DESIGN AND EXPERIMENTAL STUDY OF THE FINGER-TYPE LIFTER TEST BENCH FOR *Cerasus humilis* BRANCHES
/
拨指式钙果扶禾试验台的设计与试验

As. M.S. Stud. Eng. Yongqiang He, Prof. Ph.D. Eng. Junlin He*), Ph.D. Stud. Eng. Xiaobin Du, M.S. Stud. Eng. Dawei Fang
College of Engineering, Shanxi Agriculture University, Taigu/China;
Tel: +86-0354-6288400; E-mail:hejunlin26@126.com

Keywords: *agricultural machinery, lifter, experiment, design, Cerasus humilis*

ABSTRACT
We developed finger-type lifter test bench to address low fruit removal rate and high breakage rate during the lodging of Cerasus humilis branches. The bench is mainly composed of a frame, branches lifter, gripping delivery device, fruit removal device and control system. A single factor experiment was carried out, and fruit removal rate and breakage rate were used as the evaluation indexes. The elevation angle, declination angle, poking finger speed and conveying speed were selected as the experimental factors. Results showed that the influence of the declination angle was small. To determine the optimum parameter combination, we performed the three factors and three levels central composite orthogonal experiment, using the fruit removal rate and breakage rate as the evaluation indexes, while elevation angle, speed of poking fingers and conveying speed as the experimental factors. The results showed that elevation rate had the largest effect on removal rate, followed by poking fingers speed and conveying speed. Meanwhile, conveying speed had the largest effect on breakage rate, followed by poking fingers speed and elevation angle. The optimal parameter combination includes elevation angle of 56°, poking fingers speed of 1.02 m/s and conveying speed of 0.27 m/s and corresponding fruit removal rate of 96.07% and breakage rate of 4.58%. The bench verification experiment was performed according to the combination of the parameters, and the results showed that the removal rate was 97.28% and the breakage rate was 5.01%. The relative errors of the experimental value and the theoretical optimisation value were 1.24% and 8.58%, respectively.

摘要
针对钙果枝条倒伏造成收获时脱果率低、破损率高等问题，本文设计了拨指式钙果扶禾试验台，主要由机架、扶禾装置、夹持输送装置、脱果装置、控制系统组成。以脱果率和破损率为评价指标，选择仰角、偏角、拨指线速度、输送速度为试验因素分别进行单因素试验，试验表明偏角影响不显著。为确定最优扶禾参数组合，以脱果率和破损率为评价指标，以仰角、拨指线速度、输送速度为试验因，进行三因素三水平中心组合正交试验，试验表明：影响脱果率的主次顺序为仰角>拨指线速度>输送速度；影响破损率的主次顺序为输送速度>拨指线速度>仰角；最优参数组合为：仰角 56°、拨指线速度 1.02 m/s、输送速度 0.27 m/s，对应的脱果率为 96.07%、破损率为 4.58%。根据该参数组合进行台架验证试验，得到脱果率为 97.28%、破损率为 5.01%，与理论优化值的相对误差分别为 1.24%、8.58%。

INTRODUCTION
Cerasus humilis is a new and unique fruit plant resource in China *(Sun et al., 2016; Liang et al., 2006)*, and its yield reaches 15,000 kg/hm^2 *(Liu, 2003)*.The fruit is rich in minerals, vitamins and amino acids, has high edible and medicinal value and a broad development prospect *(Li, 2015; Liang et al., 2008)*. However, a single fruiting branch has high mass, so lodging remains a serious problem in the mature period *(Zhang et al., 2018)*. Thus, mechanical harvesting is very difficult, and thus the fruits are mainly picked by hand. Consequently, harvesting incurs substantial economic loss *(Liu et al., 2013; Kang et al., 2017)* because it has low efficiency despite the high labour intensity and the best picking time is delayed. The lodging of branches restricts the development of the *Cerasus humilis* industry, so lifting becomes a problem that needs to be solved in the process of harvesting *C. humilis*.

Crop lifting has been extensively investigated. The tilted maize stalks can be quickly straightened and fed into a picking area orderly by a new type of maize harvester with reel star wheel, which improves picking performance *(Hao et al., 2014)*. The parameters of a soybean lifter can be optimised by a virtual prototype, and lifter angle and conveying speed greatly influence the performance of a soybean lifter *(Chen et al., 2012)*.

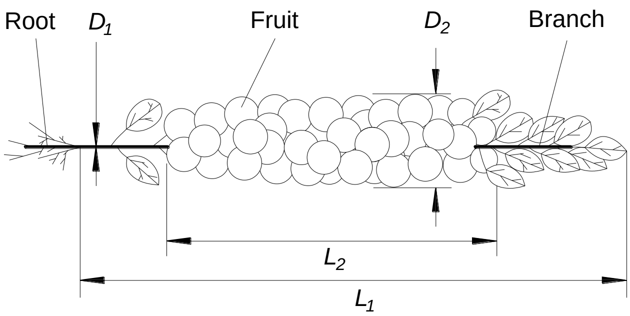
To solve the problem of rice lodging, an electric drive system was developed. Rice harvesting efficiency can be improved by automatically adjusting the speed of poking fingers in the range of 0.7–1.0 m/s with a PWM governor *(Pan et al., 2016)*. The lifting device of a safflower harvester retains its relative position with the safflower plants, thereby improving harvesting efficiency *(Gu et al., 2018)*. A study found that using a guide rod ensures that a corn stalk has a good upright posture when it enters a picking mechanism, so this device ensures orderly feeding and reduces the loss of cutting *(He et al., 2007)*. Another study found that the forward speed of the lifting device, poking fingers speed, elevation angle, declination of a lifter considerably affect the angle of lodging of sugarcane *(Mou et al., 2009)*. However, no research has been reported on lifting of *C. humilis*.

In this paper, we designed a finger-type lifter test bench to address the problem in lodging mature *C. humilis* branches. The design considers the growth characteristics of the branches. Fruit removal rate and breakage rate were used as evaluation indexes, while elevation angle, declination angle, poking fingers speed and conveying speed were used as experimental factors. Our aim is to obtain an optimal structure and working parameter combination for the design of *C. humilis* picking machine.

MATERIALS AND METHODS

Cerasus humilis variety and sample preparation

C. humilis branches were obtained from Juxin Modern Agriculture Base in Taigu County, Shanxi Province, China (E 112°29′, N 37°23′), and the variety was 'Nongda 6'. The harvest date was August 15, 2018. The diameter D_1 of the branches was 4–6 mm, the length L_1 was 600–800 mm, the diameter D_2 of the fruiting zone was 50–60 mm and the length L_2 of the fruiting zone was 400–500 mm (Fig.1a). The mass of a single-branched fruit branch was 0.8–1.2 kg, which easily caused lodging (Fig.1b).



a. The physical parameters of the Cerasus humilis branch

b. The lodging phenomenon of Cerasus humilis branch

Fig. 1 - The characteristics of *Cerasus humilis* branches

Design of lifter test bench

As shown in Fig. 2, the bench was mainly composed of a frame, branches lifter, gripping delivery device, fruit removal device and control system. The branches lifter was used to guide the fruiting branches towards the fruit removal device and straighten them. The dividing plate gathered the fruiting branches towards the branches lifter. The gripping delivery device mainly transports the initially lodging fruiting branches to the branches lifter and fruit removal device. During transportation, the branches lifter first straightened the branches, and then the fruit removal device detached the fruit. The elevation angle α of the branches lifter was adjustable from 20° to 90°, the declination angle β was −15° to +15°, the speed v_t of poking fingers was 0–4.7 m/s and the conveying speed v_m was 0–1.0 m/s.

Before the experiments, the branch root was fixed to the gripping delivery device. At this time, the branch was in a lodging state because of gravity. Then we adjusted the elevation angle α and the declination angle β of the branches lifter to change the direction angle of the poking fingers movement. During the experiments, the gripping delivery device conveyed the branch to the branches lifter in a linear motion at a speed v_m. The poking fingers turned the branches up continuously at the speed of v_t and lifted the branch up to provide good posture conditions for the follow-up fruit removal device.

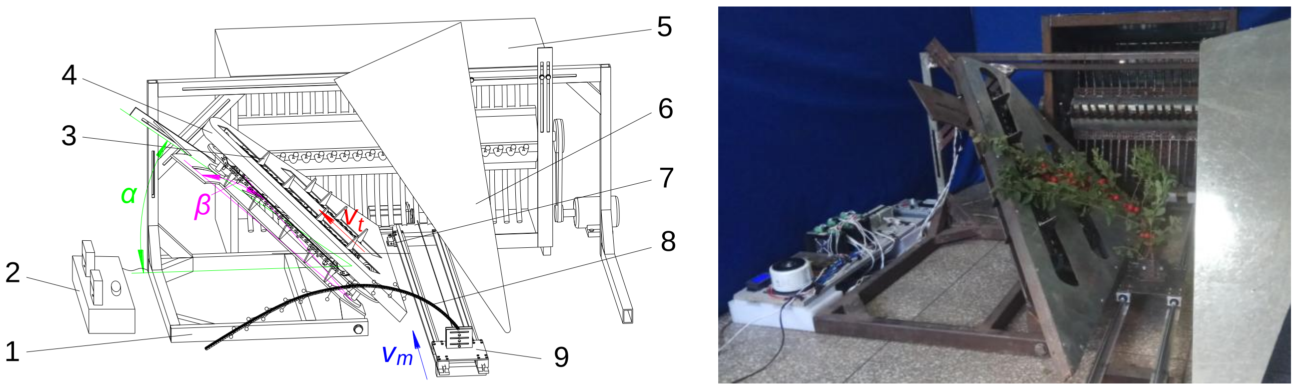


Fig. 2 - The branches lifter test bench of *Cerasus humilis*
1 – Rack; 2 – Control system; 3 – Poking finger; 4 – Stalk lifter; 5 – Fruit removal device; 6 – Dividing plate; 7 – Limit switch; 8 – Cerasus humilis branch; 9 – Gripping delivery device

Experiment design

Design of single factor experiment

To clarify the effects of elevation angle α, declination angle β, poking fingers speed v_t and conveying speed v_m on the fruit removal rate and breakage rate, we design the single factor experiment. The experimental factors and levels are shown in Table 1.

Table 1

Scheme of single factor experiment

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
α [°]	30	40	50	60	70	50					50					50				
β [°]	0					-15	-7.5	0	+7.5	+15	0					0				
v_t [m/s]	1.2					1.2					0.8	1.0	1.2	1.4	1.6	1.2				
v_m [m/s]	0.4					0.4					0.4					0.2	0.3	0.4	0.5	0.6

Design of orthogonal experiment

The results of the single factor experiment showed that the declination angle in the experiment range had no significant influence on the fruit removal and breakage rates, whereas elevation angle, poking fingers speed and conveying speed had considerable influences.

To study the influences of interactive factors on the performance of lifting, the three factors at three levels central composite orthogonal experiment was carried out. Fruit removal rate and breakage rate was used as the evaluation indexes and the elevation angle, the poking fingers speed and the conveying speed as the experimental factors. The experimental factors and levels are shown in Table 2.

Table 2

Coding schedule of experimental factors

Coded value	Elevation angle, α [°]	Poking fingers speed, v_t [m/s]	Conveying speed, v_m [m/s]
	A	B	C
Lower level (-1)	**30**	**0.8**	**0.2**
Middle level (0)	**50**	**1.2**	**0.4**
Upper level (1)	**70**	**1.6**	**0.6**

Note: factors encoding: A=α, B= v_t; C= v_m.

To reduce the number of experiments and obtain the regression equation, the mathematical method of the experiment planning based on Box-Behnken Centre combination method *(Golub et al., 2018)* was used.

Performance evaluation of lifting

The key factors affecting lifting performance were selected for the test. The factors included elevation angle, declination angle, poking fingers speed and conveying speed. Lifting performance was evaluated by using the important indicators of fruit removal rate and breakage rate during the harvesting process. The calculation method of fruit removal rate and breakage rate is shown in Formulas (1) and (2). To reduce the experiment error, each group of the tests was conducted three times, and the results were averaged.

$$\mu = \frac{N_1}{N} \tag{1}$$

$$\eta = \frac{N_2}{N_1} \tag{2}$$

Where:

μ is the fruit removal rate, [%];

η is the breakage rate, [%];

N_1 is the number of *Cerasus humilis* fruit removed;

N_2 is the number of fruit damaged in the removed *Cerasus humilis* fruit;

N is the total number of *Cerasus humilis* fruit on the branch before the experiment.

RESULTS

Results and analysis of single factor experiment

Data analysis was conducted using SAS 9.1. The results of the single factor experiment are shown in Fig.3. Fig.3a shows the polynomial relationship between elevation angle and fruit removal rate and breakage rate, with r^2 values greater than 0.93 and 0.88, respectively. With the increase of the elevation angle, the fruit removal rate increased from 91.3% to 97.7%, then decreased to 90.9%, and the breakage rate decreased from 9.7% to 2.5%.

Fig.3b shows the polynomial relationship between declination angle and fruit removal rate and breakage rate, with r^2 values greater than 0.64 and 0.80, respectively. With the increase of deviation angle, the variation trend of fruit removal rate and breakage rate was not obvious, and the difference between the maximum and minimum values of fruit removal rate and breakage rate were only 1.2% and 0.84% respectively.

Fig.3c shows the polynomial relationship between the poking fingers speed and the fruit removal rate and breakage rate, with r^2 values greater than 0.96 and 0.90, respectively. With the increase of the poking fingers speed, the fruit removal initially increased from 92.8% to 95%, then decreased to 91.8%, and the breakage rate gradually increased from 2.64% to 8.79%.

Fig.3d shows the polynomial relationship between the conveying speed and the fruit removal rate and breakage rate, with r^2 values greater than 0.83 and 0.97, respectively. With the increase of conveying speed, the fruit removal rate decreased gradually from 98.2% to 93.0%, whereas the breakage decreased initially from 8.12% to 2.82%, then increased to 10.5%.

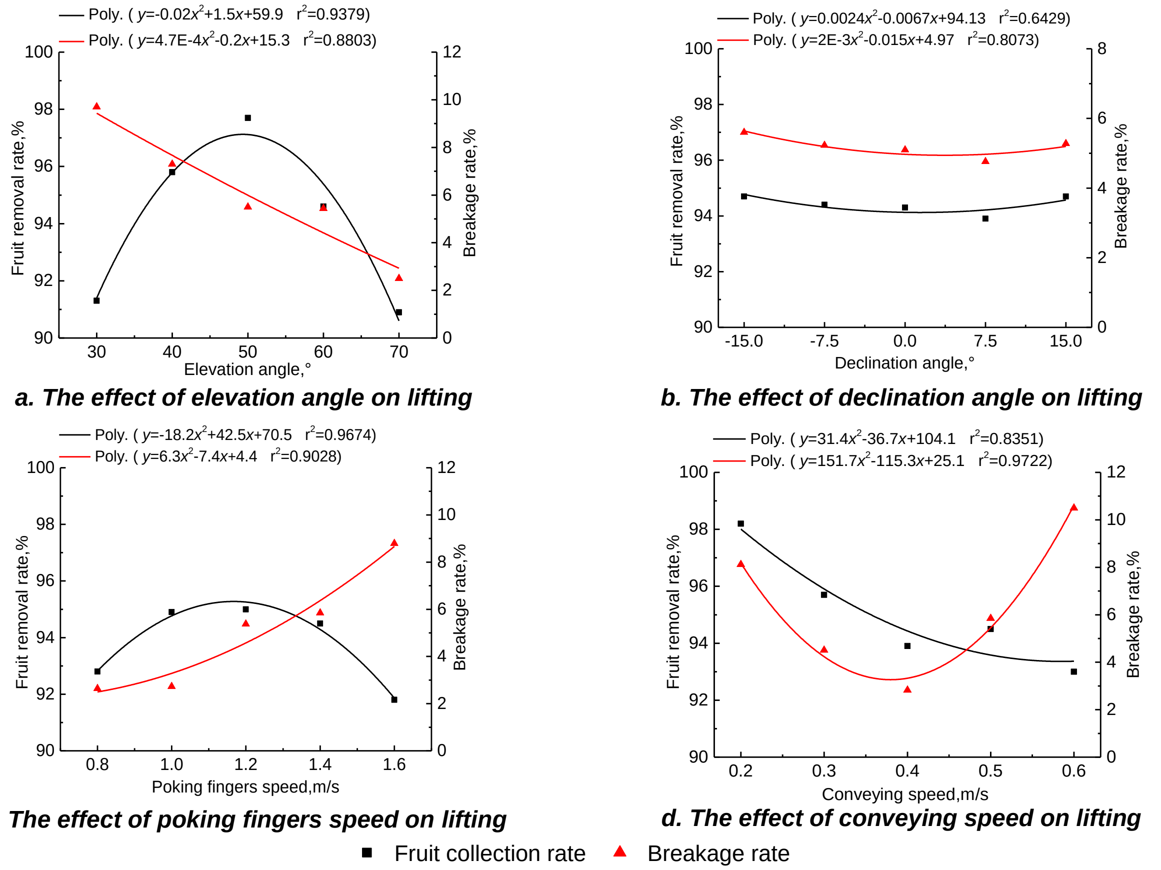


Fig. 3 - Results of single factor experiment

Results and analysis of orthogonal experiment

The Box-Behnken Centre combination plan was used for the three-factor and three-level experimental design. The plan included 17 test points, of which the points 1–12 were factorial design points and the points 13–17 were central design points for the estimation of experimental error. The results are shown in Table 3.

Table 3

The orthogonal test results

No.	Elevation angle *A* [°]	Poking fingers speed *B* [m/s]	Conveying speed *C* [m/s]	Fruit removal rate Y_1 [%]	Breakage rate Y_2 [%]
1	-1	-1	0	88.4	6.08
2	1	-1	0	90.1	3.66
3	-1	1	0	89.2	6.24
4	1	1	0	90.3	5.85
5	-1	0	-1	92.4	6.45
6	1	0	-1	94.2	5.27
7	-1	0	1	91.5	8.35
8	1	0	1	90.7	6.15
9	0	-1	-1	96.8	5.44
10	0	1	-1	96.7	7.52
11	0	-1	1	94.7	6.35
12	0	1	1	93.7	8.10
13	0	0	0	95.1	4.31
14	0	0	0	94.7	4.59
15	0	0	0	96.2	4.65
16	0	0	0	94.4	4.39
17	0	0	0	93.5	5.24

Analysis of variance and regression model

Variance analysis was performed on the experiment results (Table 4). The regression equations are shown in Equations (3) and (4). The quadratic regression models of fruit removal rate Y_1 and breakage rate Y_2 were extremely significant, and the r^2 values of the regression equation were 0.956 and 0.963, respectively. These results indicated that the predicted value of the regression model was well fitted to the actual value and thus can be used in the prediction and analysis of the influences of elevation angle, poking fingers speed and conveying speed on the fruit removal rate and breakage rate in the lifting process.

Table 4

The results of variance analysis

Item	Degree of freedom	Mean square	*F* Value	*P* Value	Item	Degree of freedom	Mean square	*F* Value	*P* Value
Model 1	9	11.87	16.87	0.0006**	Model 2	9	3.01	19.96	0.0003**
A	1	59.87	85.09	<0.0001**	*A*	1	1.03	6.82	0.0348*
B	1	4.15	5.90	0.0456*	*B*	1	1.21	8.02	0.0253*
C	1	4.17	5.92	0.0452*	*C*	1	3.51	23.24	0.0019**
AB	1	0.09	0.13	0.7312	*AB*	1	1.03	6.83	0.0348*
AC	1	1.69	2.40	0.1651	*AC*	1	0.26	1.72	0.2306
BC	1	0.20	0.29	0.6083	*BC*	1	0.027	0.18	0.6838
A^2	1	77.04	109.49	<0.0001**	A^2	1	0.29	1.92	0.2089
B^2	1	4.23	6.01	0.0440*	B^2	1	1.32	8.73	0.0212*
C^2	1	12.13	17.24	0.0043**	C^2	1	11.56	76.61	<0.0001**

*Note: P < 0.01 (extremely significant, **), P < 0.05 (very significant, *); Model 1 is variance analysis of fruit removal rate; Model 2 is variance analysis of breakage rate.*

$$Y_1 = 61.31 + 1.18 \cdot A + 17.07 \cdot B - 28.39 \cdot C - 0.16 \cdot AC - 2.81 \cdot BC - 0.01 \cdot A^2 - 6.27 \cdot B^2 + 42.44 \cdot C^2 \quad (3)$$

$$Y_2 = 18.52 - 0.15 \cdot A - 9.22 \cdot B - 26.05 \cdot C + 0.06 \cdot AB - 0.06 \cdot AC - 1.03 \cdot BC + 3.50 \cdot B^2 + 41.43 \cdot C^2 \quad (4)$$

Where:

A is elevation angle, [°]; *B* is poking fingers speed, [m/s]; *C* is conveying speed, [m/s];

Y_1 is the fruit removal rate, [%]; Y_2 is the breaking rate, [%].

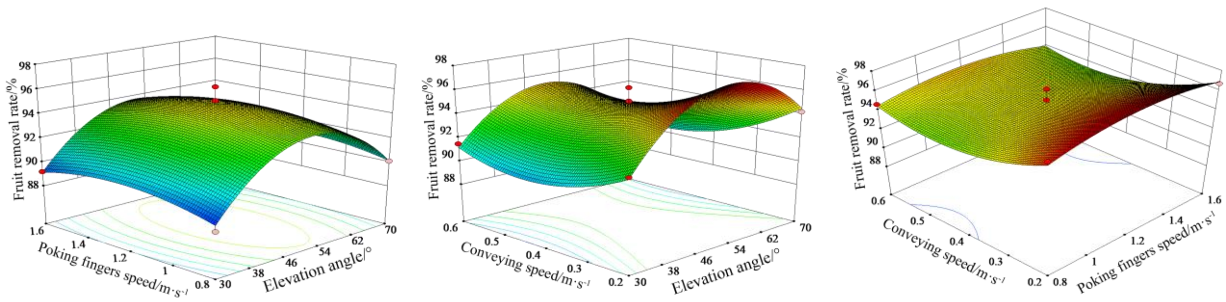
Analysis of the influence of interaction factors on lifting performance

The 3D response surface was generated according to the Box-Behnken Centre combination method, and the comprehensive influence of the three factors: elevation angle *A*, poking fingers speed *B* and conveying speed *C* on the evaluation indexes was analysed according to the response surface.

1) Analysis of the test factors on the fruit removal rate

The response surface of elevation angle *A*, poking fingers speed *B* and conveying speed *C* to the fruit removal rate Y_1 is shown in Fig.4a–4c. When the conveying speed was 0.4 m/s, the fruit removal rate increased initially before decreasing with the increase of the elevation angle and poking fingers speed. However, the variation range of the response surface along the elevation angle was large, indicating that the elevation angle had more influence than poking fingers speed (Fig.4a). When the poking fingers speed was 1.2m /s and the conveying speed was low, the influence of elevation angle on the fruit removal rate increased. With the increase of elevation angle, the fruit removal rate obviously increased first before decreasing. However, with the increase of the conveying speed, the fruit removal rate decreased significantly, indicating that the elevation angle had larger effect on the fruit removal rate than the conveying speed (Fig.4b). When the elevation angle was 50°, the interaction between poking fingers speed and conveying speed had no considerable effect on the fruit removal rate (Fig.4c).

As indicated by the change range of the response value of the experimental factors to the fruit removal rate, the order of influence of the experimental factors on the fruit removal rate was elevation angle *A* > poking fingers speed *B* > conveying speed *C*. The overall influence trend was that the poking fingers speed *B* is moderate when the elevation angle *A* is moderate and that the fruit removal rate increases when conveying speed *C* is low. The main reasons were as follows: when the elevation angle was moderate, the branches were lifted to an appropriate elevation angle. This process is conducive to the carding operation by the fruit removal device. When poking fingers speed was moderate, the branches were in the appropriate angle range under the action of the fingers. When conveying speed was low, the effect frequency of fruit removal device on branches increased, thus improving the fruit removal rate.



a. $\boldsymbol{Y_1(A,B,0.4)}$ ***b.*** $\boldsymbol{Y_1(A,110,C)}$ ***c.*** $\boldsymbol{Y_1(50,B,C)}$

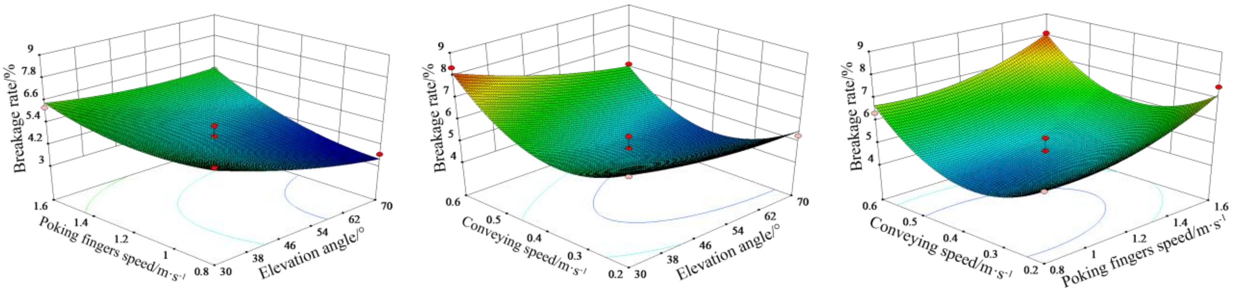
Fig. 4 - Response surface of various factors on fruit removal rate

2) Analysis of the test factors on the breakage rate

The response surface of elevation angle *A*, poking fingers speed *B* and conveying speed *C* to the breakage rate Y_2 is shown in Fig.5a–5c. When the conveying speed was 0.4 m/s, the breakage rate increased considerably with the increase of elevation angle and poking fingers speed (Fig.5a). When the poking fingers speed was 1.2 m/s, the breakage rate decreased significantly with the increase of elevation angle (Fig.5b). When the elevation angle was 50°, the breakage rate decreased first and then increased with the increase of conveying speed, and the breakage rate increased with the increase of the poking fingers speed (Fig.5c).

The change range of response value of the experimental factors to the breakage rate indicated that the significant order of influence of the experimental factors on the breakage rate was conveying speed *C* > poking fingers speed *B* > elevation angle *A*. The overall influence trend was that the poking fingers speed *B* is moderate when elevation angle *A* is large and that breakage rate decreases when conveying speed *C* is low. The main reasons were as follows: the elevation angle was extremely large, and the branches were relatively erect when they entered the fruit removal device. This condition prevented damage to the *C. humilis* fruit. When the poking fingers speed was extremely low, the impact force of the finger on the fruit was small, and the *C. humilis* fruit was not easily damaged.

At an extremely low conveying speed, the number of collisions of the fruit removal device on the *Cerasus humilis* fruit increased. At an extremely fast conveying speed, the collision speed of the *C. humilis* fruit and the fruit removal device increased the damage rate.



a.Y_2(A,B,0.4) *b.Y_2(A,110,C)* *c.Y_2(50,B,C)*

Fig. 5 - Response surface of various factors on breakage rate

<u>Parameter optimization and validation</u>

The best lifting performance yields high fruit removal rate and low breakage rate. By analysing the effects of interaction factors on fruit removal rate and breakage rate, we found that moderate elevation angle and poking fingers speed and low conveying speed are required for increasing the fruit removal rate. Moreover, breakage rate can be decreased by increasing the elevation angle, decreasing the poking fingers speed and using a moderate conveying speed. Given that the impact of each evaluation index on each factor varies, multi-objective optimisation is needed. In the range of the test factors, where the elevation angle *A* was 30–70°, poking fingers speed *B* was 0.8–1.6 m/s and conveying speed *C* was 0.2–0.6 m/s, the fruit removal rate was set to its maximum value, whereas the breakage rate was set to its smallest value. The weight coefficient was 0.5, looking for the optimal combination of parameters under the condition of the above two objective functions. Combined with the actual test conditions, the optimal results of this paper were as follows: elevation angle of 56°, poking fingers speed of 1.02 m/s, conveying speed of 0.26 m/s. The comprehensive response value of the model surface was optimal, and the fruit removal rate and breakage rate were 96.07% and 4.58%, respectively.

To verify the accuracy of the prediction model, we tested the optimised parameter combination three times, and the results were averaged. The elevation angle was set to 56°; the poking fingers speed, to 1.02 m/s and conveying speed, to 0.27 m/s. The test was carried out under this scheme and the fruit removal rate and breakage rate were 97.28% and 5.01%, respectively. The relative errors with the predicted values were 1.24% and 8.58%. The test results are consistent with the predicted values and the test error is small, so the parameter prediction model is reliable.

CONCLUSIONS

1) The finger-type lifter test bench designed in this paper is mainly composed of frame, branches lifter, gripping delivery device, fruit removal device and control system, which can adjust several key parameters, such as elevation angle, declination, poking fingers speed and conveying speed. By combining these parameters, the effect of lifting effect on the rate of fruit removal and the rate of breakage was studied.

2) The single factor experiment results found that declination had no significant effect on the effect of lifting. A quadratic multiple response model was established. The research analysed the influence of elevation angle, finger speed and conveying speed on the rate of fruit removal and breakage rate. The results showed that elevation angle had the largest effect on the removal rate, followed by poking fingers speed and conveying speed. Meanwhile, conveying speed had the largest effect on breakage rate, followed by poking fingers speed and elevation angle.

3) The Box-Behnken Centre combination test method was used for the optimisation of the analysis, the optimal parameters of the operation of lifting were as follows: elevation angle, 56°; poking fingers speed, 1.02 m/s and conveying speed, 0.27 m/s. The analysis predicted that the fruit removal rate reached 96.07%, and the breakage rate reached 4.58%. The bench verification test had an elevation angle of 56°, poking fingers speed of 1.02 m/s and conveying speed of 0.27 m/s. The fruit removal rate and breakage rate were 97.28% and 5.01%, respectively, and the corresponding relative errors with the predicted values were 1.24% and 8.58%.

ACKNOWLEDGEMENTS

This research titled 'Design and experimental study of the finger-type lifter test bench for *Cerasus humilis* branches' was funded by the Key Research and Development Plan of Shanxi Province, China (201703D221029-1). The authors are grateful and honoured to have obtained support from the Laboratory of Key Technology and Equipment for Dry Farming Machinery.

REFERENCES

[1] Chen H.T., (2012), Optimization of parameters for soybean lifter based on dynamic simulation of virtual prototype. *Transactions of the Chinese Society of Agricultural Engineering*, Vol.28, Issue 18, pp.23-29, Beijing/P.R.C;
[2] Gu L.L., (2018), Design and parameter analysis of the precision spoon-wheel seed meter for corn. *Journal of Agricultural Mechanization Research*, Vol.40, Issue 3, pp.17-21, Harbin/P.R.C;
[3] Golub G.A., (2018), Research on a boiler furnace module effectiveness working on small fracture wastes. *INMATEH-Agricultural Engineering*, Vol. 55, No.2, pp.9-18, Bucharest/Romania;
[4] He J.L., (2007), Kinematic simulation of no-row feed-in mechanism with guide-rod for corn harvester. *Transactions of the Chinese Society of Agricultural Engineering*, Vol.23, Issue 6, pp.125-129, Beijing/P.R.C;
[5] Hao F.P., (2014), Design and experiment of corn harvester head with reel star wheel. *Transactions of the Chinese Society for Agricultural Machinery*, Vol.45, Issue 6, pp.112-117, Beijing/P.R.C;
[6] Kang S.L., (2017), Design and finite element analysis of harvesting device for the *Cerasus humilis*. *Journal of Shanxi Agricultural University (Natural Science Edition)*, Vol.36, Issue 6, pp.439-443, Jinzhong/P.R.C;
[7] Liang Y.H., (2006). Development of fermented milk drinks containing calcium fruits. *Modern Food Science and Technology*, Vol.22, Issue 2, pp.183-184, Guangdong/P.R.C;
[8] Liu S.T., (2003). Cultivation technology and application prospect of red *Cerasus humilis*. Chinese *Journal of Eco-Agriculture*, Vol.11, Issue 1, pp.106-106, Hebei/P.R.C;
[9] Li X.L., (2015). Determination and analysis of nutritional content in prunus humilis. *Journal of Agriculture*, Vol.5, Issue 8, pp.97-100, Beijing/P.R.C;
[10] Liang W.Z., (2008). Study on brewing technology of Chinese dwarf cherry fermented wine. Chinese Brewing, Issue 22, pp.72-74, Beijing/P.R.C;
[11] Liu H.F., (2013). Experimental study on technical parameters of *Cerasus humilis* picking device. *Journal of Shanxi Agricultural University (Natural Science Edition)*, Vol.33, Issue 4, pp.342-345, Jinzhong/P.R.C;
[12] Mou X.W., (2009), Experiment of the finger-chain type sugarcane-lifter. *Transactions of the Chinese Society for Agricultural Machinery*, Vol.40, Issue 8, pp.49-53. Beijing/P.R.C;
[13] Pan Y.X., (2016), The design research of the electric drive type rotary taking grain system of the semi-fed rice combine harvester. *Machinery Design & Manufacture*, Issue 5, pp.79-82, Shenyang/P.R.C;
[14] Sun Z.B., (2016), Experimental on physical parameter and biomechanical properties of *Cerasus humilis* 5. *Agricultural Engineering*, Vol.6, Issue 2, pp.1-4, Beijing/P.R.C;
[15] Zhang W., (2018). Simulation analysis and experiment of combing pluck of *Cerasus humilis*. *Agricultural Engineering*, Vol.8, Issue 5, pp.89-94, Beijing/P.R.C.