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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 bamboos species *viz, Bambusa balcooa, B. bamboos, B. smultiplex, B. nutans, B. tulda, B. vulgaris, Dendrocolomus asper, D. giganteus, Dendrocolomus hamiltoni, Dendrocolomus stricus*. 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 between6.56 to 8.10 and 18.80 to 45.23 milli S/m where highest pH and EC were observed in *Dendrocolomus 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 Nitogen 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. stricus*). The highest available Pottassium 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 *Dendrocolomus gigantus* 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 bamboos 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 in 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) [32]. 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, Dinochola, 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) [13]. Bamboos species has the fast growth and high biomass production (Scurlock *et al.*, 2000; Nath *et al*., 2015) [29, 25] 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) [33]. Bamboo plays an important role in maintaining and improving the nutrient status of the soil (Kleinhenz *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 filteration hence suitable for improve 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 Himalyan Tarai rgion, 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 kankary soils.

Sample Collection

Soil samples were collected for all 10 sepecies *viz*., *Bambusa balcooa*, *B. bambos*, *B. multiplex*, *B. nutans*, *B.tulda*,*B. vulgaris*, *Dendrocalamus asper*, *D. gigantus* and *D. hamiltoni*, *D. strictus* which were available at bamboo stum at AFRC, GBPUAT, Pantnagr. 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 grinded 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) [26].

Determination of Soil pH

Soil pH was determined by digital pH meter1:2.5 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 Phosphorous

Available soil phosphorus was determined by Olsen's method of extraction with 0.5N $NaHCo_3$ 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 rhizospher 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 plantation, 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 balchoa* (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 15.708% to 31.935%. 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*. Tariyal *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 Nitogen 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 gh^{-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 kgh^{-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* foung 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) [28]. In Table 2. and Figure 2. The highest β- glucosidase activity and its specific activity was observed in *Dendrocolomus gigantus* 115.17 Catechol mg^{-1}soil g^{-1} h $^{-1}$, 355 (U mg^{-1}), whereas alkaline phosphatase enzyme activity and its specific activity was reported in *Dendrocolomus gigantus* 413.5 (mg PNP $g-^{1}$soil h^{-1}) and 200.10 (U mg^{-1}) respectively. The study showed the positive correlation (r = 0.037, n = 10) between available phosphorous 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 multistrata mixed species homegardening system, bamboo farming system in homegarden was relatively smaller carbon stock than other agroforestry systems.

Table 1: Soil physiochemical properties of bamboo rhizospheric soil

Sl. No.	Bamboos 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 tulda*	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	8.192	0.563	0.9683	0.386	0.023	0.929
	SE(m)	0.095	2.736	0.188	0.3233	0.129	0.008	0.310
	SE(d)	1.134	3.869	0.266	0.4575	0.183	0.011	0.439
	C.V	2.236	16.113	2.345	4.8334	15.408	20.596	2.747

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

Bamboos species	Protein (mg/gm soil)	β Glucosidase (Catechol mg^{-1}soil g^{-1} h $^{-1}$)	Specific activity (U mg^{-1})	Alkaline phosphatase (mg PNP $g-^{1}$soil 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 tulda	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	384.1	219.8
Dendrocolomus strictus	87.0	298.36	87.091	315.2	212.3
SD	5.052	37.043	9.327	37.219	23.577
SE(m)	1.598	11.714	2.949	11.769	7.455
C.V	5.591	10.892	10.097	10.703	9.897
C.D @ 5%	4.124	30.233	7.611	30.375	19.240

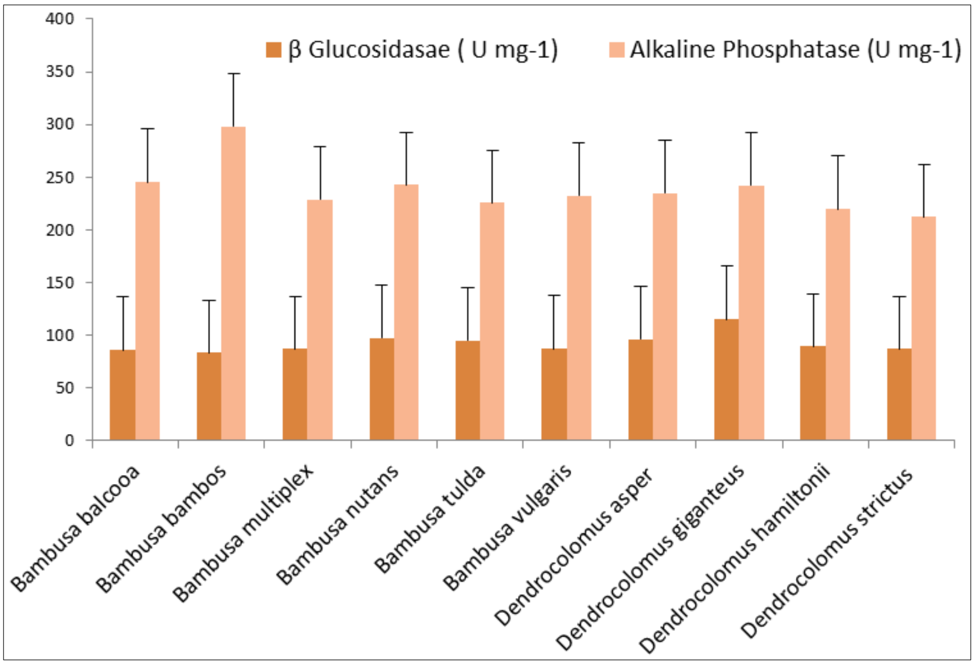

Fig 1: Rhizospheric β Glucosidase and Alkaline phosphatase enzymes Specific Activity (U mg^{-1} protein) isolated from the rhizosphere of bamboo

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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References

1. Adkoli NS. Indian bamboos in early 21st century. Bamboos for Sustainable Development 2002, 17-25.
2. Alef K, Nannipieri P. Methods in applied soil microbiology and biochemistry (No. 631.46 M592ma). Academic Press 1995.
3. Amador JA, Glucksman AM, Lyons JB, Görres JH. Spatial distribution of soil phosphatase activity within a riparian forest1. Soil Science 1997;162(11):808-825.
4. Anonymous India State Forest Report. Forest Survey of India, Dehradun, India 2017.
5. Asija S, Subbiah BV, Asija GL. Rapid procedure for the estimation of the available nitrogen in soils. Current Science 1956;25:259-260.
6. Banik RL. Silviculture and field guide to priority bamboos of Bangladesh and South Asia 2000.
7. Ben-Zhi Z, Mao-Yi F, Jin-Zhong X, Xiao-Sheng Y, Zheng-Cai L. Ecological functions of bamboo forest: research and application. Journal of Forestry Research 2005;16(2):143-147.
8. Black CA, Evans DD, White JL, Ensminger LE, Clarke FE. Methods of soil analysis. American Society of Agronomy. Madison, Wisconsin 1965;1:1-770.
9. Casida Jr LE, Klein DA, Santoro T. Soil dehydrogenase activity. Soil science 1964;98(6):371-376.
10. Christanty L, Mailly D, Kimmins JP. Without bamboo, the land dies: biomass, litterfall, and soil organic matter dynamics of a Javanese bamboo talun-kebun system. Forest Ecology and Management 1996;87(1-3):75-88.
11. Corwin DL, Rhoades JD. An improved technique for determining soil electrical conductivity-depth relations from above-ground electromagnetic measurements. Soil Science Society of America Journal 1982;46(3):517-520.
12. Divakara BN, Kumar BM, Balachandran PV, Kamalam NV. Bamboo hedgerow systems in Kerala, India: Root distribution and competition with trees for phosphorus. Agroforestry systems 2001;51(3):189-200.
13. Gaur RC. Bamboo research in India. Recent research on bamboos, 1985, 26-30.
14. Hayano K. A method for the determination of β-glucosidase activity in soil. Soil science and plant nutrition 1973;19(2):103-108.
15. Hong SS. Multiple-year response of bamboo forest to fertilization. Interciencia 1994;19:394-398.
16. Jackson ML. Soil Chemical Analysis Prentice Hall of India Pvt. Ltd., New Delhi 1967, p205.
17. Jyoti NA, Lal R, Das AK. Ethnopedology and soil quality of bamboo (Bambusa sp.) based agroforestry system. Science of the Total Environment 2015;521:372-379.
18. Kant P. Should bamboos and palms be included in CDM forestry projects (No. 07). IGREC Working Paper No. IGREC07: 2010). New Delhi: Institute of Green Economy. Web Publication 2010.
19. Kaushal R, Jayaparkash J, Mandal D, Kumar A, Alam NM, Tomar JMS, *et al*. Canopy management practices in mulberry: impact on fine and coarse roots. Agroforestry Systems 2019;93(2):545-556.

20. Kleinhenz V, Midmore DJ. Aspects of bamboo agronomy 2001.
21. Lobovikov M, Paudel S, Ball L, Piazza M, Guardia M, Ren H, *et al*. World bamboo resources: a thematic study prepared in the framework of the global forest resources assessment 2005 (No. 18). Food & Agriculture Org 2007.
22. Mehra PN, Sharma ML. Cytological studies on some grasses of Kashmir. Cytologia 1977;42(1):111-123.
23. Nath AJ, Lal R, Das AK. Ethnopedology and soil properties in bamboo (Bambusa sp.) based agroforestry system in North East India. Catena 2015a;135:92-99.
24. Nath AJ, Lal R, Das AK. Managing woody bamboos for carbon farming and carbon trading. Global Ecology and Conservation 2015b;3:654-663.
25. Nath AJ, Das G, Das AK. Above ground, standing biomass and carbon storage in village bamboos in North East India. Biomass and Bioenergy 2015;33:1188-1196.
26. Nelson DW, Sommers L. Total carbon, organic carbon, and organic matter. Methods of soil analysis: Part 2 chemical and microbiological properties 1983;9:539-579.
27. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture 1954.
28. Raghubanshi AS. Effect of bamboo harvest on dynamics of nutrient pools, N mineralization, and microbial biomass in soil. Biology and fertility of soils 1994;18(2):137-142.
29. Scurlock JM, Dayton DC, Hames B. Bamboo: an overlooked biomass resource?. Biomass and bioenergy 2000;19(4):229-244.
30. Seethalakshmi KK, Kumar MM, Pillai KS, Sarojam N. Bamboos of India: A compendium. Brill 1998, 17.
31. Shanmughavel P, Peddappaiah RS, Muthukumar T. Biomass production in an age series of Bambusa bambos plantations. Biomass and Bioenergy 2001;20(2):113-117.
32. Sharma ML, Nirmala C. Bamboo diversity of India: an update. In Proceedings of the 10th world bamboo congress, Damyang, Korea 2015, pp17-22.
33. Sheil D, Ducey MJ, Sidiyasa K, Samsoedin I. A new type of sample unit for the efficient assessment of diverse tree communities in complex forest landscapes. Journal of Tropical Forest Science, 2003, 117-135.
34. Sujatha MP, Thomas TP, Sankar S. Influence of Reed Bamboo (*Ochlandra travancorica*) on Soils of the Western Ghats in Kerala-a Comparative Study with Adjacent Non-reed Bamboo Areas. Indian Forester 2008;134(3):403-416.
35. Tabatabai MA, Bremner JM. Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. Soil biology and biochemistry 1969;1(4):301-307.
36. Takahashi M, Furusawa H, Limtong P, Sunanthapongsuk V, Marod D, Panuthai S. Soil nutrient status after bamboo flowering and death in a seasonal tropical forest in western Thailand. Ecological research 2007;22(1):160-164.
37. Takimoto A, Nair PR, Nair VD. Carbon stock and sequestration potential of traditional and improved agroforestry systems in the West African Sahel. Agriculture, ecosystems & environment 2008;125(1-4):159-166.
38. Tariyal K, Upadhyay A, Tewari S, Melkania U. Plant and soil carbon stock and carbon sequestration potential in four major bamboo species of North India. Journal of Advanced Laboratory Research in Biology 2013;4(3):100-108.
39. Toky OP, Ramakrishnan PS. Secondary succession following slash and burn agriculture in north-eastern India: II. Nutrient cycling. The Journal of Ecology, 1983, 747-757.
40. Tripathi SK, Singh KP. Culm recruitment, dry matter dynamics and carbon flux in recently harvested and mature bamboo savannas in the Indian dry tropics. Ecological Research 1996;11(2):149-164.
41. Upadhyaya K, Arunachalam A, Arunachalam K. Microbial biomass and physico-chemical properties of soil under the canopy of Bambusabalcooa Roxb. and Bambusa pallida Munro. Indian. J Soil. Conservation 2003;31:152-156.
42. Walkley A, Black TA. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Science 1934;37:29-38.
43. Xiao-Chang WANG, Qin L. Beta-glucosidase activity in paddy soils of the Taihu Lake region, China. Pedosphere 2006;16(1):118-124.
44. Yamoah CF, Agboola AA, Wilson GF, Mulongoy K. Soil properties as affected by the use of leguminous shrubs for alley cropping with maize. Agriculture, ecosystems & environment 1986;18(2):167-177.