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Status of soil chemical properties in the monoculture plots of exotic and indigenous tree species in Sakhipur upazila of Tangail district, Bangladesh

Md. Mijanur Rahman*, Saleh Ahammad Khan, Gazi Mosharof Hossain

Department of Botany, Faculty of Bilogical Sciences, Jahangirnagar University,

Savar, Dhaka, Bangladesh

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Abstract

This study has assessed the status of soil chemical properties and its probable impacts of the monoculture of exotic species *Acacia auriculiformis* A. Cunn. ex Benth. and *Eucalyptus camaldulensis* Dehnh. in comparison to the plantation of indigenous species *Shorea robusta* Roxb ex. Gaertn and *Mangifera indica* L. in twelve research plots in Sal forest area of Sakhipur area of Tangail district. Soil properties pH, N, P and K of *Acacia*-, *Eucalyptus*-, *Shorea*- and *Mangifera* plots were significantly different except in case of OC. The monoculture of exotic species *Acacia* and *Eucalyptus* might have significant impacts on pH, N, P and K of the soil of the study area, but they do not have any influence on OC. The influence of all of the soil chemical properties studied was not prominent on vegetation dynamics of the study area. Soils of all plots were found to be acidic in nature and this result was in the general agreement that *Shorea* forest occurs mainly in acidic soil, nevertheless *Acacia* also grows well in acidic soils. It seems that, clear felling, fuel wood collection, leaf litter collection, grazing, firing and making pathways for the walking by the local people etc. were recognized as soil degrading factors. Indigenous Sal forest conservation and mixed species tree plantation should be conducted which may improve soil health in the study area.

***Corresponding Author:** Md. Mijanur Rahman ✉ md.mijanur@gmail.com

Introduction

Soil properties can also be interpreted in terms of the favorability of a soil for the growth of plants. Forest management with indigenous species has been recognized to be the only way to ensure, under certain conditions, a sustainable form of land use. The plantation of indigenous plant species can maintain soil and water values, and actively protects biodiversity and always been the important sources of timber, fruits, food, fodder, fuel, bamboo, canes, medicines etc. But the landuse changes as well as exotic tree species plantation have altered the vegetation in the indigenous forests. The Sal forests are considered one of the richest ecosystems in regard to forest diversity which is playing an important role to global climate change mitigation i.e. carbon sequestration and carbon sink (biomass storage). But unfortunately this indigenous forest in Bangladesh are now threatened due to diverse anthropogenic activities (Malaker *et al.*, 2010; Motiur, 2006; Alam *et al.*, 2008; Haque, 2007 and Rahman *et al.* 2010). Anthropogenic factors like continuous removal of fallen leaves from soil surface, over-exploitation of different economically important species, illegal cutting and stealing of trees, exotic tree species plantation, indiscriminate use of herbs, shrubs and small trees, intentional forest floor fire, soil erosion, etc. were earmarked for the reduction of phytodiversity as well as the degradation of soil quality in the indigenous Sal forests (Rahman, 2001). Due to changes in the landuse pattern in the Sal forests tract, below ground soil decomposer community has been changed (Hossain *et al.* 2010). Sal (*S. robusta*) is extremely eco-friendly and its dead leaves, once mixed with the soil, increase soil fertility (Gain, 1998). The exotic tree species negatively affect the environment and ecosystems, pose threat to indigenous plants, wildlife species, soil and water resources, soil ecology and dynamics, soil nutrient loss and degradation, biological diversity and agricultural ecosystems. (Randall, 1996; Vitousek *et al.*, 1996; Williamson and Fitter, 1996; Kaiser, 1999; D'Antonio *et al.* 2001; Hulme, 2003; Kil *et al.*, 2004; Pimentel *et al.*, 2005; Simberloff, 2005; Dogra *et al.*, 2010, Cossalter and Pye-Smith, 2003; Rosoman, 1994; Dogra *et al.*, 2010). Exotic tree species, i.e. *Eucalyptus* or *Acacia,* is blamed for uptaking more water than other species, reducing soil fertility leading to soil erosion, soil degradation and loss of plant productivity, providing harmful environment for wildlife and prohibiting the formation of native understorey vegetation (EL-Khawas and Shehata, 2005; Forrester *et al.*, 2006; Dreschel *et al.,*1991; Bernhard-Reversat and Loumeto, 2002; Davidson, 1995; Lemma *et al.* (2007). Against the backdrop Forrester *et al.* (2005) reported *Eucalyptus* plantations with other nitrogen fixing tree species (polyculture) have potential to maintaining soil fertility in comparison to *Eucalyptus* monocultures. However the published information and research articles on the soil chemical properties of exotic species plots and indigenous Sal forests of the Sakhipur areas of Tangail are not available. The objective of this research was to examine the soil chemical properties and comparative status of soil nutrients of selected exotic and indigenous tree plots in different seasons.

Materials and methods

Study area and location

The Sakhipur upazila occupies an area of 435 km² including 191 km² forest area. The upazila is bounded on the north by Ghatail upazila on the east by Bhaluka upazila of Mymensingh district and Sreepur upazila of Gazipur district, on the south by Mirzapur upazila and Kaliakair upazila of Gazipur district and on the west by Basail and Kalihati upazilas (BBS, 2012). Sakhipur upazila is consisted of 6 unions, 1 pouroshova, 59 mauza, and 122 villages (BBS, 2012). Sakhipur is situated in 80 km north from Dhaka the capital city of Bangladesh. It is located between 24°11´and 24°26´ N latitudes; and between 90°04´ and 90°18´ E longitudes (Fig. 1.).

Climate

The Sakhipur area enjoys a sub-tropical monsoon climate with three distinct seasons, viz., summer (March to mid June), monsoon (mid June to mid October) and the winter (mid October to February). Among the climatic factors, rainfall, humidity, sunshine penetration, evaporation and evapo-transpiration, canopy structure etc. affect the growth and development of vegetation, woodlots and *Shorea* trees as well as the associated undergrowth species to varying extents. The climatic data has been collected from National Water Resource Database (NWRD) of the Center for Environmental and Geographic Information Services (CEGIS) and analyzed accordingly. The mean annual rainfall 1937mm (ranges from 1126 to 2748mm) and the mean annual temperature 25.86°C (ranges from 20.25°C to 31.48°C). This tropical climate condition is characterized by a distinct rainy season from April to October and a strong dry season from November to March. The relative humidity varies between 69% and 86%, the duration of sunshine ranges from 5-9 hours and average wind speed is 87 km/hour. Average MSL elevation of the area is 19 m. (NWRD/CEGIS, 2015).

Soil

Sakhipur area belongs to the bio-ecological zone of Madhupur Sal (*S. robusta*) tract (Nishat *et al.* 2002). According to Richards and Hassan (1988), the soils of this area have a moderate to strong acidic reaction. The topography of this area is characterized by plain land or low hills rising 3.0-4.5 m above the surrounding paddy fields, locally known as 'Chalas', which are intersected by numerous depressions or 'Baids' (Ismail and Miah, 1973). Three major soil types are observed in Sakhipur areas, *viz.*, deep red brown terrace soils; shallow red brown terrace soil and brown mottled terrace soils (Richards and Hassan, 1988). About half of the Sal forests land is covered by deep red brown terrace soil. The soils are moderately to strongly acidic in reaction with pH 5.0-5.5 (UNDP/FAO, 1988). Major physical problems of soils of this tract are low organic carbon content, low fertility and low moisture holding capacity (Alam, 1995). The partly weathered/unweathered Madhupur tract clay is very compact and greatly affects root penetration of crop (Amin *et al.*, 1995).

Selection of research plots

The strategies for selection of research plots were comprised of (i) data of Bangladesh Forest Department on the exotic tree plantation in Madhupur Sal tract, (ii) field reconnaissance survey, (iii) record of previous studies in Madhupur Sal tract, (iii) data on the availability of massive plantations of exotic species (*A. auriculformis*), (iv) consideration of the existence of homogeneous factors etc. and (v) relevancy with the objectives of this study. Hence purposive random sampling framework was employed to make the final selection of 12 sample plots based on the diverse ecological habitats, topography, tree species composition and vegetation cover of the forest areas of Sakhipur (Fig. 1.). These 12 research plots located in public and private land were composed of three plots of each *A. auriculiformis*, *S. robusta, E. camaldulensis* and *M. indica*. The size of research plot 36 m x 36 m = 0.132 ha was considered suitable in connection to research objectives (Fig. 1.). The exotic species *A. auriculiformis* occupied the major percentage of plantation at Sakhipur upazila of Tangail district, but the plantations of *E. camadulensis* and *S. macrophylla* represented very less percentage of plantation in that area.

Soil sample collection and analysis

Bangladesh has a subtropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Usually there are three seasons were generally recognized: a hot, humid summer from March to June; a less hot, rainy monsoon season from June to October; and a cool, dry winter from October to March. These three seasons were considered for sampling and recording data from the selected sites.

The representative data were collected over a period of two years ranging from April 2010 to November 2011. The soil samples of the selected sites were collected and recorded three times per year, i.e., 2 times in each of April, July, and November months covering summer, monsoon and winter seasons respectively. Soil samples were collected from 12 research plots (with 3 replications for each plot) of exotic (*Acacia* spp. and *Eucalyptus* spp.) and indigenous plantations (*S. robusta* and *M. indica*) of the study area to know the chemical properties.

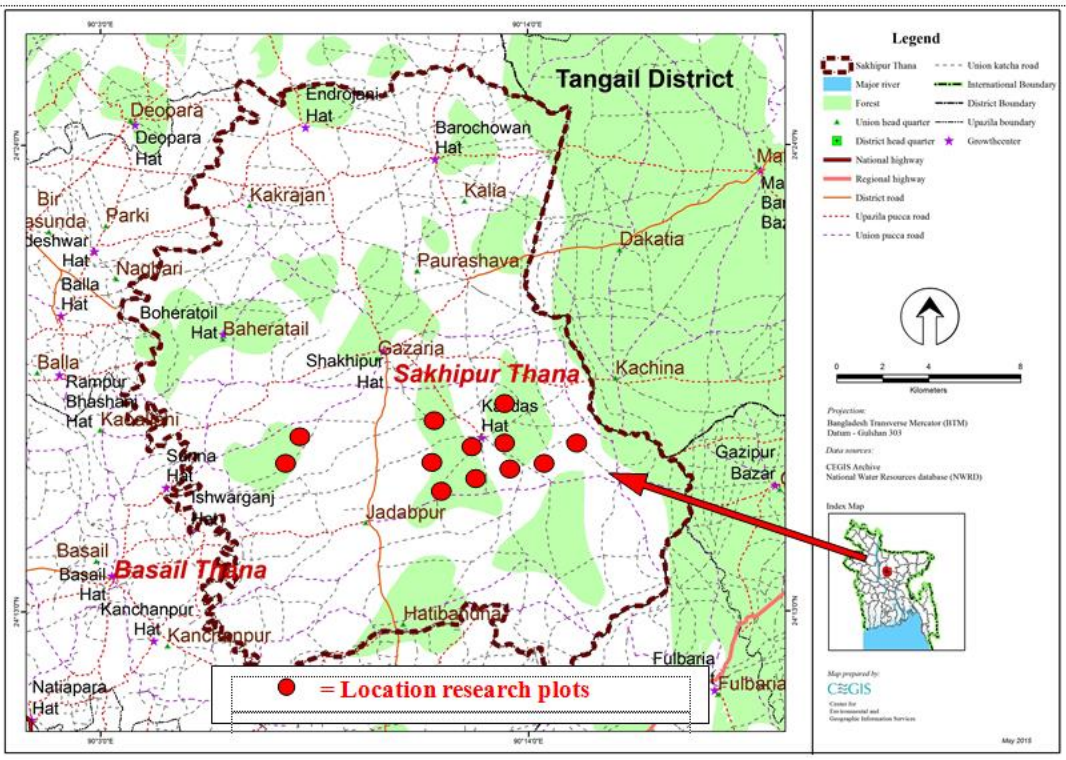

Fig. 1. Location of research plots in the study area, Sakhipur, Tangail (CEGIS, 2015).

Soil samples from surface level to 30cm depth were collected through soil augur (considering 3 replications for each plot). Three composite (mixture) soil samples, each of which was prepared by mixing two original soil samples, were collected from each study plot. The collected soil samples were then dried in shade sun and passed through a 2mm sieve. The sieved soil samples of about 500 gm were then taken into sample polybags, tagged and preserved for conducting chemical analysis. This procedure was followed in collection of soil samples from all research plots. Thus a total of 36 composite soil samples were collected from 12 research plots in each season that means a total of 216 soil samples (12 plots x 3 composite samples x 6 season) were collected from these research plots in six seasons over two years.

Soil Data Analysis

Soil sampling and testing provides an estimate of the capacity of the soil to supply adequate nutrients to growing plants. The collected soil samples were analyzed to determine some major chemical properties of soils to assess the soil nutrient status which is very important to tree growth.

The soil analysis was done to know the status of pH, OC, OM, N, P and K in the soil samples. The laboratory analyses of all soil samples were conducted in SRDI Laboratory, Farmgate, Dhaka. Standard scientific methods were followed for soil chemical properties analysis. Data were statistically analyzed using SPSS software (version 16.0). One way ANOVA (DMRT) was used to test for significant differences ($P<0.05$) for marginal means of variables. Besides, data were also analyzed through Microsoft Excel.

pH

Soil pH was measured electro-chemically by using Griffin (Model-40) glass electrode pH.

Organic Carbon

Soil organic carbon was determined by Walkley and Black's (1934) wet oxidation method using 1 gm soil outlined by Jackson *et al.* (1973).

Nitrogen

Total nitrogen was determined by micro-Kjeldahl's distillation method following extraction from 2 gm soil with concentrated H_2SO_4 (sulfuric acid) as described by Jackson *et al.* (1973).

Phosphorus

Available soil phosphorus was extracted with Bray-1 reagent (Bray and Kurtz, 1945). The phosphate content of the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962). The intensity of color was determined by using Spectrophotometer.

Potassium

Potassium was determined in the same solution (same as Phosphorus analysis) by atomic absorption spectrophotometer following the procedure mentioned by Bray and Kurtz (1945).

Results and discussion

pH

The pH values recorded from the soil samples of the selected plots during three different seasons were found to be acidic and varied from 3.80 to 6.00. The highest mean pH value 4.95±0.41 was recorded from the soil samples of *Mangifera* plot which was followed by *Shorea* (4.67±0.42) and *Acacia* (4.52±0.50) plots, whereas the lowest mean pH value 4.48±0.48 was recorded from the soil samples of *Eucalyptus* plots. On the other hand, the average values of soil pH varied among the three seasons, where the highest mean pH value 5.16±0.16 was found during winter season and followed by 4.52±0.27 during summer season, whereas the lowest value 4.29±0.22 was recorded during monsoon season. Considering the average pH values recorded from all of the four types of research plots during three different seasons showed the following sequence- *Mangifera* > *Shorea* > *Acacia* > *Eucalyptus* plots (Table 1).

The most important single electro-chemical preperties of soils that influence the physical, chemical and bilogical preperties is the soil pH. This important property of the soils of study area indicated that, in the distant past the study area was a vast area of Sal forest and geographically it is a part of Modhupur Pleistocene terrace. Soils of all of the sites were found to be acidic in nature which favors *Shorea* forests, that are acidic soil lover (Ganggopadhyay *et al*., 1990; Rashid *et al*., 1995; Rahman, 2001). These pH values indicated that, soil pH was somewhat variable in the Sakhipur areas of Tangail and no remarkable change was found between exotic monoculture planted sites with comparison to indigenous forest sites in this study (Table 1). Islam *et al*. (1999) showed presence of average pH value 5.30 in both *Acacia* and *Eucalyptus* plots of four years old plantation in the forest land of Chittagong, Chowdhury and Huda (2002) reported the average pH value 4.43 in *Acacia* plots in the forests of Bangladesh, Haque and Karmakar (2009) found the pH value 4.47 in the forest areas of Chittagong region, that are nearly consistent to the present study. Tyynela (2001) reported the average soil pH value 5.46 in *E. camaldulensis* woodlots in north-east Zimbabwe, which was slightly higher than the data recorded in this study.

The findings on pH values by this study are in consistent also with Rahman (2001) who found pH values from 4.41-4.96 in Sal forests of Bangladesh and Rashid *et al*. (1995) who showed the range of pH values from 4.47 to 5.77 in Chandra Sal forest araes.

Dutta and Agrawal (2002) found the range of pH values as 6.61–6.86 in the plots of *A. auriculiformis* which is remkarkebly higher than the finding of this research. Islam *et al*. (2001) recorded the soil pH of woodland with exotic species as 5.08-5.27 and Roy, *et al*. (2011) reported the soil pH condition in natural *Shorea* forest in Modhupur national park as 5.30 and these range of pH values are somewhat higher but in conformity with the finding of this study results (Table 1). Ganggopadhyay *et al*. (1990) reported the pH values in range of 5.30 to 6.70 in the Sal area of West Bengal, India. Nearly same results were reported by Sapkota *et al*. (2009) who found the average soil pH value 5.50 in Sal forest of Nepal and Chaturvedi and Raghubanshi (2014) who found the pH value 6.26 in Sal forest of India.

These findings of pH in India and Nepal are somewhat higher than the findings of the present research.

Table 1. Average values of pH, OC, N, P, K contents recorded from exotic and indigenous plots during different seasons in Sakhipur, Tangail (Average values shows with ±SD).

Type of plots	Season	pH	OC	N	P	K
Acacia	Summer	4.34±0.17	0.77±0.13	0.08±0.01	2.92±1.57	0.18±0.04
	Monsoon	4.13±0.12	0.92±0.21	0.09±0.02	2.12±0.46	0.19±0.03
	Winter	5.08±0.08	1.00±0.21	0.07±0.02	1.31±0.30	0.17±0.05
	Average	4.52±0.50	0.79±0.13	0.08±0.01	2.12±0.80	0.18±0.01
Eucalyptus	Summer	4.32±0.14	0.83±0.18	0.08±0.02	2.73±0.72	0.19±0.06
	Monsoon	4.11±0.11	0.83±0.18	0.08±0.02	2.89±0.67	0.16±0.05
	Winter	5.02±0.19	0.68±0.21	0.07±0.02	2.69±1.02	0.16±0.05
	Average	4.48±0.48	0.78±0.09	0.08±0.01	2.77±0.11	0.17±0.02
Exotic	Summer	4.33±0.15	0.80±0.15	0.08±0.02	2.83±1.19	0.18±0.05
	Monsoon	4.12±0.11	0.87±0.19	0.09±0.02	2.51±0.68	0.17±0.04
	Winter	5.05±0.14	0.67±0.20	0.07±0.02	2.00±1.02	0.18±0.11
	Average	4.50±0.49	0.80±0.04	0.08±0.01	2.45±0.42	0.17±0.01
Shorea	Summer	4.50±0.20	0.74±0.18	0.07±0.02	2.65±2.17	0.23±0.03
	Monsoon	4.36±0.19	0.94±0.14	0.09±0.01	1.97±0.33	0.22±0.03
	Winter	5.14±0.09	0.85±0.15	0.07±0.02	1.35±0.47	0.22±0.07
	Average	4.67±0.42	0.94±0.13	0.08±0.01	1.99±0.65	0.23±0.00
Mangifera	Summer	4.90±0.52	0.90±0.15	0.09±0.02	6.40±2.88	0.21±0.14
	Monsoon	4.57±0.70	0.96±0.21	0.10±0.02	4.41±2.70	0.22±0.04
	Winter	5.38±0.44	0.72±0.07	0.07±0.01	5.27±2.92	0.21±0.16
	Average	4.95±0.41	0.86±0.12	0.09±0.01	5.36±1.00	0.21±0.01
Indigenous	Summer	4.70±0.44	0.82±0.18	0.08±0.02	4.52±3.14	0.22±0.10
	Monsoon	4.46±0.51	0.95±0.17	0.09±0.02	3.19±2.25	0.22±0.03
	Winter	5.26±0.33	0.71±0.12	0.07±0.01	3.31±2.86	0.22±0.12
	Average	4.81±0.41	0.90±0.12	0.08±0.01	3.67±0.74	0.22±0.01

Organic Carbon (OC)

The values of OC contents (%) recorded from the soil samples of the selected plots during three different seasons were varied from 0.06% to 1.50%. The highest mean OC value 0.94±0.13% was recorded from the soil samples of *Shorea* plot which was followed by *Mangifera* (0.86±0.12%) and *Acacia* (0.79±0.13%) plots, whereas the lowest mean OC value 0.78±0.09% was recorded from the soil samples of *Eucalyptus* plots. The average values of OC also varied among the three seasons, where the highest mean OC value 0.91±0.06% was found during monsoon season and it was followed by 0.81±0.07% during summer season and by 0.69±0.02% during winter season. Based on the data regarding average values of OC contents found in four types of research plots during three different seasons showed the following sequence as- *Shorea* > *Mangifera* > *Acacia* > *Eucalyptus* plots (Table 1). In *Acacia, Eucalyptus, Shorea* and *Mangifera* plots, collectively in exotic monoculture and the indigenous tree plots the organic carbon were found more or less same percentage (Table 1). Islam *et al.* (1999) in the forest land of Chittagong found OC values 0.65% and 0.51% in *Acacia* and *Eucalyptus* plots respectively in four years old plantation which is comparatively less than the record of this study. Ganggopadhyay *et al.* (1990) reported the OC values to vary from 0.11% to 0.63% in the Sal area of West Bengal, India, Dutta and Agrawal (2002) found maximum OC value 0.60% in the plots of *A. auriculiformis* in India and Tyynela (2001) found the average soil OC value 0.47 in *E. camaldulensis* woodlots in north-east Zimbabwe. All of these findings on OC values are notably lower than that recorded by this study. But Chaturvedi and Raghubanshi (2014) found the OC value was 1.54% in Sal forest of India which is remarkably higher than the record of this study (Table 1). Rahman (2001) reported that, the OC values in the Sal forests area might be vary due to the removal of forest litter by the local forest dwellers, leaf collection, tree twigs removal and illegal cutting of trees/undergrowth, human settlement in this areas.

Nitrogen (N)

The N contents (%) values recorded from the soil samples of the selected plots during three different seasons were varied from 0.01% to 0.15%. The highest mean N value 0.09±0.01% was recorded from the soil samples of *Mangifera* plot, which was followed by

0.08±0.01% in all of *Shorea, Acacia* and *Eucalyptus* plots. On the other hand, the average values of N varied among the three seasons, where the highest mean N value 0.09±0.01% was found during monsoon season and followed by 0.08±0.00% during summer season, whereas the lowest value 0.07±0.00% was recorded during winter season.

The average values of N contents recorded from four types of research plots of this study showed the following trend- *Mangifera* > *Shorea* > *Acacia* > *Eucalyptus* plots (Table 1). In the four types of research plots in *Acacia*, *Eucalyptus, Shorea* plots, the N values was same (0.08±0.01%) except *Mangifera* plots (0.09±0.01%), collectively in exotic monoculture and the indigenous tree plots it was same (Table 1). Chowdhury and Huda (2002) found average N value 0.09% in *Acacia* plots in forests of Bangladesh which is in consistent with this study. Islam *et al.* (1999) reported N value 0.06% from four years old *Acacia* plots in Chittagong which is comparatively less than the record of this study. Dutta and Agrawal (2002) found N values ranges from 0.05% to 0.06% in the plots of *A. auriculiformis* which is comparatively less than the record of this study. Although *A. auriculiformis* had higher amounts of litter fall, a slow litter decomposition rate could have been responsible for the lack of significant variations in soil N values (Duguma and Tonye, 1994). Rahman (2001) found the N values ranges from 0.07% to 0.09% in the Sal forest and Ganggopadhyay *et al.* (1990) reported the N values ranges from 0.02% to 0.08% in the Sal forest area in West Bengal, India that are in conformity with the records of this study.

The findings of comparatively much higher soil N value 0.11% in natural degraded Sal forest in Modhupur by Roy *et al.* (2011), N value 0.16% in the Sal forest of India by Chaturvedi and Raghubanshi (2014) and N value 0.34% in Sal forest of Nepal by Sapkota *et al.* (2009) are not supported by the results of this study that might be affected by the amounts of leaf litter falls, growth of understory vegetation, mode of forest protection and conservation, and extent of climate and biological nitrogen fixation in soils. Rahman (2001) observed that, total N value were fairly good in Modhupur Sal forest areas compared to other Sal forest areas and the degraded Sal forest possesses low value of N in comparison to other ecological habitat of Sal forests, supported by this study. In this study, the N value was found comparatively more, perhaps due to fast-growing exotic trees have extensive root systems with profuse bundles of N-fixing nodules that have allowed them to survive and grow on plantation sites, compete with weeds successfully, higher amounts of litter fall and improve the soil characteristics over time (NAS, 1980 and Cole *et al.*, 1996).

Phosphorous (P)

The P values (µg/g) recorded from the soil samples of the selected plots during three different seasons were varied from 0.08 µg/g to 11.26 µg/g. The highest mean P value 5.36±1.00 µg/g was recorded from the soil samples of *Mangifera* plot which was followed by *Eucalyptus* (2.77±0.11 µg/g) and *Acacia* (2.12±0.80 µg/g) plots, whereas the lowest mean P value 1.99±0.65 µg/g was recorded from the soil samples of *Shorea* plots. On the other hand, the average values of P varied among the three seasons, where the highest mean P value 3.68±1.82 µg/g was found during summer season and followed by 2.85±1.12 µg/g during monsoon season, whereas the lowest value 2.66±1.86 µg/g was recorded during winter season. Data regarding the average P values recorded from the selected four types of research plots showed the following trend- *Mangifera* > *Eucalyptus* > *Acacia* > *Shorea* plots (Table 1). The P values (µg/g) in these four types research plots indicated that P was variable (Table 1). The soil chemical properties analyses showed that, the soil properties of exotic and indigenous tree plots notably varied only in respect to available P. The P values was exceptionally high (5.36 µg/g) in *Mangifera* plots perhaps due to different cultural practices and fertilizer application in comparison to other plots. Islam *et al.* (2001) recorded the average available soil P value 0.46 µg/g in woodlands which is comparatively less than the record of this study. Chowdhury and Huda (2002) revealed the average P value was 3.80 in *Acacia* plots in forests of Bangladesh and Dutta and Agrawal (2002) found the average available P value 3.60 µg/g in the *A. auriculiformis* plots in India that are notably higher than the available P content found in this study. Roy *et al.* (2011) reported soil P value 2.16 µg/g from natural degraded Sal forest in Modhupur which is nearly similar to the value reported by this study. Rahman (2001) reported P values the ranges from 1.96 to 34.66 µg/g in the Sal forest soils, which was very much higher than that of this research finding, though he reported that the degraded *Sal* forest possesses the exceptionally high value of available P in comparison to other ecological habitat of Sal forests.

Potassium (K)

The K values (meq/100g soil) recorded from the soil samples of the selected plots during three different seasons were varied from 0.06 meq/100g to 0.74 meq/100g. The highest mean K value 0.23±0.00 (meq/100g) was recorded from the soil samples of *Shorea* plot which was followed by *Mangifera* (0.21±0.01 meq/100g) and *Acacia* (0.18±0.01 meq/100g) plots, whereas the lowest mean K value 0.17±0.02 meq/100g was recorded from the soil samples of *Eucalyptus* plots. On the other hand, the average values of K varied among the three seasons, where the highest mean K value 0.20±0.02 meq/100g was found during summer and monsoon season and it was followed by 0.19±0.03 meq/100g during winter seasons. Thus, considering the average K values recorded from four types of research plots during three seasons showed the following trend- *Shorea* > *Mangifera* > *Acacia* > *Eucalyptus* plots (Table 1). The K values (meq/100g soil) found in the studies indicated the presence of somewhat different amounts of available K values in all types of research plots and these differences also found collectively in exotic monoculture and indigenous tree plots (Table 1). Status of K, the most important soil nutritional elements of *Shorea* forest ecosystems of Bangladesh, were studied by Rahman (2001) who reported K value ranges from 0.09 to 0.19 meq/100g in the Sal forest soil of Modhupur tract, which is in conformity with that of the present study. Ganggopadhyay *et al.* (1990) reported that K value ranges from 0.05 to 0.81 meq/100g in the Sal area in West Bengal, India that covers the range of K values reported by this study. Roy *et al.* (2011) reported K value 0.30 meq/100g in natural degraded Sal forest in Modhupur, Bangladesh which is somewhat higher than the findings of the present research.

Results of Duncan's Multiple Range Test (DMRT) analysis of the data on soil properties of four types of research plots indicate that soil pH of the four types of plots significantly differed but no difference existed between the mean values of OC (Table 2). *Acacia* and *Eucalyptus* plots showed significant difference with *Shorea* and *Mangifera* plots for N and P content. Only *Eucalyptus* plots showed significant variation to rest of the plots for K content of the soil. Based on the findings of DMRT analysis, it can be concluded that, whatever the extent is, the monoculture of exotic *Acacia* or *Eucalyptus* had significant impacts on pH, N, P and K, but no influence on OC of the soil. Soils of all plots were found to be acidic in nature and this result was in the general agreement that *Shorea* forest occurs mainly in acidic soil, nevertheless *Acacia* also grows well in acidic soils.

Table 2. Results of DMRT analysis of the data collected on soil properties of four types of research plots in Sakhipur, Tangail.

Plot type	pH	OC	N	P	K
Acacia	4.5861ab	.8088a	.0806ab	2.4494ab	.2014b
Eucalyptus	4.4833a	.7780a	.0772ab	2.7730b	.1696a
Shorea	4.6975b	.7629a	.0758a	1.9836a	.2203b
Mangifera	4.9517c	.8593a	.0859c	5.3587c	.2144b

Note: Values in the same column that do not share common letters are significantly different at 5% (α = 0.05) level among the plots after DMRT.

In general, *Shorea* prefers acidic soil with pH ranges from 4.57 to 4.81. The organic carbon values were found to be poor in the *Shorea* forests of Bangladesh which may be due to uninterrupted leaf litter collection and consequent soil erosion of the exposed forest floor. Values of total nitrogen (N) and available potassium (K) were more or less uniform both in *Shorea* forest sites as well as in other habitats of the study area. However, the soils of Sakhipur areas were found to be the most suitable for sustainable growth and development of *Shorea* and exotic tree species, especially *Acacia* and their plantations and these findings were supported by Das (2008). Soil chemical properties factors play a potential role on the vegetation dynamics in that area though the every chemical attribute of soil do not have direct influence or effect on vegetation dynamics. However, increased availability of organic carbon (OC) and occurrence of numerous leguminous plants might have enhanced the N status, and hence the supply of plant available nutrients in the area. In the study area, clear felling, fuel wood collection, leaf litter collection, grazing, firing and making pathways for the walking by the local people etc. were recognized as soil degrading factors. It was further noticed that, due to geographical location and easy encroachment, the diversity of undergrowth resources in *Shorea* forests as well as their soil nutritional potentialities are being degraded through different activities, creating severe consequences in *Shorea* forest ecosystem and these observation are mostly supported by Rahman (2001).

According to the results and field observation of this study, the influences of all of the soil chemical properties were not prominent on the vegetation dynamics in the study area (Rahman *et al.*, 2016).

In another part of this study Rahman *et al.* (2016) depicted that, in *M. indica* plots, the grasses and sedges, was higher in respect to that of other plots, whereas, in the plots of *A. auriculiformis* and *S. robusta*, the individual number of undergrowth tree seedlings and saplings were higher than that of *M. indica* and *E. camaldulensis* tree plots. During this study most of the exotic tree plots were found to be dominated by the individuals of small herbaceous species, especially of grasses and sedges, in respect to the indigenous plots due to which relatively more plant individuals were found in exotic plots. However, the number of grasses, sedges, seedlings and saplings in the study areas indicated that the natural regeneration takes place moderately satisfactorily. Another scholar Rahman (2001) also stated in his study that prominent influences of soil chemical properties on overall phytodiversity, species richness or on the vegetation dynamics were not found in Sal forest ecosystems.

Conclusion

Findings of these results concluded that, the monoculture of exotic *Acacia* and *Eucalyptus* might have significant impacts on pH, N, P and K of the soil of the study area, but they do not have any influence on OC. Monoculture of exotic tree species (woodlot) plots fails to ensure plant diversity and therefore, be discouraged for massive afforestation programs (Rahman *et al.*, 2016). Soil physical and chemical properties need to be investigated thoroughly in the Sal tract. In order to maintain proper soil health, and to address climate change mitigation as well as soil carbon sequestration Sal forest conservation management and mix species plantation is essential for the sake of environment.

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