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Betula alnoides Admixed with *Castanopsis hystrix* or *Cunninghamia lanceolata* from Two Reforestation Case Studies in Southeast China

Bihua Chen, Juan Zhang, Weiwei Xie, Junjie Wu, Hein Sebastian[1]

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ABSTRACT

Background: There was no literature showed superior provenance or clone of *B. alnoides* selected for the development of southern Fujian, as well as no suitable reforestation mixed pattern for *B. alnoides* developed for preventing the trunk pests effectively. It is significant to select an optimal reforestation pattern for *B. alnoides* to be expanded in southern Fujian.

Methods: The tissue-cultured seedlings of *Betula alnoides* were introduced to south-east China for reforestation mixed pattern tests. *B. alnoides* was admixed with *Castanopsis hystrix* with five patterns at Wanshiqing Area and admixed with *Cunninghamia lanceolata* with four patterns at Beijing Area. A sample plot of 20 m × 30 m was set in each experimental treatment and each tree was investigated in the sample plot, including tree height (m), DBH (cm), pests and diseases and freeze injury.

Result: The effects of the pure forest were better than that of the cluster mixed forest in tree height. The cluster mixed pattern was not beneficial to the tree height growth of *B. alnoides* and DBH growth of *C. lanceolata* in early stage. The average annual growth of *B. alnoides* in tree height, DBH and individual volume achieved 2.2-2.5 m, 2.8-3.0 cm and 0.0061-0.0074 m^3, respectively.

Key words: *Betula alnoides*, Diameter at breast height (DBH), Mixed forest, Reforestation, Tree height, Volume.

INTRODUCTION

Betula alnoides Buch.-Ham. ex D. Don belongs to genus *Betula* of family Betulaceae. In China the natural distribution of *B. alnoides* is concentrated in Yunnan, Guangxi and Guizhou provinces and it is a fast-growing tree species for timber production in tropical and subtropical regions. The mechanical properties of *B. alnoides* are strong and its wood property is well that no easy deformation with decorative pattern and beautiful color. It is widely used for indoor decoration, wooden floor and furniture, *etc*. *B. alnoides* is an optional tree species to develop for producing middle and high-grade wood in southern China for the market demand (Pang, 2011; Li, 2012).

Castanopsis hystrix Miq., belonging to genus *Castanopsis* of family Fagaceae, up to 25 m height and 1.5 m diameter at breast height, has hard wood. Due to less deformation with beautiful maroon heartwood color and texture, it can be made for high-grade furniture, shipbuilding, vehicles, craft carving, architectural decoration and other high-quality materials. There is natural distribution in Fujian province.

Cunninghamia lanceolata (Lamb.) Hook., belonging to genus *Cunninghamia*, family Taxodiaceae, is one of the popular tree species cultivated in southern China. The wood is yellow-white or reddish-brown, with a straight texture and easy to process widely used in house, bridge, ship and furniture making.

The growth and morphological characteristics of 20 *B. alnoides* clones at the age of 5 years old in Huizhou city, Guangdong province were determined and analyzed (Wang *et al*., 2017). The results showed there were significant differences among the clones except for tree height and branchiness.

B. alnoides provenances were introduced Fujian province in 2002. The trunk pests attacked *B. alnoides*. Zhao *et al*. (2011) found that *B. alnoides* was damaged by *Anoplophora chinensis* Forster in northern Guangdong; Liu *et al*. (2012a, 2012b), Huang (2012), Chen *et al*. (2016) and Pang *et al*. (2016) found *B. alnoides* was damaged by *Arbela spp*. in Guangxi. Chen (2013) found that the pest *Phalera flavescens* eating the leaves of *B. alnoides* in Guangxi. No literature showed superior provenance or clone of *B. alnoides* was selected for the development of southern Fujian, as well as no suitable reforestation mixed pattern for *B. alnoides* developed for preventing the trunk pests

Fujian Academy of Forestry Sciences, Fuzhou Fujian-350012, China.

[1]University of Applied Forest Sciences, Rottenburg Stuttgart-72108, Germany.

Corresponding Author: Bihua Chen, Fujian Academy of Forestry Sciences, Fuzhou Fujian-350012, China.

Email: chenbihua.happy@163.com

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effectively. It is significant to select an optimal reforestation pattern for *B. alnoides* to be expanded in southern Fujian, therefore we introduced four tissue-cultured clones of *B. alnoides* from Guangxi and conducted its mixed forest tests in Fujian Hua'an Jinshan National Forest Farm (FHJNFF) and Fujian Longhai Jiulongling National Forest Farm (FLJNFF), mixed with *C. hystrix* and *C. lanceolata*, respectively.

MATERIALS AND METHODS

Overview of the test site

The first site is located at Wanshiqing area, FHJNFF, 117°38′E and 24°44′N, with a typical south subtropical climate. The average annual temperature is about 18.0-19.0°C, the annual frost-free period is about 320 days and the average annual precipitation is about 1610.9 mm. The previous crops at this site were *Eucalyptus urophylla*× *Eucalyptus grandis* and miscellaneous woody plants, with an altitude of 500-600 m and 28 degree slope. The test site was on the lower and mid position of whole slope, westward, covered by red soil with soil layer of 80-100 cm thickness and humus layer of 5-10 cm thickness. The site quality wasa!-III grade (Fan *et al*., 2012).

The second site is located at Beijing area, FLJNFF, 117°43′E and 24°21′N. The average annual temperature is 20.5-21.0°C. The annual frost-free period is about 330 days and the average annual precipitation is about 1563 mm. The previous crops at this site were *Pinus massoniana* and miscellaneous woody plants, with an altitude of 200-300 m and 20 degree slope, covered by red soil. The overall slope orientation was southwestward and the test site was on the lower and mid position of whole slope. The site quality was II grade (Fan *et al*., 2012).

Material source and test design

The tissue-cultured seedlings of *B. alnoides* clones used in the experiments were used for reforestation in April 2017.

The experiment treatments setting at Wanshiqing area in April 2017

In the mixed forests of *B. alnoides* and *C. hystrix* at Wanshiqing area, five experiment treatments were set: T1, pure forest of *B. alnoides* (control); T2, *B. alnoides* and *C. hystrix* (admixed with 1:1 parallel row); T3, *B. alnoides* and *C. hystrix* (admixed with 2:2 parallel rows); T4, *B. alnoides* and *C. hystrix* (admixed with 2:4 parallel raws); T5, *C. hystrix* pure forest. The random block design, 0.333 hectares per plot, 4 repeats (blocks) and *C. hystrix* for protection lines were set in this experiment.

The forestland was prepared by vegetation burning, comprehensive clearing and hole preparation in November 2016. The hole size was 50 cm × 40 cm × 30 cm and the plant spacing of *B. alnoides* or *C. hystrix* was 1.8 m × 2.3 m. The tissue-cultured container seedlings of *B. alnoides* were used, with a seedling height of about 35 cm and the red soil container seedling of *C. hystrix* were applied, with a seedling height of about 25 cm in April 2017.

Tending management

1×1 square meter of block weeding around the plant for the first year after reforestation in September 2017, together with fertilizing 100 g plant^{-1} first time in May 2017 and 100 g plant^{-1} second time September 2017 and chopping shrubs and grasses twice in 2017; fertilizing 200 g plant^{-1} once, chopping shrubs and grasses twice and chemical weeding once in 2018; fertilizing 200g plant^{-1} once, chopping shrubs and grasses twice comprehensively in 2019. The compound fertilizer consisted of 45% (N-P_2O_5-K_2O= 5-15-15). No fertilization and weeding in 2020.

The experiment treatments setting at Beijing area

In the mixed forests of *B. alnoides* and *C. lanceolata* at Beijing area, four treatments were set in April 2017: E1, Pure forest of *B. alnoides* (control); E2: *B. alnoides* and *C. lanceolata* admixed with 2:6 rows; E3, 1:3 cluster mixed, 4 plants per cluster for *B. alnoides*; E4, Pure forest of *C. lanceolata*. Random block design, 4 repeats and 0.333 hectares per plot were adopted and *C. lanceolata* was used as the protection lines.

The forestland was prepared by vegetation burning, comprehensive clearing and level belts with soil deeply turned in November 2016. The plant spacing was prepared with 2.0 m × 2.0 m for *B. alnoides* and 1.5 m × 1.5 m for *C. lanceolata* in November 2016. The tissue-cultured container seedlings of *B. alnoides* were adopted, with a seedling height of about 35 cm and the bare root seedling of *C. lanceolata* were applied with a seedling height of about 30 cm in April 2017.

Tending management: no weeding in 2017, but fertilizing with 100 g plant^{-1} first time in May 2017 and 100 g plant^{-1} second time in September 2017; It was no weeding but fertilizing 200 g plant^{-1} once in 2018; chopping shrubs and grasses twice comprehensively in 2019 and fertilizing 250 g/plant once. The compound fertilizer consisted of 45% (N-P_2O_5-K_2O= 5-15-15). No fertilization but weeding once in 2020.

Survey methods

Field survey in April 2020. A sample plot of 20 m × 30 m was set in each plot and each tree was investigated in the sample plot, including tree height (m), DBH (cm), pests and diseases and freeze injury.

Data analysis

The EXCEL and SPSS17.0 software were used to conduct Duncan variance analysis on the average height, DBH and volume of trees in each mixed forest and Origin 8.5 was used for drawing pictures.

Volume calculation of *B. alnoides*: $V = \pi(d_{1.3}/2)^2 h f_{1.3}$

Among them:

$d_{1.3}$ = Diameter of the breast height.

h = Tree height.

$f_{1.3}$ = Form index of breast height.

$f_{1.3}$ = 0.45 for *B. alnoides* (Wang *et al*., 2013, 2017).

All experimental designs above were carried out by Fujian Academy of Forestry Sciences.

RESULTS AND DISCUSSION

Results and analysis of the mixed forest of *B. alnoides* and *C. hystrix* at Wanshiqing area

The ANOVA analyzed by SPSS17.0 are shown in Table 1. From four reforestation patterns, there were no or highly significant differences among the four forestation patterns in tree height, DBH or volume of *B. alnoides*, all of which were "A" or "a" (Table 1). There were no significant or highly significant differences in tree height, DBH and volume per plant among the four forestation modes, all of which were "A" or "a" (Table 2).

Results and analysis of the mixed forest of *B. alnoides* and *C. lanceolata* at Beijing area

The results analyzed by SPSS17.0 are shown in Table 3. From the three forestation patterns, there were no significant or highly significant differences among the three reforestation patterns in DBH or volume of *B. alnoides*, all of which were "A" or "a". While there were significant differences but no highly significant differences in tree height, *i.e.* E1 (pure forest) (a) was superior to E3 (cluster mixed) (b), while E2 (2:6 row mixed) (ab) had no significant difference to E1 and E3 (Table 3).

There was significant or highly significant difference in the tree height, DBH and individual volume of *C. lanceolata*. There were significant difference but no highly significant difference in the height and individual volume of *C. lanceolata* under treatments and highly significant difference in the DBH of *C. lanceolata* under treatments. In addition, E2 (Aa) and E4 (Aa) were all superior to E3 (Ab). The DBH of the treatments was high significant difference, *i.e.* both E2 (Aa) and E4 (Aa) were superior to E3 (Bb) (Table 4).

Table 1: Average growth indexes and ANOVA analysis of *Betula alnoides* (admixed with *Castanopsis hystrix*).

Treatment	Average tree height/m	Average DBH/cm	Average individual volume/m^3	Pest and disease	Freeze injury
T1	6.73±0.245 Aa	8.18±0.509 Aa	0.0175±0.00234 Aa	Longicorn beetles damage in the first year; *Lymantria xylina* damage in the second year; No damage in the third year	Only slight freeze injury in the first year
T2	6.61±0.276 Aa	8.52±0.894 Aa	0.0191±0.00405 Aa	The same as the upper	The same as the upper
T3	6.97±0.216 Aa	8.74±0.445 Aa	0.0199±0.00238 Aa	The same as the upper	The same as the upper
T4	6.49±0.242 Aa	7.92±0.500 Aa	0.0161±0.00251 Aa	The same as the upper	The same as the upper
Average	6.70	8.34	0.0182		

NB: 1. Same capital letter in same row means no highly significant difference, different capital letter in same row means highly significant difference and A>B>C, P<0.01; 2. Same lowercase letter means in same row no significant difference; different lowercase letter in same row means significant difference and a>b>c, P<0.05.

Table 2: Average growth indexes and ANOVA analysis of *Castanopsis hystrix* (admixed with *Betula alnoides*).

Treatment	Average tree height/m	Average DBH/cm	Average individual volume/m^3	Pest and disease	Freeze injury
T2	3.71±0.120 Aa	3.65±0.121 Aa	0.0023±0.00019 Aa	*L. xylina* damage in the second year only	No freeze injury
T3	3.95±0.178 Aa	3.88±0.157 Aa	0.0028±0.00037 Aa	The same as the upper	The same as the upper
T4	4.05±0.126 Aa	3.83±0.169 Aa	0.0027±0.00032 Aa	The same as the upper	The same as the upper
T5	3.83±0.305 Aa	3.93±0.274 Aa	0.0028±0.00058 Aa	The same as the upper	The same as the upper
Average	3.88	3.82	0.0027		

NB: 1. Same capital letter in same row means no highly significant difference, different capital letter in same row means highly significant difference and A>B>C, P<0.01; 2. Same lowercase letter means in same row no significant difference; different lowercase letter in same row means significant difference and a>b>c, P<0.05.

Table 3: Average growth indexes and ANOVA analysis of *Betula alnoides* (admixed with *Cunninghamia lanceolata*).

Treatment	Average tree height/m	Average DBH/cm	Average individual volume/m^3	Pest and disease	Freeze injury
E1	8.35±0.397 Aa	8.89±0.426 Aa	0.0240±0.0022 Aa	No serious	No freeze injury
E2	7.07±0.398 Aab	8.99±0.731 Aa	0.0210±0.0023 Aa	The same as the upper	The same as the upper
E3	6.79±0.928 Ab	9.27±0.684 Aa	0.0218±0.0027 Aa	The same as the upper	The same as the upper
Average	7.41	9.05	0.0223		

NB: 1. Same capital letter in same row means no highly significant difference, different capital letter in same row means highly significant difference and A>B>C, P<0.01; 2. Same lowercase letter means in same row no significant difference; different lowercase letter in same row means significant difference and a>b>c, P<0.05.

Table 4: Average growth indexes and ANOVA analysis of *Cunninghamia lanceolata* (admixed with *Betula alnoides*).

Treatment	Average tree height/m	Average DBH/cm	Average individual volume/m^3	Pest and disease	Freeze injury
E2	4.09±0.202 Aa	5.55±0.425 Aa	0.00682±0.001158 Aa	No serious	No freeze injury
E3	3.59±0.147 Ab	4.17±0.166 Bb	0.00360±0.000411 Ab	The same as the upper	The same as the upper
E4	4.08±0.114 Aa	5.60±0.171 Aa	0.00703±0.000617 Aa	The same as the upper	The same as the upper
Average	3.92	5.11	0.00581		

NB: 1. Same capital letter in same row means no highly significant difference, different capital letter in same row means highly significant difference and A>B>C, P<0.01; 2. Same lowercase letter means in same row no significant difference; different lowercase letter in same row means significant difference and a>b>c, P<0.05.

Fig 1: The adult of *Anoplophora chinensis* on *Betula alnoides* tree.

Fig 2: The adult of *Batocera lineolata* on *Betula alnoides* tree.

Fig 3: The larvae of *Lymantria xylina* on *Betula alnoides* tree.

Fig 4: The larvae of *Lymantria xylina* on *Castanopsis hystrix* tree.

The *B. alnoides* in FLJNFF was harmed by termites and crickets in summer in the mixed forest of *B. alnoides* mixed with *C. hystrix* in FHJNFF. In May 2018 in FHJNFF, the adults of *Anoplophora chinensis* (Fig 1) and *Batocera lineolata* (Fig 2) were found damaging the trees of *B. alnoides*. In September 2018 it was found that longhorn beetles damaged a few stems of *B. alnoides*, but did not cause serious harm. In May 2019, it was found that the defoliator larvae of *Lymantria xylina* (Fig 3 and 4) were harmful to both of *B. alnoides* and *C. hystrix*. The adults of longicorn beetles mainly gnawed the epidermis of top branch or shoots, while the larvae of *L. xylina* fed on the leaves. As early as 2018, that the larvae of *L. xylina* were found to harm the pure forest of *C. hystrix* nearby which might be the host plant for this species. After reforestation, no serious damage by the adults of longhorn beetle and the larvae of *L. xylina* was found without any pesticide control (Meena *et al*, 2018; Jyothi and Hebsur, 2017; Kavipriya *et al*, 2019).

No any serious pests were found in the mixed forest of *B. alnoides* and *C. lanceolata* for 3 years at Beijing area of FLJNFF.

CONCLUSION

The pure forest *B. alnoides* was superior to the cluster mixed pattern on tree height, but no significant difference between the two patterns and 1:3 rows mixed pattern in FLJNFF. There were significant or highly significant differences in tree height, DBH and individual volume of *C. lanceolata* among the three reforestation patterns, *i.e*. there were

significant differences but no highly significant differences in tree height or individual volume of *C. lanceolata* among each treatment and they were all 1:3 row mixed pattern and pure *C. lanceolata* forest superior to the cluster mixed forest.

The average tree height, average DBH and average individual volume of *B. alnoides* in Beijing Area of FLJNFF reached 7.41 m, 9.05 cm and 0.0223 m^3 respectively; the average tree height, average DBH and average individual volume in Wanshiqing Area of FHJNFF reached 6.70 m, 8.34 cm and 0.0182 m^3 respectively. In conclusion, the average annual growth of height, DBH and volume of *B. alnoides* reached 2.2-2.5 m, 2.8-3.0 cm and 0.0061-0.0074 m^3 respectively. The 3-year growth performance of mixed reforestation experiment of *B. alnoides* admixed with *B. alnoides* and *C. hystrix* does not represent the later stage performance, thus the investigation and analysis should be continued in the future consequence study.

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Conflict of interest: None.

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