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Analysis of Blue Honeysuckle Binding Force During Harvest Period

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Abstract

The purpose of this study is to understand the characteristics of proper binding force to harvest blue honeysuckle. After tracking such force over 16 days for four breeds of blue honeysuckle during the harvest period, we find that the binding force is mainly distributed in the range of 0.1 ~ 1.7N (P<0.05). This distribution range varies slightly between breeds: the picking forces of L.caerulea subsp.altaicai and Berel are greater than Bluebird and wild L.caerulea var.edulis of Changbai Mountain, and the binding forces of all breeds decrease over time with different slopes. Moreover, we also find that the binding force in the afternoon are significant larger than in the morning for the same day (P<0.05), and no significant difference is found between sunny and rainy days. We categorize factors affecting the binding force, such as testing day, morning and afternoon, relative humidity, temperature, weather conditions into environmental factors and time factor.

Keywords*: blue honeysuckle, binding force, significant differences, factor analysis*

1. Introduction

Blue honeysuckle (Lonicera Caerulea L.) is a kind of wild berry shrub and subordinates to caprifoliaceae, which grows in Changbai Mountain of Jilin province and Greater Hinggan Range eastern mountain area of Heilongjiang Province [1-3]. The fruit of Blue honeysuckle is juicy. The juice is in bright rose color, and it is known to have the function of supporting the role in adjusting the physiological function of human body, lowering blood pressure and slowing down the aging process [4-5]. In recent years, the wild blue honeysuckle area continues to decrease, however its unique medical value encourages people artificial culture it. The number of species and areas of artificial cultivation have been growing quickly recently. Since blue honeysuckle fruits are juicy and the peel is thin, they are easily damaged during harvest procedures. This issue has greatly impacts on its economic value, and such problem has hindered blue honeysuckle planting and promotion for large area. In order to reduce the breakage rate, the blue honeysuckle harvesting depends on manual picking or homemade gadgets. The harvest process has been low speed, high labor intensity and low efficiency. Therefore, it is urgent to solve the blue honeysuckle mechanical harvesting problem [6-9]. Because of the effects of light and fertilization conditions and individual differences, the picking time of blue honeysuckle may last 2-3 weeks, and fruits are typically picked 3-5 times during the harvesting period. The idea of mechanical harvesting use the inertial force generated by mechanical vibration to overcome the binding force between fruit and stalk. It is important to keep inertial force by mechanical vibration under control. Larger than

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necessary force will make the immature fruits and leaves are harvested and high rate of breakage, and small force will make harvesting efficiency drop since some mature fruits are picked by the machine. The current literature on blue honeysuckle focuses on its nutritional ingredients or cultivation technology. The mechanical harvesting, especially the research on properties and change rules of binding force between fruit and stalk during the mature period is not studied. Therefore, in order to develop blue honeysuckle planting scale, it is important to accurately understand the properties and change rules of binding force during the mature period. Furthermore, such knowledge could be used to design and develop harvest machines, which could be simple and practical, high efficient and low rate of breakage and suitable for our needs. In this paper, the research on binding force of blue honeysuckle is conducted for providing the theory basis and the essential parameters for design and development harvesting machine of blue honeysuckle.

2. Analysis of Blue Honeysuckle Vibration

The response equation of single degree freedom system under transient excitation for:

$$M\ddot{x} + c\dot{x} + kx = F \tag{1}$$

In the type, M stands for system quality (fruit equivalent quality), kg; c stands for the equivalent viscous damping coefficient of system, $N \cdot s/m$; k stands for the stiffness coefficient, N/m; x stands for the relative distance between offset system and equilibrium position, m; $\dot{x}$ stands for the speed of the system, m/s; $\ddot{x}$ stands for the acceleration, m/s^2; F stands for excited force, N.

When the machines harvest blue honeysuckle fruit, the response equation can be written as the vibration:

$$f(t) = A\sin(\omega t + \varphi) \cdot e^{-\xi\omega t} \tag{2}$$

In the type, A stands for amplitude of vibration, m; ω stands for frequency of vibration, rad/s; φ stands for the initial phase angle, rad; ξ stands for damping ratio.

The type (2) for second derivative, get:

$$f''(t) = A[\omega^2 - (\xi\omega)^2)]\sin(\omega t + \varphi) \cdot e^{-\xi\omega t} \tag{3}$$

The inertia force of fruit is obtained by Newton's second law:

$$F_{inertia} = mf''(t) \tag{4}$$

That is:

$$F_{inertia} = Am[\omega^2 - (\xi\omega)^2)]\sin(\omega t + \phi) \cdot e^{-\xi\omega t} \tag{5}$$

In the type, m stands for the quality of blue honeysuckle fruit, kg.

The principle of virtual work demonstrates that all the generalized force work done is zero in ideal conditions. So we can receive that the size of excited force as fallow as: $Am[\omega^2 - (\xi\omega)^2)]\sin(\omega t + \phi) \cdot e^{-\xi\omega t}$, the direction of excited force opposites the inertia force.

The different excited forces have different effects, when $F = -F_{inertia} > F_{bind}$, the blue honeysuckle fruit leaves stalk [10-13].

3. Materials and Methods

3.1. The Test Instrument and the Test Object

1）The test instrument

The test instrument of force and weight of blue honeysuckle is HP-2 portable digital tensimeter, which is produced by handpi instrument limited company in Leqing city (the maximum load: 2N, the smallest value: 0.001N, the output units can be selected N or kg).

2）The test object

Four kinds of blue honeysuckles have tested in the experiment, and their morphological characteristics are as shown in Table 1.

Table 1. The Main Morphological Characteristics of the Tested Blue Honeysuckle

The number of species	The name of species	The shape of fruit	The average length of fruit (mm)	The average width of fruit (mm)	The average weight of fruit(g)
Ⅰ	Blue bird	Long cylindrical	20.4	8.6	1.02
Ⅱ	L.caerulea subsp.altaicai	oval	12.5	7.8	0.64
Ⅲ	Berel	oval	16.6	10.3	1.31
Ⅳ	L.caerulea var.edulis	oval	18.3	8.6	0.80

3.2. The Test Site

The test site locates blue honeysuckle planting area of Northeast Agricultural University (45°48′14″N, 126°32′6″E).

3.3. The Weather during the Test

The test occurs for the June 7, 2012 to June 22, 2012, a total of 16 days. The sunny days were more than rainy days during test, the weather conditions during the test are as shown in the Table 2.

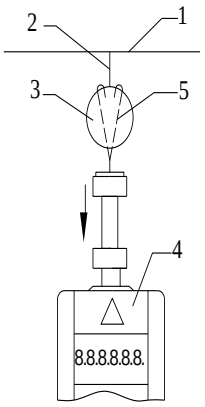
Table 2. Weather Conditions during the Test

weather		Time/d															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
weather condition	AM	R	R	S	R	R	S	S	S	R	S	R	R	S	S	S	S
	PM	S	S	S	R	S	S	S	S	R	S	S	R	S	S	S	S
Temperature (℃)	AM	19	20	23	18	14	18	19	19	18	18	18	18	20	22	23	24
	PM	26	26	27	19	18	24	22	24	23	21	22	21	26	27	27	28
Relative humidity(%)	AM	81	85	69	83	90	76	69	75	92	79	80	93	80	77	73	66
	PM	48	60	52	73	67	48	62	55	68	69	60	69	59	53	52	42

Note: “S” stands for sunny, “R” stands for rainy. The first day is June 7, 2012, and the sixteenth day is June 22 2012.

3.4. Methods

Five trees were randomly selected for four species of blue honeysuckle, and more than 3 fruits were randomly selected for the test of binding force. The force gauge must reset and set to "peak" pattern before test. When testing, the tested fruit is hooked by the hanger of the force gauge, tester pull the force gauge upwards and make the fruit leave the stalk, this moment, the value of force gauge is the binding force that must be overcome on blue honeysuckle harvest. The method of test is as shown in Figure 1. The binding force is tested two times a day, the fixed times are seven thirty and thirteen thirty, the time of each test is about 30 minutes. The test data are recorded in the card of force gauge, also make the paper records. After the test, the data are collated and analyzed by software.



1. the tree of blue honeysuckle 2. the stalk of blue honeysuckle
3. the fruit of blue honeysuckle 4. the force gauge 5. hook

Figure 1. The Schematic Diagram of Tested Binding Force

4. Results

4.1. The Distribution Characteristics of Binding Force

The binding forces of all mature fruits are smaller than 2N through the whole test. For comparison purposes, the binding forces of leaves and immature fruits were also tested, the test values are greater than 2N, which have the obvious differences with the mature fruits. The distribution characteristics of binding forces of mature fruits vary by species. So the histogram is used for the statistics of binding forces on the basis of a large number of experimental data. The statistical results are as shown in Figure 2.

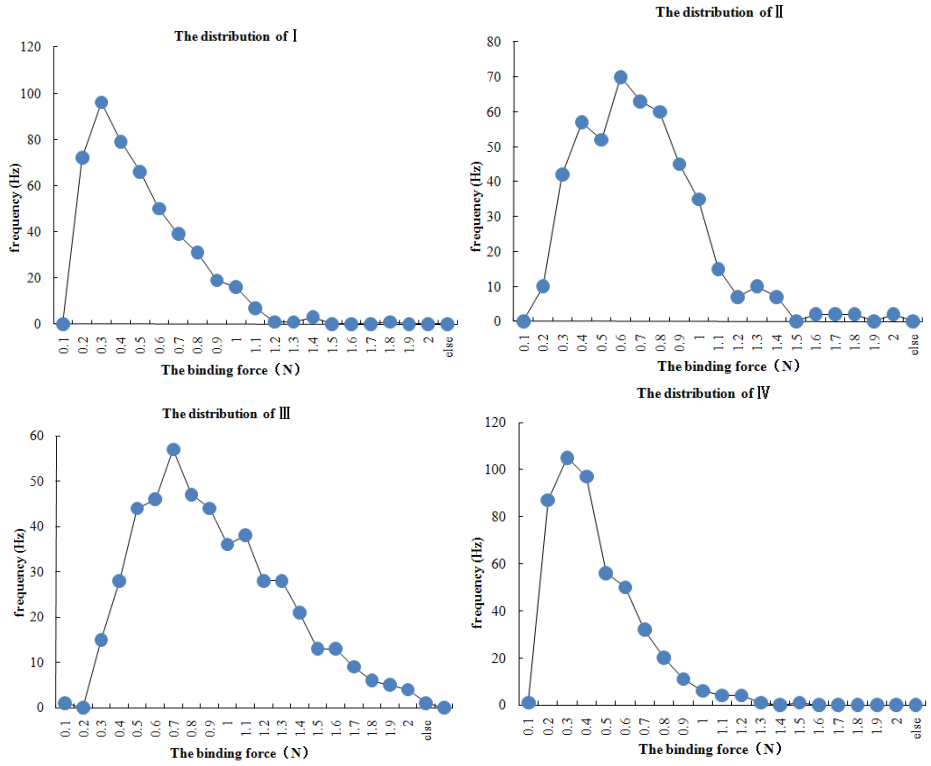


Figure 2. The Distribution of Binding Force at Maturity

As can be seen from Figure 2, the distribution of binding forces of mature fruits varies by species, and the binding forces relatively concentrate in a certain range. For accurate classification of distribution, the 95th percentile of binding force is as shown in Table 3.

Table 3. Percentile and Coefficient of Variation of Picking Force of All Varieties

Variety	$P_{2.5}$ （N）	$P_{97.5}$ （N）	The average （N）	The standard deviation （N）	Coefficient of variation （%）
Ⅰ	0.115	0.998	0.449	0.2546	56.74
Ⅱ	0.199	1.386	0.649	0.3106	47.87
Ⅲ	0.181	1.665	0.775	0.3893	50.23
Ⅳ	0.117	0.976	0.396	0.2252	56.90

As can be seen from Table 3, the 95% of binding forces of mature fruits I distributes in the region of 0.1 ~ 1N; the 95% of binding forces of mature fruits II distributes in the region of 0.2 ~ 1.4N; the 95% of binding forces of mature fruits III distributes in the region of 0.2 ~ 1.7N; the 95% of binding forces of mature fruits IV distributes in the region of 0.1 ~ 1N. The distribution of the four mature fruits binding forces is discrete, and the coefficient of variation was about 50%.

The test is carried on twice one day in the morning and afternoon, under the significant level of α =0.05, single factor analysis of variance on the test data of four mature fruits binding forces ,and the results are as shown in Table 4. The results show that: regardless of morning or afternoon, the forces between four varieties are significantly different.

Table 4. The Difference Test Results of Picking Force of Different Varieties

Time	The value of F	The value of P	The critical value of F
Morning	227.9	9.55×10-33	2.75
Afternoon	98.8	3.48×10-23	2.75

4.2. The Difference of Binding Force Between Morning and Afternoon

The test is carried on twice one day in the morning and afternoon, the experimental condition of the two test is slightly different, the temperature of morning is lower than afternoon, and the relative humidity is higher. In order to analyze the difference of the binding forces between morning and afternoon, the mean comparison of mean binding forces between morning and afternoon is as shown in Figure 3.

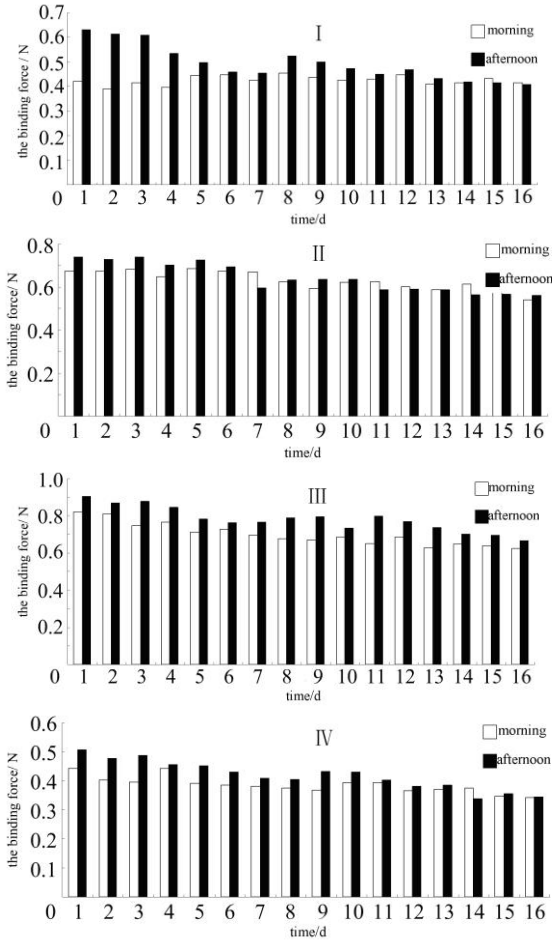


Figure 3. The Diagram of Tested Picking Force in Morning and Afternoon

As can be seen from Figure 3, the binding forces between morning and afternoon of one day are different. The data of 16 days test shows that the number of the binding force which afternoon is larger than morning is 55, which is 85.9% of all the test number. Among them, the number of I of the binding force which afternoon is larger than morning is 14, which is 87.5% of all the test number of I; the number of II of the binding force which afternoon is larger than morning is 10, which is 62.5% of all the test number of II; the number of III of the binding force which afternoon is larger than morning is 16, which

is 100% of all the test number of IV; the number of IV of the binding force which afternoon is larger than morning is 15, which is 93.8% of all the test number of IV. So there is the tendency that the binding force of afternoon is larger than morning for the 4 tested kinds.

Under the significant level of α =0.05, single factor analysis of variance on the test data of four mature fruits binding forces, and the results are as shown in Table 5. The results show that: the forces between afternoon and morning are significantly different for the 4 tested kinds.

Table 5. The Results of Significant Differences of Binding Force in Morning and Afternoon

Variety	Statistic of t	The value of P (two-tailed)	The critical value(two-tailed)
Ⅰ	3.38	0.004	2.13
Ⅱ	3.12	0.028	2.13
Ⅲ	9.66	7.8×10-8	2.13
Ⅳ	3.98	0.001	2.13

4.3. The Change of Binding Force with Time

In order to obtain the change of binding force with time, we calculate individually the binding force average of morning, afternoon and the whole day of every day during all the test time, and draw the line chart of binding force changing with time as shown as the Figure 4.

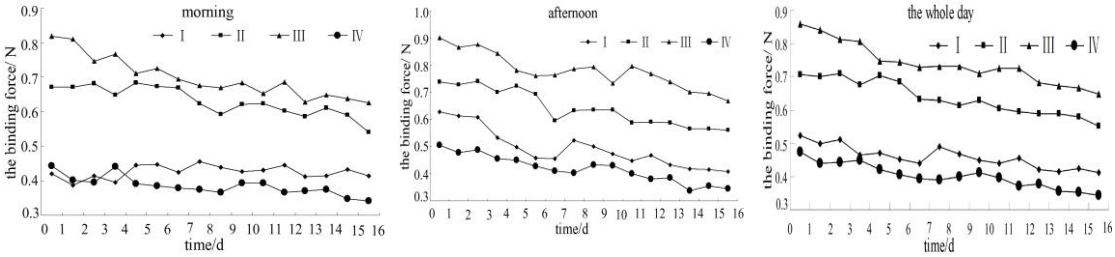


Figure 4. The Diagram of Picking Force Changes Over Time

As can be seen from Figure 4, the binding forces of morning, afternoon and the whole day decline with time, and the paces of decline are different. The binding forces of I and IV of morning, afternoon and the whole day are lower than II and III during the test. The trend that binding forces decline with time conforms to the natural law.

Research shows that: when the fruit is ripe, the cells of the handle begin aging, a layer of so-called "separation" forms in the connected place of stalk and branch, after separation cell activation, enhancement of pectinase and cellulase activity, wall material decomposition and cells lose connection, the fruits fall off under the effect of wind and the gravity[14].

As can be seen from Figure 4, the lines of II and III sits on the lines of I and IV, it mean that the forces of II and III are bigger than I and IV during picking period. The species of bigger binding force are low rate of abscission and relatively stable, because of their strong ability in against the wind and rain.

In addition, the binding forces of all the varieties in the mature period have the downward trend with time, but the rates of decrease are different, the order of rate of the whole day by linear fitting as fallows: III > II > IV > I. The varieties of declining faster

have short maturity and short picking period. So the number of picking needs to be increased in the mature period to avoid the fruit dropping off.

4.4. The Binding Forces of Different Weather Conditions

The most day of the test is sunny, the rainy day of AM is 7 days, the rainy day of PM is 3 days. In order to analyze the binding force of the different weather conditions, the data of the same time of the weather change in two adjacent days is as the object for research. The fruit itself has little influence on the binding force of two adjacent days, mainly from the external environment.

The environment changes significantly in the condition of sunny turning into rainy. But in the condition of rainy turning into sunny, the time of sunshine is relatively short, water vapor evaporates slowly, the change of temperature and relative humidity is not obvious. So we select the data of sunny turning into rainy for research. There are 6 groups of 24 teams that meet the requirements for research during the whole test. As can be seen from Figure 5, the number of the binding force that sunny day is larger than rainy day is 14 in the contrast teams, among them,I has 4 teams, II has 3 teams, III has 4 teams, IV has 3 teams.

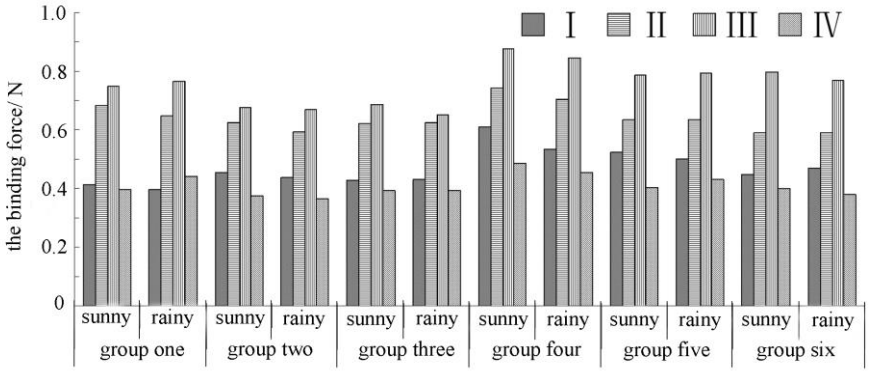


Figure 4. Comparison Chart of Picking Force under Different Weather Conditions

Under the significant level of $\alpha = 0.05$, single factor analysis of variance on the test data of four mature fruits binding forces ,and the results are as shown in Table 6. As can be seen from Table 6, the statistics of 4 varieties are all less than the critical value, the value of P is all less than 0.05, this shows that there are no significant difference about binding force between sunny and rainy. Because of the fruit peel, the weather has little influence on organizational structure, and the binding force has little change. But the relative humidity of rainy day is bigger, it will effect the feeding and cleaning mechanism of harvester, which should be envisaged in the machine design.

Table 6. The Difference Test Results of Picking Force in Different Weather

Variety	Statistic of t	The value of P (two-tailed)	The critical value(two-tailed)
Ⅰ	0.60	0.57	2.57
Ⅱ	1.35	0.23	2.57
Ⅲ	0.12	0.90	2.57
Ⅳ	0.54	0.61	2.57

4.5. Factor Analysis

In summary, the binding force of blue honeysuckle is affected by the factors of test time, morning or afternoon, temperature, relative humidity, the weather, *etc*. Although these factors can provide abundant information for the research, but the correlation of these factors brings complexity for problem analysis. So this paper use statistical software SPSS 19.0 to achieve factor analysis for the binding force, through a few unrelated variables indicate these factors to reduce dimension.

Because the factors of morning or afternoon and weather are qualitative, so they need to be converted into quantitative by the quantitative theory to meet the requirements of factor analysis [15]. The results of factor analysis are as shown in Table 7.

Table 7. The Results of Factor Analysis

Sampling enough degrees of Kaiser - Meyer Olkin measurements	.597
The spherical degree test and approximate chi-square of Bartlett	406.423
df	10
Sig	.000

a. the inspection results of KMO and Barlett

factor	ingredients	
	1	2
Test time	-0.11	.930
morning or afternoon	.858	.177
temperature	-.873	.265
relative humidity	.970	-.112
the weather	-.608	.467

b. rotating component matrix

As can be seen from Table 7a, the value of KMO is 0.597, the value of significant level (Sig) of barlett sophericity test is less than 0.05, they show the data is suitable for factor analysis[16].

As can be seen from Table 7b, according to the load capacity, the five factors can be divided into two categories by rotating component matries. The factors of morning or afternoon, temperature, relative humidity, the weather have a large load on the first factor, according to the actual situation, the first factor is named environmental factor. The factor of morning or afternoon associated with the time seemingly, but in fact, the factors of illumination, temperature, relative humidity between morning and afternoon the same day change greatly, so it can be included in the environmental factor. Test time has a large load on the second factor, so the second factor can be named as time factor.

After factor analysis, the binding forces of blue honeysuckle fruit are mainly related to environmental factor and time factor.

5. Conclusions

Through the test and analysis of the binding force of mature blue honeysuckle, we reach the following conclusions:

The 95% of binding forces of measured 4 mature blue honeysuckle fruits distribute in the region of 0.1 ~ 1.7N, and the forces of different varieties have different distribution. The 95% of binding forces distribute in the region: bluebird of 0.1 ~ 1N, L.caerulea subsp.altaicai of 0.2 ~ 1.4N, Berel of 0.2 ~ 1.7N, wild L.caerulea var.edulis of Changbai Mountain of 0.1 ~ 1N. Regardless of the morning or afternoon, the forces are significantly different for the 4 tested kinds. The test binding forces of L.caerulea subsp.altaicai and Berel are greater than Bluebird and wild L.caerulea var.edulis of Changbai Mountain,

For a single species, the binding force of two times test in morning and afternoon were significantly different, the afternoon is larger than morning.

The binding forces of all varieties of mature blue honeysuckle with time show a downward trend, but the paces of decline are different. The order from big to small: Berel, L.caerulea subsp.altaicai, wild L.caerulea var.edulis of Changbai Mountain, bluebird.

There are no significant differences between sunny and rainy days for the binding forces of mature blue honeysuckle.

Through factor analysis, the 5 factors of the test time, morning or afternoon, temperature, relative humidity and the weather conditions are changed into environment factor and time factor.

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