NOTES

MICROBIAL BIOMASS C, N AND P IN SOILS OF *PHYLLOSTACHYS BAMBUSOIDES* PLANTATION AND *PINUS ROXBURGHII* FOREST IN ARUNACHAL PRADESH, INDIA

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The vegetation of Ziro valley in the Lower Subansiri district of Arunachal Pradesh (28° 21' N, 94° 21' E), north-east India is composed of pine forest (mainly *Pinus roxburghii*), bamboo plantation (*Phyllostachys bambusoides*) and lowland paddy fields. Cultivation of *P. bambusoides* is an important activity at this locality. This bamboo species is fast growing and attains a height of about 16 m with a diameter of 13–15 cm in three years. The species is native to China and has been introduced to India in the state of Arunachal Pradesh, where it is confined to the Ziro Valley (Tewari 1992). The bamboo is an integral part of the Apatani tribal lifestyle; the bamboo is used to make houses, agricultural implements, fence, furniture and is also used in religious and spiritual activities. Almost every Apatani farmer has a plantation of this bamboo species. The culms are harvested in a rotation of not more than three years through individual selection felling. Despite the socio-economic importance and fast growing nature of this bamboo, information is lacking about its site characteristics, which otherwise can be very useful in introducing this species to similar sites in other parts of the region or elsewhere. Therefore, an effort has been made to establish a long-term field monitoring study on evaluation of site specificity and soil-plant relationships of Apatani bamboo plantations. The study was focused on soil physico-chemical and biological properties with particular emphasis on microbial biomass influencing the productivity of *P. bambusoides* at the Ziro valley. Results were compared with data obtained from a 25-year-old *P. roxburghii* (chir pine) forest adjacent to the bamboo plantation, to understand the contribution of microbial biomass C, N and P to soil nutrients in these two ecosystems.

Ten cores (6.5 cm inner diameter, 0–10 cm depth) were collected in April 1999 from three 10 × 10 m plots in a *P. bambusoides* plantation (1.2 ha, 10 years old), which has a density of 1.2×10^5 culms ha^{-1} and grows at an altitude of 1850 m asl in subtropical climate. The mean maximum and minimum temperatures during the study period were 24 and 12 °C respectively with a relative humidity of 72%. The area receives an average of 1545 mm rainfall annually. The *P. roxburghii* forest (~1 ha) is located within a distance of < 0.5 km from the bamboo plantation and sampling at this site was also carried out in April 1999.

Soil samples were pooled plot-wise at each site, and sieved through < 2 mm mesh screen. Soil moisture content (SMC), pH, ammonium-N and nitrate-N were determined immediately within 12 hours of sampling following standard procedures given in Anderson and Ingram (1993). One-third of the soil sample was air dried and analysed for total Kjeldahl nitrogen (TKN) using the semi-micro Kjeldahl procedure, while available P and

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soil organic carbon (SOC) were estimated by molybdenum blue and rapid titration procedures as given in Allen *et al.* (1974). Water holding capacity (WHC) was determined using Keen's box and the SOC values were multiplied by a constant (1.724) to obtain the soil organic matter (SOM) values (Allen *et al.* 1974). The remaining fresh soil was used for the determination of microbial biomass carbon (MBC), nitrogen (MBN), and phosphorus (MBP) using chloroform fumigation extraction (CFE) procedures (Anderson & Ingram 1993). The correction factors used for MBC, MBN and MBP were MBC/0.45, MBN/0.54 and MBP/0.40 respectively. All analyses were triplicated in each plot and the means of the three plots at each site are presented in Table 1. The contribution percentages of microbial biomass to SOC, TKN and available P were calculated to evaluate the relative effect of bamboo and pine growth on soil nutrient dynamics.

Table 1 Soil properties (0–10 cm depth) in *Pinus roxburghii* forest and *Phyllostachys bambusoides* plantation (n = 9)

Parameter	*Pinus roxburghii*	*Phyllostachys bambusoides*
Clay (%)	10.00a	10.42a
Silt (%)	10.42a	3.23b
Sand (%)	79.58a	86.35b
Textural class	Loamy sand	Loamy sand
WHC(%)	88.31a	76.81b
SMC(%)	29.35a	24.00b
pH (H_2O)	5.00a	5.21a
SOC (%)	4.06a	3.85a
SOM (%)	7.00a	6.64a
TKN (%)	0.77a	0.70a
SOC/TKN	5.27a	5.50a
Ammonium-N ($\mu g\ g^{-1}$)	0.08a	0.13b
Nitrate-N ($\mu g\ g^{-1}$)	0.19a	0.22b
Available-P ($\mu g\ g^{-1}$)	16.89a	20.76b
MBC ($\mu g\ g^{-1}$)	967.14a	1550.40b
	(2.51)	(4.03)
MBN ($\mu g\ g^{-1}$)	579.91a	388.63b
	(7.53)	(5.55)
MBP ($\mu g\ g^{-1}$)	10.98a	4.03b
	(65.01)	(19.41)
MBC/MBN	1.67	3.99
MBN/MBP	52.03	96.43
MBC/MBP	88.08	384.71

WHC: Water holding capacity
SMC: Soil moisture content
SOM: Soil organic matter
SOC: Soil organic carbon
TKN: Total Kjeldahl nitrogen
MBC: Microbial biomass carbon
MBN: Microbial biomass nitrogen
MBP: Microbial biomass phosphorus
Values having same letters across columns are not significant at $p < 0.05$, Tukey's test (Zar 1974).
Values in parentheses are the percentage contribution of microbial nutrients to the respective soil nutrients.

Results of the analyses show that soils at Apatani bamboo and chir pine sites were acidic loamy sands (Table 1). WHC, TKN and SOM were higher in the pine forest soil while available P, ammonium-N and nitrate-N were significantly ($p < 0.05$) greater in the bamboo plantation.

Soil MBC was 1.6 times greater in *Phyllostachys* plantation (1550 $\mu g\ g^{-1}$) compared with pine forest soil (967 $\mu g\ g^{-1}$), whereas MBN and MBP were higher in the latter. MBC values in soil under both vegetation types were in the higher order of the reported range (61–2000 $\mu g\ g^{-1}$) for various terrestrial ecosystems (Vance *et al.* 1987). Soil MBC in the bamboo plantation was higher than that of the pine forest. This could be due to the dense and fibrous root system of the bamboo in this study that may have favoured accumulation of larger microbial biomass at the site (Arunachalam & Arunachalam 2002). The values recorded for MBN in this study (579 and 388.63 $\mu g\ g^{-1}$ in the pine forest and bamboo plantation respectively) are greater than the values obtained for broadleaved deciduous (132–240 $\mu g\ g^{-1}$) and evergreen (42–242 $\mu g\ g^{-1}$) forests (Diaz-Ravina *et al.* 1988), coniferous forest (52–125 $\mu g\ g^{-1}$) (Martikainen & Palojarvi 1990) and regrowing subtropical forest (57.7–123.85 $\mu g\ g^{-1}$) (Maithani *et al.* 1996).

Overall, greater MBN in the soils under *Phyllostachys* plantation and *P. roxburghii* forest indicates the importance of microbial biomass in nitrogen conservation in the highly leached soils, which is also evident from the very low concentrations of nitrate- and ammonium-N (Table 1). MBP in *P. roxburghii* forest soil (10.98 $\mu g\ g^{-1}$ is slightly lower than that of *Pinus kesiya* dominated stand (11.59–18.35 $\mu g\ g^{-1}$, Maithani *et al.* 1996) and is within the range reported for arable land, grassland and woodland soils (5.3–67.2 μg^{-1}, Brookes *et al.* 1984). Soil in the *Phyllostachys* plantation recorded low MBP (4.03 $\mu g\ g^{-1}$) compared with that of a *Bambusa* plantation (8–9 $\mu g\ g^{-1}$, Arunachalam & Arunachalam 2002). Thus, it is clear that the choice of species used in plantation affect the quality of plant residues incorporated into the soil through microbial decomposition (Arunachalam *et al.* 1996). Pine litter contains certain inhibitory substances such as resin, which may affect the microbial immobilisation of biomass carbon from the existing soil nutrient pool and hence cause lower MBC compared with bamboo plantation.

As a percentage of total SOC, MBC was higher in bamboo plantation (4.03%) compared with pine forest stand (2.5%). However, contribution of MBN and MBP was significantly ($p < 0.05$) higher in the pine forest stand (7.53 and 65.01% respectively). The contribution of MBC to SOC observed in the study is comparable with the reported values for other tropical forests (1.5–5.3%, Theng *et al.* 1989, Luizao *et al.* 1992), but higher compared with subtropical forest regrowths (0.73–1.74%, Maithani *et al.* 1996) and temperate forests (1.8–2.9%, Vance *et al.* 1987). Decomposition rate in subtropical and temperate soils is slower compared with tropical soils as in the latter, there prevails a year-round biologically active temperature regime balanced by higher primary productivity. In our study, the SOC content at both sites showed much higher values (3.85% and 4.06% at the bamboo plantation and pine forest respectively) than those reported by Mohan (1992) for an undisturbed tropical forest (0.7–1.4%) but comparable with bamboo plantation soils (4.2%) in this region (Arunachalam & Arunachalam 2002).

The share of MBN to TKN in this study (Table 1) is comparable with the values recorded for forest soil (3.4–5.9%, Martikainen & Palojarvi 1990). As a percentage of soil available P, the values for MBP in the bamboo plantation (19.41%) and in the pine forest (65.01%) are greater compared with values reported by Brookes *et al.* (1984) for deciduous woodland (4.7%), grassland (2–4.3%) and arable land (1.4–3.5%), by Arunachalam *et al.* (1996) for *Pinus kesiya* forest soil (1.4–4.7%) and by Maithani *et al.* (1996) for a regrowing subtropical humid forest of this region (12.62–16.32%). In general, the greater contribution of MBC in the bamboo plantation is due to its lower SOC and higher MBC than *P. roxburghii* forest. On the other hand, contribution of microbial N and P were higher in the pine soil. A significantly greater contribution of microbial P to soil available P pool could be due to greater nutrient solubilisation by the mycorrhizal association in the pine roots (Arunachalam *et al.* 1996). These results show that MBC is an independent variable influenced by the type of species planted.

This study reveals the following:

(1) soils under *P. bambusoides* plantation had more plant available nutrients, namely, ammonium-N, nitrate-N and available P,
(2) contribution of microbial C to SOC is also higher in the bamboo plantation, and
(3) percentages of MBN and MBP to the respective soil nutrients are comparatively larger in chir pine forest soil. In general, the contribution of microbial biomass to soil nutrient pool is in the following order: MBP > MBN > MBC, indicating their significance in P and N cycling in soil.

Although sampled in the same locality, differences in soil properties of *Phyllostachys* and chir pine stands are distinct, due mainly to the plant growth characteristics and residue quality of the litter. Further, a significant difference in soil MBC/MBN ratio between the bamboo and pine stands indicates that the types of microorganisms harbouring the soil microsites are different and dynamic. Nevertheless, detailed and periodic research is required to arrive at some specific and useful conclusions to evaluate the site specificity of the Apatani bamboo.

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References

ALLEN, S. E., GRIMSHAW, H. M., PARKINSON, J. A. & GUARNBY, C. 1974. *Chemical Analysis of Ecological Materials.* Blackwell Scientific Publication, Oxford.

ANDERSON, J. M. & INGRAM, J. S. I. 1993. *Tropical Soil Biology and Soil Fertility: A Handbook of Methods.* Second edition. CAB International, Wallingford.

ARUNACHALAM, A. & ARUNACHALAM, K. 2002. Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: ground vegetation, soil and microbial biomass. *Forest Ecology and Management* 159: 231–239.

ARUNACHALAM, A., MAITHANI, K., PANDEY, H. N. & TRIPATHI, R. S. 1996. The impact of disturbance on detrital dynamics and soil microbial biomass in *Pinus kesiya* forest in north-east India. *Forest Ecology and Management* 91: 151–160.

BROOKES, P. C., POWLSON, D. S. & JENKINSON, D. S. 1984. Phosphorus in the soil microbial biomass. *Soil Biology and Biochemistry* 16: 169–175.

DIAZ-RAVINA, M., ACEA, M. J. & CARBALLAS, T. 1988. Microbial biomass and metabolic activity in four acid soils. *Soil Biology and Biochemistry* 20: 817–823.

LUIZAO, R. C. C., BONDE, R. A. & ROSSWALL, T. 1992. Seasonal variation of soil microbial biomass: the effect of clear felling in a tropical rain forest and establishment of pasture in the Central Amazon. *Soil Biology and Biochemistry* 24: 805–813.

MAITHANI, K., TRIPATHI, R. S., ARUNACHALAM, S. & PANDEY, H. N. 1996. Seasonal dynamics of microbial biomass C, N and P during regrowth of a disturbed subtropical humid forest in north-east India. *Applied Soil Ecology* 4: 31–37.

MARTIKAINEN, P. J. & PALOJARVI, A. 1990. Evaluation of the fumigation-extraction method for the determination of microbial C and N in a range of forest soils. *Soil Biology and Biochemistry* 22: 297–802.

MOHAN, S. 1992. Nutrient losses from soil due to jhumming practices in Arunchal Pradesh. *Arunachal Forest News* 10: 29–31

TEWARI, D. N. 1992. *A Monograph on Bamboo.* International Book Distributors, Dehra Dun.

THENG, B. K. G., TATE, K. R. & SOLLINS, P. 1989. Constituents of organic matter in temperate and tropical soils. Pp. 5–32 in Collman, D. C., Oades, J. M. & Uehara, G. (Eds.) *Dynamics of Soil Organic Matter in Tropical Ecosystems.* University of Hawaii Press, Honolulu.

VANCE, E. D., BROOKES, P. C. & JENKINSON, D. S. 1987. An extraction method for measuring microbial biomass C. *Soil Biology and Biochemistry* 19: 703–707.

ZAR, J. H. 1974. *Biostatistical Analysis.* Prentice-Hall, New Jersey.