DESIGN, ANALYSIS AND TEST OF CLEANING MACHINE FOR GRAPEVINE COLD-PROOF SOIL

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葡萄藤防寒土清土机设计、分析与试验

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ABSTRACT

In order to address the problems of low efficiency and low degree of mechanization of artificial soil clearing of the grapevines in spring in Xinjiang grape growing regions, a grapevine cold-proof soil clearing machine was designed. The machine is mainly composed of a frame, gearbox, suspension device, soil clearing parts, hydraulic system and mechanical transmission system, etc. The motion track of the soil clearing parts was analyzed to obtain the key factors affecting the performance of the grapevine cold-proof soil clearing machine that were determined. The three-factor, three-level quadratic regression orthogonal experiment was carried out with the forward speed, soil clearing parts' diameter and rotation rate of soil clearing parts as factors and the soil clearing distance was used as evaluation index. The results showed that the order of influence on the soil clearing distance was rotation rate of soil clearing parts > forward speed> soil clearing parts diameter. The parameters were optimized based on response surface method with the following results: the rotation rate of soil clearing parts speed was 277.7 r/min, the forward speed was 3.5 km/h, and the soil clearing parts diameter was 681.7 mm. The validation experiment was carried out with the optimal parameters' combination. The soil clearing distance was 85.44 cm, which was consistent with the predicted results of the model. This research results can provide reference for the development of other types of grapevine soil clearing machine.

摘要

为了解决目前新疆葡萄种植区春季人工进行葡萄藤清土作业效率低、机械化程度低的问题。本文设计了葡萄防寒土清土机，主要由机架、齿轮箱、清土部件、液压系统、传动系统等组成。分析了清土部件运动轨迹，确定了影响葡萄防寒土清土机性能的关键因素。为确定葡萄防寒土清土机最佳工作参数组合，以前进速度、刷片直径、清土刷转速为试验因素，以清土距离为评价指标，开展了三因素三水平二次回归正交试验。结果表明，影响清土距离的主次顺序为：清土部件转速>前进速度>清土部件直径。基于响应面法进行参数优化，优化结果为：清土部件直径为 681.7mm，前进速度为 3.5km/h，清土部件转速为 277.7r/min。以优化后参数组合进行试验验证，结果为：清土距离为 85.77cm，与模型预测结果一致。本研究结果可为其他类型葡萄藤清土机的研制提供参考。

INTRODUCTION

Xinjiang is located in the northwestern part of China, there is plentiful of heat that benefits the growth of grape. Xinjiang is one of the largest grape planting areas in the China, and the grape growing areas cover a total of 146700 hm^2. Grape is mainly planted in Changji, Turpan, Tacheng. The grape industry has become an essential pillar for the economic development in Xinjiang *(Xu L.M. et al, 2019)*. Grapevines are vulnerable to damage at low temperatures. They will cause the grapevines to dry out and frostbite, affecting the growth and yield for the next year. There are some very good management measures that can help reducing the risk of incurring cold damage during the winter. Examples of such measures include: planting cold hardy cultivars in the respective cold hardiness adapted zones; delayed pruning; burying grapevines in soil etc. *(Yuan Q.C. et al, 2017; Wisniewski and Gusta, 2014)*.

The most commonly used method for protecting grapevines in Xinjiang is burying vines in soil, which is an efficient and environmentally friendly method, completely harmless to grapevines.

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Every winter, the grapevines need to be removed from the trellis and laid on the ground to be covered with soil, and soil must be cleared in spring *(Dami, Ennahli and Zhang, 2012)*. However, clearing grapevines cold-proof soil is an extremely labor-intensive and time-consuming operation, as most grapevines need to be cleared in time and it is necessary to avoid damaging grapevines during clearing. At present, the grapevines cold-proof soil clearing mainly depends on manual clearing, which costs a large amount of labor and has low efficiency. Therefore, it is necessary to develop a grapevine cold-proof soil clearing machine characterized by a compact structure, flexible operation, transfer convenience, low price, etc. thus being able to adapt to the trellis-type planting mode, and conform to the demands of farmers and the market. *(Xu L.M. et al, 2012; Bucur and Dejeu, 2016)*. Overseas, due to the mild and humid climate in winter, in foreign grape producing areas *(Molitor, Caffarra, Sinigoj. Etal, 2014)*, there is no need to perform cold-proof soil burying operation in winter and soil removing in spring *(Zabadal, Dami, Goffinet and Martinson, 2007)*. There are few references on grapevine cold-proof soil clearing in foreign countries *(Zhou W.B. et al, 2017)*. In order to improve the soil clearing efficiency, domestic scholars have done a lot of meaningful exploration and research on cold-proof soil clearing machine, which is a promising solution. For example, the rigid structure winter protection soil clearing machine was developed, the machine structure design is reasonable, the layout is compact, supposes low cost, easy operation and maintenance *(Zeng B.N. et al, 2013; Wang Z.Q et al, 2015)*. The grapevine soil clearing machine was designed, which realized semi-mechanized cleaning of cold-proof soils *(Zhang J.J. et al, 2015).* The combined grapevine soil clearing machine was designed *(Xie D. et al, 2016; Liu S. et al, 2014; Xu L.M. et al, 2018)*. The layered-staggered structure was adopted in the form of a cross arrangement *(Ma S. et al, 2018)*; it can complete multiple operations simultaneously. The trellis-type grape winter buried soil clearing and cold-proof cloth recycling machine was developed *(Niu C. et al, 2019)*, which showed that operation efficiency of the machine was more than 10 times of the manual soil clearing efficiency. The automatic obstacle-avoiding grapevine cold-proof soil cleaner was designed *(Ma S. et al, 2020)*, which showed that the effects of the operation meet the requirements of automatic obstacle-avoiding grapevine cold-proof soil clearing. An automatic obstacle-avoid digging machine for grapevine was designed *(Liu F.J. et al, 2018)*, which showed that the volume of the cold-proof soil clearing was sufficient and the obstacle-avoiding effect was excellent.

In this paper, based on the research of the self-developed grapevine cold-proof soil clearing machine, the relationship between operating parameters of soil clearing parts and soil clearing quality is studied by taking soil clearing distance as the target and combining it with field trial. Firstly, the factors that have great impact on the soil clearing quality are find out: the forward speed, the rotation rate of soil clearing parts and the soil clearing parts' diameter. Then the response surface of soil clearing distance is established by three-factor three-level response surface test, and the response surface is analyzed to fit the quadratic regression curve and get the regression equation. The influence of each factor on the soil clearing quality evaluation index, as well as the best combination of parameters are researched in order to guide the field operation of grapevine cold-proof soil clearing machine and provide a reference for the design of grapevine cold-proof soil clearing machine.

MATERIALS AND METHODS

Overall structure

Aiming at the grape trellis-type planting mode in Xinjiang regions and meeting the design principles of a machine, a grapevine cold-proof soil clearing machine is studied and designed; it mainly consists of a frame, gearbox, soil clearing parts, suspension device, hydraulic system and mechanical transmission system, etc. The overall structure is shown in Figure 1, while the main performance indexes and technical parameters of the machine are shown in Table 1.

Table 1

Main technical parameters

Parameter	Value	Units
Overall dimension (length × width ×height)	1850×1200×750	mm
Tractor power	≥60	kW
Operation speed	3~5	Km/h
Operating width	800	mm
Driving form	Gearbox drive	-
Structure form	Three-point suspension	-
Number of working rows	1	-

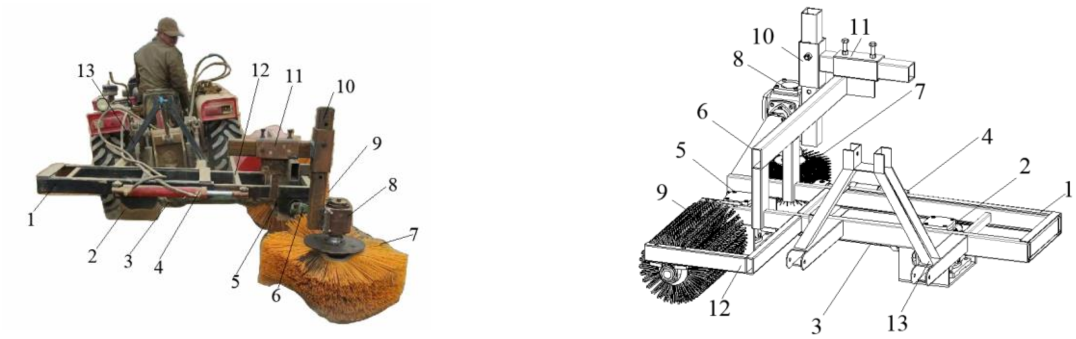


Fig. 1 - Schematic diagram of grapevine cold-proof soil clearing machine

1 – Fixed frame; 2 – Gearbox Ⅰ; 3 – Universal joint drive shaft Ⅰ; 4 – Hydraulic cylinder; 5 – Gearbox Ⅱ;
6 – Universal joint drive shaft Ⅱ; 7 – Soil clearing parts Ⅰ; 8 – Gearbox Ⅲ; 9 – Soil clearing parts Ⅱ;
10 – Longitudinal adjustment frame; 11 – Transverse regulating frame 12 – Mobile frame; 13 – Suspension device

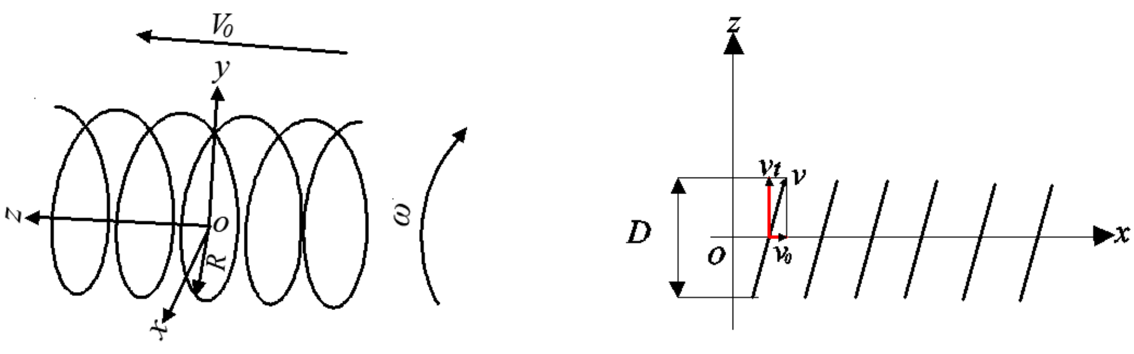
Working principle

During the field operation, the power from the tractor power output shafts is transmitted to the soil clearing parts through the mechanical transmission system, to drive all working devices to finish the clearing of soil. Firstly, the height of the soil clearing device is adjusted by a hydraulic cylinder, as to make the machine height meet the operation requirements; then the clearing machine moves forward; the mechanical transmission system will drive the soil clearing parts to take rotation motion under the joint action of the forward speed and rotation rate of soil clearing parts; the soil clearing parts entered into the soil convey the soil to one side of the machine. After clearing, the clearing devices are raised off the ground, so that the mechanized soil clearing operation is completed.

Analyzing the movement of soil clearing parts, it was found out that there were three factors that affected the soil clearing of the grapevine cold-proof soil clearing machine: the mechanical structure parameters of the machine, the characteristics of the soil itself and the environmental factors. Under the influence of irresistible environmental factors and the mechanical properties of soil itself, this paper mainly studies the influence of the structural parameters of the machine on the law of cold-proof soil clearing to solve the problems appeared during practical work.

Trajectories analysis of front soil clearing brush

During the process of soil clearing, the machine moves forward at a certain speed under the tractor's traction. The movement of the soil clearing device is the combined motion of a uniform linear motion and uniform circular motion around the axis. The soil clearing velocity can also be schematically plotted as combination of forward speed and rotational speed, and the trajectories of soil clearing parts is shown in Figure 2(a). The soil is removed under the joint action of the forward speed v_0 and the soil clearing device linear speed v_t, forming the movement trajectories on the ground that are shown in Figure 2(b).



(a) (b)

Fig. 2 - Analysis diagram of movement track of soil clearing parts

The Cartesian coordinate system was established with the center of the soil clearing parts as the origin and the left side of the x-axis as positive direction. The positive direction of the y-axis is vertical and the positive direction of the *z-axis* is the forward direction of the machine.

The trajectories of the soil clearing parts were plotted, as shown in Fig. 2(a). The motion of soil clearing device is a combined linear and circular motion; thus, the equation for the motion trajectory of soil clearing device can be represented as follows:

$$\begin{cases} x = R\cos(\omega \cdot t) \\ y = R\sin(\omega \cdot t) \\ z = v_0 \cdot t \end{cases} \tag{1}$$

The trajectories formed by the soil clearing parts on the ground is an equidistant curve, and it's clearing width *D* is related to the soil clearing parts' diameter, as shown in Figure 2. The projection of this trajectories on the *xoz* plane is:

$$x_k = R\cos\left(\frac{\omega}{v_0}x + k\phi\right) = R\cos\left(\frac{\pi n}{30v_0} + \frac{2k\pi}{m}\right) \tag{2}$$

$$\phi = \frac{2\pi}{m} \tag{3}$$

Where:

V_0 - forward speed of grapevine cold-proof soil clearing machine, km/h;

ω - soil clearing parts angular velocity, rad/s;

t - time, s;

R - radius of soil clearing parts, mm;

n - soil clearing parts rotation speed, r/min;

m - total number of brushes;

k - brush serial number;

Φ - phase difference between adjacent brushes.

Main factors impacting the clearing performance of the grapevine cold-proof soil clearing machine include the number of brushes, rotation rate of the clearing parts, diameter of the soil clearing parts, forward speed, soil moisture content. According to the analysis results in formula 2 and the previous field trials, the number of brushes is m = 17. This test mainly selects the rotation rate of clearing parts, diameter of the soil clearing parts and forward speed. If the rotation rate of the soil clearing parts is too high, it would lead to high power consumption, but if it is too low, the clearing failure would increase. According to the previous field trials, the rotation rate of the soil clearing parts is designed and calculated to be 200 ~ 300 r/min. If the diameter is too large, it would cause a waste of power, but if it is too small, it may lead to the incomplete soil clearing. As a result, the diameter of the soil clearing parts is designed to be 550 ~ 750 mm. If the forward speed is too high, it would also increase the soil clearing failure, but if it is too low, it may influence the soil clearing efficiency, thus being unable to meet the soil clearing requirements. The forward speed is designed to be 3 ~ 5 km/h.

Test conditions

To verify the soil clearing performances of the grapevine cold-proof soil clearing machine designed in this study, the experiment was conducted in Daxiqu Town, Changji City from November 1 to 5, 2021. The weather was sunny, the temperature was 3~15°C, and the filed test ground was relatively flat, with an area of about 150 m^2. The grape planting mode was trellis-type, the row spacing was 3 ~ 4 m, and the plant spacing was between 1 ~ 1.5 m, the soil moisture content was 4.4% ~ 12.5%, the soil hardness was 3.8kg ~ 6 kg/cm^2.

The matching power of the tractor used in the test was greater than 60 kw. The main instruments and equipment used in the field test are grapevine cold-proof soil clearing machine, TYD-2 soil hardness tester, QS-WT soil moisture tester, speed tester, electronic balance, tape measure, adjustable wrench, etc. Before the test, the machine should be strictly inspected to ensure that the rotating parts and the adjusting device are flexible and reliable. The machine should be installed stably and reliably. There should be no abnormal noise, so as not to affect the test results due to poor machine adjustment. In order to ensure that the test results are precise and reliable, the machine needs to be adjusted to the specified speed and the speed is stable before the test. The results showed that performance of the grapevine cold-proof soil clearing machine met the agronomic requirements of grape plantation. Figure 3 shows the field testing of grapevine cold-proof soil clearing machine.

Fig. 3 - Testing of grapevine cold-proof soil clearing machine

Evaluation of soil clearing effect

The soil clearing operation schedule of the grapevine cold-proof soil clearing machine was tested, and the soil clearing operation length of a single row is 55 m for each single-row operation, of which the length of the measuring area is 45 m and the length of the reserve area at both ends is 10 m. Each row along the advance direction was divided into 30 sections as the measuring area according to the successive length of 1.5 m, and a total of 30 sections were tested. During the test, the soil clearing device was raised in the preparation area, and the grapevine cold-proof soil clearing machine entered the working state. After that, the measuring area was passed at the normal working speed.

Due to the difference in planting patterns and varieties in different grapevine areas, and considering that there are no unified and clear requirements for the quality of cold-proof soil clearing, most of the performance evaluation of the soil clearing machine is based on the completion of the soil clearing operation, and there is no unified and clear quantitative index. In this paper, the distance between the original soil ridge center line and the new soil ridge center line was defined as the soil clearing distance *L*, the maximum value of distance between the original soil ridge center line and the new soil ridge center line was used as the optimal index, during the process of cold-proof soil clearing operation, the greater the distance *L*, the bigger the soil clearing ability of the machine. The soil clearing distance is shown in Figure 4.

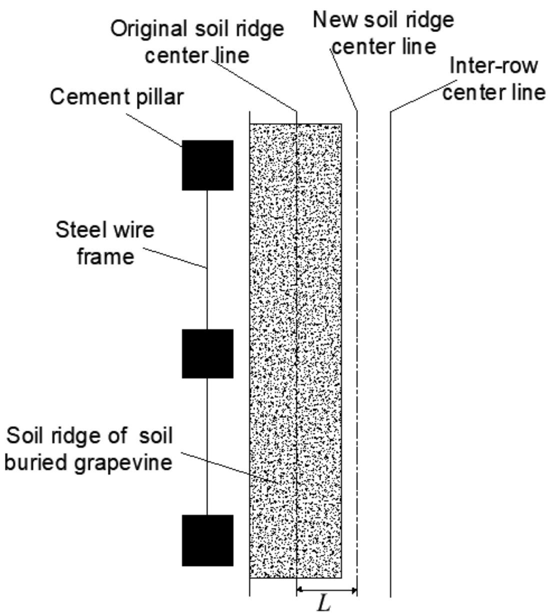


Fig. 4 - Schematic diagram of clearing distance

Test design

Based on the observation and theoretical analysis of previous field experiment, the rotation rate of soil clearing parts *A*, the soil clearing parts diameter *B*, the forward speed *C*, which have a great impact on the soil clearing performance, are selected as the experimental factors, for the response surface test research. Quadratic polynomial regression analysis is conducted for the test data using Design-Expert software *(Chen K. 2005)*, to fit the regression model equations respectively for the soil clearing distance *L*, so as to analyze the influence of factors on the evaluation indexes and the effect law of their interactions. The level of each factor was determined as shown in Table 2.

Table 2

Experimental factors and levels

Levels	Rotation rate of soil clearing parts A	Soil clearing parts diameter B	Forward speed C
	[r/min]	[mm]	[km/h]
-1	200	550	3
0	250	650	4
1	300	750	5

In Design-Expert.8.0, according to the Box-Behnken test scheme, the test results are shown in Table 3. There are 17 groups of data, and the test is repeated five times at the center point.

Table 3

Box-Behnken design scheme and response value of soil cleaning distance

Test number	Rotation rate of soil clearing parts A	Soil clearing parts' diameter B	Forward speed C	Soil clearing distance
	[r/min]	**[mm]**	**[km/h]**	**[cm]**
1	0	0	0	84.23
2	1	-1	0	85.18
3	0	0	0	83.71
4	-1	-1	0	78.95
5	0	0	0	84.04
6	0	1	1	79.28
7	1	0	-1	85.57
8	0	0	0	83.48
9	1	0	1	82.07
10	0	-1	-1	81.38
11	-1	1	0	82.28
12	-1	0	-1	80.8
13	1	1	0	85.76
14	-1	0	1	77.7
15	0	-1	1	76.84
16	0	0	0	83.54
17	0	1	-1	84.64

RESULTS AND ANALYSIS

Test analysis results

According to the data of the test, multiple regression fitting analysis is conducted using Design-Expert software. Furthermore, mathematical regression models are built for the clearing performance indexes of the soil clearing distance L, and rotation rate of soil clearing parts A, soil clearing parts' diameter B and forward speed C of the grapevine cold-proof soil clearing machine. The regression model of soil clearing distance was obtained:

$$L = 83.80 + 2.36A + 1.2B - 2.06C - 0.69AB - 0.10AC - 0.21BC + 0.12A^2 - 0.88B^2 - 2.39C^2 \quad (4)$$

where: A is rotation rate of soil clearing parts (r/min); B is soil clearing parts diameter (mm); C is the forward speed (km/h).

The above equations are further analyzed, and the significance test of regression coefficients is carried out at the same time. The analysis results are shown in Table 4.

According to the analysis results in Table 4, the response surface model *P* of the soil clearing distance L is 0.0001, which is smaller than 0.01, meaning that the significance of models conforms to the requirement. The lack of fit of indexes is 0.0627, greater than 0.05, meaning that the models are of high fitting degree, also meeting the requirement. The determination coefficient R^2 of models is 0.9819, suggesting a high degree of fitting. Besides, the response surface analysis results are of high reliability. Therefore, this model can predict and analyze the changes in the soil clearing performance of the machine.

Table 4

Variance analysis results

Source	Soil clearing distance				
	Squares	**DF**	**MS**	**F Value**	**P Value**
Model	120.34	9	13.37	42.10	0.0001
A	44.42	1	44.42	139.86	0.0001
B	11.54	1	11.54	36.35	0.0005
C	34.03	1	34.03	107.16	0.0001
AB	1.89	1	1.89	5.95	0.0448
AC	0.040	1	0.040	0.13	0.7331
BC	0.17	1	0.17	0.53	0.4905
A^2	0.062	1	0.062	0.19	0.6722
B^2	3.25	1	3.25	10.24	0.0151
C^2	23.98	1	23.98	75.50	0.0001
Lack of Fit	1.80	3	0.60	5.71	0.0627
Pure Error	0.42	4	0.11		
CorTotal	122.56	16			

The above stated significance analysis shows that A, B, C and C^2 in the soil clearing distance L response model would impact the model very significantly, AB and B^2 also have a significant impact on this model. The items that exert no significant influence on the regression model in the before-mentioned model are removed. Meanwhile, on the basis of guaranteeing that the model P<0.01 and lack of fit P >0.05, the simplified regression model is shown as follows:

$$L = 83.80 + 2.36A + 1.2B - 2.06C - 0.69AB - 0.88B^2 - 2.39C^2 \tag{4}$$

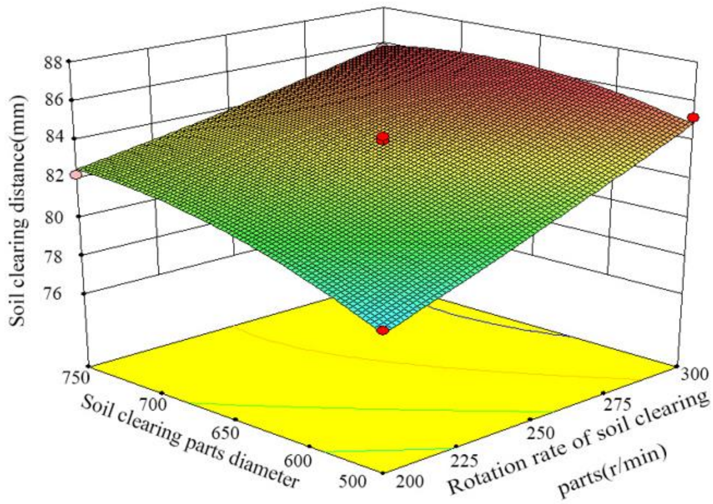
The analysis shows that the impact of three factors on the soil clearing distance rank as A>C>B.

Response surface analysis of clearing distance

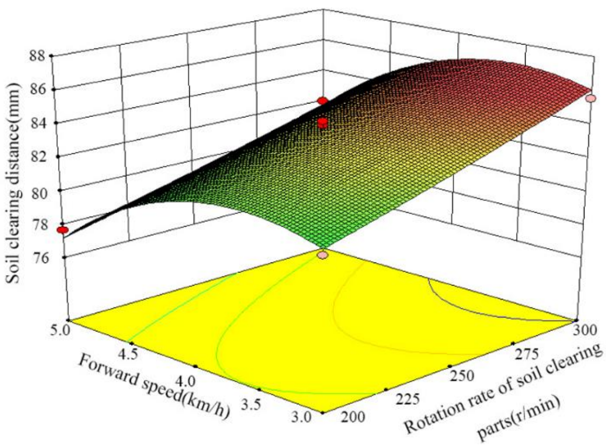
In Figure 5a, the forward speed remains at the middle level, that is C=4 km/h. It can be seen Figure 5a that the interactive effects between the two factors are significant. In case of the same soil clearing parts diameter, the soil clearing distance increases with rotation rate of soil clearing parts. In case of the same rotation rate of soil clearing parts, the soil clearing distance increases with the soil clearing parts' diameter. The influence of the soil clearing parts diameter is smaller than that of the rotation rate of soil clearing parts.

In Figure 5b, soil clearing parts diameter is in the middle level, namely, B=650 mm, and it is clear that the interactive effect of the two factors is not significant. Under the same forward speed, the soil clearing distance increases with rotation rate of the clearing parts. Under the same rotation rate of soil clearing parts, the soil clearing distance increases first and decreases afterward as the forward speed increases. The influence of forward speed is not as significant as that of rotation rate of soil clearing parts on soil clearing distance. When the forward speed is too high, it doesn't facilitate the entry of cold-proof soils into the clearing device and lowers the soil clearing distance.

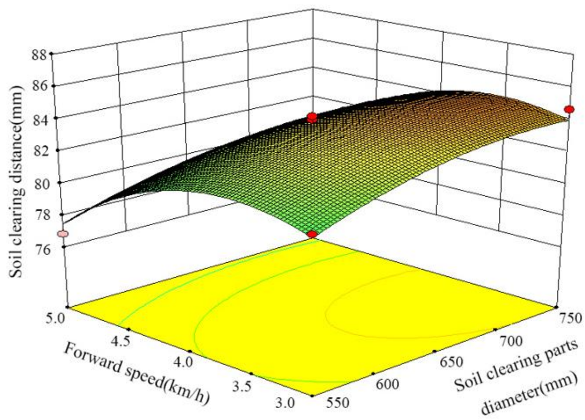
As shown in Figure 5c, the rotation rate of soil clearing parts remains at the middle level, that is, A=250 r/min. It can be seen from Figure 5c that the interactive effects between the two factors are not significant. Under the same rotation rate of soil clearing parts, the soil clearing distance, increases first and decreases afterward as the forward speed increases. A too high forward speed can lead to irregular soil clearing, missed clearing, and lowers the soil clearing distance. Under the same forward speed, the soil clearing distance increases as the forward speed increases because improving rotation rate soil clearing parts can facilitate clearing the soil and reduce soil obstruction of clearing channels.



a. L=(A,B,0)



b. L=(A,0,C)



b. L=(0,B,C)

Fig. 5 – Response surface of different experimental factors to soil clearing distance effect

Parameter optimization and validation

To improve the soil clearing performance of the machine, it is required to maximize the soil clearing distance. In order to seek the optimal parameter combination, it is required to conduct the parameter optimization on multiple targets. According to the actual production and design requirements and referring to other relevant standards, the soil clearing distance is required to be more than 80 cm. Hence, the constraint conditions are listed below:

$$\begin{cases} MaxL \\ A \in [200-300\text{r/min}] \\ B \in [550-750\text{mm}] \\ C \in [3-5km/h] \end{cases} \tag{5}$$

After optimization calculation, the optimal working parameters were obtained as follows: forward speed was 3.5 km/h, the rotation rate of soil clearing parts was 277.7 r/min, the soil clearing parts' diameter was 681.7 mm. The predicted value of soil clearing distance was 85.77cm. The validation tests were carried out using the above optimization parameters. The results show that the soil clearing distance was 83 cm, which was consistent with the prediction result of the model, and the prediction errors is less than 4%.

CONCLUSIONS

(1) A grapevine cold-proof soil clearing machine suitable for grape planting areas in the Xinjiang was developed and tested in this paper. It mainly consists of frame, gearbox, suspension device, soil clearing parts, hydraulic system and mechanical transmission system, which effectively solves the difficulties, such as low efficiency and low degree of mechanization, in soil removing by grapevine cold-proof soil clearing machine.

(2) By analyzing the movement trajectories of the soil clearing parts, the key factors affecting the performance of grapevine cold-proof soil clearing machine were determined: forward speed, rotation rate of soil clearing parts and clearing parts' diameter.

(3) The Variance analysis showed that the order of influence on soil clearing distance was rotation of soil clearing parts > forward speed > soil clearing parts' diameter.

(4) There are optimal values for the technical parameters of the grapevine cold-proof soil clearing machine. The structural parameters of the soil clearing device have a significant effect on the soil clearing distance. When the forward speed was 3.5km/h, the rotation rate of soil clearing parts was 277.7 r/min, and the soil clearing parts' diameter was 681.7mm, the soil clearing distance was optimal, Verification test results showed that the soil clearing distance was 83 cm, which was consistent with model prediction.

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REFERENCES

[1] Chen, K., (2005), *Experimental Design and Analysis. Beijing*: Tsinghua University Press.

[2] Dami I. E, Ennahli S, Zhang Y., (2012), Assessment of winter injury in grape cultivars and pruning strategies following a freezing stress event. *American Journal of Enology and Viticulture*; 63(1): 106–111.

[3] Liu, S., (2014), *Design and Experimental Study of Conical Spiral Vine Digger in Spring*. Xinjiang Agricultural University.

[4] Liu, F.J., Liu, Z. J., Wang, J. J., Mi, Y., Liu, H. K., Liu, X.Q., (2018), Design and experimental study of automatic obstacle-avoid digging machine for grapevine. *Journal of agricultural mechanization research*, vol. 40, issue 4, pp. 87-90.

[5] Ma, S., Xu, L.M., Xing, J. J, Yuan, Q. C, Yu, C. C., Duan, Z. Z, Chen, C., Zeng, J., (2018), Development of unilateral cleaning machine for grapevine buried by soil with rotary impeller. *Transactions of the Chinese society of agricultural engineering*, vol. 34, issue 23, pp. 1-10.

[6] Ma, S., Xu, L. M., Yuan, Q. C., Niu, C., Wang, S. S., Yuan, X. T., (2020), Development of automatic obstacle avoidance grape vine cold proof soil cleaner. *Journal of agricultural engineering*, vol. 36, issue 7, pp. 1-10.

[7] Niu, C., Xu, L. M., Duan, Z. Z., Liu, X. X., Ma, S., Yuan, Q. C., Wang, S. S., Yuan, X. T., Zeng, J., Chen, C., (2020), Development of hedgerow type soil removal and cold-proof cloth recovery machine for grapevine in winter. *Transactions of the Chinese society of agricultural engineering*, vol. 36, issue 2, pp. 50-58.

[8] Xu, L. M., Duan, Z. Z., Yuan, Q. C. et al. (2018), *A kind of cold-proof cloth clearing machine for grapevine buried soil:*108243638A[P].

[9] Xu, L. M., Li, C., Wang, W. B., et al. (2015) Mechanization Technology and Equipment of grape Production. *Xinjiang Agricultural Mechanization*, issue 5, pp. 24-27.

[10] Xu, L. M., Ma, S., Liu, X. X., Wu, G., Niu, C., Yuan, Q. C., (2019), Present Situation and Development Trend of Grape Production Mechanization in Xinjiang. *Agricultural Mechanization*, issue 3, pp. 10-13.

[11] Wang, Z.Q., Wang, H.B., Liu, F. Z., et al., (2015), Development and experiment of front located winter protection soil cleaning machine. *Journal of Chinese Agricultural Mechanization*, vol. 36, issue 6, pp. 88-91+107.

[12] Bucur, G. M., Dejeu, L., (2016), Research on frost injury of new Romanian grapevine cultivars in the winter 2014-2015. *Agriculture and Agricultural Science Procedia*, vol. 10, pp.233–237.

[13] Xie, D., Zhang, F. W., Zhang, T., Xie, J.H., Zhang, X. K., Dai, F., Zhang, K. Y., (2016), Design and test of a grape cleaner suitable for Hexi area. *Agricultural equipment and vehicle engineering*, vol. 54, issue 9, pp. 56-58+65.

[14] Yuan, Q. C., Xu, L.M., Ma S., Yu, C.C., Duan, Z. Z., Xing J.J., (2017) Current Situation and Thinking of mechanization of grapevine burying in winter and cleaning in spring in Northern China. *Chinese and Foreign Grape & Wine*, issue 6, pp. 66-67.

[15] Wisniewski, M., Gusta, L.V., (2014) The biology of cold hardiness: Adaptive strategies. *Environmental and Experimental Botany*, vol. 106, pp.1–3

[16] Molitor, D., Caffarra, A., Sinigoj, P., Pertot, I., Hoffmann, L., Junk, J., (2014), Late frost damage risk for viticulture under future climate conditions: a case study for the Luxembourgish winegrowing region. *Australian Journal of Grape and Wine Research*, vol. 20, issue 1, pp. 160–168.

[17] Dami, I. E., Ennahli, S., Zhang, Y., (2012) Assessment of winter injury in grape cultivars and pruning strategies following a freezing stress event. *American journal of enology and viticulture*, vol. 63, issue 1, pp. 106–111.

[18] Zabadal, T.J., Dami, I.E., Goffinet, M.C., Martinson, T.E., (2007) Winter injury to grapevines and methods of protection. *Chien M L: Michigan State University Extension*.

[19] Zhou, W.B., (2017), *Design of Grape Vine Lifting Machine*. Ningxia University.

[20] Zhang, J.J., Gou, J., Yan, W.B., Zhao, G.H., Wang, J., (2016), Technology of grape color striped cloth mechanical soil embedding, cold protection and excavation in Shacheng production area. *Chinese and foreign grapes and wine*, issue 4, pp. 32-34.

[21] Zeng, B. N., Tian, Z.D., Zhao, R. L., (2013), Design and development of grape vine machine. *Journal of Chinese agricultural mechanization*, vol. 34, issue 6, pp. 230-232+219.