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Preliminary Study on Variety Comparison of Germplasm Resources of *Vernicia fordii*

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Abstract. The Chinese National Forestry Germplasm Library collected the first batch of 54 improved Tung Tree (*Vernicia fordii*) strains in 2007. This research investigates the tree structure, fruit cluster character and yield in the 3rd year of afforestation. Then, comprehensive evaluation is conducted with fuzzy mathematics. Experiment results indicate Hongyan 3, Luxi 1 and Superior Single Plant 8-504 are the most ideal candidates for industrial scale Tung Oil production.

Keywords: Tung Oil Tree, *Vernicia fordii*, bio-diesel, comprehensive evaluation

1. Introduction

Tung Oil Tree or Tung Tree (*Vernicia fordii*) belongs to Spurge (*Euphorbiaceae*) family and Tung (*Vernicia*) genus. Deciduous trees, 3 to 8 meters high, native to subtropical regions of East Asia, including southern China, Taiwan and Burma [1], [2]. Traditionally, Tung Oil has been used as a substitute for paint oil. In recent years, declining Tung Oil price has seriously subdued the enthusiasm of growers, lead to the decrease of its plantation in China. Many growing regions cut down the trees and switch to other economic crops. Given the shrinking Tung production, and losing of Tung germplasm resources, in September of 2007, the Chinese State Forestry Administration approves the establishment of the first batch of Key National Forestry Germplasm Resources Conservation Projects. The sub-project, National Tung Oil Tree Germplasm Resources Library is established in Xiangxi Autonomous Prefecture in Hunan province. Central South University of Forestry and Technology is responsible for the collection of strains to the Library since the debut of the project. A total of 54 strains are collected in 2007, fuzzy mathematics is conducted to comprehensively evaluate the strains with higher potential for bio-diesel production in the 3rd year of afforestation. This research intends to seek breakthrough in increasing the production of Tung Oil, which would eventually supply the world with another source of cleaner renewable energy[3].

A tested conversion from Tung Oil to Bio-diesel is shown as below [4]:

$$\begin{array}{l} H_3C-(CH_2)_3-CH=CH-CH=CH-CH=CH-(CH_2)_7COO-CH_2 \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad | \\ H_3C-(CH_2)_3-CH=CH-CH=CH-CH=CH-(CH_2)_7COO-CH \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad | \\ H_3C-(CH_2)_3-CH=CH-CH=CH-CH=CH-(CH_2)_7COO-CH_2 \end{array} \xrightarrow[\text{Catalyst}]{CH_3OH}$$

(Tung Oil)

$$H_3C-(CH_2)_3-CH=CH-CH=CH-CH=CH-(CH_2)_7COO-CH_3 + \begin{array}{l} CH_2-OH \\ | \\ CH-OH \\ | \\ CH_2-OH \end{array}$$

(Bio Diesel) (Glycerin)

Results show that Tung tree is one of the most promising trees to produce bio-energy in China, it is superior to other bio-energy species such as *Swidawilsoniana* or *Pistacia chinensis*. In addition, other inherent characteristics of Tung, such as anti-drought and anti-barren ability are also desirable to protect the environment.

2. Materials and Methods

2.1. Environmental conditions on Site

Xiangxi, Hunan is located in China's eastern Yunnan-Guizhou plateau-plain transition zone, Karst topography, typical Karst soil base, also known as "the hometown of Golden Tung" [2]. The research site locates in the center of Xiangxi region. 110°29′E and 28°32′N; elevation is 530-600 meters; subtropical monsoon climate; four distinct seasons; abundant rainfall of 1290-1600 mm annually; annual average temperature of 14 ~ 19 ℃; parent soil material is limestone; adret slope of 20 °; soil layers unequal; decent soil fertility; suitable for the growth of Tung [5,6].

2.2. Materials

Central South University of Forestry and Technology collects varieties or families of Tung locally as well as from major Tung growing regions all over China in 2007. A collection of 54 strains have undergone accelerating germination before the afforestation in early 2008. Detailed name codes are shown in Table 3.

2.3. Seeds preparation

In order to prevent germplasm confusion, collected Tung fruits are given uniformed code names. Cloth bags or boxes are used to separate different germplasms, labels are attached to bags or boxes to show code names. Once the fruit shell softens, seeds are stripped out of the fruit, and put back to the bag or box. Prior to seeding, seeds are soaked in warm water of 60℃ (initial temperature) for 12 hours, then permanganate fluid (1:1000 to water) for 5-10 minutes. Eventually they are stored in shades until the afforestation[7].

2.4. Experimental design

Around 667 m^2 of soil is assigned to each strain. A minimum of 30 trees are planted for each strain. Strain sections are planted horizontally. Two to three seeds are placed per hole for strains with more than 30 seeds. For strains with less than 30 seeds, one seed per each hole is planted [7]-[9].

2.5. Research content

The 3-year Tung forest achieved some yield in the fall of 2010. This investigation is conducted on economic characters such as tree structure, fruit character, yields and so on, see Table 1 for more details [7].

Table 1. Survey of germplasm resources data and preservation data of young *Vernicia fordii* plantation

body structure									fruit character								
single plant number	branch/cm	location/cm height of the 1st branch	diameter of 1st branch	numbers of main branch	crotch angle	length of main branch/cm	branch /cm	numbers of 2nd circle branches	length of 2nd circle branch/cm	numbers of fruit per bunch	weight of fresh fruit/g	weight of dried fruit/g	fruit height/diameter	fruit diameter index	seed ratio of dried fruit/%	fruit shape	total fruits	yield/kg

3. Data Analysis

Matlab 6.5 and Excel 2003 are used to analyse the data [10].

3.1. Comprehensive analysis [10], [11]

Set the given two finite fields: A = {A1, A2, A3,... , An}, B = {B1, B2, B3,... , Bn} , among them, A is the set of comprehensive evaluation factors and B is evaluation. X is A fuzzy subset, and evaluation result Y is fuzzy subset of B (Y is, in fact, the quantity of fuzzy synthesis of X and the fuzzy relation R).

3.2. Calculation and matrix

A = {tree structure (0.3), fruit cluster character(0.3), yield(0.4)} (1*3);

Detailed value of the 54 Tung germplasm resources of each evaluation factor set (3*54), (Table 2).

The result is used to the judgment matrix for the evaluated result of Y by using matrix multiplication method, and optimize it.

Fuzzy transformation: Y = X ·R

Plant characters within a certain range is helpful towards practical productions. Suitable tree shape is beneficial to higher yield and resistance. Smaller branching angle result tighter plant structure, thus, increase plant units per area, given all other conditions equal. In addition, higher number of circles of main branches is more advantageous for Tung blossoms, which also results higher natural yield.

Table 2: Comprehensive evaluation summary

Factor			Number									
			1	2	3	…	27	28	…	52	53	54
tree structure（0.3）	height of 1st branch/cm	average	115	140	250	…	80	193	…	160	0	0
		evaluated value	0.9	0.5	0.5	…	0.9	0.5	…	0.5	0	0
	crotch angle / °	average	80	75	75	…	30	70	…	70	0	0
		evaluated value	0.7	0.7	0.7	…	0.9	0.7	…	0.7	0	0
	circle number	average	2	1	1	…	2	1	…	1	0	0
		evaluated value	0.8	0.5	0.5	…	0.8	0.5	…	0.5	0	0
	averaged evaluated value		0.8	0.57	0.57	…	0.87	0.57	…	0.57	0	0
fruit cluster character（0.3）	average		3	1	1	…	1	1	…	1	0	0
	evaluated value		0.9	0.5	0.5	…	0.5	0.5	…	0.5	0	0
yield (0.4)kg	average		1.18	0	0.195	…	1.43	0	…	0	0	0
	evaluated value		0.5	0	0.5	…	0.5	0	…	0	0	0

$$Y=A*B=(0.30\ 0.30\ 0.40)\begin{Bmatrix} 0.80\ 0.57\ 0.57\ldots0.87\ 0.57\ldots0.57\ 0.00 \\ 0.90\ 0.50\ 0.50\ldots0.50\ 0.50\ldots0.50\ 0.00 \\ 0.50\ 0.00\ 0.50\ldots0.50\ 0.00\ldots0.00\ 0.00 \end{Bmatrix}$$

=[0.710 0.321 0.521…0.611 0.321…0.321 0.000 0.000]

The scores of 54 strains in decreasing order is shown in Table 3.

3.3. Results

Table 4 shows the comprehensive evaluation results of the 54 Tung tree strains. Hongyan 3, Luxi 1,and Superior Single Plant 8-504 receive highest scores, average at 0.891, on tree structure, fruit cluster character and yields. Next to the best are Xiqi 4 and Longshan 1, which average at 0.87. Further research could be conducted on their superior characters.

Both Hongyan 3 and Luxi 1 receive the same top score, however, the latter yields higher than the former. In addition, the tree shape of Putaotong is not as desirable as Xiaomitong. Further comprehensive evaluation could be conducted on fat and oil contents for cultivars with similar scores.

Table 3: The sequence of the 54 Tung oil strains scores

No.	score	cultivar No.	cultivar name	position	score	cultivar No.	code name of cultivar
1	0.891	9	Hongyan 3	28	0.611	33	Leigongdong 38
2	0.891	17	Luxi 1	29	0.611	38	Wujiapu 31
3	0.891	29	Youshu 8-504	30	0.599	49	Wujiapu 30
4	0.870	15	Xiqi 4	31	0.590	37	Wujiapu 16
5	0.870	23	Longshan 1	32	0.590	39	Leigongdog 39
6	0.861	11	Wujiapu 22	33	0.581	34	Wujiapu 15
7	0.861	18	Luxi 2	34	0.569	8	Daxiaojiatai 4
8	0.849	19	Hongyan 5	35	0.569	21	Xiqi 1
9	0.840	10	Wujiapu 26	36	0.569	24	Wwuzhaotong
10	0.769	6	Wujiatpu 6	37	0.560	42	Leigongdong 40
11	0.769	16	Hongyan 4	38	0.521	3	Xiqi 3
12	0.731	35	Wujiapu 25	39	0.521	26	Wuzhaotongguzhaoqing
13	0.730	4	Wujiapu 17	40	0.521	36	EC37Xiaomitong EC37
14	0.730	50	Wujiapu 19	41	0.500	7	Wujiapu 23
15	0.721	14	Wujiapu 15	42	0.390	32	Wujiapu 41
16	0.710	1	Xiqi 2	43	0.381	43	Wujiapu 4
17	0.701	44	Wujiapu 20	44	0.381	48	Wujiapu 1
18	0.691	30	Damitong	45	0.339	46	Wujiapu 3
19	0.671	51	Damitong	46	0.321	2	Wujiapu 18
20	0.670	5	Wujiatong 35	47	0.321	28	Wuzhaotongguzhaoqing
21	0.670	25	Yexingcang	48	0.321	45	Wujiapu 5
22	0.641	12	Daxiaojiatai 44	49	0.321	47	Wujiapu 24
23	0.629	20	Xiqi 5	50	0.321	52	Wujiapu 24
24	0.620	22	Guzhaoqing	51	0.000	40	Wujiapu 28
25	0.611	13	Wujiapu 42	52	0.000	41	Wujiapu 33
26	0.611	27	Zhousuitong	53	0.000	53	Wujiapu 23
27	0.611	31	Wujiapu 37	54	0.000	54	Wujiapu 33

4. Conclusion

In recent years, the resources of improved Tung tree germplasm has been decreasing, endangering the Chinese Tung tree eco library. The relevant Chinese government agency should strategically protect and develop Tong tree resources to preserve Tung tree resources for future benefits such as bio energy.

This project is approved in 2007. The total of 54 strains in this research are collected in the fall of 2007 including fortunately preserved varieties in the Hunan Province as well as the National ‘6th 5-year plan’ and the ‘7th 5-year plan’ preserved strains.

Table 4: The result of selecting and the main character

Position	Score	Cultivar No.	Cultivar name	Cultivar	Note
1	0.891	9	Hongyan 3	Xiaomitong	crotch angle 50 °, single plant yield over 3 kg
2	0.891	17	Luxi 1	Putaotong	crotch angle 60 °, single plant yield over 4 kg
3	0.891	29	Suprior Single Plant 8-504	Xiaomitong	crotch angle 45 °, single plant yield over 3 kg
4	0.870	15	Xiqi 4	Putaotong	angle 75 °, single plant yield over 3 kg
5	0.870	23	Longshan 1	Xiaomitong	crotch angle 60 °, single plant yield over 3 kg

The results show that Hongyang 3, Luxi 1 and Superior Single Plant 8-504 are most suitable varieties for bio-diesel production. Since all of these strains are Xiaomitong and Putaotong, results suggest fruit cluster character and yield of Xiaomitong and Putaotong are significantly advantageous over others as candidates for industrial scale bio-diesel production.

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