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Effect of various bamboo species on soil nutrients and growth parameters in Mid hills of HP, India

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Abstract
The bamboos growing in wild play an important role in soil nutrient buildup and maintenance of soil fertility. The nutrient cycling in bamboo forests had shown improvement in soil fertility due to its vigorous growth and litter production. However, the cultivated one that has been managed by farmers in Asia over millennia for their livelihood was little studied with respect to its role in soil nutrient status and growth characteristics. Therefore, present study was carried to describe the usefulness of different species of bamboo in improving soil quality under pure plantation and its influence on growth of bamboo with age. The experiment was carried out in mid hill conditions of HP in pure plantation of bamboo species viz. *Dendrocalamus asper, D hamiltonii, Bambusa tulda, Phyllostachys aurea, D strictus, Malocana baccifera* and *Phyllostachys bambusoides.* The soil properties viz., soil pH, EC, bulk density, organic carbon, SOC stock, available N, P, K, Exchangeable Calcium and Magnesium were studied at two soil depths i.e. 0-20cm and 20-40cm. The results revealed that the bamboo species and soil layers had no significant influence on soil pH, EC and bulk density whereas, organic carbon decreased with the increase in soil depth and was found highest (16.12 g/kg) in 0-20cm soil depth and lowest (14.02 g/kg) in soil depth of 20-40cm. Among species, the soil organic carbon was found to be maximum (16.20 g/kg) under plantations of *D asper*. SOC stock was found maximum (36.41 Mg/ha) in *D hamiltonii*. Available N (333.77 kg ha^{-1}), K (319.52 kg ha^{-1}), Exchangeable Calcium (818.63 mg kg^{-1}) and magnesium (626.49 mg kg^{-1}) all were significantly higher in *D asper* whereas, the available P was maximum (44.42 kg ha^{-1}) under *D. strictus*. All mineral nutrients were observed to be maximum at soil depth of 0-20cm. The growth parameters viz., height, d.b.h, number of culm/ha, internodal length and live culm were found to be higher in *D. asper* than the rest of the species. Age classes have also influenced the different growth parameters significantly. Positive Correlation was observed between different growth and soil parameters. The higher quantity of mineral nutrients under *D asper* plantation suggest its potentials in restoring soil quality through on site enrichment, conservation and cycling of carbon and nutrients and has higher production potential in terms of growth.

Keywords: Bamboo, soil nutrients, growth, *Dendrocalamus, Bambusa, Phyllostachys, Malocana*

Introduction

Bamboo, the giant grass, is a vernacular term for members of subfamily Bambusoideae of family Poaceae. Bamboo is a predominant species of the humid subtropics/ tropics forest ecosystem of the north-east hill region of the Indian subcontinent In Asia, the history of bamboo is inextricably interwoven with human history so much that parts of Asia could be described as a “bamboo civilization.” Bamboo has unique rhizomal growth feature by which culms (individual bamboo) in the clump (cluster of culms) are interconnected and reproduce asexually to produce new culms every year. This characteristic distinguishes bamboo from most other woody plants. Bamboos are cultivated and managed in traditional homegardening system (an age old tropical agroforestry system) to fulfill diverse livelihood requirements and provide numerous environmental services to rural community. Furthermore, bamboo plantations protect traditional homesteads from winds, provide construction materials and fuel wood. Bamboo plays an important role in maintaining and improving the nutrient status of the soil (Kleinhenz *et al.* 2001) [9]. From a comparative study, it was reported that the presence of bamboo in the forest significantly affected the physical and chemical properties of soil (Christanty and Kimmins, 1996) [2]. Nutrient content in soil was positively related to yield and explained much of variation in yield across bamboo sites and regions in China (Hong S S, 1994 and Shanmughavel *et al.* 2001) [7, 14]. Hence, bamboo growth and biomass are positively related to soil organic matter, which is the primary source of nutrients in bamboo cultivation sites in Korea (Jim and Chong, 1982) [8]. Bamboo can grow in relatively poor soil and efficiently make use of the available nutrients and build up relatively fertile soil around the clumps (Singh and Singh, 1999) [15]. While studying the relationship between soil conditions and fountain bamboo (*Sinarundinaria fangiana*), it was observed that bamboo grew well on acid soil with low base saturation, deep, and low gravel content of soils but died in the alkaline, shallow, calcareous soil with high gravel content (Zhang, 1996) [20]. A canonical correlation analysis for bamboo growth showed that surface soil depth, total nitrogen (N), and soil organic matter content had high positive correlation, and clay content and cation exchange capacity were negatively correlated with the bamboo growth (Chung and Ramma, 1990) [3]. Studies related to soil and bamboo revealed emphasis has been given to forest bamboos, whereas bamboo plantations remain unexplored although it forms an important component of the agroforestry systems of south Asia, especially in India and Bangladesh. In traditional agroforestry systems, bamboos are grown on soils of poor quality or degraded site of the holdings. Therefore, bamboo has been traditionally used to reclaim degraded lands. Despite the significant impact of bamboos to the livelihood and wellbeing of farmers, there exists the need of scientific understandings of the role of pure plantations of bamboo management on sustaining soil nutrient status. Therefore, the present investigation is carried out to study the effect of bamboo plantations on soil quality and growth parameters

Material and Methods

Site description

Location

The study was carried out in Mid hill condition of Himachal Pradesh i.e. experimental field of Department of Silviculture and Agroforestry (30º 51’ N latitude and 76º 11’ E longitude and elevation; 1200m amsl) at Nauni, Dr YS Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh

Climatic and Edaphic factors

Climatically, the site lies in the sub-tropical belt but is slightly skewed towards the temperate climate and hence is regarded as a transition zone between sub-tropical and temperate climate. The area experiences a wide range of temperature with a minimum of 1 ˚C in winter to a maximum of 37 ˚C with May and June as the hottest months, whereas December and January, the coldest ones. Winters are accompanied by a fair amount of frost which kills large amount of regeneration in the area but snowfall is witnessed rarely. The area receives maximum downpour during the monsoon season (July and August)

Growth Characteristics

From the study area, five clumps were randomly selected and identified with paint marking. All observation were made for DBH, height, number of culms ha^{-1}, inter – nodal length and live in sample culmp.

Collection and preparation of soil samples

Soil samples were collected at two different depths i.e. 0-20cm and 20-40cm from experimental site during the growing season (July-Auguest) by using post hole and screw auger. Composite samples were obtained from each depth. Samples were air dried in shade, grinded with wooden pestle, passed through 2 mm sieve and stored in cloth bags for further laboratory analysis. The following physical, chemical and biological attributes of soils were determined by standard methods given below (Table 2).

Result and discussion

Soil physico-chemical properties: The bamboo species and soil layer had no significant influence on soil pH, EC and bulk density. Organic carbon (g kg^{-1}) and Soil organic carbon stock (Mg ha^{-1}) was significantly influenced by soil layer and bamboo species given in table 1. Maximum (16.20 g kg^{-1}) organic carbon was recorded under *D. asper* (T_1) which was found to be statistically at par with T_2 and T_5 whereas, minimum (14.03 g kg^{-1}) was recorded under treatment T_7 which was found to be statistically at par with T_6. In the average effect of soil layer, 0-20 cm layer of soil displayed significantly higher value (16.12 g kg^{-1}) than 20-40 cm layer. Among bamboo species Soil organic carbon stock (Mg ha^{-1}) was higher under *D. hamiltonii* (T_2) (36.41 Mg ha^{-1}) which was found to be statistically at par with T_1 and T_5, whereas minimum value carbon stock under (T_4) *Phyllostachys aurea* (33.63 Mg ha^{-1}) which was found to be statistically at par with T_3 and T_7. In the average effect of soil layer 0-20 cm soil layer displayed significantly higher soil organic carbon stock (36.39 Mg ha^{-1}) than 20-40 cm soil layer All the soil mineral nutrients Available N, P, K, Exchangeable Calcium and magnesium are significantly influenced by different bamboo species and soil depths as presented in table 2. Available nitrogen (kg ha^{-1}) was significantly influenced under different bamboo species and soil layer. Available nitrogen content was recorded maximum (333.77 kg ha^{-1} under bamboo species i.e. *D. asper* (T_1) which was significantly higher than all other bamboo species and minimum value was recorded under T_7 (315.87 kg ha^{-1}). Increase in the available nitrogen content was significantly higher (327.07 kg ha^{-1}) in upper soil layer in comparison to lower soil layer. Available phosphorous (kg ha^{-1}) was significantly influenced under different bamboo species and soil layer. Available phosphorous content was recorded maximum (44.42 kg ha^{-1}) under bamboo species i.e. *D. strictus* (T_5) which was statistically at par with *D. asper* (T_1) followed by T_6, T_3, which was statistically at par with T_4 and minimum value was recorded under T_7 (39.22kg ha^{-1}). Increase in the available phosphorous content was significantly higher (43.20kg ha^{-1}) in upper soil layer in comparison to lower soil layer. As far the available potassium (kg ha^{-1}) was concerned, the same trend was followed as maximum (319.52 kg ha^{-1}) available potassium under bamboo species i.e. *D. asper* (T_1) which was statistically at par with *D. strictus* (T_5) followed by T_2, T_4, which was statistically at par with T_6 and minimum value was recorded under T_3 (314.11 kg ha^{-1}) which was found to be statistically at par with T_7. Increase in the available potassium content was significantly higher (318.68 kg ha^{-1}) in upper soil layer in comparison to lower soil layer. Likewise Exchangeable calcium (mg kg^{-1}) content was recorded maximum (818.63 mg kg^{-1}) under bamboo species i.e. *D. asper* (T_1) which was statistically at par with *D. hamiltonii* (T_2) and *D. strictus* (T_5) minimum value was recorded under T_7 (811.03 mg kg^{-1}) which was found to be statistically at par with T_6. Increase in the Exchangeable calcium content was significantly higher (816.21 mg kg^{-1}) in upper soil layer in comparison to lower soil layer. The exchangeable magnesium (mg kg^{-1}) was also maximum (626.49 mg kg^{-1}) under bamboo species i.e. *D. asper* (T_1) which was statistically at par with *D. hamiltonii* (T_2) followed by T_5, T_6, T_3 which was statistically at par with T_4 and minimum value was recorded under T_7 (617.59 mg kg^{-1}). Increase in the exchangeable magnesium content was significantly higher (624.12 mg kg^{-1}) in upper soil layer in comparison to lower soil layerIn the present study OC and SOC were significantly higher in top soil (0-20cm) may be owed to deposition and decomposition of leaf litter. Such observations were also made by Kumar *et al.* (2002) [10]. And Gupta *et al.* (2010) [5]. These results are in line with (Upadhyaya *et al.,* 2003) [18]. *Gigantochloa spp*. and *B. vulgaris* (Christanty *et al.* 1996) [2]. They also found that SOC and OC decreases along with the increase in soil depth, it might be due to addition of fine roots biomass distributed in topsoil layer might have helped in buildup in soil OC and SOC as reported for *B. pallida*. Among bamboo species, maximum value of available N (333.77 kg ha^{-1}), P (44.20 kg ha^{-1}) and K (319.52 kg ha^{-1}) were recorded under *D. asper*. This might be due to comparatively higher leaf litter production and its deposition through leaf litter shedding under *D. asper* than *other species* Yamoah *et al.* (1986) [19]. also reported that pruning of three leguminous trees improved the available N, P and K status of soil. Available N, P and K were found significantly higher in upper soil layer (0-15 cm) when compared to subsurface soil layer (15-30 cm). Most of the nutrients were concentrated within the upper layer, where almost all bamboo roots are found (Rui *et al*. 1999) [12]. Singh and Dutta (1988) [16]. Also reported decreasing trend for available nitrogen with depth. Exchangeable calcium and magnesium content (mg kg^{-1}) was significantly influenced by bamboo species and were reported maximum in soil under *D. asper than other species.* Dalland *et al*. (1993) [4]. reported increase in Mg content under *leucaena leucocephala*. Further, Tian *et al.* (1996) also reported that leaves of multipurpose trees increase soil Ca and Mg content

Table 1: Effect of different bamboo species, soil depth and interaction effect of bamboo species and soil layer on physico-chemical properties (i.e. pH, EC, BD, OC and SOC) of soil in mid-hill of HP.

Treatments(species)	pH (1:2)			EC (dS m^{-1})			Bulk density (g cm^{-3})			Organic carbon (g kg^{-1})			SOC (Mg ha^{-1})		
	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean
T_1 *(Dendrocalamus asper)*	7.02	6.97	7.00	0.50	0.44	0.47	1.09	1.11	1.10	17.26	15.13	16.20^{a}	37.71	33.60	35.65^{a}
T_2 *(Dendrocalamus hamiltonii)*	7.00	6.99	6.99	0.49	0.41	0.45	1.12	1.15	1.14	17.00	15.10	16.05^{a}	38.08	34.73	36.41^{a}
T_3 *(Bambusa tulda)*	6.93	6.89	6.91	0.44	0.37	0.40	1.15	1.18	1.17	15.63	13.40	14.52^{b}	36.06	31.71	33.89^{b}
T_4 *(Phyllostachys aurea)*	6.95	6.88	6.91	0.46	0.38	0.42	1.14	1.17	1.16	15.54	13.62	14.58^{b}	35.30	31.97	33.63^{b}
T_5 *(Dendrocalamus strictus)*	6.97	6.96	6.97	0.48	0.40	0.44	1.10	1.13	1.12	16.99	15.00	15.99^{a}	37.37	33.90	35.63^{a}
T_6 *(Malocana baccifera)*	6.94	6.83	6.88	0.42	0.35	0.38	1.13	1.15	1.14	15.23	12.97	14.10^{c}	34.33	29.90	32.11^{c}
T_7 *(Phyllostachys bambusoids)*	6.92	6.84	6.88	0.39	0.32	0.36	1.18	1.19	1.19	15.17	12.90	14.03^{c}	35.90	30.63	33.26^{b}
Mean	6.96	6.91		0.45	0.38		1.13	1.16		16.12^{a}	14.02^{b}		36.39^{a}	32.35^{b}	
CD $_{0.05}$															
Treatments			NS			NS			NS			0.26			1.75
Soil layers			NS			NS			NS			0.14			0.94
Interaction			NS			NS			NS			0.37			2.48

Table 2: Effect of different bamboo species, soil depth and interaction effect of bamboo species and soil layer on physico-chemical properties (Available N, P, K and exchangeable Ca and Mg) of soil in mid-hill of HP.

Treatments (species)	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})			Exchangeable Ca (mg kg^{-1})			Exchangeable Mg (mg kg^{-1})		
	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean	L_1	L_2	Mean
T_1 *(Dendrocalamus asper)*	336.27	331.27	333.77^{a}	46.33	41.83	44.08^{a}	321.61	317.43	319.52^{a}	820.87	816.39	818.63^{a}	629.16	623.83	626.49^{a}
T_2 *(Dendrocalamus hamiltonii)*	334.33	330.07	332.20^{b}	45.53	41.80	43.67^{b}	320.73	316.04	318.39^{b}	819.52	815.62	817.57^{a}	628.17	623.59	625.88^{a}
T_3 *(Bambusa tulda)*	320.93	317.57	319.25^{d}	40.66	38.49	39.57^{d}	316.19	312.03	314.11^{d}	812.38	809.69	811.03^{b}	620.39	616.72	618.55^{d}
T_4 *(Phyllostachys aurea)*	321.17	317.73	319.45^{d}	41.55	38.98	40.27^{d}	317.74	313.35	315.55^{c}	813.23	809.99	811.61^{b}	621.21	616.87	619.04^{d}
T_5 *(Dendrocalamus strictus)*	332.83	330.10	331.47^{b}	45.73	43.10	44.42^{a}	320.81	316.97	318.89^{a}	820.19	815.43	817.81^{a}	628.13	622.98	625.56^{b}
T_6 *(Malocana baccifera)*	325.93	322.67	324.30^{c}	42.10	40.17	41.13^{c}	317.97	313.00	315.49^{c}	813.26	810.49	811.88^{b}	622.01	617.97	619.99^{c}
T_7 *(Phyllostachys bambusoids)*	318.03	313.70	315.87^{e}	40.48	37.97	39.22^{e}	315.69	312.68	314.19^{d}	814.05	809.49	811.77^{b}	619.78	615.40	617.59^{e}
Mean	327.07^{a}	323.30^{b}		43.20^{a}	40.33^{b}		318.68^{a}	314.50^{b}		816.21^{a}	812.44^{b}		624.12^{a}	619.62^{b}	
CD $_{0.05}$															
Treatments			1.02			0.71			0.72			1.44			0.75
Soil layers			0.55			0.38			0.38			0.77			0.40
Interaction			NS			NS			1.01			NS			NS

Growth studies

Data presented in table 3 showed the significant difference in age classes and bamboo species for all growth parameter (i.e culm diameter, culm height, intermodal length and number of culm per hectare). Culm diamerter was maximum (4.67) in A_1 (<1 year old) which is statistically at par with A_2 (1-3 year old) and minimum culm diamerter (2.42cm) in case of A_3 (> 3 years old). In case of Species *Dendrocalamus hamiltonii* had maximum culm diameter (6.33cm), statistically at par with T_5 *Dendrocalamus strictus* (6.06cm), and all other are found to be significantly different from *Dendrocalamus hamiltonii* and *Phyllostachys aurea*, which recorded minimum culm diameter (1.70cm). Culm height was maximum (5. 87) in A_1 which is statistically at par with A_2 and A_3. Among Species T_2 *Dendrocalamus hamiltonii* had maximum culm height (9.32m), and all other are found to be significantly different from *Dendrocalamus hamiltonii* and T_4 *(Phyllostachys aurea),* which recorded minimum culm height (3.15m). Inter-nodal length was observed maximum in A_3 (21.24cm) which is statistically at par with A_2 and A_3. Among species T_3 *(Bambusa tulda*) had maximum culm height (29.44cm), and all other are found to be significantly different from *Bambusa tulda* and T_6 *(Malocana baccifera),* which recorded minimum inter-nodal length (15.00cm). Number of culm per hectare: was found maximum (4781.43) in A_3 which is significantly different from A_2 and A_3. Species also showed significant differences for the number of culm per hactare where T_3 *(Bambusa tulda)* had maximum number of culm per hactare (5244.44) and T_5 *(Dendrocalamus strictus),* which recorded minimum number of culm per hactare (1777.78). Interactions between species and age also yielded significant results for live culms where maximum live culms (9466.67) was observed in T_3A_3 i.e. *Bambusa tulda* at age of three year and T_5 A_1 *(Dendrocalamus strictus)* which recorded minimum number of culm per hactare (800.00). Live culm was recorded maximum (14.76) in A_3 which is significantly different from A_2 and A_3. Species also showed significant differences for the live culms where T_3 *(Bambusa tulda)* had maximum live culm (12.67), which is statistically at par with T_6 *(Malocana baccifera) (11.* 89*)* while minimum live culm (3.78)

In present study *D. hamiltonii* showed its superiority over with respect to growth parameters like average height (6.33 m) and average diameter (9.35 cm). Growth and developmental behaviour of individual species depends upon its genetic makeup, environment and genotype and environment interaction. *D. hamiltonii* falls under one of the giant bamboo species of the world, the other two being *Phyllostachys pubescence* and *D. giganteus.* Therefore, its superiority over species is somewhat natural. The DBH and height of the bamboo species decreases with increasing age these results are supported by Tian-Ming Yen *et al.* 2010 revealed that makino bamboo showed the similar trend of DBH and height. Above ground biomass as well as dry matter accumulation increases concomitant with DBH and culm height which contribute a major share to the total biomass (Shanmughavel and Francis, 1996) [13].

Table 3: Effect of age and species on growth characteristics of different bamboo species in mid hills of HP, India.

Species	Culm diameter (cm)				Culm height (m)				Number of culms ha^{-1}				Inter-nodal length (cm)				Live Culm			
	A1	A2	A3	Mean	A1	A2	A3	MEAN	A1	A2	A3	Mean	A1	A2	A3	MEAN	A1	A2	A3	MEAN
T_1 *(Dendrocalamus asper)*	6.14	5.78	3.30	5.07^{b}	4.45	3.83	3.66	3.98^{c}	1200.00	2400.00	4400.00	2666.67^{b}	20.67	21.00	21.33	21.00^{b}	5.33	7.33	21.00	11.22^{b}
T_2 *(Dendrocalamus hamiltonii)*	7.64	6.98	4.36	6.33 ^{a}	9.40	9.34	9.32	9.35^{a}	933.33	1600.00	5733.33	2755.56^{b}	18.67	19.00	19.33	19.00^{c}	5.67	8.33	11.00	8.33^{c}
T_3 *(Bambusa tulda)*	3.34	3.12	1.68	2.71^{c}	8.27	8.22	8.20	8.23^{b}	3066.67	3200.00	9466.67	5244.44^{a}	29.00	29.33	30.00	29.44^{a}	6.00	11.00	21.00	12.67^{a}
T_4 *(Phyllostachys aurea)*	2.17	1.98	0.95	1.70a	3.19	3.15	3.12	3.15a	666.67	1600.00	4400.00	2222.22^{b}	18.67	18.67	19.33	18.89^{c}	4.33	6.33	12.00	7.56^{c}
T_5 *(Dendrocalamus strictus)*	7.42	6.84	3.93	6.06^{a}	8.62	8.58	8.56	8.59^{b}	800.00	1200.00	3333.33	1777.78^{b}	20.33	21.00	21.33	20.89^{b}	2.33	2.67	6.33	3.78^{d}
T_6 *(Malocana baccifera)*	2.91	2.79	1.11	2.27^{c}	3.71	3.68	3.66	3.68^{c}	2666.67	1200.00	2803.33	2223.33^{b}	14.67	15.00	15.33	15.00^{d}	4.67	10.00	21.00	11.89^{a}
T_7 *(Phyllostachys bambusoids)*	3.07	2.93	1.61	2.54^{c}	3.47	3.44	3.42	3.44^{d}	534.00	1866.67	3333.33	1911.33^{b}	21.33	21.67	22.00	21.67^{b}	5.33	9.00	11.00	8.44^{c}
Mean	4.67^{a}	4.35^{a}	2.42^{b}		5.87^{a}	5.75^{a}	5.71^{a}		1409.62^{b}	1866.67^{b}	4781.43^{a}		20.48^{a}	20.81^{a}	21.24^{a}		4.81^{c}	7.81^{b}	14.76^{a}	
CD 5%																				
Age				0.35				0.30				1119.66				0.98				0.63
Treatment				0.53				0.47				1710.30				1.50				0.97
Age * Treatment				0.92				0.81				2962.33				2.60				1.67

Correlation Study

Karl Pearson's coefficient of correlation was worked out between different growth and soil physico chemical parameters viz., Culm diameter, culm height, Internodal length, number of culm per hectare, Available N, P, K, Exchangeable Calcium and magnesium on the basis of data collected in field. It is evident from Table 4 that the most of growth and soil physico chemical parameters were positively correlated with each other's. Among the growth and soil nutrients the highest correlation coefficient was 0.937 between Exchangeable Ca and Culm diameter followed by between Exchangeable Mg and Culm diameter, Soil organic carbon stock and culm diameter 0.924 and 0.921 respectively while, minimum positive correlation coefficient was 0.003 between intermodal length and soil pH. Within soil nutrients the highest correlation was 0.989 between organic carbon and pH followed by between Exchangeable Mg and Phosphorus 0.986. He and Ye (1987) reported soil organic matter as one of the most important factors influencing plant growth. These results are supported by Kleinhenz *et al*. (2001) [9]. Bamboo plays an important role in maintaining and improving the nutrient status of the soil. From a comparative study, it was reported that the presence of bamboo in the forest significantly affected the physical and chemical properties of soil (Christanty *et al.* 1996) [2]. Chung and Ramma, 1990 revealed that the bamboo growth is positively related to soil organic matter and other soil nutrients, which is the primary source of nutrients in bamboo cultivation sites in Korea. Similar results were obtained by Amin *et al*. 2010 [1]. And Lincy *et al*. 2008 [11].

Table 4: Simple correlation coefficient (r) between growth and soil physic-chemical parameters under bamboo plantations in mid-hill of HP during full growth period.

	Culmdia	**Cht**	**IntNodalL**	**Culmha**	**Newshoot**	**N**	**P**	**K**	**ExCa**	**EchMg**	**OC**	**EC**	**pH**	**BD**	**SOC**
Culmdia	1														
Cht	.680**	1													
IntNodalL	-0.034	0.405	1												
Culmha	-0.163	0.393	.780**	1											
Newshoot	-0.371	-0.057	0.509	.772**	1										
N	.877**	0.422	-0.279	-0.206	-0.292	1									
P	.901**	0.425	-0.294	-0.324	-0.437	.981**	1								
K	.866**	0.319	-0.291	-0.353	-0.461	.964**	.983**	1							
ExCa	.937**	0.411	-0.175	-0.303	-0.41	.943**	.964**	.975**	1						
EchMg	.924**	0.452	-0.213	-0.234	-0.37	.985**	.986**	.983**	.983**	1					
OC	.921**	0.521	-0.023	-0.126	-0.388	.919**	.932**	.950**	.964**	.967**	1				

EC	.718**	0.376	-0.036	0.004	-0.312	.847**	.828**	.874**	.824**	.871**	.922**	1			
pH	.897**	0.500	0.003	-0.065	-0.33	.897**	.891**	.922**	.943**	.947**	.989**	.933**	1		
BD	-.697**	-0.193	0.329	0.264	0.281	-.937**	-.929**	-.931**	-.853**	-.902**	-.829**	-.829**	-.787**	1	
SOC	.914**	.638*	0.148	-0.027	-0.393	.775**	.797**	.818**	.882**	.861**	.948**	.838**	.957**	-.608*	1

Table 5: Soil physical, chemical and biological analysis: methods and instruments used

SR. No	Parameters	Methods Employed	Instrument/apparatus used
1	EC	1:2 soil water suspension	
2	pH	1:2 soil water suspension (Jackson, 1973)	pH meter
	Bulk density (g/cc)	Core method	Core method
3	Organic Carbon (%)	Wet Combustion method (Walkley and black, 1934)	-----
4	Available Nitrogen (kg ha^{-1})	Alkaline potassium permanganate method (Subbiah and Asija, 1956)	Kjeldahl distillation unit
5	Available Phosphorus (kg ha^{-1})	Olsen *et al.* (1954)	Specrtronnic 20 D^{+}
6	Available Potassium (kg ha^{-1})	Neutral 1 N ammonium acetate solution method (Merwin and Peach, 1951)	Flame photometer
7	Exchangeable Calcium (mg ka^{-1})	Neutral 1 N ammonium acetate solution method	
8	Exchangeable Magnesium (mg ka^{-1})	Neutral 1 N ammonium acetate solution method	

Conclusions

The enriched soil nutrient status and SOC under bamboo clump suggests the potential of bamboo in soil restoration, onsite nutrient conservation, nutrient cycling, and Carbon sequestration. Measured SOC stock and sequestration rate are comparable to those of other agroforestry and bamboo-based agro ecosystems elsewhere for similar soil depths, suggesting the high potential of traditionally managed pure bamboos in sustaining productivity and restoring soil quality. The DBH and height of the bamboo species decreased with increase in age which may be due to its fast growing behavior as bamboo attains its maximum growth within 4-5 months. Among different species of bamboo *D. asper* displayed better growth and development behavior, better nutrient cycling and carbon sequestration under mid hill sub humid conditions of Himachal Pradesh. There is also a positive correlation between growth parameters and soil nutrients in the soil. However, more research is needed to evaluate the management systems that can further promote SOC sequestration rate and improve soil quality under bamboo plantations

References

1. Amin MR, Ikbal TMT, Miah MMU, Hakim MA, Amanullah ASM. Performance of ginger under agroforestry system. Bangladesh Research Publications Journal. 2010; 4(3):208-217.
2. Christanty L, Mailly D, Kimmins JP. Without bamboo, the land dies: Biomass, litter fall, and soil organic matter dynamics of a Javanese bamboo talon-kebun system. Forest Ecology and Management, 1996; 87(1-3):75-88.
3. Chung YG, Ramm CW. Relationships between soil-site properties and bamboo (*Phyllostachys bambusoides*) growth. J. Korean Forest Soc. 1990; 79:16-20.
4. Dalland A, Vaje PL, Mathews RB, Singh BR. The potential of alley cropping in improvement of cultivation systems in the high rainfall areas of Zambia. Effect on soil chemical and physical properties. Agroforestry Systems, 1993; 21:117-132.
5. Gupta RD, Sanjay A, Gupta GD, Sumberia NM. Soil physical variability in relation to soil erodibility under different land uses in foothills of Siwaliks in northwest India. Tropical Ecology, 2010; 51(2):183-190.
6. He LM, Ye ZJ. Application of multiple statistical analysis on the study of bamboo (*P. pubescens*) soils. J. Bamboo Res. 1987; 6(4):28-40.
7. Hong SS. Multiple-year response of bamboo forest to fertilization. Interciencia, 1994; 19:394-398.
8. Jin HS, Chong HP. Studies on fertilizer-managements and growth analysis in the rejuvenating bamboo grove. J. Korean Forest Soc. (in Korean). 1982; 56:51-65.
9. Kleinhenz V, Midmore DJ. Aspects of bamboo agronomy. Adv. Agron. 2001; 74:99-153.
10. Kumar S, Sharma JC, Sharma IP. Water retention characterstics and erodibility indeces of some soil under different land uses in North West Himalayas. Indian Journal of Soil Conservation. 2002; 30(1):29-35
11. Lincy AK, Jayarajan K, Sasikumar B. Relationship between vegetative and rhizome characters and final rhizome yield in micropropagated ginger plants (Zingiber officinale Rosc.) over two generations. Scientia Horticulturae, 2008; 118:70-73
12. Rui L, Werger MJA, During HJ, Zhong Z. Biomass distribution in a grove of the giant bamboo Phyllostachys pubescens in Chongqing. China Flora, 1999; 194:89-96.
13. Shanmughavel P, Francis K. Above ground biomass production and nutrient distribution growing bamboo Bambusa bambos (L. Voss). Biomass and Bioenergy, 1996; 10:383-391.
14. Shanmughavel P, Peddappaiah RS, Muthukumar T. Biomass production in an age series of Bambusa bambos plantations. Biomass Bioenergy, 2001; 20(2):113-117.
15. Singh AN, Singh JS. Biomass, net primary production and impact of bamboo plantation on soil redevelopment in a dry tropical region. Forest Ecology and Management, 1999; 119:195-207.
16. Singh OP, Datta B. J. lndian Soc. Soil Sci. 1988; 36:414-420
17. Tian-Ming Ye, Yi-JiaJi, Joou-Shian Lee. Estimating biomass production and carbon storage for a fast-growing makino bamboo (Phyllostachys makinoi) plant based on the diameter distribution model. Forest Ecology and Management, 2010; 260:339-344.
18. Upadhyaya K, Arunachalam A, Arunachalam K. Microbial biomass and physico-chemical properties of soil under the canopy of Bambusa balcooa Roxb. and Bambusa pallida Munro. Indian Journal of Soil Conservation. 2003; 31:152-156.
19. Yamoah CF, Agboola AA, Wilson GF, Mulongoy K. 1986. Soil properties as affected by the use of leguminous shrubs for alley cropping with maize.

Agriculture, Ecosystems and Environment, 2003; 18(2):167-177.
20. Zhang X, Zhang XM. Wang JP. Mass distribution and nutrient content circulation of short rotation Phyllostachys nidularia forest. J. Bamboo Res. (in Chinese) 1996; 15(3):67-81.