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Growth pattern and photosynthetic activity of different bamboo species growing in the Botanical Garden of Rome

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Abstract

Growth pattern and photosynthetic activity of different bamboo species (*Phyllostachys viridi-glaucescens* Rivière et C. Rivière, *Phyllostachys pubescens* Mazel ex Lehaie, *Phyllostachys bambusoides* Siebold et Zucc., and *Bambusa ventricosa* McClure) growing at the Botanical Garden of Rome were studied. Among the considered species, *P. pubescens* had the highest mean culm height (14.3 ± 0.6 m) and diameter (10.7 ± 1.5 cm), while *B. ventricosa* had the lowest mean culm height (6.0 ± 0.2 m) and internodes number (35 ± 1). The highest net photosynthetic rates (NP) of the considered species were measured in early autumn, while the lowest ones in spring (30% of the maximum in the genus *Phyllostachys*), in the period of vegetative activity, and in winter (10% of the maximum in *B. ventricosa*). The correlation between NP and leaf temperature (LT) indicated that the favourable temperature enabling 50–100% of NP was in the range 2.2–32.1 and 16.2–36.3 °C for the genus *Phyllostachys* and *B. ventricosa*, respectively. According to their origin, the species of the genus *Phyllostachys*, originating in a temperate climate had a higher sensibility to high air temperatures than *B. ventricosa*, originating in a tropical and subtropical climate, and having a lower sensibility to low air temperatures. Owing to the great potential for biomass production bamboos could be a significant net sink for CO_2 carbon sequestration; nevertheless, by the highest whole culm photosynthetic rate (WNP = $272 \pm 7.2\,\mu mol\,CO_2\,s^{-1}$), calculated by the total leaf surface area per culm ($28.6 \pm 1.1\,m^2$) and the mean maximum yearly assimilation rate ($9.5 \pm 4.5\,\mu mol\,m^{-2}\,s^{-1}$), *P. pubescens* contributed in major role to carbon sequestration ($14 \pm 0.6\,kg\,CO_2\,year^{-1}$ per culm) compared with the other considered species (on the average $3.0 \pm 1.6\,kg\,CO_2\,year^{-1}$, mean value).

Keywords: *Bambusa*; *Phyllostachys*; Growth pattern; Gas exchange; Carbon sequestration; Air temperature

Introduction

Bamboos (more than 70 genera and about 1000 species) occur naturally in tropical, subtropical and temperate regions of all the continents in the world (except Europe), from sea level to 4000 m (Cortés Rodriguez, 2000; Fu, 2000; Isagi et al., 1997, 2004; Kleinhenz et al., 2003; Scurlock et al., 2000). Among the countries of the Asia-Pacific region, China has the highest bamboo diversity (626 species), followed by India (102) and Japan (84) (Bystriakova et al., 2003). The bamboo area in China is more than 4 million ha and occupies 1/4 of the world total, 2.3 million of which are

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covered by *Phyllostachys pubescens* Mazel ex Lehaie (Kleinhenz et al., 2003; Yuming and Jiru, 1998). The climate of the native range of the bamboo taxa is a typical monsoon climate (Maoyi, 1998). Although some bamboos can adapt to varying environments, most require relatively warm and humid conditions (e.g., mean annual temperature of at least 15–20 °C and annual precipitation of at least 1000–1500 mm) (Scurlock et al., 2000).

Normally, in natural forests, bamboo grows as understorey under other timber species; a mixture of two species or more is rare (Maoyi and Banik, 1995; Saitoh et al., 2002). The range of bamboo uses for humans is remarkable (Bystriakova et al., 2003; Franklin, 2005; Kleinhenz and Midmore, 2001; Rao and Rao, 1995; Sundriyal et al., 2002), in addition, its ecological functions, such as soil and water conservation, and erosion control (Kleinhenz and Midmore, 2001; Nandy et al., 2004), are considerable.

Morphologically, all bamboo species can be categorised as either monopodial or sympodial ones (Maoyi and Banik, 1995; Valade and Dahlan, 1991), and differences in rhizome system can be regarded as adaptations to the climatic conditions to which bamboos are native to; monopodial bamboos are native to; temperate climates with cool wet winters, while sympodial bamboos to tropical climates with a pronounced dry season (Kleinhenz and Midmore, 2001). The tight-clumping habit of tropical species provides less rhizome surface to dehydration during extended dry seasons (Farrelly, 1984). The genus *Phyllostachys*, a temperate monopodial one, originates mainly to Central China and Japan (Abd. Razak and bin Mohamad, 1995; Maoyi and Banik, 1995). Among the genus, *Phyllostachys viridi-glaucescens* Rivière et C. Rivière is indigenous in East China (Huxley, 1992); *Phyllostachys pubescens* Mazel ex Lehaie is native to China, where it occurs extensively (Li et al., 1998a; Scurlock et al., 2000); *Phyllostachys bambusoides* Siebold et Zucc. is native to China, but it is more cold tolerant than *P. pubescens* (Chao, 1989; Scurlock et al., 2000). The genus *Bambusa* (sympodial one) develops in tropical and subtropical Asia (Sun et al., 2006), and *Bambusa ventricosa* McClure is native to South China (Huxley, 1992).

The present study was undertaken to analyse the growth pattern of different bamboo species, cultivated in the same environmental conditions. Despite the ecological importance of bamboos, there are few studies on gas-exchange response to air temperature and on its effect on growth and culms productivity. To this end, the objective of this research was to evaluate the most favourable temperature range for growth activity of the cultivated bamboo species. Identification of relationships between growth activity and the physiological response, including the integrative effects on carbon gain and water relations, will provide insight towards understanding the plant response to variations in resource supply and demand (Knapp, 1992), also in consideration of global change. Moreover, due to its great potential for biomass production (Li et al., 2000; Pearson et al., 1994), bamboo might be a net sink for CO_2 carbon sequestration (Jones et al., 1992) in particular in the native areas.

Material and methods

Study site and climate

Outdoor experiments were carried out on *P. viridi-glaucescens* Rivière et C. Rivière, *P. pubescens* Mazel ex Lehaie, *P. bambusoides* Siebold et Zucc., and *B. ventricosa* McClure, growing in the Botanical Garden of Rome (41°53′53″N, 12°28′46″E, 53 m a.s.l., Italy), in the period January–December 2005. The area climate is of Mediterranean type, and most of the total annual rainfall (695 mm) occurs in autumn and winter. The mean minimum air temperature of the coldest month (February) is 5.6 °C and the mean maximum air temperature of the hottest months (July–August) 31 °C. Dry period lasts from May to August (mean maximum air temperature 29 °C; total rainfall of the period = 127 mm) (data by the Meteorological Station of the Collegio Romano for the period 1995–2005).

Phenology and growth dynamics

Phenological observations (new culms growth, shed of sheath, leafing, maximum leaf fall) were carried out weekly, during the study period. Ten new culms (per species) were selected randomly and identified with numbered labels. Culms height was measured until maximum one was attained. Each culm at maximum height was harvested and the diameter at breast height and the internodes number were measured; culms were oven dried at 105 °C to constant mass.

Total leaf area per culm was calculated by counting the total number of leaves per culm, and multiplying it by mean leaf area. Leaf area was measured by an Image Analysis System (Delta-T Devices, UK). The growth rate in terms of culm height (GR_l, cm day^{-1}) was calculated as $GR_l = l_2 – l_1/\Delta t$, where l_1 and l_2 were culm height at time t_1 (beginning of culm growth) and t_2 (maximum height), respectively, according to Nath et al. (2004). The culm height growth efficiency (LE, m^3 g^{-1}) was calculated as $LE = \Delta l \times TLA/\Delta M$, where Δl was the culm height growth during the growing season, TLA was the total leaf area per culm, and ΔM was the total dry mass per culm (King, 1994, 1997).