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SUPERIOR PROVENANCE AND PLUS TREE SELECTION FOR *BETULA ALNOIDES* IN SOUTHERN FUJIAN CHINA

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Abstract

The 14-year-old provenance and family test plantation of *Betula alnoides* in Fujian Hua'an Jinshan National Forest Farm was investigated. Eight growth traits, including tree height, diameter at breast height (DBH), individual volume, height to crown base, crown diameter, crown form index, stem form index and branching index, were analyzed for all 25 provenances tested. The superior provenances were selected: Provenance G (Tengchong, Yunnan) performed the best, followed by Provenance L (Jiangcheng, Yunnan) with the best stem form; Provenance U (Pingguo, Guangxi), J (Fengqing, Yunnan), R (Tianlin, Guangxi), C (Mojiang, Yunnan) and P (Longzhou, Guangxi) were the alternative. These provenances were not severely damaged by trunk borer. It is suggested the seeds for nursery should be collected from the Provenance G or L for plantation forestry of *B. alnoides* in Southern Fujian, and Provenance U, J, R, C and P could be used for the alternative seed sources. 182 plus trees were also screened out and could be applied for grafting and tissue culture.

Key words: *Betula alnoides*, Superior provenance, Plus tree, Growth traits, Genetic variation.

Introduction

Betula alnoides belongs to the family Betulaceae, and the species naturally distributed the most south in the hemisphere in genus *Betula*. In China *B. alnoides* naturally distributes in Yunan Province, Guangxi Autonomous Region and Guizhou Province. These regions are connected with Vietnam, Laos and Myanmar. All these areas form the central distribution area of *B. alnoides*. As a fast-growing tree species in the tropical and subtropical zones, this species presents high qualified wood, non-deformable and attractive decorative pattern. Its timber is of moderate density, and is suitable for application in interior decoration, wooden floor and furniture production, etc. Under natural conditions, its rotation age is generally 20~30 years old. It is an ideal tree species for large-sized timber production, and has been widely expanded in Southern China (Pang, 2011; Li, 2012).

The elite trees of *B. alnoides* can be propagated by seeds, but their progenies may genetically differ from each other without keeping the good characteristics of the mother tree.

Significant genetic variation among provenances and progenies of this species has been observed in growth traits in several previous studies. The individuals of the most productive provenance in volume should be selected to establish commercial plantations of this species. For example, among 25 provenances of *B. alnoides* (at 8-year-old) introduced to Xishuangbanna, Yunan Province, the Tianyang provenance was selected as the best one in volume, and the Lancang, Jinghong, Fengqing and Tian'e provenances were suitable for Xishuangbanna. These five provenances demonstrated 6.08%, 9.40%, 9.21%, 9.40% and 1.91% in tree height, 17.22%, 13.27%, 6.80%, 6.35% and 6.15% in DBH, and 36.74%, 35.74%, 21.30%, 12.29% and 13.04% in volume higher than the mean level of all provenances, respectively (Shi *et al.*, 2011). Provenace and progeny test of this species in Ruili, Yunnan Province also confirmed that there were significant differences in seedling height and root length among 13 provenances and 79 progenies (Peng *et al*., 2010).

B. alnoides was also introduced to Zhangzhou, Fujian Province, and relevant provenance and family tests were conducted. It was showed in the previous study that there were significant differences among provenances or families in tree height and other traits at the age of 2 years old (Liu, 2005; Chen, 2005) and it was worth to select the elite provenances for *B. alnoides* in Southern Fujian (Liu 2005).

Due to the difference in environmental factors such as local climate, as well as the differences in selection between the early and late stages, here it is necessary to investigate *B. alnoides* provenance and family test plantation at the age of 14 years old, and to screen out the optimal provenances and plus trees for plantation forestry of *B. alnoides* in southern Fujian Province in the future.

Materials and Methods

The test site: The test site is located at Shakengkou (117°34'E, 24°48'N) of Hua'an Jinshan National Forest Farm, Zhangzhou City, Fujian Province. It belongs to a typical subtropical climate, annual mean temperature was 21.1°C with January and July mean temperature 16.0°C and 30.0°C, respectively. The extremely lowest temperature is -3.8°C, and the highest temperature is 41.2°C. Annual frost free period is 320 days, annual mean precipitation is 1610.9 mm, and relative humidity is 78%.

The plantation was established in cut-over land of *Cunninghamia lanceolata* with II-III class site quality on westwards slope (mid and low slope position, about 25° slope degree) at altitude of 150-400 m. The soil is red soil.

Seed source and experimental design: The tested seeds are half sibs of *B. alnoides*, collected from the mother trees in Guangxi and Yunnan provenances in November 2002. The provenance and family test was established in April 2003 with 299 families of 25 provenances involved and 12 repeats were set up according to the random block design (See Table 1). In each block, the

families were randomly arranged with single plant per plot. *Paramichelia baillonii* (Pierre) Hu was planted as the border rows. The understorey vegetation was comprehensively cleaned and horizontal bands were prepared with row distance of 3 m and band width of 1.2 m. The size of planting holes were 70 cm×40 cm×30 cm, and the spacing was 3 m×3 m. Container-grown seedlings of *B. alnoides* were used with container size of 10 cm×15 cm.

Investigation method: In February 2017, tree height (m), DBH (cm), height to crown base (m), crown diameter (m), crown shape, stem form, branchiness and number of insect damage were investigated for each tree in the 14-year-old *B. alnoides* provenance and family test plantation. The scoring criteria were shown in Table 2 for crown shape, stem form, branchiness of this species (Zhang, 2002).

Data analysis: All sorts of traits were analyzed by ANOVA using EXCEL 2007 and SPSS17.0 software to select the optimal provenances.

The individual volume for *B. alnoides*: $V=\pi(d_{1.3}/2)^2hf_{1.3}$.

NB: $d_{1.3}$ is the diameter at breast height, h is the tree height; $f_{1.3}$ is the form index at breast height, and $f_{1.3}$ = 0.45 (Wang, 2013; Wang, 2017).

Results and Analysis

Superior provenance selection: As Provenance A was of low survival rate, here only other 24 provenances were involved in the ANOVA analysis on 8 growth and form quality traits including tree height, DBH, volume, height to crown base, crown diameter, crown form index, stem form index and branchiness (See Table 3). It was shown that there were significant differences in all 8 traits among the provenances. Of these traits, crown form index demonstrated great significant difference ($p<0.01$), while other traits showed significant difference ($p < 0.05$). Taking individual volume as the first selection factor, Provenance G performed the best, Provenance B, D, F, M, N and S were remarkably poorer than Provenance G in volume, and were excluded. Of the left provenance, E, Q, V and W performed the worst in branchiness, and E and W were also the worst in height to crown base; M and Q were found susceptible to trunk borer attack, and X and Y showed their individual volume much lower than mean level of whole population, and these provenances were also be excluded.

Fig. 1 intuitively showed that Provenance G performed in tree height, DBH, individual volume, and branchiness among the 24 provenances, and also well in height to crown base, crown diameter, crown form index and stem form index, so Provenance G (Tengchong, Yunan) was determined as the best one. Provenance L (Jiangcheng, Yunnan) was considered as the second one because it performed the best stem form index and showed no significant difference from G in other traits. Provenance U (Pingguo, Guangxi), J (Fengqing, Yunnan), R (Tianlin, Guangxi), C (Mojiang, Yunnan) and P (Longzhou, Guangxi) did not considerably differ from G in all traits, and were regarded as the third choice.

Table 1. The overall information of 25 provenances of *Betula alnoides*.

Provenance code	Locality	Longitude	Latitude	Altitude (m)	Family number
A	Mengla,Yuannan	101º29′	21º33′	950-1100	3
B	Yuanyang,Yuannan	103º01′	23º07′	1000-1130	4
C	Mojiang,Yuannan	101º46′	23º30′	1500-1600	19
D	Jianghong,Yuannan	100º59′	22º24′	1300	13
E	Xichou,Yuannan	104º33′	23º15′	1400-1460	9
F	Zhenyuan,Yuannan	101º09′	23º59′	1570-1900	10
G	Tengchong,Yuannan	98º36′	24º56′	1820-2100	3
H	Jianggu,Yuannan	100º34′	23º29′	1650-1800	17
I	Ruili, Yuannan	98º03′	23º56′	1120-1250	17
J	Fengqing,Yuannan	99º55′	24º54′	1380-1850	20
K	Pingbian,Yuannan	103º38′	23º03′	1230-1320	12
L	Jiangcheng,Yuannan	101º47′	22º35′	1190-1280	15
M	Shuangjiang,Yuannan	99º39′	23º26′	1560-1670	17
N	Lancang,Yuannan	99º59′	22º36′	1280-1500	17
O	Lingyun,Guangxi	106º35′	24º00′	700-900	6
P	Longzhou,Guangxi	106º40′	22º25′	600-800	10
Q	Donglan,Guangxi	107º34′	24º29′	500-680	3
R	Tianlin,Guangxi	105º43′	24º25′	740-920	16
S	Debao,Guangxi	106º38′	23º20′	800-900	6
T	Tian'e,Guangxi	107º13′	25º11′	650-750	7
U	Pingguo,Guangxi	107º23′	23º42′	650-800	14
V	Baise,Guangxi	106º30′	23º47′	500-900	13
W	Tianyang,Guangxi	107º08′	23º52′	550-700	17
X	Jingxi,Guangxi	106º20′	23º01′	800-1000	14
Y	Napo,Guangxi	105º51′	23º11′	600-850	17

Table 2. The scoring criteria of crown form and branchiness form for *Betula alnoides*.

Score	Crown form			Stem form	Branchiness
1	Spire	Obvious top	Vigorous growth	Stem straight and round	0-8 m stem with no lateral branch or less and small lateral branch
2	Cylindric	Obvious top	Moderate-vigorous growth	Above 2/3 stem bent or stem cross section round but uneven on the stem surface	0-8 m stem with less lateral branch and the biggest branch diameter less than 1/3 stem diameter
3	Umbrella	Weak top	General growth	Above 1/2 stem bent or stem cross section ovale but smooth on the stem surface	0-8 m stem with less lateral branch and the biggest branch diameter less than 1/2 stem diameter
4	Long round	No obvious top	Weak growth	Under 1/2 stem bent or stem cross section non-round but uneven on the stem surface	0-8 m stem with more lateral branch and branch diameter more than 1/2 stem diameter

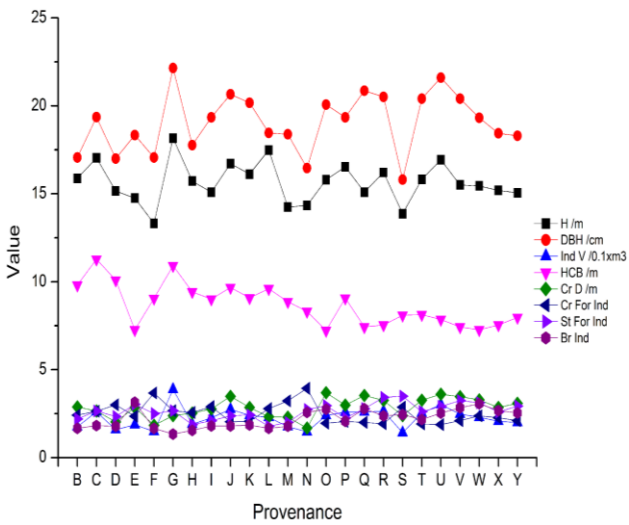

Fig. 1. Average growth indexes of 24 provenances of *Betula alnoides*
NB: H: Tree height; DBH: Diameter of breast height; Ind V: Individual volume; HCB: Height to crown base; Cr D: Crown diameter; Cr For Ind: Crown form index; St For Ind: Stem form index; Br Ind: Branchiness index.

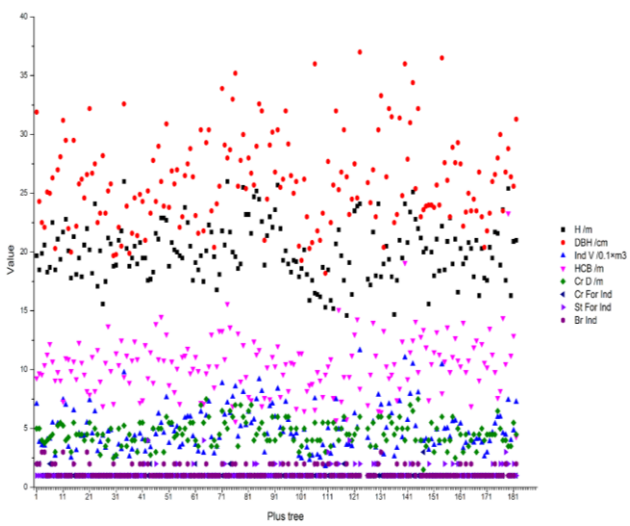

Fig. 2. The growth indexes of 182 plus trees of *Betula alnoides*
NB: H: Tree height; DBH: Diameter of breast height; Ind V: Individual volume; HCB: Height to crown base; Cr D: Crown diameter; Cr For Ind: Crown form index; St For Ind: Stem form index; Br Ind: Branchiness index.

Compared with the population mean of the 24 provenances (Shown in Table 4), Provenance G showed increase of 16.12% in tree height, 16.12% in DBH, and 72.25% in individual volume. Provenance L increased tree height by 11.75% and individual volume increased by 1.6%. Provenance U, J, R, C and P showed increase of 8.21%, 6.88%, 3.62%, 8.94% and 5.68% in tree height, 13.37%, 8.42%, 7.63%, 1.63% and 1.51% in DBH, and 34.15%, 22.14%, 17.43%, 15.83% and 15.12% in individual volume, respectively.

Plus tree selection: The plus tree selection of *B. alnoides* was carried out with the Dominant Tree Comparision Method (Zhang, 2002) like eucalypts: Taking the candidate tree as the central, five dominant trees are selected by eyes in the radius of 10 m, followed by the comparison of growth values and form quality between the plus tree and dominant trees. The tree with the symptom of trunk-boring pests was excluded. 182 plus trees were selected in the study (See Fig. 2). Compared with their relative block mean values, the tree height, DBH and individual volume of the best plus tree increased 57.6%, 89.5% and 343.9% respectively, and their stem form indexes mainly on the grade "1".

Conclusion and Discussion

Since the introduction of *B. alnoides* in Fujian Province in 2002, the problem of provenances matching with site conditions has been found in this area. Some of the trees suffered from attack of trunk borer such as species of Cerambycidae, so local people concerned about the future of *B. alnoides*.

The superior provenances were selected from 299 families of 25 provenances of *B. alnoides* at 14-year-old in Fujian Hua'an Jinshan National Forest Farm, Fujian Province. The provenance G was the best choice. The provenance L was the second choice because of its best stem form. The provenance U, J, R, C and P could also be used for the alternative seed sources. These provenances were less suffered from serious pest damage.

We recommend to collect seeds from the original provenance G and L, and propagate seedlings for afforestation in Zhangzhou, Fujian Province. The seeds of original provenance U, J, R, C and P are the alternative.

We hope the plantations of *B. alnoides* will be seen in the near future by using these superior provenances.

182 plus trees were also screened out in the present study, next step we will propagate these plus trees by grafting or tissue culture and develop clone forestry of *B. alnoides* in southern Fujian Province, China.

Table 3. Growth performance of *Betula alnoides* provenances.

Tree height /m	DBH /cm	Individual volume /m^3	Stem form index	Height to crown base /m	Crown diameter /m	Crown form index	Branchiness index	Number of borer-attacked trees
15.875±1.2160ab	17.064±0.5695abc	0.1753±0.03062b	2.194±0.4819ab	9.808±1.0271ab	2.883±0.2421ab	2.417±0.4883ABab	1.667±0.3333abc	0
17.043±2.1594ab	19.365±3.0232abc	0.2605±0.10997ab	2.650±0.8401ab	11.282±1.2257a	2.650±0.6874ab	2.633±0.8172ABabc	1.817±0.4086abcd	0
15.156±0.9127ab	17.000±0.4234abc	0.1586±0.01278b	2.333±0.8389ab	10.100±0.4765ab	2.033±0.1740ab	3.000±0.1925ABabc	1.778±0.2222abcd	0
14.753±1.0184ab	18.338±0.5728abc	0.1869±0.02670ab	3.028±0.1211ab	7.261±1.0426b	2.850±0.3753ab	2.350±0.4537ABab	3.144±0.2982d	0
13.317±1.2988b	17.067±0.4177abc	0.1484±0.00514b	2.500±0.2887ab	9.050±0.9278ab	1.833±0.1667ab	3.667±0.1667ABbc	1.667±0.3333abc	0
18.167±2.6523a	22.150±4.6761a	0.3874±0.21675a	2.667±0.7265ab	10.917±0.9671ab	2.383±1.6295ab	2.667±0.8819ABabc	1.333±0.1667a	0
15.720±0.2926ab	17.769±1.0280abc	0.1901±0.02333ab	1.875±0.1250ab	9.423±1.0624ab	2.533±0.3941ab	2.562±0.3698ABabc	1.548±0.2486ab	0
15.086±0.5799ab	19.349±1.2736abc	0.2259±0.02749ab	2.095±0.5852ab	9.013±0.9284ab	2.767±0.4333ab	2.897±0.3374ABabc	1.794±0.4828abcd	0
16.722±0.7676ab	20.660±1.7019abc	0.2747±0.04753ab	2.375±0.1909ab	9.679±0.6593ab	3.483±0.3983ab	2.042±0.5221ABa	1.799±0.5075abcd	0
16.118±0.8718ab	20.173±1.1885abc	0.2401±0.02425ab	2.426±0.1646ab	9.081±1.0511ab	2.850±0.3329ab	2.065±0.6095ABa	1.852±0.1481abcd	0
17.483±1.0529ab	18.461±1.8092abc	0.2285±0.06209ab	1.778±0.4006 a	9.606±1.6398ab	2.317±0.6405ab	2.778±0.4006ABabc	1.667±0.3333abc	0
14.244±1.4224ab	18.383±0.4656abc	0.1758±0.02111b	2.000±0.6939ab	8.861±0.9463ab	2.300±0.2784ab	3.222±0.4006ABabc	1.778±0.4843abcd	1
14.337±1.7340ab	16.463±0.4926bc	0.1471±0.01784b	2.733±0.6227ab	8.307±1.2639ab	1.683±0.5630b	3.933±0.0667Bc	2.567±0.7881abcd	0
15.800±0.6506ab	20.075±1.4497abc	0.2393±0.02747ab	2.952±0.5793ab	7.228±2.0142b	3.683±0.9094a	1.952±0.5793Aa	2.752±0.7524bcd	0
16.533±1.9262ab	19.343±1.8066abc	0.2589±0.06700ab	2.253±0.5830ab	9.069±0.4845ab	2.983±0.3371ab	2.051±0.3112ABa	2.061±0.2018abcd	0
15.094±1.3691ab	20.861±0.8533abc	0.2590±0.05246ab	2.778±0.2222ab	7.428±1.1805ab	3.533±0.2603ab	2.000±0.5774ABa	2.778±0.7778bcd	1
16.212±0.7618ab	20.509±0.1969abc	0.2641±0.01005ab	3.418±0.7007ab	7.540±0.9578ab	3.250±0.2566ab	1.920±0.2120Aa	2.374±0.1492abcd	0
13.873±2.2429ab	15.811±1.8880c	0.1411±0.04936b	3.489±0.4151b	8.093±2.0406ab	2.383±0.3528ab	2.867±0.1333ABabc	2.444±0.2940abcd	0
15.827±0.9238ab	20.408±1.0071abc	0.2534±0.03590ab	2.606±0.1056ab	8.121±0.8357ab	3.267±0.3371ab	1.917±0.0833Aa	2.167±0.1667abcd	0
16.930±0.2554ab	21.602±0.7078ab	0.3017±0.01010ab	2.905±0.0952ab	7.853±1.0991ab	3.600±0.5530a	1.876±0.3600Aa	2.531±0.3599abcd	0
15.504±1.5437ab	20.409±1.6828abc	0.2465±0.04796ab	3.244±0.4640ab	7.424±1.5724ab	3.467±0.5085ab	2.100±0.3786ABa	2.833±0.4410bcd	0
15.447±1.1688ab	19.321±1.0486abc	0.2298±0.03684ab	3.115±0.1893ab	7.262±0.5768b	3.283±0.2603ab	2.373±0.0448ABab	3.058±0.0830cd	0
15.193±0.6156ab	18.439±2.1525abc	0.2061±0.05819ab	2.590±0.0787ab	7.534±0.4912ab	2.850±0.2566ab	2.267±0.3170ABab	2.670±0.0287abcd	0
15.057±0.1965ab	18.299±0.2280abc	0.1988±0.00467ab	2.926±0.1335ab	7.967±0.5725ab	3.083±0.2333ab	2.103±0.1238ABa	2.541±0.2695abcd	0
15.645±0.2577*	19.055±0.3328*	0.2249±.012134*	2.622±0.0962*	8.663±0.2333*	2.831±0.1112*	2.486±0.0970**	2.192±0.0908*	

NB: 1. Provenance A was not involved here due to less survival rate. 2. *: $\rho<0.05$; **: $\rho<0.01$

Table 4. Comparison of growth performance for each *Betula alnoides* provenances with the population level.

Provenance code	Tree height /m	Tree height compared with population level /%	DBH /cm	DBH compared with population level /%	Individual volume /m^3	Individual volume compared with population level /%
B	15.875	1.47	17.064	-10.45	0.1753	-22.05
C	17.043	8.94	19.365	1.63	0.2605	15.83
D	15.156	-3.13	17.000	-10.78	0.1586	-29.48
E	14.753	-5.70	18.338	-3.76	0.1869	-16.90
F	13.317	-14.88	17.067	-10.43	0.1484	-34.02
G	18.167	16.12	22.15	16.24	0.3874	72.25
H	15.72	0.48	17.769	-6.75	0.1901	-15.47
I	15.086	-3.57	19.349	1.54	0.2259	0.44
J	16.722	6.88	20.66	8.42	0.2747	22.14
K	16.118	3.02	20.173	5.87	0.2401	6.76
L	17.483	11.75	18.461	-3.12	0.2285	1.60
M	14.244	-8.95	18.383	-3.53	0.1758	-21.83
N	14.337	-8.36	16.463	-13.60	0.1471	-34.59
O	15.8	0.99	20.075	5.35	0.2393	6.40
P	16.533	5.68	19.343	1.51	0.2589	15.12
Q	15.094	-3.52	20.861	9.48	0.259	15.16
R	16.212	3.62	20.509	7.63	0.2641	17.43
S	13.873	-11.33	15.811	-17.02	0.1411	-37.26
T	15.827	1.16	20.408	7.10	0.2534	12.67
U	16.93	8.21	21.602	13.37	0.3017	34.15
V	15.504	-0.90	20.409	7.11	0.2465	9.60
W	15.447	-1.27	19.321	1.40	0.2298	2.18
X	15.193	-2.89	18.439	-3.23	0.2061	-8.36
Y	15.057	-3.76	18.299	-3.97	0.1988	-11.61
Population mean	15.645		19.055		0.2249	

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