A preamble study on ecophysiological impact of bamboo species for sustaining soil health

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Abstract
Bamboo, perennial flowering plant species of family Poaceae, was studied in present study to estimate the effect of different bamboo species on physico-biochemical properties of soil collected from rhizosphere of ten bamboo species viz., Bambusa balcooa, B. bamboos, B. smutiplex, B. nutans, B. tulda, B. vulgaris, Dendrocalamus asper, D. giganteus, Dendrocalamus hamiltonii, Dendrocalamus strictus. In the present study soil macronutrients and enzyme activities were analyzed that play role in soil physical, chemical and biological properties that in turn help in crop production, soil health improvement, biomass production with enhanced microbial activities. In the bamboo rhizosphere the pH and EC correspondingly ranged between 6.56 to 8.10 and 18.80 to 45.23 milli S/m where highest pH and EC were observed in Dendrocalamus strictus and Bambusa balcooa respectively. While in the bamboo rhizosphere total organic carbon and total organic matter respectively ranged between 9.133% to 18.567% and 15.708% to 31.935%. The highest total organic carbon and total organic matter was recorded in Bambusa bambos. The highest available Nitrogen was found in the B. tulda(1.833 kgh⁻¹) whereas highest available Phosphorus was observed to be 0.088 kgh⁻¹ (D. asper and D. strictus). The highest available Potassium was found in biosphere of B. balcooa (33.167 kgh⁻¹). The highest β glucosidase and alkaline phosphatase enzyme activity and its specific activity was reported in Dendrocalamus gigantis 115.17 (Catechol mg⁻¹ soil g⁻¹ h⁻¹), 355 (U mg⁻¹) and 413.5 (mg PNP g⁻¹ soil h⁻¹) and 200.10 (U mg⁻¹) respectively. The inputs of organic matter through bamboo species increased crop roots density and better microbial and enzymatic activities. The results indicate that adoption of the agroforestry practices help to improved organic matter status of the soil, which is also reflected in the increased nutrient pool necessary for long-term productivity of the soil.

Keywords: Bamboo, agroforestry, biomass, soil health, soil enzymes

Introduction
Bamboo is a grass place with the Poaceae family and it has around 90 genera with 1200 species circulated everywhere in the world (Lobovikov et al., 2007) [21]. It is by and large circulated in the tropical and subtropical area between roughly 46° north and 47° south scope. It is normally found in Africa, Asia and Central and South America Among Asian nations, India and China are the two significant bamboo delivering nations (Maxim et al., 2005). Bamboo covers a zone of ~37 million ha on the planet (Kant, 2010) [18]. There are 3 enormous genera (Bambusa, Dendrocalamus, and Ochlandra) of bamboos in India which around 10 species each. Together, these three genera speak to about 45% of the all out bamboo species found in India. (Sharma and Nirmala, 2015) [19]. The bamboo forests cover more than 19,000 km which is about 2.48 per cent of the total recorded forest area. India is the second richest country of the world after China in respect bamboo genetic resources (Kaushal et al., 2018) [19]. There are about 125 indigenous and 11 exotic species of bamboo belonging to 23 genera reportedly found in India (Anonymous 2017). About 66% of the growing stock is concentrated in the North Eastern states of the country (Adkoli 2002). The principal bamboo genera occurring in India are Arundinaria, Bambusa, Chimonobambusa, Dendrocalamus, Dinobola, Gigantochloa etc. Over half of the bamboos species found in Eastern India-Arunachal Pradesh, Assam, Manipur, Meghalay, Mizora0m, Nagaland, Sikkim, Tripura and Best Bengal. The bamboo species Dendrocalamus strictus structures a predominant center story yield of sub tropical timberlands of the Garhwal Himalaya. (Gaur 1985) [11]. Bamboos species has the fast growth and high biomass production (Scurlock et al., 2000; Nath et al., 2015) [20, 21] so due to this reason bamboos possess high potential for biomass production and carbon sequestration.
The underground portion of the bamboo plant consists of rhizome system contains food reserve that helps in growth of the bamboo plant (Banik 2000) [6]. Bamboo produce new culms annually from underground rhizomes allow sustainable annual harvesting without disturbing the soil (Zhou et al., 2005) and also helps in soil and water management (Sheil et al., 2003) [103]. Bamboo plays an important role in maintaining and improving the nutrient status of the soil (Kleinhennz et al., 2001) [20]. Due to its fast growth and extensive root system bamboo improves soil physical, chemical and biological properties also controls soil erosion and make possible sediment filtration hence suitable for improvement of degraded lands. In degraded soils the roots of bamboo fix carbon and nutrients to the soil that helps in improving soil health (Christanty et al., 1996, Sujatha et al., 2008) [10, 34]. Planting of bamboo on degraded soils improves soil quality and sequesters carbon in the soil (Nath et al., 2015a, 2015b) [23, 24]. It was reported that the presence of bamboo in the forest significantly affected the physical and chemical properties of soil (Christanty and Kimmins, 1996) [10]. Nutrient content in soil was positively related to yield and explained much of variation in yield across bamboo sites and regions in China (Hong, 1994; Shanmughavel et al., 2001) [15, 31]. Hence, bamboo growth and biomass are positively related to soil organic matter, which is the primary source of nutrients in bamboo cultivation.

Material and Methods

Site of soil samples

Soil samples were collected from Agroforestry research center, GBPUAT Pantnagar, which is situated at the foothills of north-western Himalayan Tarai region, at Latitude: 29° 02’ 60.00” N and Longitude: 79° 30’ 59.99” E, 243.80 m above the mean sea level. The climate of Pantnagar comprises of sub-humid to sub-tropical with hot dry summers and cool winters. The mean annual rainfall is 1433.4 mm. temperature generally rises up to 45.5±1.5 °C. Highest relative humidity remains in the range of 90-95 percent which is experienced during monsoon season and also during winter. The U. S. Nagar soils are mainly considered as a Tarai soil which has major deposition of alluvium material with partial kankay soils.

Sample Collection

Soil samples were collected for all 10 species viz., Bambusa balcooa, B. bambos, B. multiplex, B. nutans, B. tulda, B. vulgaris, Dendrocalamus asper, D. gigantus and D. hamiltonii, D. strictus which were available at bamboo stump at AFRC, GBPUAT, Pantnagar. These bamboo species were planted in Randomized Block Design (RBD) with three replications at spacing of 5 m x 4 m in July 2017, i.e. 2 years old bamboo plants. Soil samples were collected from the rhizosphere close to bamboo rhizome at the depth of 30 cms soil samples were randomly selected as the training set of model, were mixed, dried, sieved and ground to fine particles individually and then used for further analysis.

Determination of total organic carbon

The total organic carbon was analyzed by Walkley and Black’s method (Jackson, 1973).

Determination of total organic matter

The total organic matter was determined by the % of total organic carbon by method (Nelson and Sommers 1996) [126].

Determination of Soil pH

Soil pH was determined by digital pH meter 1:2.5 soil:water suspension. (Jackson, 1967) [16].

Determination of Electrical Conductivity

The soil electrical conductivity was measured by the method given by (Convin and Rhoades 1982) [11].

Determination of available Nitrogen

Available soil nitrogen was determined by alkaline potassium permanganate method (Asija, S., et al., 1956) [5].

Determination of available Phosphorus

Available soil phosphorus was determined by Olsen’s method of extraction with 0.5N NaHCO3 at pH 8.5 (Olsen et al. 1954) [27].

Determination of available Potassium

Available soil potassium was determined by neutral normal ammonium acetate extractable determined by flame photometer (Black, 1965) [8].

Soil enzyme activity

The activity of the enzymes i.e. β-glucosidase (EC 3.2.1.21), alkaline phosphatase (EC 3.1.3.1) were determined by the procedure described by (Hayano, K. 1973) [14], and (Tabatabai and Bremer, 1969) [35].

Result and Discussion

From the rhizosphere physiochemical studies and enzyme specific activity were reported. As given in Table. 1 In the bamboo rhizosphere the pH and EC respectively ranged between 6.56 to 8.10 and 18.80 to 45.23 milli S/m where highest pH was observed in Dendrocolomus strictus (8.10) and Bambusa bambos (7.83) respectively. As compared to other bamboo plantations, soil pH reduced slightly in Dendrocolomus asper (6.56) followed by B. nutans (7.07). Reduction in soil pH may be related to high leaf litter production, whose decomposition may have produced weak acids which in turn caused reduction in pH. Highest soil electrical conductivity was recorded in Bambusa balcooa (45.23 milli S/m) and the lowest electrical conductivity was Dendrocolomus asper (18.80 milli S/m). While in the bamboo rhizosphere total organic carbon and total organic matter respectively ranged between 9.133% to 18.567% and 31.935% to 15.708% respectively. The highest total organic carbon (18.567%) and total organic matter (31.935%) was recorded in Bambusa bambos. Upadhyaya et al., (2003) [41] reported highest soil organic carbon values in D. hamiltonii. Taraiyar et al., (2013) [38] studied highest total carbon stock in D. strictus (381.50 t ha-1) while the lowest stock was shown by B. vulgaris (160.11 t ha-1). The highest available Nitrogen was found in the B. tulda (1.833 kg h-1) and the lowest Nitrogen was reported in Dendrocolomus strictus (0.733 kg h-1), whereas highest available phosphorus was observed to be in (D. asper and D. stricus) 0.088 k g h-1 and the lowest available phosphorus was reported in Bambusa vulgaris (0.035 kg h-1).

The correlation between soil pH and available nitrogen was (r= 0.437, n= 10), resulted that at low pH value nitrification rates decreases. In this result soil pH and available nitrogen are negatively correlated. Yamoah et al., (2003) [44] also reported highest available phosphorus in D. asper. The highest available potassium was found in rhizosphere of B. balcooa (33.167 kg h-1) followed by the lowest value in Bambusa multiplex.
(11.633 kg h⁻¹). Similar study was reported by (Toky and Ramakrishnan 1983, Upadhyaya et al., 2003) [39, 41] that highest soil organic carbon values were recorded in D. hamiltonii. The role of roots and root hairs of the bamboo root system play a very important role in supporting high productivity and soil organic carbon studied. (Tripathi and Singh 1996) [40]. Similar results were reported for B. pallida young highest organic carbon (Upadhyaya et al., 2003) [41] and Gigantochloa spp. and B. vulgaris by (Christanty et al., 1996) [10]. Increase in nitrogen mineralization in bamboo soils was also reported by Raghubanshi (1994) [29]. In Table 2. and Figure 2. The highest β-glucosidase activity and its specific activity was observed in Dendrocolomus giganteus 115.17 Catechol mg⁻¹soil g⁻¹ h⁻¹, whereas alkaline phosphatase enzyme activity and its specific activity was reported in Dendrocolomus giganteus 413.5 (mg PNP g⁻¹soil h⁻¹) and 200.10 (U mg⁻¹) respectively. The study showed the positive correlation (r = 0.037, n = 10) between available phosphorus and alkaline phosphatase in the bamboo rhizosphere soil. It the result of rizosphere of bamboo available phosphorous was very low and specific activity of alkaline phosphatase was high that indicates that soil need phosphorous recycling. Phosphatases are involved in the transformation of organic and inorganic phosphorus compounds in soil (Amador et al., 1997) [33], and their activities are an important factor in maintaining and controlling the rate of phosphorous cycling through soils. Numerous studies pertaining to nutrient cycling have shown the improvement in soil health under bamboo (Toky and Ramakrishnan 1983; Christanty et al., 1997; Sujatha et al., 2008; Takahashi et al., 2007) [39, 34, 36]. High soil pH and rizosphere soil was also close linear correlation (r=0.031,n=10) that means increased in soil pH decreased available phosphorous. So hogh organic carbon and organic organic matter is important for maintaining phosphorous availability at high pH. In Table 2. and Figure 2. As compare to alkaline phosphatase activity soil β glucosidase activity was low. It is because β glucosidase activity mostly depends on substrate supply and the microorganisms that largely produce this enzyme are active in the top soil (Xiao - Chang and Qin, 2006) [43]. Therefore, β-glucosidase activity can be used to indicate the presence of higher simple sugars for microbial population in the soil surface layer. Biomass carbon stock ranged from 0.7 to 54.0 mg h⁻¹ in traditional and improved agroforestry systems in the West African Sahel (Takimoto et al., 2008) [37]. Since bamboo is one of the components in multisrrata mixed species homegardening system, bamboo farming system in homegarden was relatively smaller carbon stock than other agroforestry systems.

**Table 1: Soi physiochemical properties of bamboo rhizospheric soil**

| Sl. No. | Bamboo species         | pH  | EC mili S/m | Total organic carbon (%) | Total organic matter (%) | Available (N/kg ha⁻¹) | Available (P/kg ha⁻¹) | Available (K)/kg ha⁻¹ |
|---------|------------------------|-----|-------------|--------------------------|--------------------------|-----------------------|-----------------------|-----------------------|
| 1       | Bambusa balcooa        | 7.17| 45.23       | 15.800                   | 27.176                   | 1.400                 | 0.037                 | 33.167                |
| 2       | Bambusa bambos         | 7.83| 28.28       | 18.567                   | 31.935                   | 1.533                 | 0.057                 | 15.067                |
| 3       | Bambusa multiplex      | 7.44| 28.42       | 12.833                   | 20.072                   | 1.500                 | 0.065                 | 11.633                |
| 4       | Bambusa nutans         | 7.07| 22.33       | 9.133                    | 15.708                   | 1.467                 | 0.084                 | 21.867                |
| 5       | Bambusa tuldia         | 7.28| 21.46       | 14.533                   | 24.996                   | 1.833                 | 0.075                 | 16.367                |
| 6       | Bambusa vulgaris       | 7.30| 25.04       | 13.533                   | 23.276                   | 1.500                 | 0.035                 | 18.600                |
| 7       | Dendrocolomus asper    | 6.56| 18.80       | 14.667                   | 25.227                   | 1.400                 | 0.088                 | 14.400                |
| 8       | Dendrocolomus giganteus| 7.61| 40.42       | 12.333                   | 21.212                   | 1.567                 | 0.085                 | 24.500                |
| 9       | Dendrocolomus hamiltonii| 7.19| 25.75       | 14.867                   | 25.422                   | 1.600                 | 0.049                 | 22.967                |
| 10      | Dendrocolomus strictus | 8.10| 38.35       | 12.533                   | 21.556                   | 0.733                 | 0.088                 | 16.967                |
| CD      |                        |    |             |                          |                          |                       |                       | 0.284                 |
| SE(m)   |                        |    |             |                          |                          |                       |                       | 0.095                 |
| SE(d)   |                        |    |             |                          |                          |                       |                       | 1.134                 |
| CV      |                        |    |             |                          |                          |                       |                       | 2.236                 |

**Table 2: Bamboos species rhizosphere soil enzyme activity and specific activity**

| Bamboo species     | Protein (mg/gm soil) | β-Glucosidase (Catechol mg⁻¹soil g⁻¹ h⁻¹) | Specific activity (U mg⁻¹) | Alkaline phosphatase (mg PNP g⁻¹soil h⁻¹) | Specific activity (U mg⁻¹) |
|--------------------|----------------------|------------------------------------------|---------------------------|-------------------------------------------|---------------------------|
| Bambusa balcooa    | 86.0                 | 324.09                                   | 86.013                    | 361.7                                     | 245.3                     |
| Bambusa bambos     | 83.0                 | 345.2                                    | 83.064                    | 302.9                                     | 298.3                     |
| Bambusa multiplex  | 87.0                 | 342.04                                   | 87.047                    | 325.8                                     | 228.7                     |
| Bambusa nutans     | 95.0                 | 387.13                                   | 97.068                    | 303.6                                     | 242.5                     |
| Bambusa tuldia     | 97.0                 | 398.36                                   | 95.049                    | 333.5                                     | 225.42                    |
| Bambusa vulgaris   | 87.2                 | 280.4                                    | 87.245                    | 362.9                                     | 232.6                     |
| Dendrocolomus asper| 96.43                | 356.1                                    | 96.431                    | 374.1                                     | 234.9                     |
| Dendrocolomus giganteus | 95.0          | 355                                    | 115.17                    | 413.5                                     | 242.3                     |
| Dendrocolomus hamiltonii | 89.5     | 314.15                                   | 89.562                    | 364.1                                     | 219.8                     |
| Dendrocolomus strictus | 87.0            | 298.36                                   | 87.091                    | 315.2                                     | 212.3                     |
| SD                 | 5.082                | 37.043                                   | 9.327                     | 37.219                                    | 23.577                    |
| SE(m)              | 1.598                | 11.714                                   | 2.949                     | 11.769                                    | 7.455                     |
| CV                 | 5.591                | 10.892                                   | 10.097                    | 10.703                                    | 9.897                     |
| C.D @ 5%           | 4.124                | 30.233                                   | 7.611                     | 30.375                                    | 19.240                    |
Fig 1: Rhizospheric β Glucosidase and Alkaline phosphatase enzymes Specific Activity (U mg⁻¹ protein) isolated from the rhizosphere of bamboo

Conclusion
Conclusion of this study is that Bamboo plantation help in the nutrient cycling, soil organic carbon, organic matter increases in the soil. High organic carbon, organic matter are directly related to high microbial activity and enzymatic activity in the soil. The soil which has very low phosphorous content means the soil are deficient in phosphorous need application of phosphate related fertilizer. High β glucosidase activity on upper surface of soil indicate the substrate i.e. it can help in degrading plant litter which can increase organic carbon, organic matter in soil. High alkaline phosphatase activity shows that this soil requires phosphorous recycling.

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