Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer Reviewed Journal

Open Access
Research Article

Res. Agric. Livest. Fish.
Vol. 2, No. 1, April 2015: 17-25

INFLUENCE OF DIFFERENT STANDS OF SAL (*Shorea robusta* C. F. Gaertn.) FOREST OF BANGLADESH ON SOIL HEALTH

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ARTICLE INFO

Received
15.03.2015

Accepted
12.04.2015

Online
15.04.2015

Key words
Soil health
Sal forests
Chemical properties
Fungi

ABSTRACT

The study was conducted in Dukhula sadar and Gasabari forest range under Madhupur Sal Forest of Bangladesh to determine the soil nutrient composition and isolation of fungi with varying stands. Three stands viz. pure sal, plantation and mixed were considered as treatment of the study. A quadrate sample plot of 10×10 m^2 size was measured to collect soil samples for both chemical analysis and fungi isolation. Soil pH, electrical conductivity, organic matter content, total N, available P, exchangeable K, available S, fungal abundance and colony character (cm) were determined to achieve the objective of the study. The results revealed that soil pH and electrical conductivity were highest (6.61 and 21.10µS/cm) in mixed stand and lowest (6.38 and 10.75µS/cm) in pure stand. Organic matter content and total N were highest (2.24 and 0.145%) in plantation stand and lowest (1.65 and 0.112%) in mixed and pure stand, respectively. Available P, exchangeable K and available S were highest (3.65, 98.66 and 17.53ppm) in pure stand and lowest (1.97, 79.49 and 10.25ppm) in plantation stand. In addition, four fungal genera *Sclerotium, Rhizoctonia, Pythium* and *Verticillium* were identified in the study area soils. The highest fungal population (entire genus except *Verticillium)* (colony number/g soil) was found in mixed stand while it was found lowest in pure (*Sclerotium*) and plantation stand (*Rhizoctonia* and *Pythium*). There was no significant variation in colony diameter of the fungi among the treatments. Therefore, it can be concluded that better soil health was maintained in natural forest rather than plantation forest.

To cite this article: MK Hasan and MB Mamun. 2015. Influence of different stands of sal (*Shorea robusta* C. F. Gaertn.) forest of Bangladesh on soil health. Res. Agric. Livest. Fish. 2 (1): 17-25.

INTRODUCTION

Every country has needs at least 25% of forest coverage of its total area for balance environmental condition. But Bangladesh has only 17.08% of forest coverage (Bangladesh Forest Department, 2013). For sustainability of existing forest coverage, it is essential to ensure the soil fertility of the forest. Soil nutrient content and the maintenance of site fertility is one of the most important factors to consider when designing forest management systems. Although forest productivity is influenced by other factors such as temperature, water availability, and incoming radiation, nutrients are essential to forest growth and directly influenced by forestry operations. The most important nutrients in forests are the macronutrients such as N, P, S, K, Ca, and Mg, each of which is needed directly for plant growth. Micronutrients such as Mn, Fe, Cl, Cu, Zn, B, Mo, and Co are also required by plants, but are usually abundant in soils and rarely limit plant growth (Binkley, 1986). Within a forest stand, nutrients exist in many forms and distinct pools and are cycled between soils and plants. Plants uptake nutrients from the soil solution and incorporate them into biomass, which is then returned to the soil through litterfall, root turnover, and tree mortality. This biomass or organic matter is then decomposed by soil organisms such as bacteria and fungi that excrete enzymes to breakdown organic molecules into smaller units, liberating nutrients and making them available to plants again (Chapin et al., 2002). This cycle regulates fluxes between individual nutrient pools, which vary in size and turnover rates.

Forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigor of natural reproduction and other silviculturally important factors (Bhatnagar, 1965). For instance, growth of *Shorea robusta* (Sal) and other tree species, such as *Terminalia alata* and *Syzygium cumini*, in tropical forests is highly influenced by nitrogen, phosphorus, potassium, and soil pH (Bhatnagar, 1965). Physiochemical characters of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic and abiotic factors. Vegetation plays an important role in soil formation. For example, plant tissues both from aboveground litter and belowground root detritus are the main source of soil organic matter, which influences physiochemical characteristics of soil such as pH, texture and nutrient availability (Johnston, 1986).

The plain land 'Sal' forest is situated in central and northern parts of the country covering an area of 1, 20,000 ha about 0.81% of total land mass of the country and 7.8% of the country forest land. Most of the Sal forest areas are covered by Madhupur Sal forest. Sal (*Shorea robusta*) is the dominant species of this forest. The importance of Sal forests lies in the fact that these are the only natural forest resources of the central and northern parts of Bangladesh where the vast majority of the population dwells. These forests have a high economical and ecological significance in the central part of Bangladesh. Historically, the agrarian rural people around the forests have been heavily dependent on Sal forest resources for their livelihood. People living in close proximity to the Sal forest, particularly various ethnic groups such as the Garos, Koch and Hajongs totally depend on its resources to meet their subsistence needs (Rahman et al., 2010). The study area of this research has high population density, 1485 persons per km^2 (BBS, 2011). As a result, demand for land for both settlement and agricultural uses within forested areas have accelerated the rate of deforestation with loss of ecosystem productivity and biological diversity, leading to overall environmental degradation in the area. Various forestry activities, human disturbances, industrialization and climate change have significant impacts on Sal forest ecosystems of Bangladesh. Therefore, the Forest Department of Bangladesh has been taken some initiatives to save the Sal forests of Bangladesh like reforestation, afforestation, etc. through participatory forestry programme under the social forestry with *Acacia* spp. and *Eucalyptus* spp. (Bangladesh Forest Department, 2013). This social forestry or plantation forestry activities can bring change to the rural people lifestyle, but it is not sure that it can sustain the soil fertility and microbial activities of natural forest. Therefore, it is necessary to examine the soil health besides the plantation forestry for sustainable forest coverage. This is indeed needed for understanding the biogeochemical processes that shape the forests in order to ensure their protection specially the soil properties of the forests. An understanding of these conditions is also essential for developing forest management policies in Bangladesh. Several studies have been investigated on several aspects of soils in various forest types throughout the world and in Indian sub-continent by many more researchers (Rawat et al., 2009). Some studies on soil and leaf litter nutrients and their effects on crops have been carried out for individual forest by Iltuthmish et al. (2006), Chowdhury et al. (2007), Zaman et al. (2008), Haider et al. (2009), Sarker et al. (2010), Hossain et al. (2011) in Bangladesh. However, the information on soil analysis of Madhupur Sal forest of Bangladesh is still in small pockets.

Therefore, it thought necessary to analyze biological and chemical characteristics of soils of the Madhupur Sal forest of Bangladesh. Keeping in view of the above aspects the study was undertaken to characterize the nutritional composition and isolation of major fungi present in soils of Madhupur Sal forest of Bangladesh with varying stands.

MATERIALS AND METHODS

Study area and sampling design

The study was conducted in Dukhula sadar and Gasabari forest range under Madhupur Sal Forest of Tangail district. The soils of the areas are highly oxidized reddish brown clay with moderate to strong acidic reaction. Sal (*Shorea robusta*) is the dominant species of this forest and usually it forms 75% to 25% of the upper canopy in the natural habitat (Alam, 1995). Besides, other species like mixture of Sal (*Shorea robusta*), Koroi (*Albizzia* spp.), Azuli (*Dillenia pent*agyna), Sonalu (*Cassia fistula*), Bohera (*Terminalia bellir*ica), Haritaki (*Terminalia chebula*), Kanchan (*Bauhinia acuminata*), Jarul (*Lagerstroemia speciosa*), Jam (*Syzygium* spp.), etc. are grown in this forest. Presently participatory forestry programs are being implemented here under the social forestry initiatives with *Acacia* spp. and *Eucalyptus* spp. According to the above information and species distribution, three stands were distinguished from the selected forest ranges which were considered as treatments of the study. These are:

T_1= Pure stand (including *Shorea robusta*)

T_2= Plantation stand ((including *Acacia* spp., *Eucalyptus* spp.)

T_3= Mixed stand (including *Shorea robusta, Albizzia* spp., *Dillenia pentagyna, Cassia fistula, Terminalia bellirica, Terminalia chebula*, *Bauhinia acuminata*, *Lagerstroemia speciosa*, *Syzygium* spp., etc.).

Within the above mentioned stands, a 10×10 m^2 quadrate plot with four replications following random sampling was made for each stands of the selected forest ranges in Madhupur Sal forest to collect soil sample.

Soil samples collection

From each quadrate plots, five soil cores was taken with an auger at 0-15 cm depth randomly. A total of 20 soil cores were collected from four replicated plots for each stand. Then the collected soil cores from the same plot were well mixed to make one composite sample. Each sample was placed in a sterile plastic bag, sealed and transported to the laboratory. All soils were air dried and grounded and passed through a 2.0 mm sieve and stored at 4^0C until the chemical analysis was conducted. For fungal isolation same procedure was followed to collect soil cores from each quadrate plots. Then the collected soil cores were placed plot wise in a sterile polybag, wrapping with brown paper, sealed and carefully transported to the laboratory and stored at 4^0C until the isolation was started.

Soil chemical analysis

From the collected soil samples, soil pH was determined by Glass electrode pH meter (WTW pH 522) at a soil-water ratio of 1:2.5 as described by Ghosh et al. (1983) and electrical conductivity by a conductivity meter method as described by Jackson (1958). Percentage soil organic carbon was determined using Walkley–Black method modified by Anderson and Ingram (1989). Organic matter was calculated from the content of organic carbon by Van Bemmelen factor, 1.73. Assuming that organic matter contains approximately 58% C. Total N was determined by semi-micro Kjeldahl method. Available P was measured by Bray and Kurtz method outlined by Tandon (1995) where phosphorus extracted from soil using 0.5M $NaHCO_3$ at a nearly constant pH 8.5. Exchangeable K was extracted by ammonium acetate (1NNH_4OAc) and measured by digital flame photometer and S (extractable sulphate) was extracted by 0.15% $CaCl_2$ and measured following turbidimetric procedure improved by Hunter (1984) where the turbidity measured by spectrophotometer at 420 nm wavelengths.

Soil biological analysis

Soil fungi were isolated by using dilution plate technique (Warcup, 1955). For making dilution of soil samples, 1 g working sample was prepared from the composite soil sample and dilution was made up to 10^{-4}.

Then diluted soil sample (10^{-4}) was placed at the center of Potato dextrose agar (PDA) in the glass petri-dish and spreaded well with a glass rod. Five petri-dishes for each treatment were inoculated with 1 ml of diluted sample. This was repeated with every soil sample. Potato dextrose agar (PDA) media was prepared with potato (peeled and sliced), dextrose, agar and water. The inoculated PDA plates were incubated for 4-5 days at room temperature (25±1°C). The colonies grow out on PDA medium was recorded every day after 3-5 days of incubation. The number and diameter of colonies developed in each PDA plates were counted and average values were calculated for each sample. Number of colonies per ml of soil suspension was calculated by its colony forming units (CFU). The number of CFU/g sample was calculated by using following formula:

Population of fungi= Average number of total colonies/ml in five Petri-dishes × Dilution factor (10^{-4})

Most of the isolated fungi were identified up to genera level with the help of the book "Illustrated Genera of Imperfecti Fungi" (Barnett, 1965) and a manual of soil fungi (Gilman, 1957). Moreover, morphology and taxonomy of Fungi (Bessay, 1964), Fungi in Agricultural Soils (Domsch and Gams, 1972) were also consulted to identify fungi.

Data analysis

The collected data were tabulated and analyzed through a standard computer package statistical procedure MSTAT-C (Gomez and Gomez, 1984). Duncan's Multiple Range Test (DMRT) was used to rank the results of soil samples analysis.

RESULTS AND DISCUSSION

Soil chemical properties

Soil pH

The result shows that chemical and biological reactions of soils are regulated by soil pH. The average pH values of the study soils such as pure stand, plantation stand and mixed stand were recorded as 6.38, 6.55 and 6.62, respectively (Table1). Soil pH of mixed stand was the highest (6.62) which was statistically higher compare to the pH of pure stand and plantation stand. Similar results was also found by Khan et al. (1997) who reported that the pH values of the different soil series of the Madhupur clay soils of Madhupur tract ranged from 5.6 to 6.1.

Electrical Conductivity (EC)

The average electrical conductivity values of the study soils such as pure stand, plantation stand and mixed stand were recorded as 20.11, 10.75 and 21.10µS/cm, respectively (Table 1). The highest (21.10µS/cm) soil electrical conductivity was measured in mixed stand which was statistically different to the electrical conductivity of pure stand and plantation stand. The lowest EC was found in plantation stand (Table 1). Gomes (2005) also found that the electrical conductivity of Madhupur Sal forest soil ranged from 6 to 57µS/cm which was supportive to the present study.

Organic matter (OM)

The result shows that the highest (2.24%) organic matter content of Madhupur Sal forest was appeared in plantation stand compare to both pure (1.72%) and mixed stand (1.65%) (Table 1). Accumulation of plant leaves might have caused to the increment of organic matter in case of plantation stand. Leaf litter of plantation species might add huge amount of organic matter to the soil in plantation stand. It is in line with Gomes (2005) who found that organic matter content of the surface soil (0-15 cm depth) of Madhupur Sal forest varies from 0.70% to 2.11%.

Total nitrogen (N)

Soil total N content in different treatments followed the similar trend like soil organic matter content (Table 1). The highest total nitrogen content (0.145%) was measured in plantation stand soil which was statistically different from the total nitrogen in soil of pure stand (0.112%) and mixed stand (0.112%). Basically there was no significant difference between pure stand and mixed stand total N content. Gomes (2005) found that the total nitrogen content of Madhupur Sal forest soil varies from 0.026% to 0.105% at 0-30 cm soil depth which was strongly supported by the present findings.

Available phosphorus (P)

The average available phosphorus content of the study soils such as pure, plantation and mixed stand was recorded as 3.65, 1.97 and 2.39ppm, respectively (Table 1). The available phosphorus in soil of pure Sal stand was the highest (3.65ppm) which was statistically differ to available phosphorus content in soil of plantation and mixed stand. The higher levels of soil nutrients in the pure forest were due partly to reduction in the loss of top soil and partly to the increased supply of nutrients in the form of leaf litter and biomass from the larger number of Sal trees and their saplings rather than plantation stand and mixed stand.

Exchangeable potassium (K)

The result shows that the exchangeable potassium content in soil of pure Sal stand was the highest (98.66ppm) which was statistically dissimilar from exchangeable potassium content in soil of plantation and mixed stand soils of Madhupur Sal forest area. Paudel and Sah (2003) also found the same kind of result that higher values of humus, organic matter, nitrogen and potassium (7.34%, 2.42%, 0.117%, 267.73 kg/ha, respectively) were found in pure forest soils.

Available sulphur (S)

The available sulphur in soil of pure Sal stand was the highest (17.53 ppm) which was statistically differing to available sulphur content in soil of plantation (10.25 ppm) and mixed stand (13.85 ppm) (Table 1). Similar results also found by Akter (2009) who stated that the available S content of Madhupur forests soil was 13.41 ppm at upper 0-15 cm soil layer which was highly supported by the above findings.

Table 1. Chemical properties such as Soil pH, Electrical Conductivity (EC), Organic matter, Total N, Available P, Exchangeable K and Available S of study areas soils in Madhupur Sal forests of Bangladesh.

Treatments	Soil pH	EC (µS/cm)	OM (%)	N (%)	P (ppm)	K (ppm)	S (ppm)
T_1	6.38 c	20.11 b	1.72 b	0.112 b	3.65 a	98.66 a	17.53 a
T_2	6.55 b	10.75 c	2.24 a	0.145 a	1.97 c	79.49 c	10.25 c
T_3	6.62 a	21.10 a	1.65 c	0.115 b	2.39 b	84.57 b	13.85 b
LSD $_{(0.05)}$	0.024	0.121	0.014	0.005	0.004	0.033	0.043
CV (%)	0.234	0.469	0.484	2.809	0.226	0.023	0.200
Level of significance	**	**	**	**	**	**	**

T_1= Pure stand, T_2= Plantation stand, T_3= Mixed stand. **= significant at 1% level of probability. In the column figure(s) having same letter(s) do not differ significantly. LSD= Least Significant Difference; CV= Co-efficient of variation

Soil biological properties

Biological properties of studied three soils such as pure stand, plantation stand and mixed stand were presented by the diversity and abundance of major fungal genera isolated from soil samples. Based on the colony color and microscopic observation of different structures, four genera of fungi were identified in the studied soils. The genera were *Sclerotium*, *Rhizoctonia*, *Pythium* and *Verticillium*.

Fungal abundance (Colony number/g soil)

For *Sclerotium* spp. colony number/g soil at 5 Days after incubation (DAI) was significantly higher (9.75) in mixed stand than pure (3.75) and plantation stand (5.50). At 6 DAI, colony number/g soil was also significantly higher in mixed stand (12.00) than pure (8.00) and plantation stand (8.00). Accordingly at 7 DAI colony number/g soil was significantly higher in mixed stand (12.50) than pure (8.25) and plantation stand (8.25) (Figure 1, Figure 2 and Figure 3).

In case of *Rhizoctonia* spp. at 5 DAI colony number/g soils was significantly highest (7.50) in mixed stand and lowest (4.00) in plantation stand which was statistically similar to pure stand (5.50). At 6 DAI, colony number/g soil was significantly higher in mixed stand (10.75) compare to pure (6.00) and plantation stand (6.00). At 7 DAI, colony number/g soil was found in similar pattern stated above at 6 DAI (Figure 1, Figure 2 and Figure 3).

In case of *Pythium* spp. highest (5.25) colony number/g soil was observed in mixed stand and lowest (2.25) in plantation stand at 5 days after interval. At 6 and 7 DAI colony number/g soil was significantly higher in mixed stand (5.25 and 6.00) than pure (3.00 and 3.50) and plantation stand (3.50 and 3.75) (Figure 1, Figure 2 and Figure 3).

For *Verticillium* spp. colony number/g soil was found similar in case of all treatments at 5 DAI, 6 DAI and 7 DAI. It means that there was no significant variation appeared among pure, plantation and mixed stand soils of Madhupur Sal forest areas (Figure 1, Figure 2 and Figure 3).

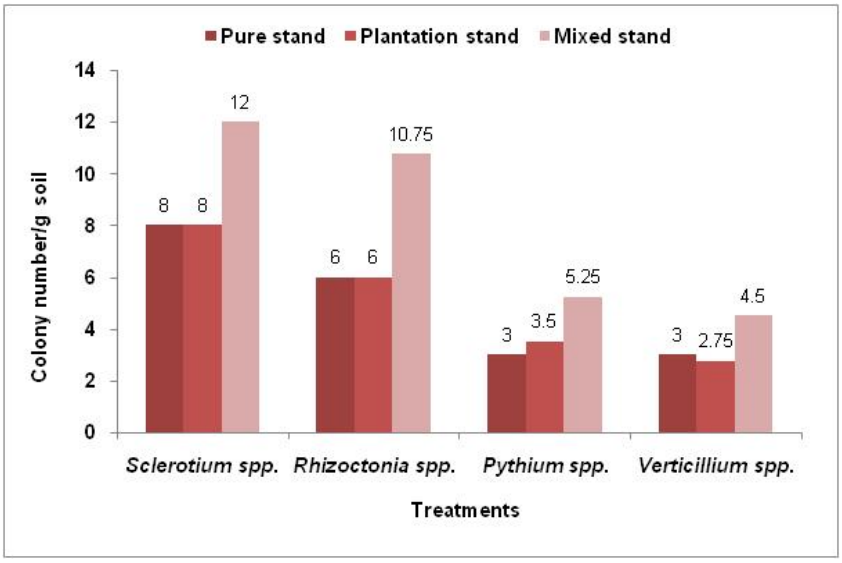

Figure 1. Bar graph showing colony number/g soil of four identified fungi (*Sclerotium* spp., *Rhizoctonia* spp., *Pythium* spp., *Verticillium* spp.) of study area soils at 5 DAI

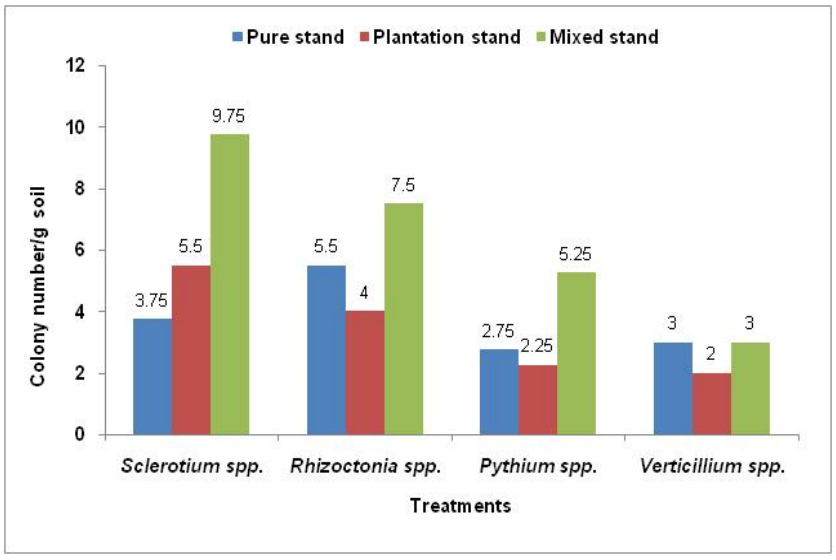

Figure 2. Bar graph showing colony number/g soil of four identified fungi (*Sclerotium* spp., *Rhizoctonia* spp., *Pythium* spp., *Verticillium* spp.) of study area soils at 6 DAI

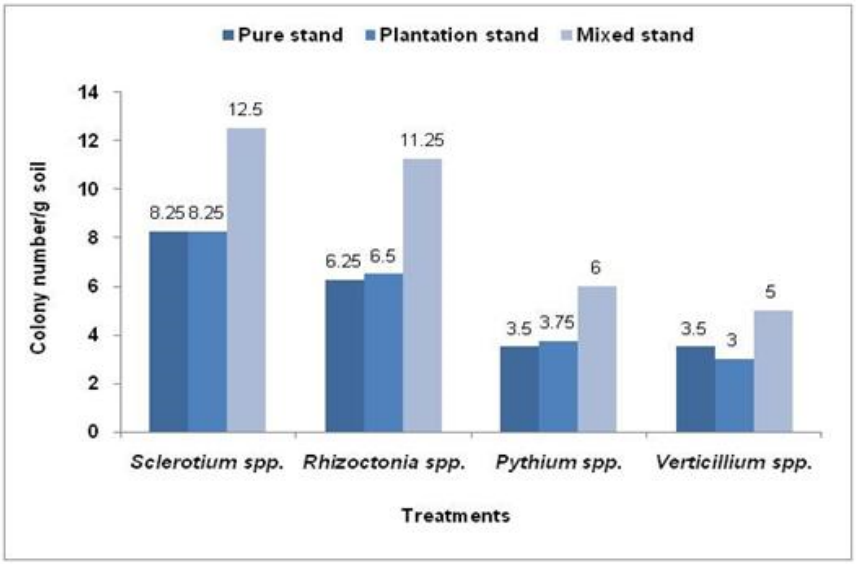

Figure 3. Bar graph showing colony number/g soil of four identified fungi (*Sclerotium* spp., *Rhizoctonia* spp., *Pythium* spp., *Verticillium* spp.) of study area soils at 7 DAI

Colony character

For the all four genera (*Sclerotium, Rhizoctonia, Pythium* and *Verticillium*) stated in the above section, colony diameter (cm) or colony growth was observed similar and there was no significant variation among the treatments at 5 DAI, 6 DAI and 7 DAI (Table 2).

Table 2. Colony diameter (cm) of four identified fungal genera at 5 DAI, 6 DAI and 7 DAI

Fungal genera	Colony diameter (cm)								
	5 DAI			6 DAI			7 DAI		
	T_1	T_2	T_3	T_1	T_2	T_3	T_1	T_2	T_3
Sclerotium	1.75	2.25	1.75	2.5	2.75	2.25	2.75	3.0	3.25
Rhizoctonia	1.5	2.0	2.5	2.0	2.0	2.75	2.0	2.25	3.0
Pythium	1.0	1.25	1.0	1.5	2.0	1.75	2.0	2.25	2.0
Sclerotium	1.0	1.0	1.25	1.75	1.75	1.75	2.0	2.0	2.0
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS

T_1=Pure stand, T_2=Plantation stand, T_3=Mixed stand; 'NS' mean non-significant; CV=Co-efficient of variation

CONCLUSION

From this experiment it can be concluded that the overall nutrient content was higher in pure and mixed stands compare to plantation stand of Madhupur Sal forests. Similarly total fungal population was higher in pure and mixed stands characterized as less undisturbed forest sites rather than highly disturbed plantation stand. The higher amount of soil nutrients and fungal population in the pure forest and mixed forest were due partly to reduction in the loss of top soil and partly to the increased supply of nutrients in the form of leaf litter and biomass from the larger number of trees and their saplings rather than plantation stand.

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