateral symmetrical nozzles, and the spraying fan was vertical to the ground (Figure 1).

a. Spraying test site



Note: H_1 is hang boom height, cm; H_2 is horizontal boom height, cm; α is nozzle angle, (°).

b. Schematic diagram

Figure 1 Spraying test site and schematic diagram of experimental set-up

The sprayer was reconstructed in this test so that the horizontal boom height, hang boom height and nozzle angle were adjustable, and the sprayer traveling speed was 6 km/h. The nozzle type was NLanao F110-02, and the flow rate was 0.8 L/min. To reduce the test error and ensure the sprayer travels stably, a farm with uniform ridges and no trench was selected for testing. The test was made in September, 2014 on Farm 105 of Xinjiang Production and Construction Corps, the cotton species was Xinluzao #48, the plant height was 90-100 cm, the small row space was 10 cm, the big row space was 66 cm and the plant density was 165 000 plants/hm^2. To reduce the influence of leaf area index on the droplets coverage, a farm of 40 m×60 m was selected with plants in uniform heights and growing ways.

A digital temperature and humidity gauge WY-05 (Shenzhen WYT Instrument Company) and an anemometer GM8901 (Shenzhen WYT Instrument Company) were used in the test, the temperature, humidity and wind speed from 10:00 to 18:00 were measured and recorded, the maximum temperature was 37.8°C, the minimum temperature was 25.5°C, and the mean temperature was 30.56°C; the maximum humidity was 47.7%, the minimum humidity was 23%, and the mean humidity was 30.92%; the maximum wind speed was 2.5 m/s, the minimum wind speed was 0 m/s, and the mean wind speed was 1.4 m/s.

2.2 Test method

2.2.1 Distribution of sample points

The distribution of droplets was measured by image processing, to ensure the sampling conformity, water sensitive papers were fixed to a support which was divided into three layers, upper layer (80 cm high from the ground), middle layer (50 cm) and lower (20 cm) and inserted into the middle of the 10 cm row space. Five sampling points were set along the spraying traveling direction (Figure 2), spaced by 1 m, and each process was repeated for three times. Clear water was used as the medium for spraying to stabilize the spray, the sprayer was started at 10 m from the spraying area before passing through in a uniform speed and stopped at 5 m away from the spraying area. When the droplets on the water sensitive paper were naturally dried after each time of spraying test, papers were collected by tweezers or with waterproof gloves, marked and sealed in sealed bags, and brought back to the lab for analysis.

2.2.2 Response surface test design

The Box-Behnhen design plan was used on the response surface based on the single factor test, the droplets coverage on cotton canopy Y was used as the index to evaluate the defoliant spraying effect of boom sprayer. The response surface test was performed with the hang boom height X_1, horizontal boom height X_2 and nozzle angle X_3, and totally 15 groups of test were made. Code variables and their code levels are shown in Table 1.

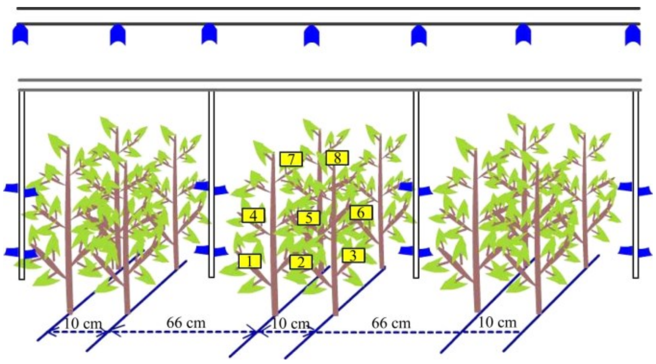


Figure 2 Sketches of sampling collectors

Table 1 Coded variables and their coded levels in response surface analysis

Process parameter	Notation	Code	Actual	Levels		
				−1	0	1
Height of hang spray boom/cm	H1	x_1	X_1	20	30	40
Height of horizontal boom/cm	H2	x_2	X_2	130	140	150
Nozzle angle/(°)	α	x_3	X_3	0	20	40

Note: $x_1=(X_1-30)/10$; $x_2=(X_2-140)/10$; $x_3=(X_3-20)/20$.

In the Box-Behnken model, the hang boom height, horizontal boom height and nozzle angle are selected as the main factors (independent variables) symbolized by X_1, X_2 and X_3; +1, 0 and −1 represent the high, middle and low levels of each independent variable, and the independent variables are coded by Equation $x_i=(X_i-X_0)/\Delta X$. Where, x_i is the code value of an independent variable, X_i is the true value, X_0 is the true value at the experimental central point, ΔX is the step size, and the coded variables and their code levels are shown in Table 1.

According to the test design, the quadratic polynomial for test data postulated to be fitted by the least square method is:

$$Y = b_0 + \sum_{i=1}^{n} b_i X_i + \sum_{i=j=1}^{n} b_{ij} X_i X_j \tag{1}$$

In Equation (1), when n=3, it can be transformed into:

$$Y=b_0+b_1X_1+b_2X_2+b_3X_3+b_{11}X_1^2+b_{22}X_2^2+b_{33}X_3^2+b_{12}X_1X_2+b_{13}X_1X_3+b_{23}X_2X_3$$

where, Y is the response value; b_0 is the intercept term; b_1, b_2 and b_3 are linear coefficients; b_{12}, b_{13} and b_{23} are the interaction term coefficients; b_{11}, b_{22} and b_{33} are the quadratic term coefficients. Test designing and data processing were performed using software Design Expert 7.0.0 (State-Ease Inc., USA).

2.2.3 Sedimentation coverage rate measurement and statistical method

The droplets sedimentation state parameters are the droplets coverage rate and droplets distribution uniformity[20]. The droplets coverage rate on the sampling card can be obtained by ratio of the droplets pixel count on the image analysis area to the total analysis area[21], and the calculation equation is:

$$\delta = \frac{\sum_{i=0}^{M}\sum_{j=0}^{N} f(i,j)}{MN} \times 100\% \tag{2}$$

where, M and N are the width and height of the analysis area, pixel; $f(i,j)$ are the pixel grey scale mark at coordinate (i, j) on the image analysis area, and $f(i,j)=1$ if the pixel is black; or $f(i j)=0$.

3 Results and discussion

3.1 Single factor test

3.1.1 Hang spray boom height

When the horizontal boom height was 135 cm and the nozzle angle was 15°, the influence of hang boom height on the droplets coverage rate was tested. As shown in Figure 3, with the increase of hang boom height, the droplets coverage basically did not changed on the upper layer, linearly increased on the middle layer, and decreased on the lower layer.

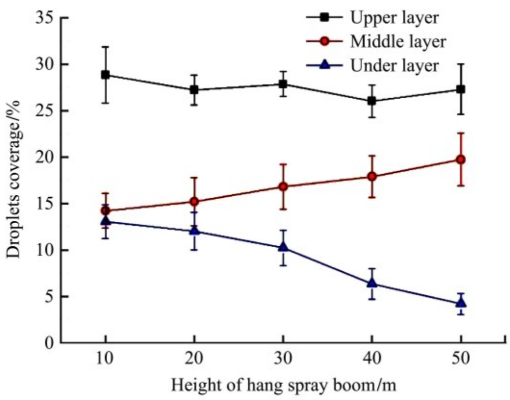


Figure 3 Influence of hang spray boom height on droplets coverage in cotton canopy layer

When the hang boom height increased in a specific range (10-30 cm), the droplets coverage on the lower layer gradually decreased by 2.9% from 13.1% to 10.2%; when the height increased (30-50 cm), the coverage rate on the lower layer distinctly decreased by 6% from 10.2% to 4.2%. Therefore, the hang height must be 10-30 cm to reach high droplets coverage on the lower layer and improve the droplets coverage on the middle layer.

3.1.2 Horizontal spray boom height

When the hang boom height was 30 cm and the nozzle angle was 15°, the influence of horizontal boom height on the droplets coverage rate was tested. As shown in Figure 4, with the increase of horizontal boom height, the droplets coverage basically gradually decreased on the upper and middle layers, and basically did not changed on the lower layer. When the boom height increased from 125 cm to 135 cm, the coverage on the upper layer decreased slowly by 2% from 29.5% to 27.5%; the coverage on the middle layer distinctly decreased by 7.8% from 18.8% to 10.9%. When the boom height increased from 135 cm to 145 cm, the coverage on the upper layer distinctly decreased by 5.9% from 27.5% to 21.6%; the coverage on the middle layer slowly decreased by 2.6% from 10.9% to 8.3%. Therefore, in a specified range (125-135 cm), the influence of horizontal boom height increase on the droplets coverage is small on the upper layer, the influence on the penetrability of droplets is large on the cotton canopy, and thus the droplets coverage on the middle layer decreases distinctly; When the horizontal boom was excessively high (145 cm), the coverage on the upper layer decreased distinctly. The droplets coverage on the lower layer basically did not influenced by the horizontal boom height because the lower layer is sheltered leaves.

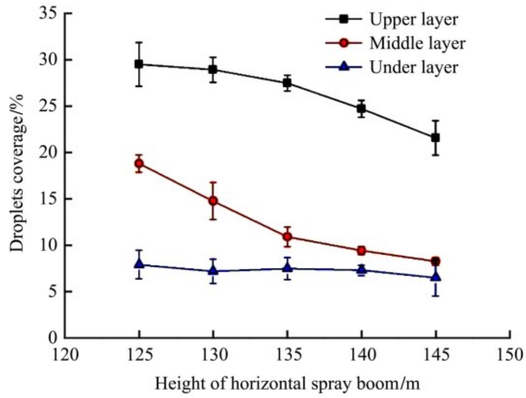


Figure 4 Influence of horizontal spray boom height on droplets coverage in cotton canopy layer

3.1.3 Nozzle angle

When the horizontal boom height was 135 cm and the hang boom height was 25 cm, the influence of nozzle angle on droplets coverage was tested. As shown in Figure 5, the change of nozzle angle had no influence on the droplets coverage of the upper layer, but with the increase of nozzle angle, the droplets coverage on the middle layer increased linearly, and the influence on the droplets coverage on the lower layer was distinct. When the nozzle angle increased in a specific range(5°-30°), the droplets coverage on the lower layer increased and then decreased; when the angle further increases(30°-50°), the coverage on the middle layer increased but on the lower layers decreased distinctly by 9% from 12.4% to 3.2%. Therefore, the angled nozzles must be 15°-30° to ensure the middle and lower layers are highly covered by droplets.

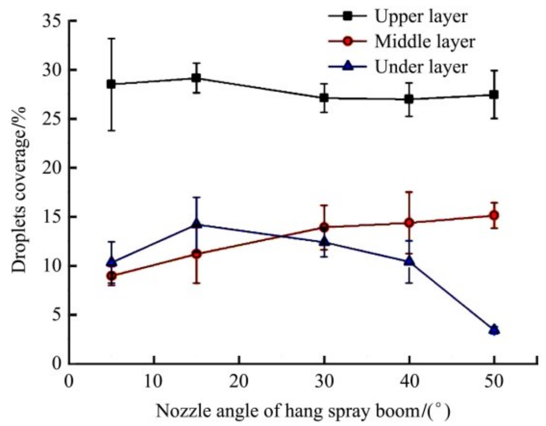


Figure 5 Influence of nozzle angle of hang spray boom on droplets coverage in cotton canopy layer

3.2 Response surface experiment design results and analysis

3.2.1 Experiment design and results

The range of parameters influencing the droplets coverage was studied in the single factor test. To further fix the optimal working parameters, the mean droplets coverage on the cotton canopy was used as the response value, and three factors including the hang boom height, horizontal boom height and nozzle angle were selected for the response surface regression analysis. The experiment design and results are shown in Table 2, where, tests of No.1-12 are for the factorial experiment and No.13-15 are for the central experiment, and they are used to estimate the experiment error.

3.2.2 Analysis of variance for droplets coverage

The experimental results of droplets coverage were analyzed using Design-Expert software, as shown in Table 2. To check the adequacy of the model, three different tests, sequential model sum of squares, lack of fit test, and model summary statistics were made. The results of the quadratic model analyzed using ANOVA reveal that there are a few insignificant terms in the model. Table 3 shows the results of pooled ANOVA.

Table 2 Experiment design and results

Run No.	Variables (original and coded values)			Responses[a]
	X_1/cm	X_2/cm	X_3/(°)	Droplets coverage/%
1	20(−1)	130(−1)	20(0)	18.83±2.52
2	40(1)	130(−1)	20(0)	15.72±1.51
3	20(−1)	150(1)	20(0)	15.62±1.9
4	40(1)	150(1)	20(0)	12.59±2.47
5	20(−1)	140(0)	0(−1)	11.87±3.12
6	40(1)	140(0)	0(−1)	12.86±1.2
7	20(−1)	140(0)	40(1)	14.58±2.22
8	40(1)	140(0)	40(1)	9.61±2.12
9	30(0)	130(−1)	0(−1)	14.70±2.09
10	30(0)	150(1)	0(−1)	12.22±1.43
11	30(0)	130(−1)	40(1)	15.74±2.26
12	30(0)	150(1)	40(1)	11.61±2.27
13	30(0)	140(0)	20(0)	19.84±1.46
14	30(0)	140(0)	20(0)	20.94±1.47
15	30(0)	140(0)	20(0)	18.57±2.22

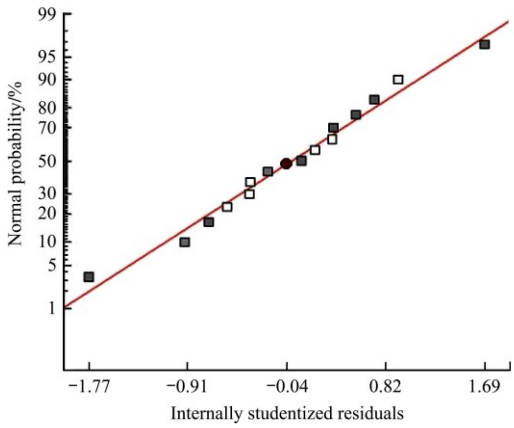
Note: X_1 is height of hang boom, X_2 is height of horizontal boom, X_3 is nozzle angle of hang boom; [a]All of the experimental data were mean values of triplicate determinations.

Table 3 ANOVA for regression models and model terms

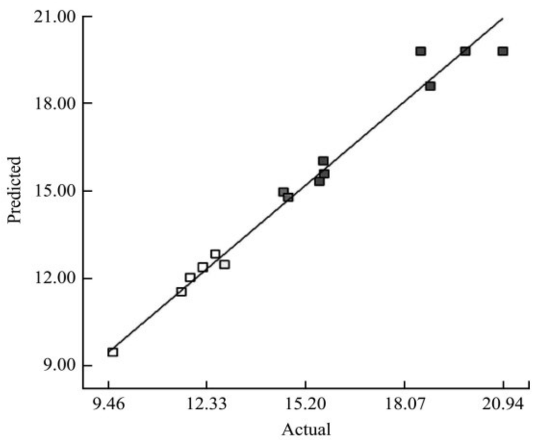
Source	Droplets coverage: Y/%					
	Sum of squares	Degree of freedom	Mean square	F value	Prob>F	
Model	152.87	9	16.99	23.96	0.0014	significant
X_1	12.81	1	12.81	18.07	0.0081**	
X_2	20.98	1	20.98	29.59	0.0028**	
X_3	0.001	1	0.001	0.002	0.9681	
X_1X_2	0.002	1	0.002	0.002	0.9649	
X_1X_3	8.87	1	8.87	12.51	0.0166*	
X_2X_3	0.69	1	0.69	0.97	0.3707	
X_1^2	27.27	1	27.27	38.46	0.0016**	
X_2^2	6.99	1	6.99	9.86	0.0257*	
X_3^2	86.49	1	86.49	122.00	0.0001**	
Residual	3.54	5	0.71			
Lack of fit	0.71	3	0.24	0.17	0.9099	insignificant
Pure error	2.83	2	1.42			
Cor total	156.42	14				
Standard deviation	0.84		R^2	0.9773		
Mean	15.02		R^2_{adj}	0.9365		
C.V./%	5.61		Pred R^2	0.8864		
PRESS	0.49		Adeq precision	15.017		

Note: X_1 is height of hang boom; X_2 is height of horizontal boom; X_3 is nozzle angle of hang boom.

The normal probability plot of the residuals (Figure 6a) shows that 95% of residuals are falling within three sigma limits and lying on a straight line. This means that the errors are normally distributed[22]. Further, it can be seen in Figure 6b that the actual value are following the predicted ones calculated from the model. As both the plots (Figure 6) satisfy the error normality and prediction capability criteria, it is inferred that ANOVA results listed in Table 3 are reliable.



a. Normal probability plot of residuals for droplets coverage



b. Plot of predicted vs. actual response for droplets coverage

Figure 6 Normal probability of the residuals and errors

The model F value can be calculated as: "model" mean square divided by the "residual" mean square. Similarly, an F value on any individual factor term is calculated as the term mean square divided by the residual mean square. The F value test is used to compare the model (or term) variance with the residual variance. If the variances are nearly same, the ratio will be close to 1 and it is less likely that model has a significant effect on the response. A particular source of variation may be significant if the calculated F value at a certain confidence level is greater than the tabulated F value at the same confidence level. Confidence level is chosen to be 95% in this study. If Prob>F value of the model is considerably less than 0.05 (i.e., at 95% confidence level), then the terms in the model have a significant effect on the response. The Model F-value of 23.96 implies the model is significant. There is only a 0.14% chance for a "Model F-Value" of this large could occur due to noise. Values of "Prob>F" less than 0.0500 indicate model terms are significant.

In this case, the linear terms X_1 (hang boom height, cm) and X_2 (horizontal boom height, cm) (P_r<0.01) influence significantly while X_3 (nozzles angle) (p=0.9681) influences insignificantly; the quadratic term X_1^2 (P_r=0.0016), X_2^2 (P_r=0.0257) and X_3^2 (P_r=0.0001) influence significantly; the alternative term X_1X_3 (P_r=0.0166) influences significantly, and the other two influence insignificantly. It means the droplets coverage on cotton canopy was significantly influenced by the hang boom height and horizontal boom height, and is alternatively influenced by the hang boom height and angled nozzles. According to the coefficient estimated values X_1=1.63, X_2=3.73 and X_3=1, it is known the main influencing factors are in sequence as horizontal boom height > hang boom height > nozzle angle.

The "Lack of Fit F-value" of 0.17 (Table 3) implies that the Lack of Fit is not significant relative to the pure error. There is a 90.99% chance for a "Lack of Fit F-value" of this large could occur due to noise.

To further check whether the fitted models actually describe the experimental data, determination coefficient (R^2) is computed. The determination coefficient is defined as the ratio of explained variation to the total variation and is a measure of the degree of fit. When it approaches unity, the response model fits better to the actual data and shows less difference between the predicted and actual values. The determination coefficient for droplets coverage percentage of 0.9773 (Table 3) shows that the quadratic model can explain the variation in the droplets coverage up to the extent of 97.73%. On the basis of the high values of the determination coefficient, it can be said that the proposed model is adequate in representing the process. The Pred R^2 (0.8864) is in good agreement with the R^2_{adj} (0.9365). The coefficient of variation (CV) of the model is defined as the ratio of the standard deviation to the mean. The lower value (5.61%) of CV given in Table 3 indicates improved precision and reliability of the conducted experiments[23]. Further, the Adeq Precision measures the signal-to-noise ratio. Generally, a ratio greater than 4 is desirable[24]. The Adeq Precision obtained for the model is 15.017, which is well above the desired value and thus indicates an adequate signal for the model. Hence, this model can be used to show the design space and predict the values of the droplets coverage percentage within the limits of the factors studied.

As the obtained model presents higher value of R^2 (0.9773) and Adeq Precision (15.017) for the droplets coverage percentage, therefore, this mathematical model can be regarded as significant for fitting and predicting the experimental results.

In terms of actual factors, the final empirical relationship between droplets coverage percentage (response characteristic) and input process parameters can be expressed by the following second-order polynomial Equation (3):

$$Y=-262.15808+1.62570X_1+3.72620X_2+0.99641X_3+1.94444\times10^{-4}X_1X_2-7.44446\times10^{-3}X_1X_3-2.06944\times10^{-3}X_2X_3-0.027176X_1^2-0.013759X_2^2-0.01210X_3^2 \quad (3)$$

The coefficients of the process parameters in Equation (3) are computed by Design-Expert software after analysis of the data as shown in Table 3.

3.2.3 Validation of models

In order to validate the droplets coverage percentage model, five additional experiments were conducted using same parameter settings within the range of selected parameters. The results of validation experiments are shown in Table 4.

The prediction error (%) listed in Table 4 is calculated by the following Equation (4):

$$\text{Prediction error}(\%)=(\text{Experimental result}-\text{Predicted result})/\text{Experimental result}\times100 \quad (4)$$

As the predicted results obtained from regression equations are found to be in agreement with the experimental findings and also the prediction errors are less than ±10%, therefore, the developed models can be regarded as a reliable representative of the experimental results.

Table 4 Results of validation experiments for droplets coverage

Experiment number	Variables			Responses/%		Prediction error/%
	X_1/cm	X_2/cm	X_3/(°)	Experimental value	Predicted value	
1	27.5	134	21	19.60±2.62	20.43	-4.25
2	30	135	15	18.33±0.46	19.90	-8.57
3	30	130	15	17.87±1.00	19.63	-9.87
4	25	135	30	18.40±1.95	19.47	-5.83
5	20	140	30	18.37±1.11	17.79	3.15

Note: X_1 is height of hang boom; X_2 is height of horizontal boom; X_3 is nozzle angle of hang boom.

3.2.4 Interactive effect of process parameters on droplets coverage percentage

In this section, the effects of individual process parameters as well as their interactions on the performance measures were discussed with the help of three-dimensional (3D) response curves and contour plot.

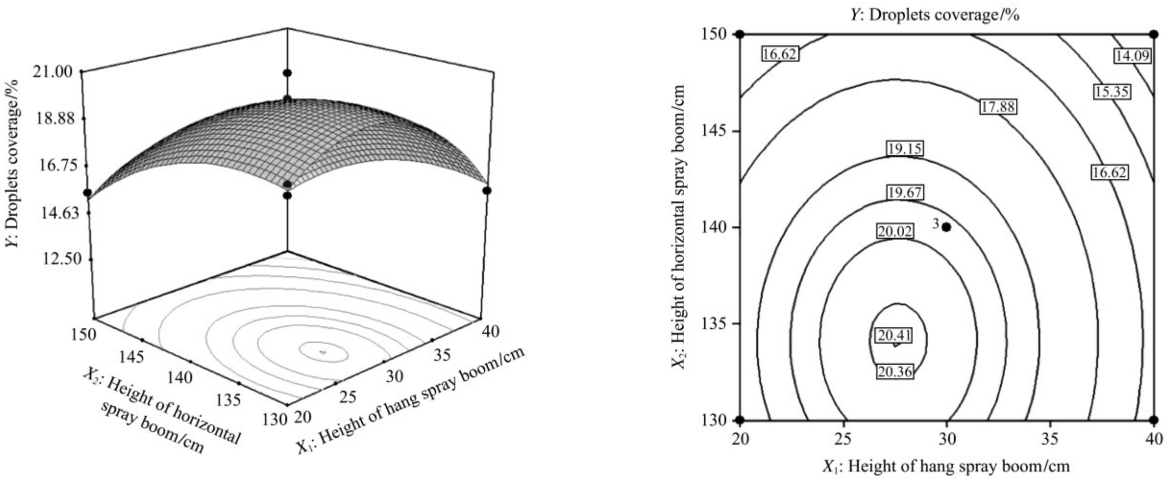
From Table 3, it is clearly showed that the interaction which contributes significantly to the model is between the height of hang boom and nozzle angle of the hang boom (X_1X_3). The interaction which contribute not significantly to the model are those between the height of hang boom and the height of horizontal boom (X_1X_2), height of horizontal boom and nozzle angle of the hang boom (X_2X_3). The interaction plots corresponding to these are shown in Figures 7-9, respectively.

The 3D surface plot in Figure 7 shows that the droplets coverage increases when the horizontal boom height and hang boom height increases in a specified range; in the experimental range, the surface plot of droplets coverage is a crown, and there is a peak on the crown. Contours are ellipses, and the center is at the experimental range, and the figures show that the droplets coverage is the largest when the hang boom is 26.5-28 cm high and the horizontal boom is 132-136 cm high, and the coverage decreased when both are excessively high or excessively low. So the hang boom height and horizontal boom height must be controlled at suitable levels.

The 3D surface plot in Figure 8 shows the droplets coverage can be improved by increasing the hang boom height, but the droplets coverage will decrease from a top limit when the nozzles angle is about 21°. The contour chart shows that the droplets coverage is the largest when the hang boom is 26-28 cm high and the nozzles angle is

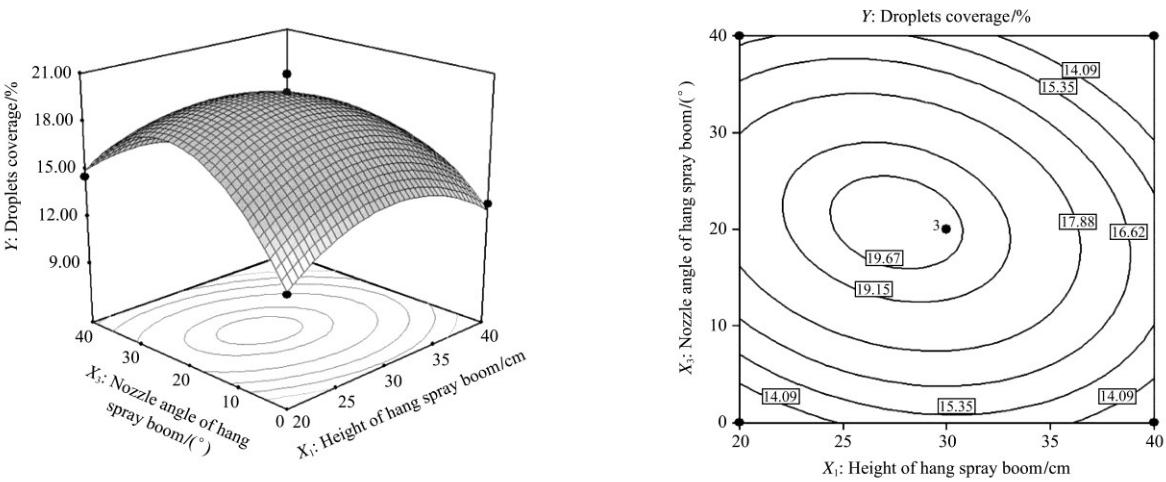
21°-23°, and the coverage will not increase further from then on.

The 3D surface plot in Figure 9 shows the droplets coverage can be improved by increasing the horizontal boom height and nozzles angle in a specified range, but it will decrease from a top limit. The contour chart shows that the droplets coverage is the largest when the horizontal boom is 134-135 cm high and the nozzles angle is 20-22°, and the coverage will not increase further from then on.



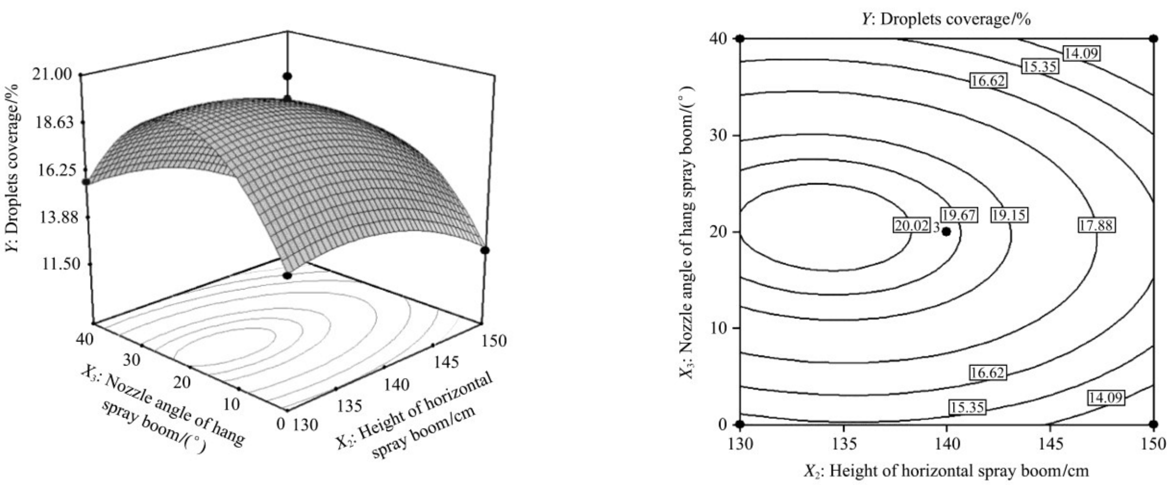
a. Plot of response surface b. Plot of contour

Figure 7 The effects of X_1, X_2 and their mutual interaction on droplets coverage percentage



a. Plot of response surface b. Plot of contour

Figure 8 The effects of X_1, X_3 and their mutual interaction on droplets coverage percentage



a. Plot of response surface b. Plot of contour

Figure 9 Effects of X_2, X_3 and their mutual interaction on droplets coverage percentage

Figures 7-9 show that the droplets coverage has a maximum value, because the surface plot is a crown and contours are ellipses, and the center is at the experimental range. The response surface is a highly crowned surface, it means the correlation between variables and the corresponded value is complicated, so we cannot analyze it by a linear equation. The optimal hydrolysis conditions are obtained by the optimizing function of Design Expert, the estimated maximum droplets coverage is 20.43% under the condition that the three key factors are hang boom height of 27.49 cm, the horizontal boom height of 134 cm, and the nozzle angle of 21.26°.

4 Conclusions

In this research, the response surface method was used in the optimization design for spraying parameters of a pesticide sprayer, and an approximate model for the spraying parameters was made with the horizontal boom height, hang boom height and nozzles angle as the variables and the mean droplets coverage on the cotton canopy as the optimization target. The model was verified and proved reasonable and reliable, and the key factors and interaction were analyzed by the model response surface and contours. The results showed that the spraying coverage on cotton canopy was influenced by three factors, boom height, sprayer height and nozzles angle sequentially from large to small, and the optimal combination of spraying parameters was horizontal spraying boom height 134 cm, hang spraying boom height 27.5 cm and nozzles angle 21°C. The mean spraying coverage of experimental value and predicted value on cotton canopy were 19.6% and 20.43%, respectively in such conditions, and the relative error to the estimated value on the model was –4.25%. Because the prediction errors are less than ±10%, therefore the developed models can be regarded as a reliable representative of the experimental results.

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