Aboveground biomass and bamboo shoot nutrients of high altitude bamboos (*Fargesia yunnanensis* Hsueh et Yi) from different sites in Yunnan province, China

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Abstract

Aboveground biomass production and the crude fat, total sugar, protein, ash, and tannin contents of three geographic provenances of Yunnan Jianzhu bamboo (*Fargesia yunnanensis*) were evaluated. Results showed variations in biomass production and nutritive values. Average aboveground culm biomass was highest for the Jizhushan provenance (7.88 kg per culm), presumably because of the higher total N (39.06 mg·100 g^{-1}) and organic matter status (10.20%) of Jizhushan soils compared to other sites. However, the nutritive value of bamboo shoots from Baimahe forest reserve was higher than that of other sites – with the highest protein (32.40%) and total amino acid (18.94%) contents and the lowest tannin (1.71%) content. The Jizushan provenance of *F. yunnanensis* is thus suitable for popularization as a timber yielding type while the Baimahe provenance is appropriate as a vegetable bamboo.

Keywords: Biomass production; Nutrition quality; Provenances.

Introduction

Bamboos are multipurpose plants with high economic and environmental values and have the potential to convert solar radiation into useful goods and services better than most other tree species (Embaye et al., 2005). With global climate change, aspects such as carbon sequestration and biomass production potential of bamboo have been receiving increasing attention (Kumar et al., 2005; Das and Chaturvedi, 2006; Nath and Das, 2008). Recent studies on bamboo stand management are also numerous (Embaye et al., 2005; Nath and Das, 2008). However, there are no reported studies concerning the natural stands of alpine bamboos. *Fargesia yunnanensis* is an alpine bamboo distributed mainly in the Sichuan and Yunnan provinces of China, occurring up to an altitude of 1500 to 2800 m, and grows to ~10 m in height. It has a near-solid culm bottom and can tolerate relatively low temperatures and droughts. It is one of the most easily available resources to supplement the local woods and is also known for its edible shoots. New shoots grow up to their maximum size in 7–8 months and produce branches with small leaves in the following spring (April to June). The growth characteristics, however, are variable among the geographical provenances, which nonetheless has not been elucidated. A study, therefore, was conducted to survey the extent of morphological variability in this species, evaluate aboveground biomass production potential and shoot nutrient (crude fat, total sugar, protein, ash and tannin) contents, and to select the most suitable provenance for popularization as vegetable and timber-purpose bamboos. Our objectives were to raise concerns about the importance of choosing the best provenances for popularization and to highlight the implications for managing natural bamboo forests, so as to realize economic and environmental benefits.

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Materials and Methods

The study was conducted at three sites in Yunnan province, China, where *F. yunnanensis* occur naturally — Baimahe (101°702 E and 26°062 N; 1800 to 2300 m), Xishan (100°202 E and 25°562 N; ~2000 m), and Jizushan (102°732 E and 25°052 N; 1700 to 2840 m) forest reserves. The extent of *F. yunnanensis* forest in Jizushan, Xishan and Baimahe were ~200, 30, and 70 ha respectively and the mean clump diameter ranged from 2 to 3 m. The study sites experience a sub-tropical warm climate. Mean annual temperature, accumulated temperature (≥10°C) and annual precipitation were 15.80°C, 4991.40°C, and 830.70 mm respectively at Baimahe, 12.7°C, 4479.7°C, and 1011.8 mm at Xishan, and 15.8°C, 5918.1°C, and 578.2 mm at Jizushan. The soil of the study locations was clayey with a pH of 6.40 at Baimahe, 6.65 at Xishan, and 6.54 at Jizushan. Soil organic matter content were 5.7, 7.3, and 10.2% at Baimahe, Xishan, and Jizushan respectively and total N, 19.13 mg·100 g^{-1} (Baimahe), 28.58 mg·100g^{-1} (Xishan), and 39.06 mg·100g^{-1} (Jizushan).

Fifty bamboo culms of (1, 2, and ≥3 year-old) at each site were felled to determine the diameter at breast height (DBH), diameter at culm bottom (DBC), and wet weight of culm, branches, and leaves. Regressions linking wet weight of different culm components and culm DBH were developed. Culms were also divided into three parts, based on internode number: up to 3rd for bottom, 8th for middle, and 15th for top. The branches and leaves were also divided into upper, middle, and lower regions. The culms, branches, and leaves of a total of 15 bamboos per age class were taken to the laboratory for moisture determination. Five bamboo new shoots (two weeks old) collected randomly from three sites were cut into slices, oven-dried at 105°C for 3.5 h, and then at 70°C for 12 h and weighed. Dry weights of the samples were estimated from the moisture content. Amino acid contents were determined using automatic amino acid analyzer and total sugar determined using dinitrosalicylic acid colorimetric assay (Chunshui et al., 2000). Crude fat contents were determined using Soxhlet extraction and tannin contents determined by the method of Folin's assay (Chaozong et al., 1984). All chemical analyses were conducted based on standard methods (CSTM, GB/T, 2003).

Results and Discussion

Our survey revealed two types of *F. yunnanensis* in Jizhushan, locally known as Xiangsunzhu and Donpozhu. The morphological traits (e.g., persistent culm sheath, multi-branches, and lack of auricles and oral setae) of these both types were similar except for internode length, culm wall thickness, new shoot sheath color, and taste of new shoots. The local farmers consider Xiangsunzhu shoots much more delicious than Dongpozhu. Xiangsunzhu also has longer mean internodes and thicker bamboo culm wall than Dongpozhu. Shoot sheath of Xiangshunzhu is light yellow and glabrous while Dongpozhu shows purple color in the back with heavy spine hairs (Fig. 1).

As expected, foliar moisture contents were higher than that of culms and branches (58.51 to 63.36% for foliage, 44.36 to 53.53% for culms, and 8.03 to 54.09% for branches). With increasing age, moisture contents of branches and culms diminished, but foliar moisture contents remained more or less stable. Moisture content decreased in the order: upper part<middle part<lower part. Of the total stand biomass 15.11 to 17.89% was contributed by leaves, followed by branches (19.28 to 21.87%) and culms (60.31 to 65.34%).

As can be seen from Table 1, mean aboveground biomass of individual bamboo in Jizushan (7.88 kg) was significantly higher than that in Xishan (4.23 kg) and Baimahe (3.60 kg). The mean DBH and DBC of bamboos at Jizushan (5.09 and 5.76 cm) were also much higher than that of bamboos from Baimahe (2.99 and 3.34 cm) and Xishan (3.47 and 4.34 cm). The vegetation resources in Jizushan site is better protected than the other two sites and the bamboo forests there also associated with many other species of trees such as *Cinnamomum glanduliferum*, *Cyclobalanopsis glaucoides* and *Castanopsis delavayi* (author's observations). Furthermore, the soil of Jizushan site is more fertile with higher N (39.06 mg·100 g^{-1}) and organic matter status (10.20%), which explains the

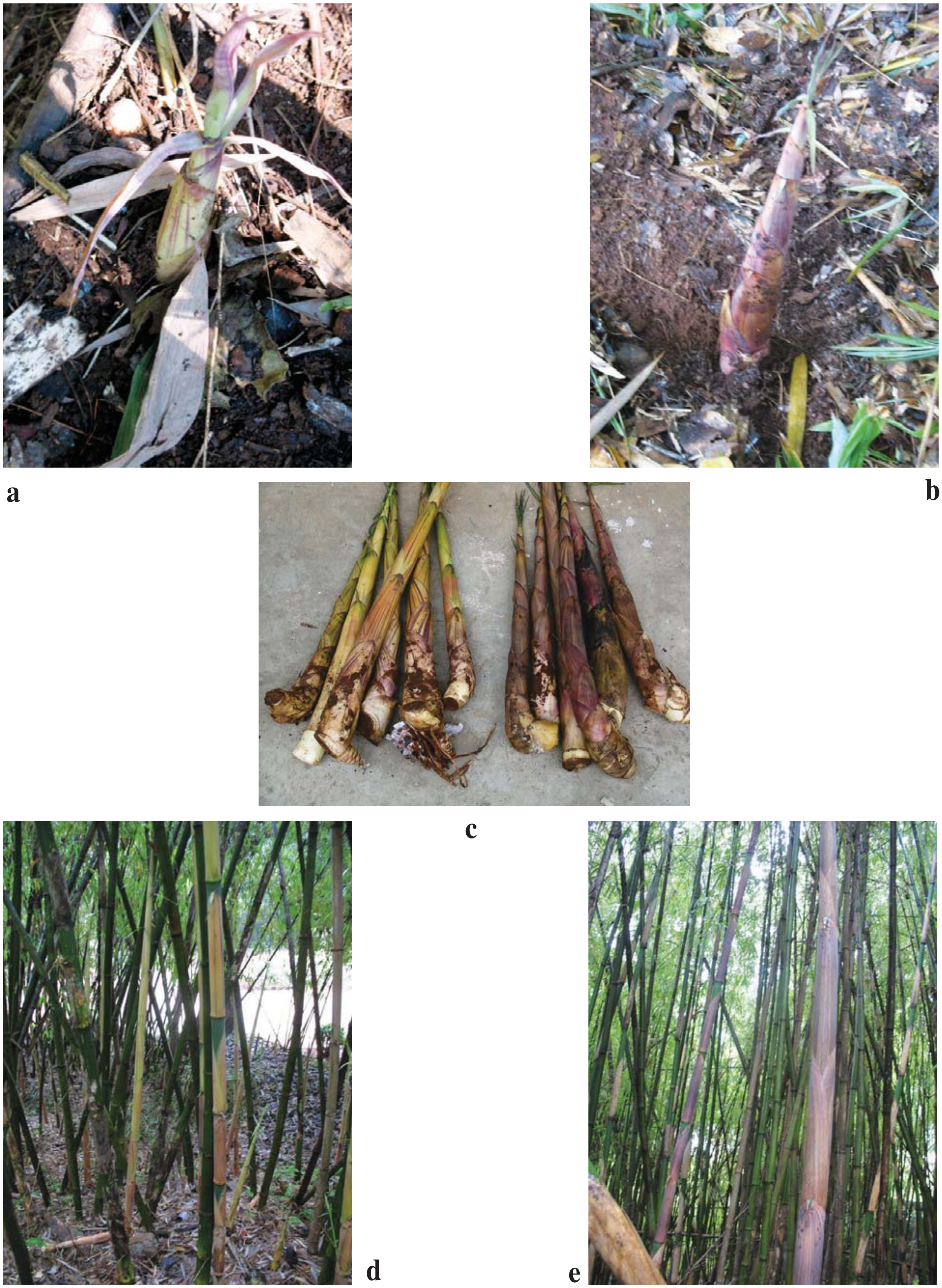

Figure 1. New bamboo shoots of Xiangsunzhu (a) Dongpozhu (b) growing in Jizhushan. Harvested bamboo shoots (c) of Xiangsunzhu (right) and Dongpozhu (left). New bamboos of Xiangsunzhu, in which the culm sheath color is light yellow (d), and Dongpozhu, in which culm sheath color is purple (e).

Table 1. Growth and mean aboveground biomass production of bamboo culms from three different sites in Yunnan province, China.

Culm age (yr)	Baimahe			Xishan			Jizushan		
	DBH (cm)	DBC (cm)	Biomass (kg·culm^{-1})	DBH (cm)	DBC (cm)	Biomass (kg·culm^{-1})	DBH (cm)	DBC (cm)	Biomass (kg·culm^{-1})
1	3.11^{b}	3.45^{b}	3.85^{b}	3.57^{b}	4.56^{c}	4.43^{b}	5.29^{b}	6.02^{c}	8.38^{b}
2	3.01^{ab}	3.36^{ab}	3.56^{ab}	3.39^{a}	4.31^{b}	4.08^{a}	5.19^{ab}	5.73^{b}	8.12^{b}
≥3	2.86^{a}	3.22^{a}	3.38^{a}	3.45^{ab}	4.15^{a}	4.19^{a}	4.80^{a}	5.54^{a}	7.15^{a}
Mean	2.99^{a}	3.34^{a}	3.60^{a}	3.47^{b}	4.34^{b}	4.23^{b}	5.09^{c}	5.76^{c}	7.88^{c}

DBH and DBC are diameter at breast height and diameter of bottom culms respectively. Means with similar letters for comparison between different ages are not significantly different at p= 0.05.

higher growth and biomass production at Jizushan. Prediction models for culm length, culm weight, branch weight and leaf weight as a function of DBH gave high R^2 values (93 to 99%; $p < 0.01$; Table 2).

The taste of bamboo shoots depend on total sugar, aspartic acid (ASP), glutamic acid (Glu), glycin (Gly) and tannin contents. While the amino acids increase the deliciousness of bamboo shoots, tannins increase the offensive taste (Xia-Bo, 2006). Total sugar, Glu, and Gly contents were higher in Xiangsunzhu than that of Dongpozhu, while tannin contents were relatively higher in Dongpozhu implying better taste for Xiangsunzhu bamboo shoots. This is consistent with the views of the local people. Bamboo shoots from Baimahe had higher protein (32.40%), crude fat (3.56%), ASP (7.10%), Glu (1.95%), and Gly (0.70%) contents than other three specimens and lower tannin (1.71%) and crude fiber (11.73%) contents although the total sugar contents (7.77%) of bamboo shoots from Baimahe were lower than Xiangsunzhu shoots (Tables 3 and 4).

Table 2. Mathematical models for height and biomass estimation of *Fargesia yunnanensis* in Yunnan province, China.

Component	Prediction models	R^2	Sig F
Culm height (CH)	$CH=4.083D^{0.550}$	0.944	0.001
Culm weight (CW)	$CW=0.318D^{1.753}$	0.992	0.000
Branch weight (BW)	$BW=0.135D^{1.412}$	0.964	0.001
Leaf weight (LW)	$LW=0.140D^{1.216}$	0.932	0.001

D is the mean diameter at breast height of bamboo culms.

Table 3. Nutritional quality attributes in bamboo shoots of *Fargesia yunnanensis* from different sites in Yunnan province, China.

Nutrition components	Quality attributes (%)			
	Jizhushan			
	Baimahe	Xishan	Xiangsunzhu	Dongpozhu
Moisture	93.43^{a}	92.92^{a}	93.08^{a}	94.21^{a}
Crude fiber	11.94^{a}	11.80^{a}	11.73^{a}	16.00^{a}
Total sugar	13.80^{b}	10.64^{b}	7.77^{ab}	4.79^{a}
Crude fat	3.16^{a}	2.78^{a}	3.56^{a}	3.09^{a}
Protein	21.19^{a}	28.80^{ab}	32.40^{b}	23.60^{a}
Ash	15.20^{a}	11.20^{a}	13.70^{a}	10.40^{a}
Tannin	2.60^{ab}	2.80^{ab}	1.71^{a}	3.03^{b}

Means with similar letters for comparison between different sites are not significantly different at p= 0.05.

Table 4. Amino acid concentrations in bamboo shoots of *Fargesia yunnanensis* from three different sites in Yunnan province, China.

Amino acids	Content (%)			
	Jizhushan			
	Xiangsunzhu	Dongpozhu	Baimahe	Xishan
Aspartic acid	4.35[a]	6.68[b]	7.10[b]	4.52[a]
Threonine	0.88[b]	0.61[a]	0.94[b]	0.72[ab]
Serine	0.93[b]	0.68[a]	0.99[b]	0.71[a]
Glutamic acid	1.83[b]	1.40[a]	1.95[b]	1.29[a]
Glycin	0.66[b]	0.48[a]	0.70[b]	0.50[a]
Alanine	0.91[b]	0.72[ab]	0.96[b]	0.66[a]
Cystine	-	0.03	-	-
Valine	0.95[c]	0.74[b]	1.01[c]	0.65[a]
Methionine	0.21[b]	0.06[a]	0.23[b]	0.12[ab]
Isoleucine	0.57[a]	0.40[a]	0.61[a]	0.40[a]
Leucine	0.98[b]	0.67[a]	1.05[b]	0.69[a]
Tyrosine	0.73[b]	0.44[a]	0.78[b]	0.67[b]
Phenylalanine	0.56[a]	0.45[a]	0.59[a]	0.44[a]
Lysine	0.71[bc]	0.55[a]	0.75[c]	00.67[b]

Means with similar letters for comparison between different sites are not significantly different at p= 0.05.

In the present study, the Jizushan provenance of *F. yunnanensis* was found to be the best for timber purposes due to its rapid growth and biomass production. For vegetable purposes, however, the Baimahe provenance was the best in view of its high nutritional quality. Although the influences of soil nutrients and genetic factors on growth and biomass production were not evaluated in this study, the fact that the soil of Jizushan was more fertile than other two sites (high organic matter and total N contents) cannot be overlooked. This calls for more detailed investigations on the impact of soil fertility variations on the growth and nutritional quality of bamboos.

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