IOSR Journal Of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399. Volume 7, Issue 5 (Nov. - Dec. 2013), PP 11-16
www.iosrjournals.org

Changes in soil physico-chemical parameters of *Dendrocalamus hamiltonii* Nees and *Melocanna baccifera* (Roxb.) Kurz forests during pre-flowering, flowering and post-flowering phases in Eastern Himalayas, India

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Abstract: *Gregarious flowering in D. hamiltonii and M. baccifera were occurred in the north eastern region of India. Due to sudden dead in larger scale, considerable changes in particular bamboo forests were witnessed. An approach was made to examine the changes in soil parameters during pre-flowering, flowering and post-flowering phases. Soil nutrients such as N, P and K were decrease, though, oxidizable organic carbon, soil moisture increases in flowering and post-flowering sites. Besides, soil acidity also increases in these sites. Thus, changes in soil physico-chemical parameters were observed in these bamboo forests. Such changes in soil were either the reason for gregarious flowering and dead in bamboo or vice versa.*

Keywords: *Gregarious flowering, bamboo forest, phase, changes, mass dead, soil nutrients*

I. Introduction

Bamboo is among the most important natural resources with multiple applications. Around 60 percent of bamboo genetic resources are available in the north eastern region of India. *D. hamiltonii* and *M. baccifera* are among the important species for food, raw material for paper industries with several other applications in the Eastern Himalayan region. Periodic flowering cycle in bamboo is a major threat in socio-economic as well as their natural habitat. Most bamboo species flower after long vegetative phase ranging from 3 to more than 120 years (Janzen 1976, John and Nadgauda 1999). In gregarious flowering, all members of the cohorts enter the reproductive phase approximately at the same time and after flowering and seeding, the parents die *en mass* (Tewari 1992, John and Mascarenhas 1994). Gregarious flowering of bamboo alarms different magnitude of impacts, be it socio-economic or environmental issues; it causes drastic change in forest ecosystem and environmental conditions including decline of soil nutrient pool and microbial population (Chauhan and Saxena 1985, Marod *et al*. 2002, Takahashi *et al*. 2007, Rai 2009). Nutrient uptake by the bamboo ceases after the completion of mass flowering and fruiting huge quantity of dry matter are deposited in the forest (Takahashi *et al*. 2007). Decline in primary nutrients status might involve many factors including nutrient imbalances, excess foliar, drought sensitivity, pathogen attack and soil acidification (Nihlgard 1985). Hence, the study attempts to illustrate the changes in soil physical and chemical parameters during pre-flowering, flowering and post-flowering phases of *Dendrocalamus hamiltonii* forests in Arunachal Pradesh and *Melocanna baccifera* forests in Mizoram of Eastern Himalayas, India.

II. Materials And Methods

Detail study in *Dendrocalamus hamiltonii* forest in East Siang District in Arunachal Pradesh located between 27°58′ N latitude and 95°17′ E longitude with an elevation ranging from 247- 305m asl and *Melocanna baccifera* forest in Mamit District in Mizoram located between 23°54′ N latitude and 92°29′ E longitude with an elevation range from 115 - 695m asl, respectively, were carried out considering Pre-flowering, Flowering and Post-flowering phases during gregarious flowering episodes in 2008- 2010. Three plots each for pre-flowering, flowering and post-flowering phases were selected within. Soil samples from surface (0-15cm depth) and sub-surface (15- 30cm depth) layer were collected in the form of composite soils on seasonal basis for a period of two consecutive years from October 2008 till July 2010. Samples were air dried, sieved through a mesh of 2mm to remove stone particles and gravels; and then passed through 0.5mm mesh screen for the determination of chemical properties of soil. Soil samples were examined accordingly on seasonal basis through periodic sampling. Soil moisture content was determined gravimetrically by taking 10g of fresh soil and the result were expressed in oven-dry weight basis. Soil pH was determined electrometrically by a digital pH meter (SYSTRONICS-335) in 1:2.5 suspension of soil in deionized water (Anderson and Ingram 1993). Oxidizable soil organic carbon was determined by rapid titration method (Walkley and Black 1934). Total kjeldahl nitrogen

(TKN) was determined by digesting air-dried soil samples with concentrated sulphuric acid using Kjeltab (TECATOR) as catalyst, on a block digester followed by distillation in a KEL PLUS distillation system and manual titration. Available forms of P and K were determined by UV-VIS spectrophotometry (LABOMED) and photometry (SYSTRONICS), respectively, following the methods as outlined by Allen *et al.* (1974) after extraction through standard solutions. Data were statistically treated using STATISTICA 6 and graphical presentation were made through ORIGIN 7.0 to study the changes in different phases, sampling period, soil depth and study years on edaphic variables.

III. Results And Discussion

Soil moisture content in *D. hamiltonii* and *M. baccifera* forests differ significantly among pre-flowering, flowering and post-flowering phases and in all the sampling months (Table 1). However, difference between the two soil depths was significant only in *D. hamiltonii* forest. On the other hand, significant decrease in soil moisture content from first year to the second study years was only observed in *M. baccifera* forest of Mizoram (Table 1). Soil moisture content was observed highest in Post-flowering phase (PF) and lowest in Pre-flowering phase (NF) in both forests, where peak moisture content was recorded during July and least in January in both forests (Fig. 1). Soil moisture content was comparatively higher in *D. hamiltonii* forest in Arunachal Pradesh to that of *M. baccifera* forest in Mizoram during the study period. Seasonal variations in precipitation play a significant role in the soil moisture content in the forests. In Post-flowering and flowering phase soil moisture accumulation and absorption capacity increases with the increasing quantity of organic matters due to large scale dead in bamboos. Presence of non-capillary pores increases in dead bamboo forest, through which water are accumulated (Wu *et. al* 1992, Ben-zhi *et al*. 2005, Takahashi *et al.* 2007).

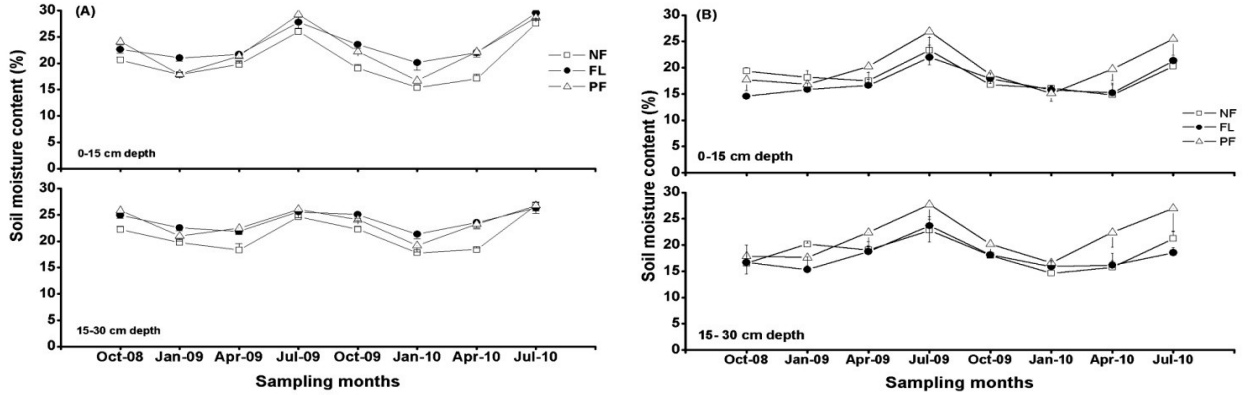

Figure 1. Temporal variation in soil moisture content in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

Variation in soil pH was significant among the three phases, different sampling months, soil depths and studied years in *D. hamiltonii* forest, although in *M. baccifera* significant variation was observed in three phases, sampling months and soil depths (Table 1). pH declined from Pre-flowering to Post-flowering phase in both the bamboo forests, where highest pH value was recorded in April and lowest in July in all the three phases and acidity decrease with the increase in soil depth (Fig. 2). After gregarious flowering in bamboo forests, soil increase vulnerability to leaching, which is a major source and one of the most important limiting factors for soil pH in the hilly topography that cause to increase in soil acidification (Rowell 1998, von Uexkull and Mutert 1995). Seasonal variation in pH has been resulted mainly due to the variation in precipitation and soil microbial actions. Consequently, acid soils incorporate with number of problems, including toxicity of aluminium, manganese and iron as well as deficiencies of phosphorus, calcium, magnesium, potassium and micronutrients (Schroth and Sinclair 2003). Thus increase in soil acidity could become an issue for insufficient NPK in the long run (Gazey 2009).

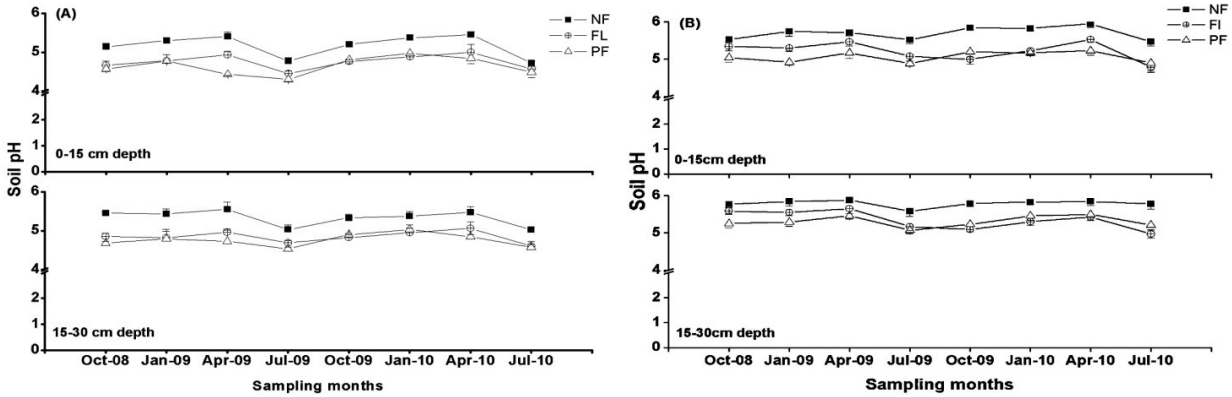

Figure 2. Temporal variation in soil pH at 0-15cm and 15-30cm depth in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

Soil organic carbon varies significantly among the three phases, different soil depths and among the sampling months in all the phases for both bamboo forests (Table 1). Soil organic carbon declined from post-flowering to pre-flowering phases in both the bamboo forests, where higher value of soil organic carbon was recorded in the surface soil layer than the subsurface soil layer and it was peak in October and least in April (Fig. 3). Bamboo proliferates through rhizome during spring season in which huge sum of soil organic carbon must be utilized. Decomposition of accumulated organic matters resulted in increasing soil organic carbons. Post-flowering and Flowering sites accumulated higher quantity of organic matters especially in these gregarious flowering instances that could be gradually incorporated with soil organic pools (Takahashi *et al.* 2007). On the other hand, organic carbon recorded in pre-flowering sites could be an optimum quantity for the maintenance of their ecosystem, although, factors such as loading of dry leaves, twigs, branches and culms from dying bamboo lead to increase soil organic carbon after initiation of gregarious flowering in bamboo forest.

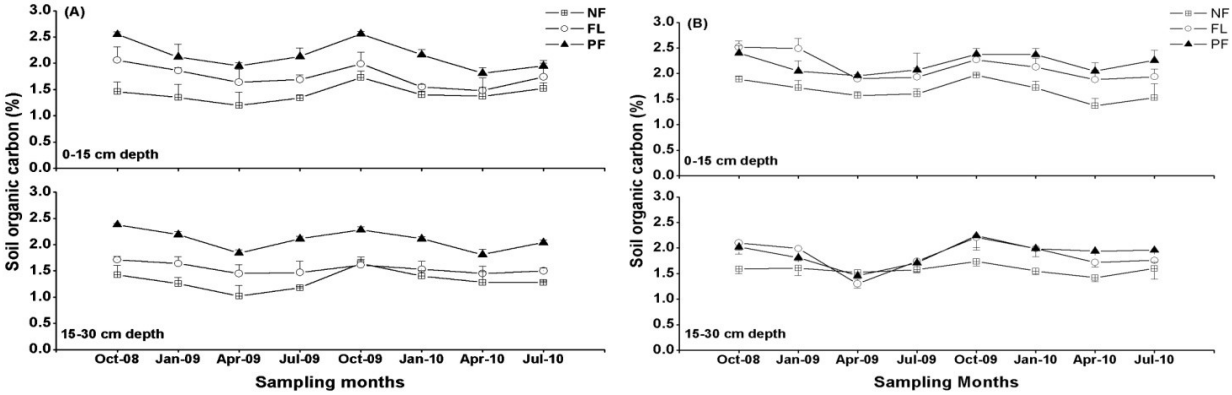

Figure 3. Temporal variation in soil organic carbon at 0-15cm and 15-30cm depth in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

Soil total nitrogen varied significantly among the three phases, different soil depths, sampling months in both the bamboo forests, although, in the studied year, there was only significant change in *M. baccifera* forest (Table 1). Total N content was recorded highest during pre-flowering phase to that of flowering and post-flowering phases in both bamboo forests, however, the difference in N content between the flowering and post-flowering phases was insignificant in both bamboo forests (Fig. 4). Soil total N was peak in April and lowest in July and also significantly higher in surface soils to that of subsurface soils in both study years in all phases (Fig. 4). Nitrogen loss in flowering and post-flowering phases may be incorporated with denitrification due to higher moisture content in soil and it increases when the soil remains saturated. It also losses during breaking down of organic matters in low oxygen, generally in saturated soil (Laboski 2008). Leaching is also a major influencing factor for reducing N being a precipitous and hilly region (Berg and Staaf 1980)

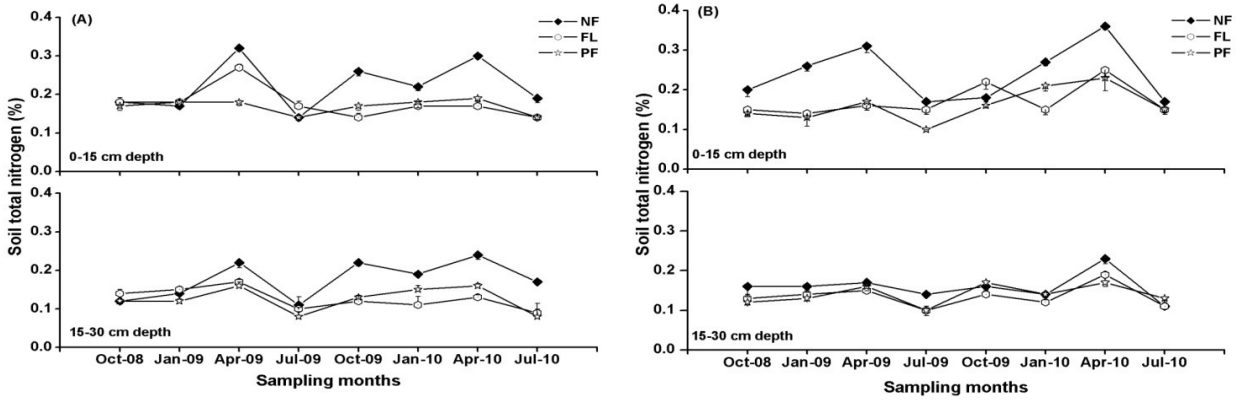

Figure 4. Temporal variation in soil Total nitrogen at 0-15cm and 15-30cm depth in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

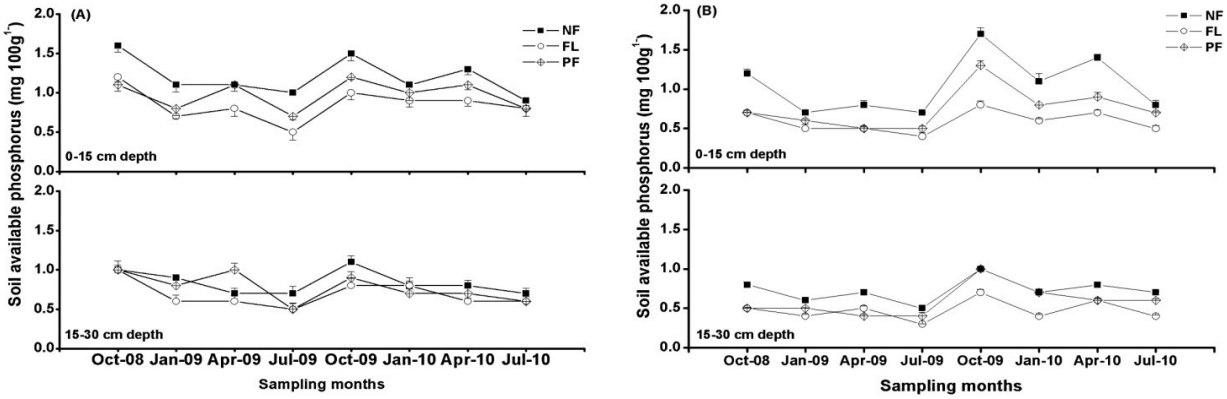

Figure 5. Temporal variation in soil available phosphorus at 0-15cm and 15-30cm depth in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

Soil available P content in the surface soils of *D. hamiltonii* and *M. baccifera* forests show significant variations among the three phases, different sampling months as well as two soil depths (Table 1). P content was significantly high during the pre-flowering phase followed by post-flowering and lowest during flowering phase in both *D. hamiltonii* and *M. baccifera* forests (Fig. 5). Peak value was observed in October and lowest in July (Fig. 5). During pre-flowering phase, peak available P in soil was recorded in the month of October with a gentle decline till July and a sharp increase in October of next year and follows the similar trend of the previous year. In case of flowering phase, available P decline sharply by January and lowest in July with a sharp increase in October which continued till January of next year. In case of post-flowering phase, available P was highest in October and April months with a lowest value in July in both study years. Low P availability could be link with the uptake of more P during reproductive stage; as in bamboo, gregarious flowering and seeding occurred in mass scale. Besides, in most environmental conditions P act as limiting element due to smaller concentration in soil against the demand of plants and microbes (Hopkins and Huner 2008). In addition, unavailability of P could as well be related with the tied up of P in organic matter and inorganic sediments; adsorption of phosphate onto clay particles, iron and aluminium hydroxides, etc. (Mitch and Gosselink 1993). It also becomes difficult with the mobilization of reserves in acid soils (Duchaufour 1998). Due to high precipitation and being hilly gradient in both study sites, soil P is regularly eroded from ecologically disturbed sites.

Significant variation in soil available potassium content among the three different phases, sampling months, two soil depths and study years were observed in both forests (Table 1). Highest value of soil available K was recorded during pre-flowering phase, however, lowest was recorded during post-flowering phase in *D. hamiltonii* and flowering phase in *M. baccifera* forest (Fig. 6). Peak soil available K was recorded in April and lowest in October, where surface soil contains higher K than the subsurface soils in both the study sites (Fig. 6). K leaching could be a factor for the low content in soils in the flowering and post-flowering sites, besides, excess water due to high precipitation increase the risk of K leaching in sandy soils including low CEC values, high sodium, calcium and magnesium content (Hodges 2006, McAfee 2008). After mass flowering in bamboo a large stock of standing crops died in a short span which is similar to removal of crops, such events moreover influence to depletion in K rapidly by escalating soil compaction, acidity, etc. (Taylor 1998).

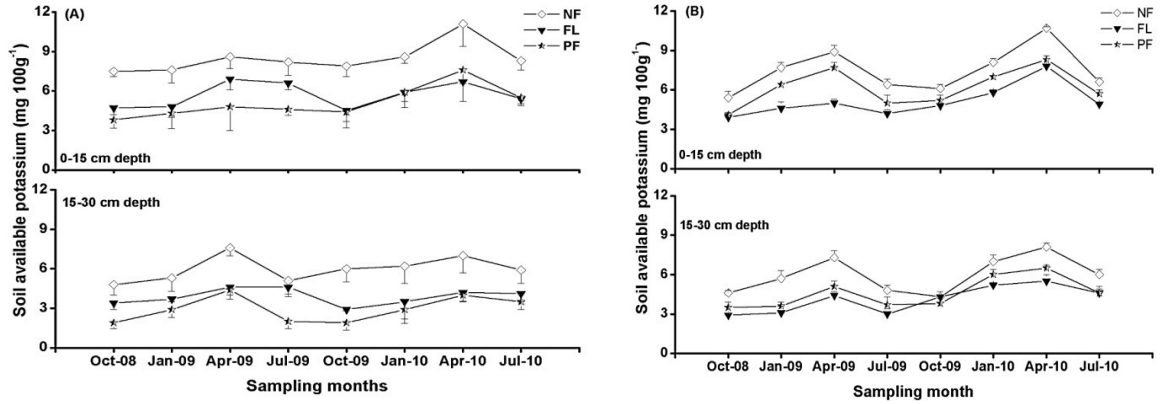

Figure 6. Temporal variation in soil available potassium at 0-15cm and 15-30cm depth in pre-flowering (NF), flowering (FL) and post-flowering (PF) phases in *D. hamiltonii* (A) and *M. baccifera* (B) forests

TABLE 1. Analysis of variance of soil physical and chemical parameters in *D. hamiltonii* and *M. baccifera* forests

Source of variance	Soil parameters (N= 144) *Dendrocalamus hamiltonii* forests						Soil parameters (N= 144) *Melocanna baccifera* forests					
	Soil moisture	Soil pH	Soil organic carbon	Total N	Available P	Available K	Soil moisture	Soil pH	Soil organic carbon	Total N	Available P	Available K
	F value	F value	F value	F value	F value	F value	F value	F value	F value	F value	F value	F value
Phases	65.7*	109.8*	106.3*	85.0*	45.0*	175.8*	25.3*	54.2*	37.9*	77.7*	29.5*	412.1*
Sampling month	241.7*	34.9*	16.9*	73.6*	59.7*	32.5*	66.3*	10.8*	19.4*	90.1*	7.9*	373.9*
Soil depth	9.4**	14.4*	8.5**	163.2*	121.6*	218.2*	3.3 NS	10.5**	28.5*	44.3*	22.2*	516.6*
Study year	1.4 NS	6.7***	0.03 NS	3.2 NS	2.9 NS	10.0**	8.7**	0.1 NS	2.0 NS	171.7*	1.5 NS	308.9*
Phases X Month	6.3*	2.7***	0.6 NS	7.7*	2.8***	1.5 NS	4.9*	0.5 NS	1.1 NS	9.7*	1.2 NS	16.5*
Phases X Depth	0.5 NS	0.5 NS	1.0 NS	0.3 NS	6.9**	1.8 NS	0.9 NS	1.0 NS	2.4 NS	23.2*	1.8 NS	9.7*
Month X Depth	20.6*	0.9 NS	0.7 NS	1.3 NS	3.0***	0.3 NS	0.9 NS	0.1 NS	0.3 NS	7.1*	0.3 NS	12.6*
Phases X Year	2.5 NS	4.2***	3.9***	43.5*	0.1 NS	6.3**	3.2***	5.2**	3.3***	5.4**	2.6 NS	11.8*
Month X Year	6.8*	0.4 NS	0.2 NS	6.2*	1.4 NS	0.7 NS	4.2*	0.2 NS	0.2 NS	8.0*	0.7 NS	8.6*
Depth X Year	1.1 NS	2.1 NS	0.1 NS	3.0 NS	2.0 NS	5.0***	0.04 NS	0.9 NS	3.7 NS	12.6*	2.9 NS	2.5 NS
Phases X Month X Depth	0.9 NS	0.2 NS	0.4 NS	3.0 ¯	0.5 NS	0.3 NS	0.3 NS	0.2 NS	0.5 NS	6.5*	1.3 NS	0.6 NS
Phases X Month X Year	1.6 NS	0.1 NS	0.3 NS	2.8***	3.6**	0.7 NS	0.8 NS	0.5 NS	0.9 NS	3.3**	2.4***	1.4 NS
Phases X Depth X Year	1.2 NS	0.03 NS	0.1 NS	0.1 NS	1.6 NS	0.9 NS	1.0 NS	0.1 NS	0.7 NS	2.4 NS	0.5 NS	1.8 NS
Month X Depth X Year	0.6 NS	0.2 NS	0.2 NS	0.8 NS	0.6 NS	4.4**	0.3 NS	0.8 NS	0.6 NS	1.3 NS	1.0 NS	13.2*
Phases X Month X Depth X Year	0.4 NS	0.4 NS	0.1 NS	1.1 NS	0.9 NS	1.1 NS	0.9 NS	0.1 NS	0.3 NS	1.8 NS	0.2 NS	4.9*

*= P< 0.001, **= P< 0.01, ***= P< 0.05 , NS= not significant

IV. Conclusion

Role of bamboo in nutrient cycling is contrasted when it approaches reproductive and senescent phase. During the phenomena of gregarious flowering particularly in these two species, primary macronutrients such as NPK in soil were less in bamboo flowering and post-flowering phases. However, soils in the pre-flowering phase follows usual trend of nutrient variation and the ratio among the soil nutrients must be under optimum requirement for the support of the forests. Producing huge quantity of inflorescence during gregarious flowering may be responsible for rapid uptake and translocation of nutrients to the sink i.e. developing flowers and fruits in *D. hamiltonii* and *M. baccifera*. Therefore, soil degradation in flowering and post-flowering phases in the respective bamboo forests might be a result of imbalances in the cycling of nutrients on the occasion of gregarious flowering. Hence, present findings illustrate that soil NPK decreases, whereas soil moisture, acidity and organic carbon increases when bamboo approached to flowering and post-flowering phase. Such variations in soil parameters were similarly observed among the two different bamboo forests. Therefore, either gregarious flowering in bamboo lead in the alteration in soil properties or changes in soil properties lead to the induction of flowering in bamboo. Although, a thorough studies on the relationship among plants, soil and environments during pre-flowering, flowering and post-flowering phases would be required to fully understand for the variations in soil parameters and the dead of bamboo.

Acknowledgement

The authors wish to thank the Department of Science and Technology, New Delhi, India, for the support in part through a grant during the study.

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