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Genetic Variation in Growth Traits of *Toona ciliata* Families in Guangdong Province

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Abstract

The height and diameter at breast height were assessed for 173 *Toona ciliata* families at age 18 months. Analysis of variance showed that there were highly significant differences on height and diameter at breast height at Xinhui with 4.60 to 15.08 of F value, indicating the family and replicate could affect the growth. The significant differences were also found on height and diameter at breast height among provennances and replicates, however there was no significant differences on diameter at breast height among families at Liangping, indicating the nearly growth speed on diameter at breast height. The coefficient of genetic variation of height and diameter at breast height were 42.19% and 44.89% at Xinhui while those were 42.10% and 44.23% at Liangping. Heritabilities were were 0.88 for height, 0.90 for diameter at breast height at Xinhui and 0.97 for height, 0.37 for diameter at breast height at Liangping. Family No. 169, 143, 154, 149 and 153 had significantly slowest growth whereas family No. 8, 1, 4, 116 and 39 were the higher growing at Xinhui. Family No. 134, 11, 86, 121 and 43 had significantly slowest growth whereas family No. 123, 24, 89, 105 and 51 were the higher growing on height at Liangping. Furthermore, the mean values of height were nearly in two sites, however the diameter at breast height at Xinhui were bigger than Lianping probably due to the insect pest.

Keywords: Genetic Variation; T. Ciliata; Family; Growth Traits

1 INTRODUCTION

The protection of forest species has become more and more important to ecosystem and meet the increasing demand for wood products, particularly in developing countries such as China because of the global population grows and areas of native forest decreases (Xu and Dell 2002; Wu et al. 2012; Wu et al. 2013). As an important type of forestry, commercial forest plantations such as *Eucalyptus* have become a competitive alternative to harvesting natural forests in southern China. And the area of *Eucalyptus* has increased rapidly and by late 2011 there were more than 3.6 M hectares in China (Arnold et al. 2013). However, the government of Guangdong decided to decrease the E*ucalyptus* area and increase the domestic species area. Among the genera selected for protection and timber, *Toona ciliata* seems to be a suitable tree species to supply the wood on a long-term sustainable basis because of fast-growing, well adaptability, wide-distribution, excellent wood properties, vigorous sprout and wide-use (Xie 2010; Zhao et al. 2005; Liang et al. 2011; Wu et al. 2006; Wu et al. 2011; Cheng and Cui 2010; Wang et al. 1999). *T. ciliata*, distributed from 24°21′ N to 30°31′N and 100°16′ E to 119°40′ E, mainly including Gunagdong, Guangxi, Fujian, Sichuan, Guizhou and Yunnan provennances, belongs to *Toona* of *Meliaceae*, is a rare and native timber species and became the national second class endanger species in China (Wu et al. 2011; Xie 2010; Liang et al. 2011).

Unfortunately, very little information about breeding and provennance/family test of *T. ciliata* in China has been published. Huang (2010) summarized the nature distribution and protection status of *T. ciliata*. Wu (2011) reported

This study was undertaken as a project for "Investigation, Collection and Introduction of Germplasm of *Toona ciliata*" (2011KJCX007-01).
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that there was significant difference in the rooting rate among different *T. ciliata* clones and the cuttings with two pieces of leaves could improve the rooting rate significantly. The objectives of this study were to: (1) compare growth traits of different provennances, different families and different sites, (2) estimate among-family variation and heritability of traits, (3) select the growth quickly families, (4) explore the implications of breeding for *T. ciliata* improvement. This information will be used to develop appropriate selection strategies for *T. ciliata* protection and utilization in China.

2 MATERIAL AND METHODS

2.1 Seed Collection and Seedlings Production

At least 10g *T. ciliata* seeds of each family were collected from 173 plus trees distributed in Yunnan, Fujian and Jiangxi provennances from July to December 2011 (Table 1).

TABLE 1 THE DETAILS OF THE FAMILIES ASSESSED

Family No.	Location	Longitude and latitude	Altitude(m)
1-5	Yongding Town, Yongren, Yunnan	E:101°39′40.2″N:26°02′48″	1500
6-15	Yongding Town, Yongren, Yunnan	E:101°40′31.3″N:26°02′34.2″	1522
16-40,50-5	Yongding Town, Yongren, Yunnan	E:101°41′42.2″N:26°02′23.2″	1500
41-46,48-49	Yongding Town, Yongren, Yunnan	E:101°42′0.01″N:26°01′55.6″	1500
47	Yongding Town, Yongren, Yunnan	E:101°51′04.7″N:25°48′24.2″	1050
53-55	Yongren County, Yunnan	E:101°40′46.5″N:26°03′54.1″	1630
56-68	Yongding Town, Yongren, Yunnan	E:101°39′0.29″N:26°04′0.13″	1545
69-74,81-87	Yongding Town, Yongren, Yunnan	E:101°38′48″N:26°04′40.5″	1550
75-78	Yongding Town, Yongren, Yunnan	E:101°38′0.26″N:26°05′49.7″	1560
79-80	Yongren County,Yunnan	E:101°37′563″N:26°08′22.2″	1642
88-96	Yongding Town, Yongren, Yunnan	E:101°39′48.8″N:26°04′56.4″	1521
97-111	Yongding Town, Yongren, Yunnan	E:101°40′0.24″N:26°05′46.9″	1530
112-118	No. 1, 14, 3, 16, 15, 23, 24 in Fujian	E:117°24′0.24″N:25°05′46.9″	300
119-139	No. 1-5, 8 , 10-18, 20-25 in Gaunshan Jiangxi	E:114°33′23″N:28°33′16″	300～374
140-169	No. 1-29 in Jinggangshan Jiangxi	E:114°16′9″N:26°45′17″	340～400
170-173	No. 6-7, 9, 19 in Guanshan Jiangxi	E:114°33′59″N:28°32′32″	298～326

2.2 Trial Description

The trial was established at Shuangshui town of Xinhui City (22°33′N, 113°02′E, 45m asl) and Lianping county (22°20′N, 114°32′E, 400m asl) of Guangdong, and is affected by the south subtropical monsoon with annual mean temperature of 19.9 to 22.3℃ and annual mean rainfall of 1750 to 1800m. Mean January temperature at this location is 2 to 6.7℃. There is not frost period and average annual mean accumulated temperature is 7653℃ at Shuangshui, but there is little frost period at Lianping. The details of soil are presented in Table 2.

TABLE 2 THE DETAILS OF SOIL SAPLED FROM LIANPING AND XINHUI

Site	pH	Organic Matter g/kg	Total Nitrogen g/kg	Total Phosphorus g/kg	Total Potassiumm g/kg	available Nitrogen mg/kg	Available Phosphoru mg/kg	Available Kaliam mg/kg	Available Boron mg/kg
Lianping	4.50	30.37	1.30	0.33	10.51	155.37	0.42	109.11	0.47
Xinhui	4.9	7.99	2.9	0.44	25.32	30.33	1.00	29.77	0.34

2.3 Experiment Design

The sowing and transplant seedlings were carried in 2012. All families were planted in April to May 2013 and were tested in November 2014. The field design was randomized compete block with 5-tree line plots with 2×3m spacing.

Planting pits (50cm×50cm×40cm) were prepared and one kilogram compound fertilizer was applied in first two years for individual tree. The height of families (H) was measured by ruler, and the diameter at breast height (DBH) was measured by calipers.

2.4 Data Collection and Statistical Analysis

The significance of fixed effects was assessed using F-tests. Meanwhile, the analysis of variance was performed using the PROC GLM.

$$y_{ij} = \mu + \alpha_i + \beta_i + p_i + \varepsilon_{ij} \quad (1)$$

where y_{ij} is the performance of the ramet of i^{th} families within the j^{th} replicate, and μ is the general mean, α_i is the random effect of the i^{th} families, β_j is the random effect of the j^{th} replicate, p_i is the random effect of the j^{th} provennance ε_{ij} is the random error.

The heritability of the family mean was calculated following Hai et al. (2008a):

$$R = \sigma^2_a / (\sigma^2_a + \sigma^2_e), \quad (2)$$

where σ^2_a is the additive genetic variance of clone, σ^2_e is the residual variance.

The genetic coefficient of variation (CV) was calculated as (Pliura et al. 2007; Hai et al. 2008a):

$$CV = (100\sigma_c / x) \times 100\%, \quad (3)$$

where x is the phenotypic mean. The equation expresses a standardized measure of the genetic variance relative to the mean of trait.

3 RESULTS AND DISCUSSION

3.1 Variance among Provennances, Replicates and Families

The analysis of variance of studied traits among provennances, replicates and families is presented in Table 3. The results showed that there were highly significant differences on height and DBD at Xinhui with 4.60 to 15.08 of F value, indicating the family and replicate could affect the growth. The significant differences were also found on height and DBH among provennances and replicates, corresponding with the results at Xinhui. However, there was no significant differences on DBH among families at Liangping, indicating the nearly growth speed on DBH.

TABLE 3 ANALYSIS OF VARIANCE OF THE STUDIED TRAITS WITH DIFFERENT PROVENNANCES, REPLICATES AND FAMILIES

Site	Trait	Type	DF	F Value	Pr>F
Xinhui		Provennance	15	5.33	<0.0001
	H	Family	150	8.05	<0.0001
		Replicate	7	4.60	<0.0001
		Provennance	15	7.13	<0.0001
	DBH	Family	150	9.72	<0.0001
		Replicate	7	15.08	<0.0001
Lianping		Provennance	15	8.24	<0.0001
	H	Family	102	41.78	<0.0001
		Replicate	5	2.42	<0.0001
		Provennance	15	9.87	<0.0001
	DBH	Family	102	1.59	0.2046
		Replicate	5	13.30	<0.0001

3.2 Family Value, Variation and Heritability

Mean value and ranges, SD, SE, coefficient of variation and heritabilities of height and DBH with two sites are presented in Table 4. The mean, minimum and maximum of height were 1.94, 0.20 and 4.00 m at Xinhui and 1.89, 0.10 and 5.00 m at Liangping. The mean, minimum and maximum of DBH were 2.42, 0.50 and 5.80 m at Xinhui and 2.06, 0.40 and 5.00 m at Liangping. The coefficient of variation of height and DBH were 42.19% and 44.89% at

Xinhui while those were 42.10% and 44.23% at Liangping. In general, the coefficient of variation of DBH was bigger than H, indicating that the scope for selection among families would be considerable. These results were bigger than the previous studies by Liu et al. (2008), in which coefficients of variation of HGT and GD were 27% and 21% for *T. ciliata var. Pubescens* in Jiangxi provennance. The heretabilities of studied traits ranged from 0.37 to 0.97. This conclusion was consistent with previous studies in *Toona sinensis* (Liu et al. 2010) and some bigger than in *T. ciliata var. Pubescens* (Liu et al. 2008). Liu et al. (2010) reported that the heritabilities of HGT and GD were 0.76 and 0.78 for *Toona sinensis* collected from 17 provennances and cultivated in Fujian provennance.

TABLE 4 MEAN VALUE, RANGES COEFFICIENT OF VARIATION AND FAMILY HERITABILITY OF THE STUDIED TRAITS

Site	Trait	Mean	Minimum	Maximum	SD	SE	CV(%)	H
Xinhui	H(m)	1.94	0.20	4.00	0.82	0.02	42.19	0.88
	DBH(cm)	2.42	0.50	5.80	1.06	0.03	44.89	0.90
Lianping	H(m)	1.89	0.10	5.00	0.86	0.03	42.10	0.97
	DBH(cm)	2.06	0.40	5.00	0.83	0.02	44.23	0.37

H height; DBH diameter at breast height; SD standard deviation; SE standard error; CV genetic coefficient of variation; H heritability

3.3 Differences among Families in Growth

The 10th slower and higher mean family values of height and DBH at two sites are presented in Table 5. Family No. 124, 129, 142, 136, 157, 169, 143, 154, 149 and 153 had significantly slowest growth, ranging from 1.00 to 1.20 m whereas family No. 57, 106, 100, 29, 14, 8, 1, 4, 116, 39 were the higher growing ranging from 2.32 to 3.55 m on height at Xinhui. Family No. 130, 18, 97, 20, 73, 134, 11, 86, 121 and 43 had significantly slowest growth, ranging from 0.60 to 1.38 m whereas family No. 68, 137, 106, 26, 79, 123, 24, 89, 105, 51 were the higher growing ranging from 2.68 to 2.96 m on height at Liangping. In addition, differences families between sites had different growth, suggesting that further work about selection need to be done.

TABLE 5 THE 10TH SLOWER AND HIGHER MEAN FAMILY VALUES OF HEIGHT AND DBH AT TWO SITES

Xinhui			Lianping		
Family No.	**H(m)**	**DBH(cm)**	**Family No.**	**H(m)**	**DBH(cm)**
57	2.32	2.73	68	2.68	2.04
106	2.33	2.89	137	2.72	2.61
100	2.33	2.54	106	2.72	1.87
29	2.35	2.58	26	2.73	1.63
14	2.38	2.25	79	2.73	2.99
8	2.39	2.73	123	2.80	2.45
1	2.50	3.60	24	2.80	2.28
4	2.66	2.83	89	2.86	2.69
116	2.87	3.77	105	2.95	2.64
39	3.35	2.28	51	2.96	3.04
Mean	**2.55**	**2.82**		**2.79**	**2.42**
124	1.00		130	0.60	0.97
129	1.10		18	0.83	1.38
142	1.10		97	1.17	1.46
136	1.10		20	1.17	2.08
157	1.10		73	1.24	1.73
169	1.15		134	1.30	1.70
143	1.18	1.50	11	1.32	1.63
154	1.18	3.00	86	1.36	1.62
149	1.20		121	1.37	1.32
153	1.20		43	1.38	1.29
Mean	**1.13**	**2.25**		**1.17**	**1.52**

3.4 Differences among Sites in Growth

The mean growth of studied families in two sites is presented in Figure 1. The mean height were nearly in two sites, consist with the value in Table 5. However, the DBH at Xinhui were bigger than Lianping probably due to the insect pest.

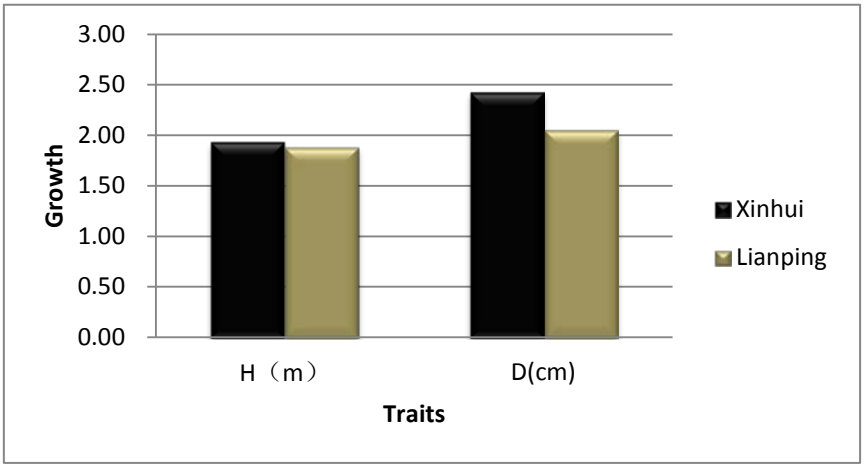

FIGURE TREE HEIGHT AND DBH IN TWO SITES

4 MAJOR CONCLUSIONS AND IMPLICATIONS FOR BREEDING PROGRAMS

In the present study, the variance among provennances, families and replicates, the genetic parameters of the studied traits and contrast growth between sites were examined.

Joint analysis in the present study showed four implications for tree improvement in *T. ciliata* in China. Primarily, there were highly significant differences on height and DBD at Xinhui while the significant differences were also found on height and DBH among provennances and replicates at Liangping. Secondly, the coefficient of variation of height and DBH were 42.19% and 44.89% at Xinhui while those were 42.10% and 44.23% at Liangping. Thirdly, Family No. 124, 129, 142, 136, 157, 169, 143, 154, 149 and 153 had significantly slowest growth whereas family No. 57, 106, 100, 29, 14, 8, 1, 4, 116, 39 were the higher growing at Xinhui. Family No. 130, 18, 97, 20, 73, 134, 11, 86, 121 and 43 had significantly slowest growth whereas family No. 68, 137, 106, 26, 79, 123, 24, 89, 105, 51 were the higher growing on height at Liangping. Furthermore, the mean height was nearly in two sites, however the DBH at Xinhui were bigger than Lianping probably due to the insect pest.

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