

Response of clonal plasticity of *Fargesia nitida* to different canopy conditions of subalpine coniferous forest

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Abstract The aim of this study is to explore the effects of canopy conditions on clump and culm numbers, and the morphological plasticity and biomass distribution patterns of the dwarf bamboo species *Fargesia nitida*. Specifically, we investigated the effects of canopy conditions on the growth and morphological characteristics of *F. nitida*, and the adaptive responses of *F. nitida* to different canopy conditions and its ecological senses. The results indicate that forest canopy had a significant effect on the genet density and culm number per clump, while it did not affect the ramet density. Clumps tended to be few and large in gaps and forest edge plots, and small under forest understory plots. The ramets showed an even distribution under the closed canopy, and cluster distribution under gaps and forest edge plots. The forest canopy had a significant effect on both the ramets' biomass and biomass allocation. Favourable light conditions promoted ramet growth and biomass accumulation. Greater amounts of biomass in gaps and forest edge plots were shown by the higher number of culms per clump and the diameter of these culms. Under closed canopy, the bamboos increased their branching angle, leaf biomass allocation, specific leaf area and leaf area ratio to exploit more favourable light conditions in these locations. The spacer length, specific spacer length and spacer branching angles all showed significant differences between gaps and closed canopy conditions. The larger specific spacer length and spacer branching angle were beneficial for bamboo growth, scattering the ramets and exploiting more favourable light conditions. In summary, this study shows that to varying degrees, *F. nitida* exhibits both a wide ecological amplitude and high degree of morphological plasticity in response to differing forest canopy conditions. Moreover, the changes in plasticity enable the plants to

optimize their light usage efficiency to promote growth and increase access to resources available in heterogeneous light environments.

Keywords *Fargesia nitida*, clonal plant, plasticity, subalpine coniferous forest, Wolong Nature Reserve

1 Introduction

Interactions between forest canopy and forest understory plants have been recognized as important determinants of community structure and dynamics in many forests (Denslow et al., 1991; Griscom and Ashton, 2003; Nakashizuka, 1987; Taylor et al., 2004). Composition and density of forest canopy influence the patterns of light, soil water and soil nutrient availability on the forest floor (Taylor et al., 2004). A number of studies have shown that growth of dwarf bamboo changes in different forest canopies (Liu et al., 2004; Qin et al., 1993; Song et al., 2006; Wang and Ma, 1993). The growth of *Bashania fangiana* was inhibited in subalpine coniferous forest, while there were higher and denser culms in broadleaved forest and forest gaps in southwest China (Qin et al., 1993; Taylor and Qin, 1988a, 1988b, 1992; Taylor et al., 2004, 2006). Dwarf bamboos, perennial, and monocarpic woody clonal plant species (Liu et al., 2004; Qin et al., 1993), were dominant species in the shrub layer and were widely distributed in forest gaps, understories and open areas of subalpine forest (Qin et al., 1993; Taylor et al., 2004). In forest gaps, clonal growth of dwarf bamboo was quick due to better resource conditions; however, the dense culms and interlaced roots had significant effects on the settling and growth of seedlings and species diversity of forest communities (Liu et al., 2004; Noguchi and Yoshida, 2004; Tabarelli and Mantovani, 2000; Taylor et al., 2004; Widmer, 1998). At present,

Translated from *Acta Ecologica Sinica*, 2006, 26(12): 4019–4026
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much attention is paid to the effects of existence and density of dwarf bamboo on forest regeneration because the bamboos could inhibit arbor seed germination and seedling establishment, and focus is also given to the relationship between the process of dwarf bamboo flowering and forest gap regeneration (Abe et al., 2002, 2005; Narukawa and Yamamoto, 2001; Iida, 2004; Holz and Veblen, 2006; Noguchi and Yoshida, 2004; Qin et al., 1993; Takahashi et al., 2003; Taylor and Qin, 1992; Taylor et al., 2004, 2006). In subalpine regions, dominant tree species mainly regenerate in forest gaps. However, after gap formation, dwarf bamboos have a competitive advantage over saplings and seedlings, and weaken the effects of gaps on forest regeneration until bamboo flowering. Therefore, research on the plasticity response of dwarf bamboo to canopy conditions and its effects on forest gaps in forest cycle succession can help understand the relationship between dwarf bamboo and subalpine forest regeneration.

For clonal plants, phenotype plasticity was found to be an important strategy in adapting to environmental heterogeneity (Dong, 1996; Zhang et al., 2003). The objectives of the present study are to clarify clonal bamboo quantitative characteristics, biomass distribution and morphological plasticity of a 23 year old *Fargesia nitida* ramet population in different canopy conditions and, specifically, to explore the effects of different canopy conditions on ramet quantitative characteristics and rhizome characteristics of *F. nitida*, and determine the adaptation sense of *F. nitida* to different canopy conditions.

2 Materials and methods

2.1 Study site

The study was carried out at the Wolong Subalpine Dark Coniferous Forest Ecosystem Research Station (102°58'21" N, 30°51'41" E, 2800 m above the sea level) in Wolong Nature Reserve, Sichuan Province, China. It is a transitional area from the Sichuan Basin to the Qingzang (Tibetan) Plateau. This area is classified as Qingzang Plateau climate (Qin et al., 1993; Li and Zheng, 2004), determined by westerly jet and southeast monsoons, and characterized by cool weather, with small annual temperature differences. It has distinctive dry and wet seasons, a high relative humidity with an annual average temperature of 4.3°C, precipitation of 848.9 mm, evaporation of 772.5 mm, and sunshine duration of 1185.4 h. The soil substrate is mountain dark-brown coniferous soil (Yu et al., 2006).

The selected *Abies faxoniana* forest, possessing the widest distribution, is a typical subalpine coniferous forest in central and northwest Wolong. The composition is abundant and forest layers are distinct. *A. faxoniana* is

the constructive species, together with other interspersed canopy trees including *Betula utilis*, and *B. albo-sinensis*. Understory species include dwarf bamboo (*F. nitida* and *B. fangiana*), *Salix dissa*, *Viburnum betulifolium* and *Sorbus rufopilosa*. *Elatostema obtusum*, *Cacalia tangutica* and *Carex* sp. are the dominant species in the herb layer. Ground layer contains some moss species (Wang et al., 2004).

2.2 Plant materials

Fargesia nitida (Mitford) Keng f. is a dwarf bamboo and acts as food source for the giant panda. It is a perennial but monocarpic woody clonal plant with a flowering periodicity of 50–60 yrs. Gregarious culms, 2–5 m in height and 1–2 cm in width, form a fasciculate ramet group or show a scattered ramet distribution. The clonal growth of *F. nitida* depends on rhizomatous expansion, actually belonging to phalanx type. The plant is distributed in southern Gansu Province and western Sichuan Province, China (Qin et al., 1993).

2.3 Field investigation

Measurement was mainly conducted in typical understory, gaps and open areas of the subalpine forest (2800 ± 25 m a.s.l.) at similar slope angles and aspects from August to September 2004 and in August 2005. Classification of gap size was based on the data collected in 2003 in the same area (Wang et al., 2004). We chose a middle-sized forest gap (MG, area of canopy gap is about 160 m²), large forest gap (LG, area of canopy gap is about 400 m²), forest understory (FU) and forest edge wilderness (FEW, open area is more than 1500 m²) representing four canopy conditions. To a great extent, topography, canopy species composition and soil conditions in the four canopy conditions were the same. Light intensity was 100% in forest edge wilderness, 35.3% above bamboo canopy and 22.7% below bamboo canopy in the forest understory, 55.0% above bamboo canopy and 22.7% below bamboo canopy in the intermediate gap, and 64.7% above bamboo canopy and 25.0% below bamboo canopy in the large gap.

2.3.1 Quantitative investigation

Each plot was composed of eight quadrats of 4 m × 4 m. The density of *F. nitida* was measured and ramet number, size of each clump and genet number were recorded in each quadrat.

2.3.2 Morphology and biomass investigation

One hundred ramets were chosen randomly to measure the culm height and basal diameter, of which forty ramets were marked in each canopy plot. Furthermore, the num-

ber of culm nodes, number of branching node, culm inter-node length, specific culm length, leaf number per ramet and branching angle (each ramet with three value) of 20 ramets within the above 40 marked ramets were measured; the remaining 20 ramets in each condition were divided into leaves, branch, culm, rhizome, thick root (diameter >0.5 mm) and thin root (diameter ≤0.5 mm), cleaned with water and dried for 72 hours to obtain the dry mass. Thirty leaves from different parts of each ramet were taken to the laboratory, and single leaf biomass and specific leaf areas were measured.

2.3.3 Rhizome characteristics of clone population

The whole underground part of *F. nitida* in five 0.5 m × 0.5 m quadrats of each canopy condition were dug out. Spacer length, spacer diameter (mean value of two vertical directions), specific spacer length, the branching angle between parent spacer and daughter spacer (°), the branching angle between two daughter spacers (°), and the branching intensity of each spacer were recorded respectively.

2.4 Data analysis

The following formulas were used: Leaf area ratio (LAR) = leaf area/total biomass; Specific leaf area (SLA) = leaf area/leaves biomass; Allocation percentage to modular (including culm, branch, leaf, rhizome, thick root and thin root) (APM) = modular biomass/total biomass × 100%; Specific culm length (SCL) = culm length/culm biomass; Branching ratio of spacer (BRS) = number of parent spacer producing two or more daughter spacers/total number of parent spacers; Specific spacer length (SSL) = spacer length/spacer biomass; Branching intensity of spacer (BIS) = total number of daughter spacers.

All statistical analyses were carried out with SPSS 11.0. One-way ANOVA and *LSD* multiple comparison were used to test the differences of clonal characteristics, biomass and morphological characteristics in four canopy conditions (MG, LG, FU and FEW).

3 Results

3.1 Quantitative characteristics of clone

Genet population density showed significant differences ($p < 0.05$) among different canopy conditions except between MG and FEW (Fig. 1A); the mean values, in descending order, were FU (1.13 clumps/m²), MG (0.433 clumps/m²), FEW (0.420 clumps/m²) and LG (0.190 clumps/m²). The difference in the number of ramets per genet was significant ($p < 0.05$) among different canopy conditions (Fig. 1B); the mean values, in descending order, were LG (58.34 culms per genet), FEW (40.76 culms per genet), MG (24.56 culms per genet) and FU (8.51 culms per genet). Ramet density was not significantly different among the four canopy conditions (Fig. 1C), with the values in FU, MG, LG and FEW being 9.31, 10.10, 8.27 and 12.86 culms/m², respectively.

3.2 Ramet biomass characteristics

Ramet biomass, each modular biomass and allocation patterns of ramet population showed a significant difference ($p < 0.05$) among the four different canopy conditions (Table 1). Ramet biomass and each modular biomass in FU were significantly lower than those in the other three canopies, while allocation percentage to blades was highest in FU ($p < 0.05$). Allocation percentage of branch and thick root biomass in MG was lower than

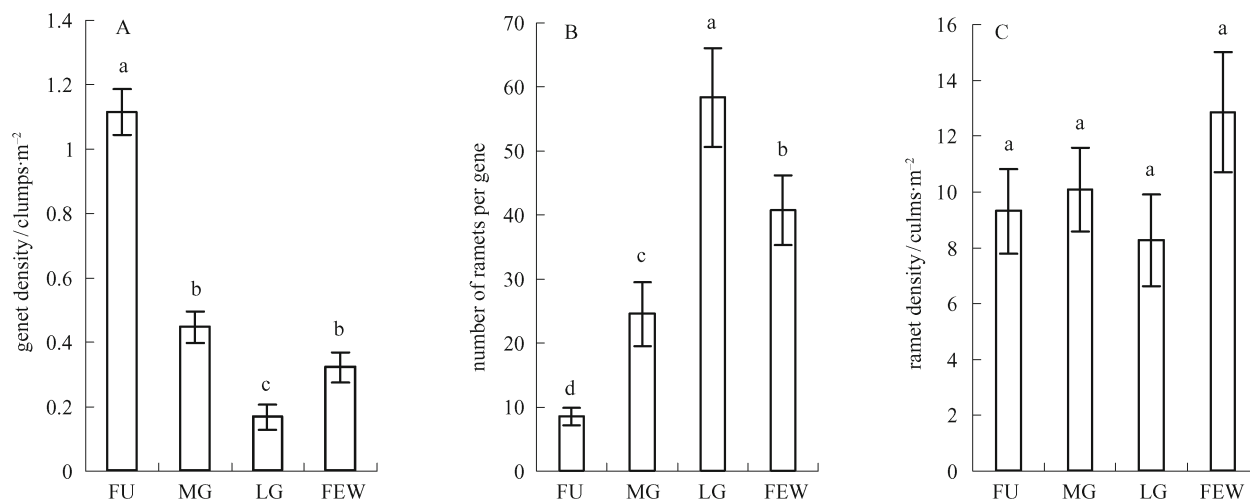


Fig. 1 The quantitative characteristics of *Fargesia nitida* under different canopy conditions (means ± SE). Note: The different letters mean differences at $p < 0.05$. FU: Forest understory; MG: middle-size gap; LG: Large gap; FEW: Forest edge wilderness

Table 1 The biomass and biomass allocation of *Fargesia nitida* ramet population in different canopy conditions (mean ± SE)

item	FU	MG	LG	FEW	F
B _r /g·clum ⁻¹	41.879 ± 3.727 ^d	103.410 ± 5.350 ^c	168.914 ± 6.174 ^a	121.824 ± 4.276 ^b	111.760 [*]
C _r /g·clum ⁻¹	22.921 ± 1.498 ^d	64.305 ± 2.678 ^c	110.262 ± 2.846 ^a	72.370 ± 2.006 ^b	238.306 [*]
Br _r /g·clum ⁻¹	6.712 ± 0.753 ^c	14.464 ± 1.018 ^b	26.959 ± 1.142 ^a	15.958 ± 0.831 ^b	77.307 ^{**}
Bl _r /g·clum ⁻¹	8.221 ± 0.929 ^c	14.373 ± 1.249 ^b	18.766 ± 1.511 ^a	14.575 ± 0.925 ^b	13.564 [*]
R _r /g·clum ⁻¹	2.190 ± 0.162 ^d	6.674 ± 0.151 ^c	8.262 ± 0.122 ^b	11.171 ± 0.202 ^a	537.941 ^{**}
Tc _r /g·clum ⁻¹	1.649 ± 0.169 ^d	3.245 ± 0.243 ^c	4.206 ± 0.301 ^b	6.482 ± 0.294 ^a	61.681 [*]
Tn _r /g·clum ⁻¹	0.185 ± .030 ^c	0.349 ± .028 ^b	0.459 ± .0510 ^b	1.270 ± .0480 ^a	142.688 ^{**}
CP _r /g·clum ⁻¹	58.357 ± 1.030 ^c	63.013 ± 1.033 ^b	65.842 ± 0.779 ^a	58.498 ± 0.802 ^c	15.790 [*]
BrP _r /g·clum ⁻¹	15.744 ± 0.817 ^a	13.773 ± 0.566 ^b	16.180 ± 0.667 ^a	12.944 ± 0.643 ^b	5.212 [*]
BIP _r /%	19.348 ± 0.775 ^a	13.376 ± 0.666 ^b	10.799 ± 0.488 ^c	11.511 ± 0.472 ^c	40.034 [*]
RP _r /%	5.501 ± 0.130 ^c	6.651 ± 0.197 ^b	4.978 ± 0.125 ^d	9.072 ± 0.131 ^a	149.419 [*]
TcP _r /%	3.989 ± 0.110 ^b	3.092 ± 0.078 ^c	2.435 ± 0.088 ^d	5.182 ± 0.082 ^a	173.730 ^{**}
TnP _r /%	0.409 ± 0.036 ^b	0.334 ± 0.018 ^{bc}	0.259 ± 0.021 ^c	1.027 ± 0.032 ^a	161.455 ^{**}

Note: Br: Ramet biomass; Cr: Culm biomass; Br_r: Branch biomass; Bl: Blades biomass; R_r: Rhizome biomass; Tc_r: Thick root biomass; Tn_r: Thin root biomass; CP_r: Allocation percentage to culm; BrP_r: Allocation percentage to branch; BIP_r: Allocation percentage to blades; RP_r: Allocation percentage to rhizome; TcP_r: Allocation percentage to thick root; TnP_r: Allocation percentage to thin root. The values sharing the different letters mean differences at $p < 0.05$ (ns: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$); The abbreviations FU, MG, LG, FEW are the same as Fig. 1.

those in FU ($p < 0.05$). In LG, ramet biomass and over-ground biomass of each module were highest, while underground biomass of each module was lower only to those in FEW ($p < 0.05$). Allocation percentages to culm and branch in LG were highest and allocation percentages to other modular were lowest compared with those in the other three conditions ($p < 0.05$). In FEW, biomass and allocation percentage of rhizome, thick root and thin root were highest compared with the other three canopies ($p < 0.05$).

3.3 Ramet morphological characteristics

Morphological parameters of the *F. nitida* ramet population in different canopy conditions are shown in Table 2. In FU, culm height, basal culm diameter, number of nodes, internode length and number of branching nodes were lowest, and specific culm length, branching angle, specific leaf area and leaf area ratio were highest

compared with those in the other three canopies ($p < 0.05$). Single leaf area was highest in MG ($p < 0.01$). Culm height, basal culm diameter, internode length and leaf number per ramet were highest in LG ($p < 0.01$). Branching angle and specific leaf area decreased sequentially as FU, MG, LG and FEW ($p < 0.01$).

3.4 Ramet rhizome characteristics

Spacer length increased in the sequence of FU, MG, LG and FEW ($p < 0.01$) (Fig. 2A). Spacer diameter in FU was lowest (Fig. 2B). Specific spacer length and the branching angle between two daughter spacers in FU and MG were higher than those in the other two conditions and were highest in FU ($p < 0.01$) (Fig. 2C, E). Branching angle between parent spacer and daughter spacer was highest in FEW and was lowest in FU ($p < 0.01$) (Fig. 2D). Branching intensity of spacer was highest in LG and was lowest in FU ($p < 0.05$) (Fig. 2F).

Table 2 The morphological characteristics of *Fargesia nitida* ramet population in different canopy conditions (means ± SE)

item	FU	MG	LG	FEW	F
CH/m	2.339 ± 0.065 ^d	3.292 ± 0.061 ^b	3.723 ± 0.058 ^a	3.026 ± 0.068 ^c	84.340 ^{**}
CD/cm	0.902 ± 0.024 ^c	1.202 ± 0.021 ^b	1.310 ± 0.019 ^a	1.228 ± 0.020 ^b	71.553 ^{**}
NN	22.350 ± 0.734 ^c	25.700 ± 0.436 ^{ab}	26.400 ± 0.622 ^a	24.500 ± 0.766 ^b	7.403 [*]
IL/cm	10.776 ± 0.387 ^c	12.817 ± 0.231 ^b	14.159 ± 0.308 ^a	12.560 ± 0.339 ^b	18.738 ^{**}
SCL/cm·g ⁻¹	10.345 ± 0.313 ^a	5.319 ± 0.275 ^b	3.376 ± 0.171 ^c	4.357 ± 0.241 ^d	145.259 ^{**}
NBN	13.500 ± 0.560 ^b	18.000 ± 0.611 ^a	16.950 ± 0.713 ^a	16.400 ± 0.853 ^a	7.718 ^{**}
BA/°	55.750 ± 0.809 ^a	48.533 ± 0.839 ^b	43.600 ± 0.894 ^c	39.483 ± 0.707 ^d	73.721 ^{**}
ILA/cm ⁻²	4.342 ± 0.154 ^c	5.836 ± 0.091 ^a	4.067 ± 0.152 ^c	5.095 ± 0.130 ^b	35.196 ^{**}
SLB/mg	13.000 ± 0.528 ^b	18.200 ± 0.296 ^a	13.350 ± 0.563 ^b	17.400 ± 0.489 ^a	31.468 ^{**}
LNR	514.350 ± 54.039 ^b	504.250 ± 44.107 ^b	911.000 ± 63.262 ^a	650.150 ± 58.149 ^b	11.719 ^{**}
SLA/cm ² ·mg ⁻¹	0.336 ± 0.004 ^a	0.322 ± 0.004 ^b	0.306 ± 0.003 ^c	0.294 ± 0.003 ^d	22.583 [*]
LAR/cm ² ·mg ⁻¹	51.851 ± 1.898 ^a	27.195 ± 1.359 ^b	22.111 ± 1.563 ^b	26.516 ± 2.656 ^b	48.616 ^{**}

Note: CH: Culm height; CD: Basal culm diameter; NN: Number of nodes; IL: Internode length; SCL: Specific culm length; NBN: number of branching node; BA: Branching angle; ILA: Single leaf area; SLB: Single leaf biomass; LNR: Leaf number per ramet; SLA: Specific leaf area; LAR: Leaf area ratio

The values sharing the different letters mean differences at $p < 0.05$ (ns: $p > 0.05$; *: $p < 0.05$; **: $p < 0.01$). The letters FU, MG, LG, FEW are the same as Fig. 1.

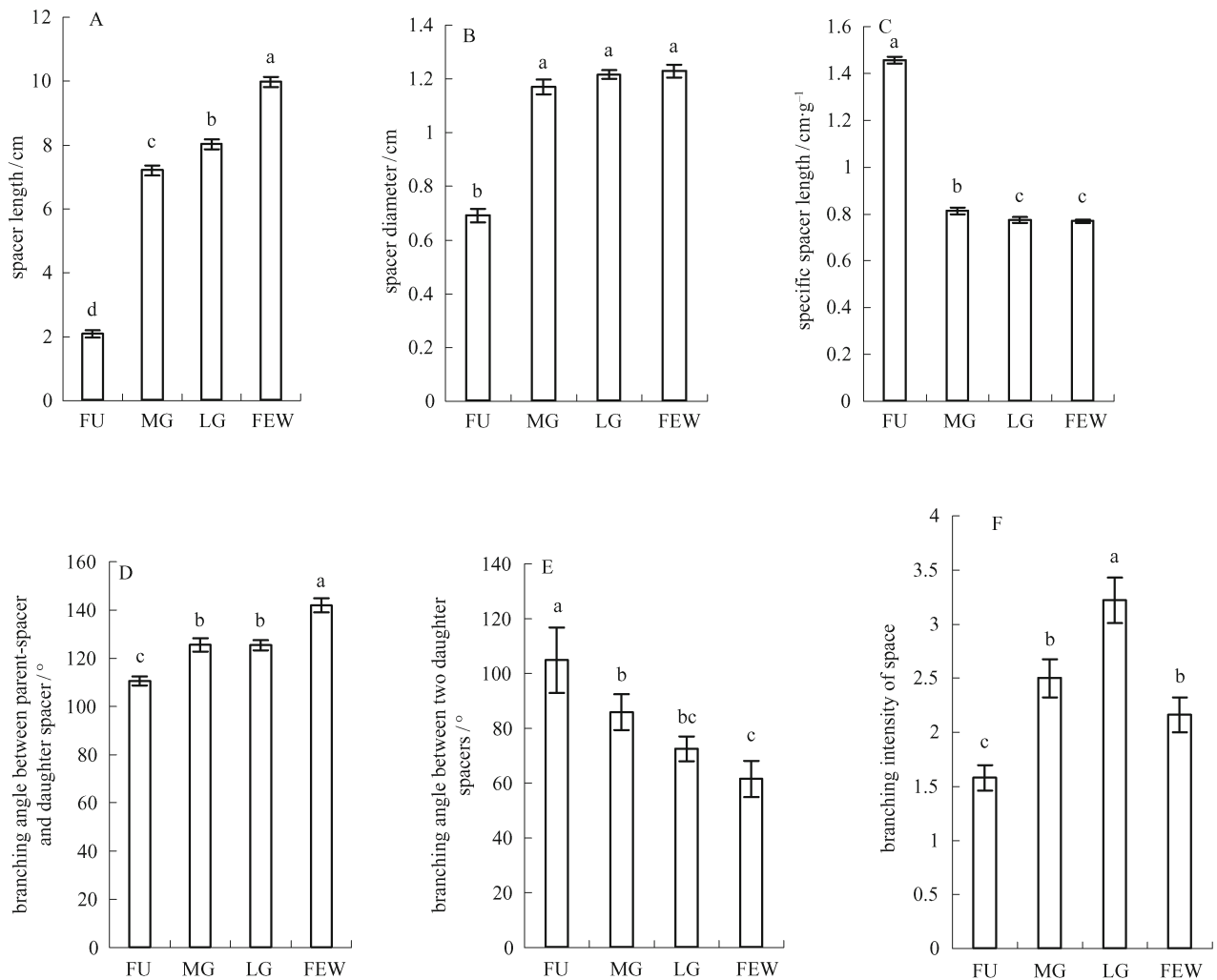


Fig. 2 The morphological characteristics of rhizomes of *Fargesia nitida* under different canopy conditions (means \pm SE). Note: The different letters mean differences at $p < 0.05$; The abbreviations FU, MG, LG, FEW are the same as Fig. 1.

4 Discussion

Shrub layers of some subalpine forests are dominated by dwarf bamboos, whose dense coverage affects patterns of availability of light on the forest floor, thus influencing the distribution and dominance of understory plants, the density and growth of arbor seedlings, and diversity of understory species (Taylor et al., 2004). Bamboos affect long-term canopy structure and composition by impeding the establishment and growth of tree species' seedling and sapling bank populations in forests with dense dwarf bamboo. Forest composition and structures in many forests were deficient in the pool of seedlings and saplings in the forest understory because they died due to the influence of dwarf bamboo (Nakashizuka, 1987; Taylor and Qin, 1988a; Taylor et al., 1995). On the other hand, canopy structure and composition may affect the distribution and growth of understory dwarf bamboo; however, few relevant studies have been reported. Forest canopy composition and density affect patterns of resource availability (i.e., light,

precipitation, soil nutrients) on the forest floor. In Chilean beech forests, understory bamboos (*Chusquea tenuiflora* Phil.) grew taller and distributed widely beneath the broadleaved evergreen *Nothofagus betuloides* forest than under the deciduous *N. pumilio*. Under the evergreen canopy, snow was less persistent and in growing season light penetration was stronger which increased the growing season length for *C. tenuiflora* (Veblen et al., 1979). On the other hand, evergreen conifer trees in Japanese and Chinese forests inhibited dwarf bamboo growth and culms were taller and denser under a deciduous canopy and in gaps (Franklin et al., 1979; Reid et al., 1991; Taylor and Qin, 1988a, 1988b). In our study, the genet density of *F. nitida* population significantly increased (Fig. 1A) and the number of ramets per genet significantly decreased (Fig. 1B) with increasing canopy density from LG to FU. These show that the *F. nitida* population in different canopy conditions exhibit morphological plasticity. Bamboo clumps became smaller, and the distribution area of ramets increased with increasing canopy density, though bamboo ramet density

was not different in the four canopy conditions (Fig. 1C). The results are consistent with the findings reported by Widmer (1998), that the scattered pattern of *Chusquea* spp. was advantageous in making the most use of the limited light resource in different canopies.

In different canopy conditions, variance of light resource availability was a key to morphological plasticity of understory clonal plants (Chen et al., 2004; Ma and Zhong, 1998). Leaf area, position, and direction of stretching influence their photosynthetic efficiency and biological output (Chen et al., 2004). From FEW to FU, with the decrease in light intensity, branching angle, allocation percentage to blades, specific leaf area and leaf area ratio all increased utilization efficiency of the limited light resource in order to adapt to low light conditions (Table 2). The study on the clonal plant *Lysimachia congestiflora* by Chen et al. (2004) showed that low R/FR would promote plant stretching in forest understory, and plant height decreased with the increase in light intensity from forest understory to the forest gap and the open area of forest edge. In the present study, specific culm length significantly increased with the increasing canopy density and the decreasing light intensity, though culm length did not decrease. These revealed that specific culm length increased in low light conditions, which is consistent with result of *L. congestiflora*. Culm height, number of nodes and internode length were lowest in FU (Table 1), which may be related to low light intensity. With the increase in light intensity, culm height, basal diameter, culm internode length, branching intensity of spacer, biomass and number of genets were highest in LG.

Morphology and number of rhizomes (spacers) is related to the scattered pattern of clonal ramets. Spacer plasticity is a significant reflection of foraging for available resources (i.e., light, water content, soil nutrients) in micro-habitat. Previous studies showed that several important factors would affect distribution and growth of dwarf bamboo, including canopy density (Wang and Ma, 1993; Widmer, 1998), temperature, thickness of lichen (Wang and Ma, 1993), topography (especially slope angle) and canopy composition (Noguchi and Yoshida, 2005). Variances in morphology and biomass of spacers may be the plasticity response of *F. nitida* rhizomes to canopy conditions. Spacer length, spacer diameter and branching angle were higher in FEW and in gap (MG and LG) than in FU (Fig. 2A, B), and was related to the high accumulation of biomass in FEW and gap. Specific spacer length and the branching angle between two daughter spacers in FU were significantly highest in FU (Fig. 2C, E). Variances in specific spacer length and branching angle of spacers were helpful in scattering the ramets in FU, suggesting that the ramets display plasticity in light conditions under different canopies.

Dwarf bamboos were widespread and dominant in the shrub layer of the subalpine forest in southwest China (Nakashizuka, 1987; Qin et al., 1993; Taylor and Qin,

1988a, 1988b, 1992; Taylor et al., 2004). Dense dwarf bamboo affected patterns of light resource availability on the forest floor which, in turn, influenced the distribution and dominance of understory plants (Taylor et al., 2004). A large number of studies of dwarf bamboo have been reported in China (Qin et al., 1993; Taylor and Qin, 1988a, 1988b, 1992; Taylor et al., 2004, 2006), Japan (Abe et al., 2002, 2005; Iida, 2004; Nakashizuka, 1987; Noguchi and Yoshida, 2004, 2005; Narukawa and Yamamoto, 2001; Takahashi et al., 2003) and Chile (Holz and Veblen, 2006; Veblen et al., 1979). Tree seedlings and saplings grew slowly in dense bamboo and could regenerate successfully after bamboo flowering due to the abundant resource availability (i.e., light, water and soil nutrients) (Taylor et al., 2004, 2006). Therefore, the flowering cycle of dwarf bamboo could influence the regeneration cycle of tree species in subalpine forest.

In our study, clonal quantitative characteristics, morphology and growth of *F. nitida* showed different performances in four canopy conditions. In open areas, the bamboo grew better and had higher stems and larger basal diameters. Moreover, they showed wide crown and dense culms. On the contrary, height, basal diameter and culm density were lower in dense canopy. The plasticity response of *F. nitida* is probably related to the regeneration of canopy tree species, which may affect the long-term co-existence of the *F. nitida* population and canopy tree species. Therefore, we suggest that the plasticity response of *F. nitida* and its ecological senses should be emphasized in researches on the succession and regeneration of subalpine forests in this region.

Acknowledgements The study was supported by the National Basic Research Program of China (No. 2002CB111505) and The National Natural Science Foundation of China (Grant Nos. 30500388, 30300047). We are sincerely grateful to Yu Xiaohong, Li Yuan and Xi Yi from the Southwest University, for their assistances in the field survey.

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