SURVIVAL AND CULM YIELD OF SIX BAMBOO SPECIES IN A 5-YEAR EXPERIMENTAL STAND IN SOUTHERN BRAZIL

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Abstract

Brazil has a great potential for growing bamboo, both for industrialand environmental purposes. Nevertheless, there are few scientific studies on the potential of different native and exotic species, particularly with planned experimental designs. This study aimed to test six bamboos species in field conditions in southern Brazil, three native and three exotic ones. This paper deals with the evaluation of survival and culm yield until the end of the fifthexperimental year. Arandomized block design, with six treatments (species) and four replications,was adopted. Each repetition was composed of 12 plants spaced 4 m x 4 m one another. The treatments tested were: native: T1 – *Guadua chacoensis*; T2 – *Guadua angustifolia*; T3 - *Merostachysskvortzovii*; exotic: T4 - *Dendrocalamus asper*; T5 - *Bambusa vulgaris* and T6 - *Bambusaoldhamii*. Survival, culm density and apparent basal area were evaluated year by year, from 2009 to 2014, always in April of the corresponding year. The medium survival by treatment at the end of the evaluation period varied significantly among species, as follows: 100% (T5), 95.8% (T2), 97.5% (T6), 87.5 (T3), 75% (T4) and 66.7% (T1). The average densities per treatment were the following: 2,604 (T3); 1,731 (T6); 1,021 (T5), 352 (T1), 264 (T4) and 114 (T2) culms per hectare. The apparent medium basal area per treatment calculated at breast height were: 27.56 (T6), 12.86 (T5), 3.27 (T4), 3.15 (T1) and 0.07 (T2) $m^2.ha^{-1}$. It was concluded that *Bambusa oldhamii* was the species of greatest growth performance in the experiment, taking into account the combination of survival, density and basal area.

Key words: basal area, density, experiment, growth, statistical analysis.

Introduction

Brazil is the country with the second largest area of forests in the world, behind only Russia (FAO 2010). It has also the greatest diversity of bamboo species in the New World (Judziewicz et al. 1999). Altogether there are 34 genera and 232 species occurring in Brazil, some of which have not yet been formally described, being 174 species (75%) endemic (Filgueiras&Santos-Gonçalves2004).

However, scarce information on the occurrence of bamboo forests in Brazilis available. It is known that there are about 9 million hectares in southwestern Amazonia dominated by native bamboos. Data on commercial plantations are mismatched, but the recognized sources state that there is a private bamboo area planted with 30,000 ha of *Bambusa vulgaris*, which provides raw material for a paper mill in the north of the country (FAO 2010).

Nowadays there is growing interest in bamboo cultivation in Brazil, which has led the government to sanction recently a law that establishes the National Policy of Incentive to Bamboo Sustainable Management and Cultivation (Brasil 2011).
There are many species with potential use for commercial and industrial purposes and many others that can be grown for environmental ends. Londoño (1998) refers to genera Actinocladum, Apoclada, Chusquea, Guadua and Merostachys as those of greatest possibility to cultivation and utilization. The author also mentions that several exotic bamboo species were introduced into Brazil during the period of colonization by the Portuguese and Bambusa and Dendrocalamus are the most remarkable genera.

Although many initiatives and experiences on the cultivation and utilization of bamboo exist in the country, unfortunately they are isolated and discontinuous. They are mostly based on empiricism of a few experienced people and scientific rigor is not the rule. In the First National Seminar on Research and Development of the Brazilian Bamboo Network - RBB, held in Brasilia in 2011, it becameevident the lack of knowledge on bamboo cultivation in the country. Only two technical articles of the 22 presented at the eventdealt with bamboo cultivation. Unfortunately most studies on bamboo growth do not fulfill the statistical requirements.

The objective of this study was to analyze survival and culm yield in terms of density and apparent basal area of six species of bamboo (three native and three exotic), in afield experiment, during the first five years of monitoring.

Material and Methods

Study Site

This study was carried out at the Canguiri Experimental Farm of the Federal University of Parana, Pinhais County, Parana State (PR), in Southern Brazil. The central geographic coordinates of the site are: 25°23'30"S and 49°07'30" W and 688200/7190200 according to the UTM projection system (SAD-datum 69, area 22S) (Figure 1).

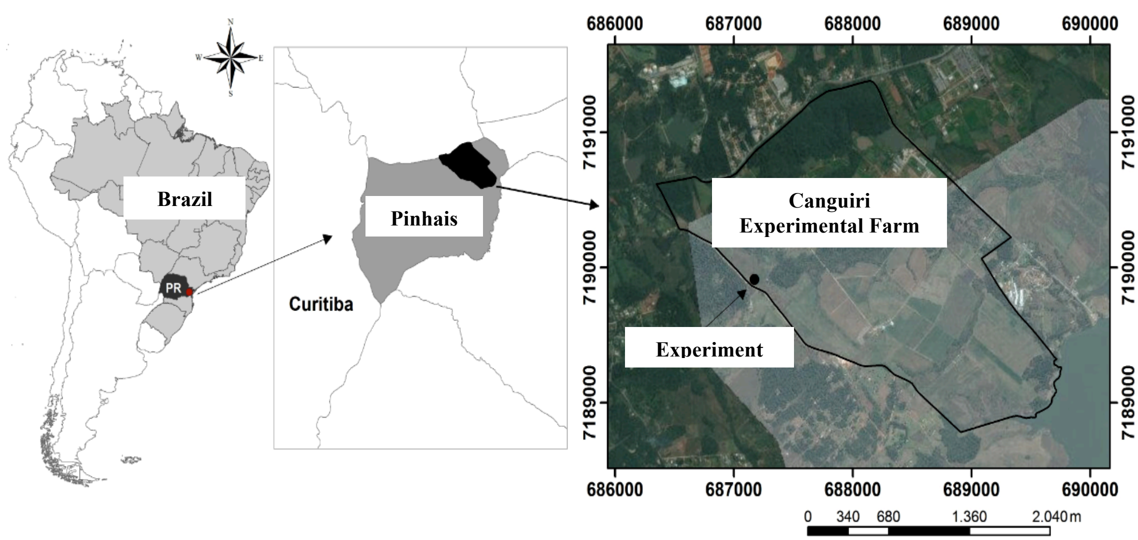


Figure 1. Location of the study site

Climate type is subtropical Cfb according to Köppen´s classification. Mean monthly temperature ranges from 12.5 to 22.5°C, subject to severe frost every year during the winter (IAPAR, 1994). Altitude ranges from 889 to 950 m above the sea level and slope from 3 to 20%. Historical annual precipitation is of 1,452 mm (Maack 1981). There are varied soil classes on the study as described by Sugamosto (2002).

Experiment Description

The experiment was established in December 2008 in a randomly block design with 6 treatments and 4 replications. Three native and three exotic species constituted the treatments, as described below:

Native:

T1 – *Guadua chacoensis* Londoño& Peterson;
T2 – *Guadua angustifolia* Kunth;
T3 – *Merostachys skvortzovii* Sendulski;

Exotic:
T4 - *Dendrocalamus asper* (Schult. &Schult. F.) Backer ex k. Heyne;
T5 - *Bambusa vulgaris*Schrad. ex J.C. Wendl., and;
T6 - *Bambusaoldhamii*Munro.

Before seedlings planting the site was fertilized using a mixture of dolomitic limestone (300 g per pit, 86.4 kg for the whole experiment), simple superphosphate (150 g per pit, 43.2 kg for the whole experiment), potassium chloride (150 g per pit, 43.2 kg for the whole experiment) and tanned cattle manure (20 L per pit, 5,760 L for the whole experiment), as recommended by Pereira &Beraldo (2007).

The experimental unit has a square area of 400 m^2 (20 m x 20 m) with an edge of 10 m surrounding it. The number of seedlings was 12 plants per plot, totaling 48 seedlings per treatment and 288 useful seedlings in the experiment. The spacing between the seedlings was 5 m x 5 m, thus defining the plot area of 300 m^2.

Measurement and Experimental Analysis

The measurements were carried out in every April since 2009. Survival and various biometrical variables were recorded, including culm density and diameter at breast height (dbh). Apparent basal area was calculated from dbh obtained from the external girth including the hollow part (Figure 2).

(a) (b)

Figure 2. Measurement of the crown (a) and diameter (b) size

In this study, survival, culm density and apparent basal area were analyzed at the last measurement (2013) by means of Analysis of Variance and the Scott-Knott test, using ASSISTAT© software.

Results and Discussion

Survival

The species analyzed in this study showed different behaviors in terms of survival (Figure 3a). The survival rates of the treatments T2 (*G.angustifolia*), T3 (*M.skvortzovii*), T5 (*B. vulgaris*) and T6 (*B. oldhamii*) were higher, with values of 95.85%, 87.5%, 100% and 97.9%, respectively, which were not statistically different from each other. T1 (*G. chacoensis*) and T4 (*D. asper*) showed statistically lower survival compared to the first group of species, with values of 66.7% and 75%, respectively, which showed no significant difference between them.

The main cause of the higher mortality in T1 (*G. chacoensis*) was assigned to the phenological cycle of the species, since at the time of establishment of the experiment the species was in the process of blossoming and subsequent death. This happens under natural conditions and is common for most bamboos. They are perennial plants that die simultaneously after blossoming, but the gregarious cycle is variable from species to species, ranging from years to decades. Due to the long intermast period for the mass flowering of the majority of bamboo species (Janzen 1976), very few reports have investigated their sexual reproduction. Among the Brazilian species, only the woody bamboos *Actinocladum verticillatum* (Nees) McClure (Filgueiras&Pereira 1988) and *Merostachys riedeliana* Döll (Guilherme&Ressel 2001) have been studied with respect to reproductive biology (Grombone-Guaratiniet al. 2011).

On the other hand, the major cause of mortality in T4 (*D. asper*) was the low temperatures observed in the winters, which reached negative values in June 2009 and 2011 and in July and August 2013, when unusually happen to snow in the study site after four decades. Low temperatures severely affected T4 (*D.asper*), but some affected clumpsre-sprouted and survived. On the contrary, T1 (*G. chacoensis*) was not affected by low temperatures, which indicates its resilience to the colder climate. Young & Haun(1922) reported that *D. asper* is a fairly-cold resistant bamboo, but it was not proved by this study.

Culm Density

T3 (*M. skvortzovii*) was the species that reached the highest culm density during the 5-year evaluation of the experiment, with 2,604 units per hectare, on average, that means 6.5 times the initial density (Figure 3b). This shows the great capacity of this species to sprout.

Moreira et al. (2013) analyzed the regrowth potential of *M. multiramea*, species close to *M. skvortzovii* and often confused with it, and concluded that areas of edge and greater insolation tremendously favor the production of culms in comparison to conditions under forest cover. Santos et al. (2012) stated that the vegetative reproduction by rhizomes, very common in these species, in addition to rapid growth and high stem density per area, make this bamboo species highly competitive.
T6 (*B. oldhamii*) also showed high culm density, with 1,731 units per hectare. No statistical difference was noticed to T2 (*G.angustifolia*). The other species had lower densities, with 114, 264, 352 and 1,021 culms per hectare, respectively for T2 (*G.angustifolia*), T4 (*D.asper*), T1 (*G. chacoensis*) and T5 (*B. vulgaris*), which did not differ significantly from each other. It should be noted that T1 (*G. chacoensis*) density was affected by high initial mortality rate, the same occurring with T4 (*D.asper*), despite the different causes, as explained previously. On the other hand, T2 (*G.angustifolia*) showed low mortality, but also low capacity to sprout and increase its culm densities during the five initial years of the experiment.

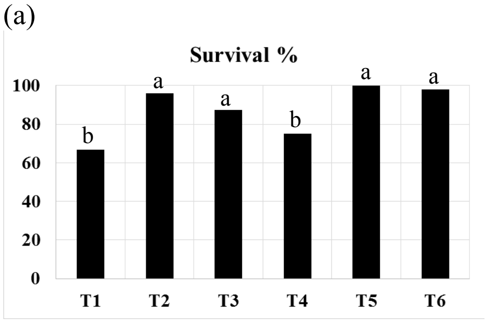
It is noteworthy that T5 (*B. vulgaris*) was affected by low temperatures during winter, which was reflected by the large number of dead (dry) culms. However, clump´s base re-grew repeatedly after the early spring, maintaining the mortality ratelow. Nevertheless, this process greatly affected its growth and the diameter size of the new culms.

Apparent Basal Area

Despite the high density of culms produced by T3 (*M.skvortzovii*), its apparent basal area was only 3.15 m^2.ha^{-1}. This happen sdue to the small diameter of the culms of this species. The basal area of T1 (*G.chacoensis*), T2 (*G. angustifolia*), T4 (*D. asper*) and T5 (*B. vulgaris*) were not statistically different from each other as well as from T3 (*M.skvortzovii*), with values of 2.99; 0.07; 3.27 and 12.86 m^2.ha^{-1} on average, respectively (Figure 3c).

T6 (*B. oldhamii*) showed the highest apparent basal area in the experiment, with 27.56 m^2.ha^{-1}. This resulted from a combination of low mortality rate, high culm density and larger size of the sprouts in comparison to those of the other species.

(a)



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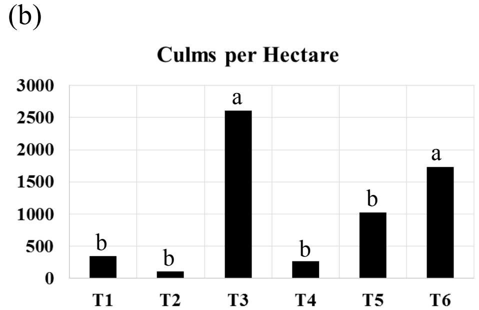

(c)

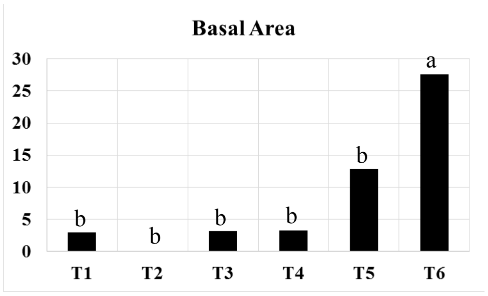

Figure 3. Survival (a), culm density (b) and apparent basal area (c). Letters denote statistical differences by Tukey´s test

There is no published research on survival and growth of*Bambusaoldhamii* in Brazil. Most of the commercial-scale area planted with bamboo in the country is occupied by *B. vulgaris*, which is found in the North and Northeast and that is used for pulp and paper industry (CechinelFilho&Yunes 1998; Resende et al. 2011). This study revealed that *B. oldhamii*showed better performance in termsof survival and growth in the first 5 years of planting as compared to other species of bamboo tested in southern Brazil. Therefore, it can be recommended to be more deeply studied in demonstrative experiments and perhaps used in large scale industrial plantations. Research on the physical and mechanical properties of the wood of this species is also needed.

Conclusions

Bambusa oldhamii (T6) was the species of greatest growth performance in the experiment among the six analyzed, taking into account the combination of survival, density and basal area.

This species proved to be resilient to the colder climate of southern Brazil, where frostis frequent and snow can fall, showed good capacity to sprout and produce large-sized culms suitable for commercial and industrial uses.

On the other hand, *Merostachys skvortzovii* (T3) proved to be an interesting native species for used in revegetation of degraded lands, due to its adaptation and capability to form dense clumps of culms.

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Figure 1 – Study site
Figure 2 – Measurements of the experiment: (a) crown measurement; (b) culm measurement
Figure 3 – Survival (a), culm density (b) and apparent basal area (c) of the six species evaluated