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ORIGINAL ARTICLE

# Effect of Arbuscular Mycorrhizal Inoculations on Seedling Growth and Biomass Productivity of Two Bamboo Species

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**Abstract** A study was conducted to identify suitable arbuscular mycorrhizal (AM) fungi for inoculation of *Bambusa bambos* and *Dendrocalamus strictus* at nursery stage for increasing growth and productivity. Twelve AM species, isolated from bamboo and other common trees of Bundelkhand were used for inoculations. In *B. bambos*, total dry weight and phosphorus (P) uptake were significantly increased by all studied fungi and shoot length was increased by eight AM inoculants. Maximum mycorrhizal dependency (MD) was recorded for *Acaulospora scrobiculata* (44.2%), followed by *Glomus cerebriforme* (41.6%) and *G. intraradix* (41.0%). In *D. strictus,* all tested AM inoculants significantly increased shoot length, dry shoot weight and P uptake, except *Glomus* 1. Dry root weight was significantly increased by only two inoculants namely, *G. cerebriforme* and *G. etunicatum*. Total dry weight was significantly increased by eight AM fungi. Maximum MD was recorded for *G. cerebriforme* (62.9%), followed by *G. diaphanum* (55.0%) and *G. etunicatum* (51.3%). Thus, the results showed that utilization of effective AM fungi can enhance the productivity of bamboo in the region.

**Keywords** Arbuscular mycorrhizal fungi · *Bambusa bambos* · Biomass productivity · *Dendrocalamus strictus* · Seedling growth

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## Introduction

In India, bamboo encompasses about 8.96 million hectares of forest area and its present usage is to the tune of Rs. 2,043 crores. Over the next 2 years the projected rate of growth could be as high as 20% per year. Bamboo, being an important forest produce, plays a vital role in the rural economy of our country. In order to meet the future demand of bamboo, its growth and productivity has to be hastened from the nursery stage onwards. Inoculations of different bamboo species with bio-fertilizers including arbuscular mycorrhizal (AM) fungi have been shown to significantly increase the plant growth and yield under variable conditions. In Tamilnadu, Ravikumar et al. [1] have reported significant increase in the growth and biomass production of *Dendrocalamus strictus* Nees. After inoculation with *Glomus aggregatum* Schenck & Smith emend. Koske, *G. fasciculatum* Becker & Gerdemann and *G. mosseae* Gerdemann & Trappe. Similarly, Muthukumar and Udaiyan [2] have reported that combined microbial inoculations (*Glomus aggregatum*, *Bacillus polymixa* and *Azospirillum brasilense*) in two soil types (alfisol and vertisol) with or without fertilizer application significantly increased growth of *D. strictus*. From Central India, Dash et al. [3] have reported higher growth and biomass production of *D. strictus*, *Bambusa bambos* (L.) Voss. and *B. vulgaris* Wendl. ex Nees, after inoculation with an unidentified AM species. Gautam and Maitra [4] have reported increase in height and culm production in *D. strictus* after inoculation with *G. macrocarpum* Tul. et Tul. Jamaluddin et al. [5] have reported significant increase in growth and biomass of *B. nutans* G. C. Wall. ex Munro after inoculation with AM inoculum obtained from rhizosphere of field grown plants of *B. nutans*, which contained *G. mosseae*, *G. intraradix* Schenck & Smith and an unidentified species of *Gigaspora*.

Above-mentioned information is mostly based on commercial formulations involving unknown AM endophytes or limited number of AM species. The present study was carried out to find out the effect of common AM fungi isolated from rhizosphere of bamboo and other important agroforestry tree species of Bundelkhand region on seedling growth and biomass production of two bamboo species viz., *B. bambos* and *D. strictus*. Both bamboo species have been found suitable for cultivation in semi-arid conditions of Bundelkhand region [6].

## Materials and Methods

The study was conducted at National Research Centre for Agroforestry (NRCAF), Jhansi (25°27′ N latitude, 78°35′ E longitude and at 271 m above msl) during 2008–2009. On agro-ecological zone map of India, Jhansi lies in the hot semi-arid region. The area receives annual rainfall between 700 and 1150 mm mostly during South West monsoon period (Mid June–September) with an average of 52 rainy days per year. Mean maximum temperature ranges from 47.4°C (June) to 23.5°C (January) and mean minimum temperature from 27.2°C (June) to 4.1°C (December). Diurnal variation in temperature is quite high. May and June are the hottest months. The maximum recorded temperature on a particular day often touches 47–48°C during summer.

Native AM fungi were isolated from the soil samples collected from rhizosphere of *D. strictus* from five sites of Baruasagar, district Jhansi by following procedure. Each sample was mixed in 1:1 ratio (v/v) with autoclaved coarse sand, separately and transferred to 15 cm plastic pots, which were seeded with maize and black-gram. The trap plants were grown in greenhouse for 4 months. For purification of AM fungi, spore/sporocarps were extracted by wet sieving and decantation method [7] from the pot culture material and were used to inoculate pre-geminated seedlings of sorghum, which were immediately transplanted, watered gently and placed in a room with indirect lighting for 24 h and then moved to greenhouse. Purified AM species were characterized by using standard methods [8] and multiplied on maize.

Separate net house experiments were laid out for *B. bambos* and *D. strictus* on the response of their seedlings to AM inoculations. Treatments consisted of five AM species isolated from rhizosphere of *D. strictus* (*Acaulospora scrobiculata* Trappe, *Glomus aggregatum* Schenck & Smith emend. Koske, *G. arborense* McGee, *G. diaphanum* Morton and Walker and *G. intraradix* Schenck and Smith), seven other purified cultures available in lab (*A. mellea* Spain & Schenck, *G. cerebriforme* McGee, *G. etunicatum*

**Table 1** Characteristics of arbuscular mycorrhizal (AM) species isolated from rhizosphere of *Dendrocalamus strictus*

| AM species | Characteristics of AM species | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A[a] | B | C | D | E | F | G | H | I | J | K | L | M |
| *A. scrobiculata* | Yellow to brown | (108–) 115 (–130) | (4.8–) 6.0 (–7.2) | 2 | NA | NA | A(Uo)B(UM) | + | – | – | – | – | Pitted |
| *Glomus aggregatum* | Hyaline to yellow | (38–) 65 (–84) | (2.4–) 2.8 (–4.8) | 2 | (7.2–) 8.7 (–12.0) | (1.5–) 4 (–9.0) | A(L) or A(L)B(L) | + | + | + | + | Hyaline to yellow | – |
| *G. arborense* | Hyaline to yellow | (19–) 40 (–67) | (2.4–) 3.6 (–4.8) | 1 | (4.8–) 5.8 (–7.2) | (3.6–) 4.8 (–6.0) | A(L) or A(L)B(L) | – | + | + | + | Hyaline | – |
| *G. diaphanum* | Hyaline | (24–) 51 (–62) | (4.8–) 6.2 (–7.2) | 1 | (4.8–) 7.2 (–9.6) | (3.6–) 4.3 (–4.8) | A(LM) | + | + | – | – | – | – |
| *G. intraradix* | Turmeric | (50–) 77 (–100) | (2.4–) 6.7 (–9.6) | 2 | (7.2–) 11.3 (–14.4) | (3.6–) 4.6 (–6.0) | A(L) or A(E)B(L) | + | + | – | + | Brown | – |
| *G. invermayanum* | Brown | (41–) 46 (–55) | (4.8–) 6.6 (–7.2) | 2 | (7.2–) 9.6 (–13.9) | (4.8–) 6.0 (–7.2) | A (UL) | – | – | – | + | Brown | – |

*NA* Not applicable

(+) Present, (−) Absent

[a] *A* Spore color, *B* Spore size (μ), *C* Composite spore wall width (μ), *D* Number of wall groups, *E* Hyphal attachment width (μ), *F* Pore size (μ), *G* Muronym, *H* Wall reaction to Melzer's reagent

*I* Spore formation with in root, *J* Presence of spores with extrametrical mycelium, *K* Sporocarp, *L* Sporocarp color, *M* Surface ornamentation of spore

Becker & Gerdemann, *G. fasciculatum* Thaxter, *G. hoi* Berch & Trappe, *G. occultum* Walker and an unidentified *Glomus* species) and control (un-inoculated seedlings). Each treatment was replicated four in completely randomized design (CRD). Red soil (alfisol) was used as substrate, its chemical properties were as follows: pH 6.29 (1:2.5 $H_2O$), EC 134 μS $cm^{-1}$, OC 0.27%, Olsen P 2.5 ppm. The soil was passed through 2 mm sieve, moistened and filled in cotton bags and autoclaved for 8 h at 15 psi. The sterilized soil was potted in 7–8 kg capacity plastic pots, seeds were sown and inoculation with different AM fungi was done by using 50 gm of mycorrhizal inoculum as per treatments. The pots were kept under green house conditions and watered as and when required. After germination one healthy plant was maintained in each pot. The observations were recorded after 4 months of sowing on shoot length, fresh and dry weights and P concentration [9]. Mycorrhizal dependency (MD) was calculated according to Plenchette et al. [10]: [(M-NM)/M] × 100, where: M is the total dry biomass of mycorrhizal plant; NM is the total dry biomass of non-mycorrhizal plant. The data were statistically analyzed by ANOVA and the differences among means were tested by using critical difference (C.D.) values at 5% level of probability [11].

## Results and Discussion

Six AM species, one belonging to genus *Acaulospora* (*A. scrobiculata*) and five to *Glomus* (*G. aggregatum*, *G. arborense*, *G. diaphanum*, *G. intraradix* and *G. invermayanum*) were recorded and isolated from rhizosphere of naturally growing plants of *D. strictus* from local forest area (Table 1; Fig. 1). Appasamy and Ganapathy [12] have reported the presence of *G. albidum* Walker & Rhodes from the rhizosphere of a bamboo species, *Ochlandra travancorica* Benth. from Ponmudi, Kerala. Results on effect of inoculation of different AM species on growth and P uptake by the bamboo seedlings are presented in Table 2. In *B. bambos*, eight AM inoculants (*G. aggregatum*, *G. arborense*, *G. cerebriforme*, *G. fasciculatum*, *G. hoi*, *G. intraradix*, *G. occultum* and an unidentified *Glomus* 1) significantly increased shoot length. Dry shoot weight was increased by all the treatments, except *G. etunicatum* while dry root weight was increased by all the treatments, except *G. diaphanum*. Total dry weight and P uptake were significantly increased by all studied fungi. Maximum MD values were recorded for *A. scrobiculata* (44.2%), followed by *G. cerebriforme* (41.6%) and *G. intraradix* (41.0%). MD of AM fungi isolated from *D. strictus* (*A. scrobiculata*,

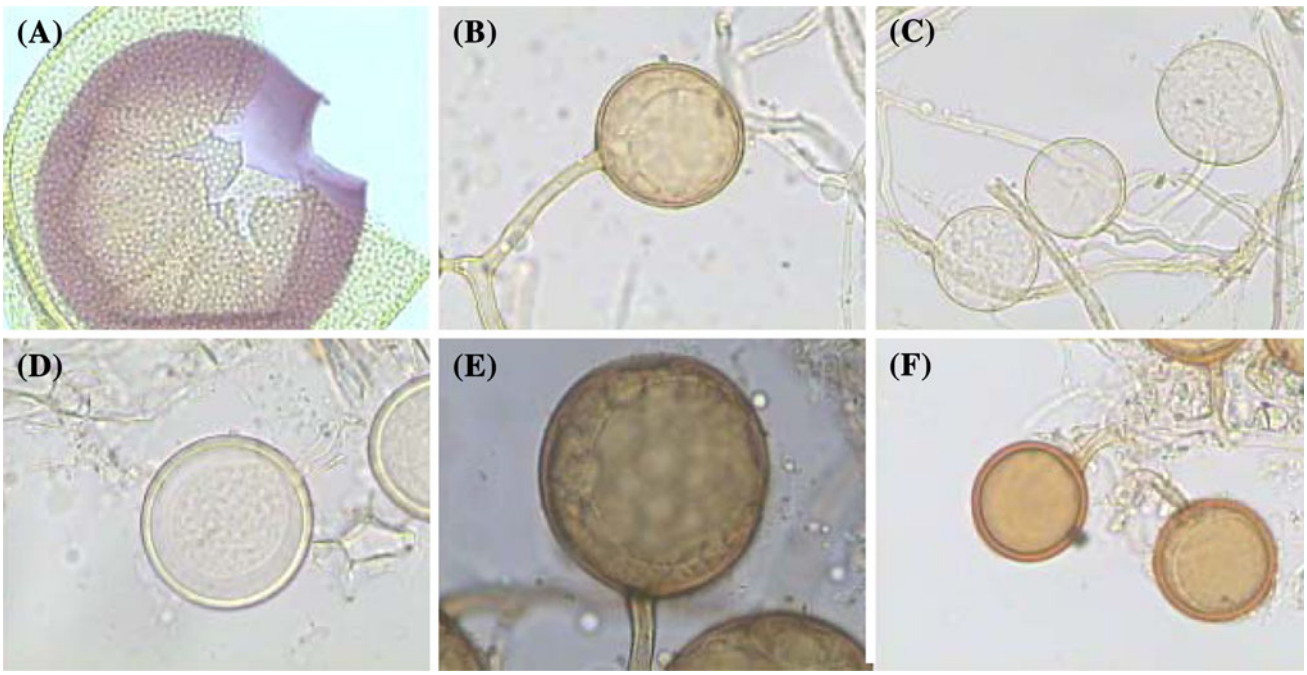


**Fig. 1** Common arbuscular mycorrhizal species recorded in rhizosphere of bamboo in Bundelkhand region **a** *Acaulospora scrobiculata* in melzer's reagent (×400); **b** *Glomus aggregatum* (×400); **c** *G. arborense* (×400); **d** *G. diaphanum* (×400); **e** *G. intraradix* (×400); **f** *G. invermayanum* (×400)

**Table 2** Effect of inoculation of different arbuscular mycorrhizal species on growth and phosphorus uptake of *Bambusa bambos* and *Dendrocalamus strictus* 4 months after sowing

| AM species | Shoot length (cm) | Fresh weight (g) | | Dry weight (g) | | MD[a] (%) | P uptake plant$^{-1}$ (mg) |
|---|---|---|---|---|---|---|---|
| | | Shoot | Root | Shoot | Root | | |
| *Bambusa bambos* | | | | | | | |
| *Acaulospora mellea* | 65.5 | 31.3 | 20.9 | 13.8 | 5.8 | 36.2 | 19.925 |
| *A. scrobiculata* | 62.3 | 35.2 | 19.6 | 15.0 | 7.4 | 44.2 | 25.053 |
| *Glomus aggregatum* | 77.9 | 33.4 | 19.4 | 15.0 | 5.8 | 39.9 | 21.329 |
| *G. arborense* | 71.3 | 27.7 | 21.3 | 13.8 | 5.2 | 34.2 | 19.321 |
| *G. cerebriforme* | 82.0 | 37.5 | 23.1 | 15.0 | 6.4 | 41.6 | 28.485 |
| *G. diaphanum* | 64.8 | 19.0 | 13.3 | 13.9 | 3.6 | 29.0 | 17.518 |
| *G. etunicatum* | 64.8 | 30.8 | 26.4 | 11.8 | 5.4 | 27.3 | 17.245 |
| *G. fasciculatum* | 84.5 | 32.9 | 21.7 | 13.2 | 6.7 | 37.2 | 22.593 |
| *G. hoi* | 81.0 | 30.4 | 32.4 | 13.3 | 5.9 | 34.9 | 25.150 |
| *G. intraradix* | 71.0 | 28.4 | 20.1 | 15.1 | 6.1 | 41.0 | 24.932 |
| *G. occultum* | 80.0 | 35.5 | 21.7 | 14.1 | 5.1 | 34.9 | 22.375 |
| *Glomus* 1 | 69.9 | 25.0 | 17.3 | 14.8 | 5.8 | 39.3 | 24.314 |
| Control | 52.3 | 21.5 | 12.5 | 9.5 | 3.0 | | 7.820 |
| S Em± | 5.0 | 3.7 | 2.8 | 0.8 | 0.7 | | 2.998 |
| $CD_{0.05}$ | 14.2 | 10.5 | 7.9 | 2.4 | 1.9 | | 8.568 |
| *Dendrocalamus strictus* | | | | | | | |
| *A. mellea* | 67.9 | 14.9 | 8.7 | 7.6 | 3.1 | 28.3 | 11.820 |
| *A. scrobiculata* | 60.5 | 15.4 | 17.8 | 7.9 | 5.4 | 42.9 | 14.425 |
| *G. aggregatum* | 73.3 | 15.1 | 12.6 | 8.6 | 4.6 | 42.9 | 11.696 |
| *G. arborense* | 67.8 | 20.4 | 12.4 | 8.2 | 4.3 | 39.2 | 17.777 |
| *G. cerebriforme* | 69.1 | 31.4 | 24.6 | 11.2 | 9.3 | 62.9 | 26.601 |
| *G. diaphanum* | 67.8 | 17.7 | 10.9 | 12.8 | 4.1 | 55.0 | 11.026 |
| *G. etunicatum* | 71.4 | 22.6 | 18.1 | 8.8 | 6.8 | 51.3 | 13.665 |
| *G. fasciculatum* | 75.4 | 16.8 | 8.5 | 8.1 | 3.2 | 32.7 | 11.712 |
| *G. hoi* | 68.8 | 22.1 | 11.2 | 9.9 | 4.1 | 45.3 | 13.527 |
| *G. intraradix* | 65.0 | 23.5 | 12.8 | 9.8 | 4.8 | 47.9 | 17.240 |
| *G. occultum* | 76.5 | 16.4 | 13.3 | 7.2 | 4.9 | 37.2 | 14.756 |
| *Glomus* 1 | 53.0 | 7.8 | 5.9 | 4.3 | 2.2 | −15.2 | 4.709 |
| Control | 47.5 | 8.2 | 7.4 | 4.5 | 3.0 | | 4.291 |
| S Em± | 4.1 | 1.3 | 2.8 | 0.8 | 1.2 | | 2.285 |
| $CD_{0.05}$ | 11.6 | 3.6 | 8.1 | 2.4 | 3.4 | | 6.530 |

[a] *MD* Mycorrhizal dependency

*G. aggregatum*, *G. arborense*, *G. diaphanum* and *G. intraradix*) varied from 29.0 to 44.2 and other AM fungi from 27.3 to 41.6. In *D. strictus,* all tested AM inoculants significantly increased shoot length, dry shoot weight and P uptake, except *Glomus* 1. Dry root weight was significantly increased by only two inoculants namely *G. cerebriforme* and *G. etunicatum*. Total dry weight was significantly increased by eight AM fungi (*A. scrobiculata*, *G. aggregatum*, *G. arborense*, *G. cerebriforme*, *G. diaphanum*, *G. etunicatum*, *G. hoi* and *G. intraradix*). Maximum MD values were recorded for *G. cerebriforme* (62.9%), followed by *G. diaphanum* (55.0%) and *G. etunicatum* (51.3%). MD of AM fungi isolated from *D. strictus* varied from 39.2 to 55.0 and other AM fungi from −15.2 to 62.9.

Bamboo, being a fast growing plant, requires more nutrients during the initial stage of seedling establishment. During this period, the root system is not well developed and the AM fungal symbiosis might play a vital role by supplying the nutrients to the host plant [2]. The results of present study showed that mycorrhizal inoculations increased the plant growth and P uptake in different treatments with a few exceptions. Similar results have been reported in different bamboo species viz., *D. strictus* [1], *B. bambos* and *B. vulgaris* [3] and *B. nutans* [5] under

variable conditions. This can be due to increase in the soil volume explored for nutrient and water uptake by the mycorrhizal plants from soil solution as compared to non-mycorrhizal plants. Generally, better nutrient (especially P) and water uptake leads to increase in biomass [13]. Among the two bamboo species studied, higher growth was noticed in *D. strictus* over *B. bambos*. The results are in conformity with Dash et al. [3].

Thus, in conclusion, it can be stated that in *B. bambos,* best results were obtained with *A. scrobiculata* (MD: 44.2%), *Glomus cerebriforme* (MD: 41.6%) and *G. intraradix* (MD: 41.0%) whereas, in *D. strictus,* higher growth and P uptake were noticed with *G. cerebriforme* (MD: 62.9%), *G. diaphanum* (MD: 55.0%) and *G. etunicatum* (MD: 51.3%). Among the two bamboo species studied, higher growth was recorded for *D. strictus* over *B. bambos*.

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