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# NITROGEN TRANSFORMING ORGANISMS IN SOME FOREST SOILS OF CHITTAGONG UNIVERSITY CAMPUS

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## ABSTRACT

Association of nitrogen transforming bacteria in soils under six-forest tree plantations viz. *Lagerstroemia speciosa, Acacia auriculiformis, Acacia mangium, Dipterocarpus turbinatus, Tectona grandis,* and *Eucalyptus camaldulensis* were assessed in the present study. *Azotobacter* population was the least among the nitrogen-transforming bacteria in all soils. Soils under *L. speciosa* had the lowest population of ammonifying, *Nitrosomonas, Nitrobacter* and denitrifying bacteria and *A. auriculiformis* had higher average MPN values, although *E. camaldulensis* had the highest *Nitrobacter* population. Population of the microorganisms was positively and significantly correlated with each other, except *Azotobacter*. *Azotobacter* was only significantly correlated with the denitrifying bacteria. The nitrogen-transforming microorganisms were significantly related with the total nitrogen content and pH of the forest soils.

**Key words**: Nitrogen transforming organisms, Forest soils, Tree Plantation.

## INTRODUCTION

There are 1.43 million ha reserve forests and 0.73 million ha state forests corresponding to 10 and 6.7 percent respectively of the total land area in Bangladesh. The actual area under forest cover is much less, possibly less than 6 percent of the total land area (Hassan 1994). Efforts have been taken to combat the situation by afforestation and reforestation considering the economic and environmental aspects. Evergreen and mixed evergreen tropical rain forests once existed in the southeastern hills of Bangladesh. As the original dense natural cover has largely been removed, land and vegetation have been severely degraded. The Forest Department has planted several fast growing exotic tree species, such as acacias and eucalypts. There are plantations of some other indigenous fast growing species such as *Albizia lebbeek, Albizia procera, Dalbergia sisso,* etc., and slow growing species, such as *Dipterocarpus turbinatus, Eugenia grandis, Hopea odorata, Chikrassia tabularis,* etc.

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Forest vegetation mostly depends on the biological cycling of nutrients. Under natural undisturbed conditions, the nutrient cycling remains in an equilibrium with the ecosystem. When the forests are cleared or reforested by destroying the past vegetation, this balance is shifted and both soil fertility and tree nutrition are affected. Among all the nutrients, nitrogen is affected more because the sole source of nitrogen is the organic matter. For these reasons, transformation of nitrogen in forest soils has received much attention. Some workers (Zhang *et al.* 1988) have indicated that nitrogen transformation is related with the forest type and some others (Muller *et al.* 1980) showed that it could depend on forest management. There are some reports that the nitrogen supply to forest plants and nitrogen nutrition depend to a considerable extent on the ammonification and nitrification rates (Knowles 1981). Nitrogen fixation and denitrification are respectively two important processes of gain and loss of nitrogen in forest ecosystems (Muller *et al.* 1980).

Chittagong University is situated in the hilly area of Chittagong. The present work deals with study the soil properties of different forests of hilly areas of Chittagong University Campus and the association of nitrogen transforming soil bacteria with different tree species.

## MATERIALS AND METHODS

*Site condition*

As there were appreciable variations within the same plantation area in either growth or soil or slope or all in some localities, due care was taken to identify the appropriate location. Conditions of the studied sites and associated tree species are shown in Table 1.

*Collection of soil samples*

Soil samples at 0-6cm depths were collected with spade. To represent the site, several soil samples were collected from a particular depth in a sample plot. Then soils of a particular slope of a site were mixed in equal proportion to have a composite sample. The samples were taken in polythene bags and brought into laboratory. Each soil sample was divided into two sub-samples, one for the determination of physical and chemical properties and the other was used for the estimation of nitrogen-transforming microorganisms including *Azotobacter*, ammonifying bacteria, *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria.

TABLE 1: CONDITIONS OF THE STUDY SITES OF DIFFERENT PLANTATIONS.

| Site No. | Species | Study Area in Chittagong University Campus | Site Characteristics |
|---|---|---|---|
| 1 | *Acacia auriculiformis* | East side of Godown | Very steep slope, medium hill |
| 2 | *Eucalyptus camaldulensis* | Beside University play ground | Steep sloping, medium hill |
| 3 | *Lagerstroemia speciosa* | Pump house | Steep sloping, medium hill |
| 4 | *Tectona grandis* | East of Science Cafetoria | Flat top of very steep slope, high hill |
| 5 | *Acacia mangium* | West side of Institute of Forestry and Environmental Sciences | Gently sloping, low hill |
| 6 | *Dipterocarpus turbinatus* | South side of Shahjalal Hall | Steeply sloping, medium hill |

*Laboratory analysis*

Soil samples were air dried and passed through a 2mm sieve. Soil samples were kept in refrigerator for prior to microbial study.

Soil pH was determined in 1:2 soils (air dry): 0.01M $CaCl_2$ suspensions with an electronic digital pH meter (Jackson 1973). Particle size analysis was done according to Bouyoucos Hydrometer method (Day 1965) and the textural class names were those of USDA (1951). Soil organic carbon was determined by Walkley and Black's wet oxidation method (Jackson 1973). Cation exchange capacity was determined by 1N $NH_4OAC$ saturation followed by 10% KCl displacement (Jackson 1973). Exchangeable $Na^+$, $K^+$ were extracted with 1N $NH_4OAC$ solutions (pH 7.0). Available phosphorus was extracted from field moist soil samples by Bray and Kurtz No. 1 extractant (0.03N $NH_4F$ in 0.025N HCl) and determined according to the $SnCl_2$ reduced molybdophosphoric blue colour method (Jackson 1973). Potassium and sodium were determined by flame photometer.

*Estimation of microbial population*

*Soil sample dilution*

Ten gram of each soil sample was suspended in 95 ml sterile distilled water in a conical flask, and mixed well with the help of a stirrer to get $10^{-1}$ dilution of the soil sample. Ten ml of this suspension was transferred to another conical flask containing 90 ml sterile distilled water and mixed well with the help of a magnetic stirrer to get $10^{-2}$ dilution. In this way by gradual transfer and mixing $10^{-3}$, $10^{-4}$, $10^{-5}$, $10^{-6}$, $10^{-7}$ dilutions were prepared.

*Estimation of Azotobacter*

Five tubes containing 10 ml sterile solution (Mineral salt solution: $K_2HPO_4$-5g, $MgSO_4.7H_2O$-2g, $CaSO_4$-1g, $FeSO_4$-0.2g, $MnSO_4$ - 0.2g, $MoO_3$. $H_2O$- 0.1g, KI-0.1g, Distilled water-1000 ml. 10 g sucrose, 3g $CaCO_3$ and 900 ml of distilled water was added to 100 ml of the mineral salt solution) were inoculated with 1 ml of particular dilution. In this way the dilutions from $10^{-1}$ to $10^{-3}$ were used for the inoculation of tubes of solution. The inoculated tubes were incubated at 28ºC for 1 week. Development of skin or pellicle on the surface of the culture fluid showed the positive result. Most Probable Number (MPN) of *Azotobacter* was calculated with the help of MPN chart from the number of positive tubes inoculated with higher dilutions (Rao 1986).

*Estimation of ammonifying bacteria*

Five tubes containing 7 ml sterile nutrient broth solution (Peptone-5g, Beef extract-3g, NaCl- 1g, Distilled water-1000 ml) were inoculated with 1 ml of particular dilution. In this way the dilutions from $10^{-4}$ to $10^{-7}$ were used for the inoculation of tubes of nutrient broth. The inoculated tubes were incubated at 30°C for 30 days. After incubation, 3 to 5 drops of Nessler's reagent (Solution-A: Potassium iodide-70g, Mercuric iodide-100g, Distilled water-500ml. Solution-B: Sodium hydroxide-100g, Distilled water-500ml. Solution B was added into solution A in a 1000 ml volumetric flask. Then it was shaken well and distilled water was added to make 1000 ml) was added to each tube. Development of brown colour showed the positive result. Most Probable Number of ammonifying bacteria was calculated with the help of MPN chart from the number of positive tubes inoculated with higher dilutions (Alexander 1965).

*Estimation of Nitrosomonas*

The population of *Nitrosomonas* was determined using ammonium-calcium carbonate medium {$(NH_4)_2SO_4$-0.5g, $K_2HPO_4$ -1.0g, $FeSO_4.7H_2O$-0.03g, NaCl-0.3g, $MgSO_4.7H_2O$-0.3g, $CaCO_3$ -7.5g, Distilled water - 1000ml}. Tubes of medium were inoculated with 1 ml of each of soil dilutions from $10^{-3}$ to$10^{-7}$. Five tubes containing 3 ml medium were inoculated with each dilution. The inoculated tubes were incubated at 28°C for 3 weeks. A set was included as uninoculated controls. After incubation, 3 to 5 drops of Griess-Ilosvay reagent was added to each tube. The presence of *Nitrosomonas* was indicated if the solution in inoculated tubes showed purplish-red colour. To all tubes that showed negative result, a small pinch of the Zn-Cu-$MnO_2$ (1:1:1) mixture was added. Development of reddish colour showed the positive result for the presence of *Nitrosomonas*. Most Probable Number of *Nitrosomonas* was calculated with the help of MPN

chart from the number of positive tubes inoculated with higher dilutions (Alexander and Clark 1965).

*Estimation of Nitrobacter*

The population of *Nitrobacter* was determined by nitrite-calcium carbonate medium ($KNO_2$ -0.006g, $K_2HPO_4$ -1.0g, $FeSO_4.7H_2O$ - 0.03g, NaCl-0.3g, $MgSO_4.7H_2O$-0.1g, $CaCO_3$ -1.0g, $CaCl_2$ -0.3g, Distilled water – 1000 ml). Tubes of the medium were inoculated with 1ml of each of soil dilutions from $10^{-3}$ to $10^{-7}$. Five tubes containing 3 ml medium were inoculated with each dilution. The inoculated tubes were incubated at 28°C for 3 weeks. After incubation, 3 drops of Griess-Ilosvay reagent was added to each tube. The presence of *Nitrobacter* was indicated if the solution in inoculated tubes remained colourless. Most Probable Number of *Nitrobacter* was calculated with the help of MPN chart from the number of positive tubes inoculated with higher dilutions (Alexander and Clark 1965).

*Estimation of denitrifying bacteria*

Each of 5 tubes containing 10 ml liquid medium (Solution-A: $KNO_3$ -1.0g, Asparagine-1.0g, Bromothymol blue (1% in ethanol)-5.0 ml, Distilled water-500 ml. Solution-B: Na-Citrate-8.5g, $KH_2PO_4$ -1.0g, $MgSO_4.7H_2O$ -1.0g, $CaCl_2.6H_2O$ -0.2g, $FeCl_3.6H_2O$- 0.05g, Distilled water-500 ml. After preparation of solution A and B, they were mixed and pH of the medium was adjusted within the range of 7.0 to 7.2) for denitrification test was inoculated with 1 ml of each of soil dilutions from $10^{-3}$ to $10^{-7}$. The inoculated tubes were incubated at 30°C for 7 days. Vigorous gassing and blue colouration showed the positive result. Most Probable Number of denitrifying bacteria was calculated with the help of MPN chat from the number of positive tubes inoculated with higher dilutions (Alexander 1965).

## RESULTS AND DISCUSSION

Populations of some nitrogen-transforming microorganisms– *Azotobacter*, ammonifying bacteria, *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria in surface soils of different forest plantations under different slopes of Chittagong University Campus were estimated. Microbial populations, their variations with forest tree species and their relation with soil properties are discussed in the following sections.

*Population*

The average populations of *Azotobacter*, ammonifying bacteria, *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria in soils under each tree

species are summarized in the Table 2. *Azotobacter* population was the lowest among the nitrogen-transforming bacteria in any of the tree species and ranged from 2.2 x $10^3$ to 74.1-x $10^3$/g soil. The lowest population was found in soils under *E. camaldulensis*. Soils under *D. turbinatus, T. grandis* and *A. auriculiformis* had *Azotobacter* population more than twice the average value under *E. camaldulensis*. Populations of ammonifying bacteria, *Nitrosomonas, Nitrobacter* and denitrifying bacteria did not differ appreciably within the soil of a particular species. There were, however, some variations in soils among species.

TABLE 2: AVERAGE VALUES OF *AZOTOBACTER*, AMMONIFYING BACTERIA, *NITROSOMONAS*, *NITROBACTER* AND DENITRIFYING BACTERIA IN SOILS OF DIFFERENT FOREST TREE SPECIES OF CHITTAGONG UNIVERSITY CAMPUS.

| Microorganisms | Slope | *Azotobacter* (No. of total MPN/g soil x$10^3$) | Ammonifying bacteria (MPN/g soil x$10^6$) | *Nitrosomonas* (MPN/g soil x$10^6$) | *Nitrobacter* (MPN/g soil x$10^6$) | Denitrifying bacteria (MPN/g soil x$10^6$) |
|---|---|---|---|---|---|---|
| *Lagerstroemia speciosa* | Level | 11.6 | 0.67 | 0.79 | 0.77 | 0.71 |
| | Medium | 49.5 | 0.89 | 1.01 | 0.93 | 0.88 |
| | Top | 17.7 | 0.69 | 0.94 | 0.89 | 0.77 |
| *Acacia auriculiformis* | Level | 8.3 | 0.87 | 1.03 | 0.92 | 0.88 |
| | Medium | 63.1 | 1.28 | 1.13 | 1.27 | 1.28 |
| | Top | 22.8 | 1.21 | 1.25 | 1.25 | 1.13 |
| *Dipterocarpus turbinatus* | Level | 5.5 | 0.89 | 0.90 | 0.95 | 0.88 |
| | Medium | 34.2 | 0.92 | 1.21 | 1.16 | 0.92 |
| | Top | 15.0 | 0.89 | 0.99 | 1.02 | 0.91 |
| *Tectona grandis* | Level | 13.9 | 1.01 | 0.89 | 0.91 | 0.88 |
| | Medium | 74.1 | 1.10 | 1.06 | 1.10 | 1.01 |
| | Top | 25.3 | 0.91 | 1.05 | 1.09 | 0.94 |
| *Acacia mangium* | Level | 5.5 | 0.92 | 0.95 | 0.94 | 0.89 |
| | Medium | 58.3 | 1.06 | 1.05 | 1.05 | 1.21 |
| | Top | 8.4 | 0.96 | 0.95 | 1.00 | 1.06 |
| *Eucalyptus camaldulensis* | Level | 2.2 | 0.88 | 0.94 | 1.16 | 0.78 |
| | Medium | 23.2 | 1.21 | 1.25 | 1.39 | 1.05 |
| | Top | 15.4 | 1.21 | 1.32 | 1.43 | 1.05 |

Thus, the ranges of MPN values of ammonifying bacteria, *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria were 0.67 x $10^6$ to 1.21 x $10^6$, 0.79 x $10^6$ to 1. 32 x $10^6$, 0.77 x $10^6$ to 1.43 x $10^6$ and 0.71 x $10^6$ to 1.28 x $10^6$/g soil respectively. *L. speciosa* soils had generally lower populations of these organisms. On the other hand, *A. auriculiformis* had higher values average MPN, although *E. camaldulensis* had the highest *Nitrobacter* population. In all the forest

hills the numbers of microorganisms were found highest in mid hill as this layer was less disturbed due to steep slopes. The top hill and the hill base were anthropogenically disturbed as surrounding human population collect their fuel from the forests as leaves and twigs.

Soils under *A. auriculiformis, E. camaldulensis* and *T. grandis* plantations had no significant difference in population of ammonifying bacteria. Same was the case with *A. mangium,* and *T. grandis*; with *A. mangium, D. turbinatus* and with *D. turbinatus,* and *L. speciosa*. Both *A. auriculiformis* and *E. camaldulensis* differed significantly with *A. mangium, D. turbinatus*, and *L. speciosa* in population of *Nitrosomonas*. Its population in soils of *A. auriculiformis*, *E. camaldulensis* and *T. grandis* did not differ significantly with each other. On the other hand, there was no significant difference in population of *Nitrosomonas* under soils of *A. mangium, D. turbinatus, L. speciosa* and *T. grandis*. *Nitrobacter* population in soils of *E. camaldulensis* did not differ significantly with *A. auriculiformis* but differed significantly with all other species. There was no significant difference in soils of *A. mangium, D. turbinatus* and *L. speciosa*. Population of denitrifying bacteria in soils of *A. auriculiformis* differed significantly with all other species. On the other hand, denitrifying bacteria in soils of *A. mangium, D. turbinatus, E. camaldulensis* and *T. grandis* had no significant difference among themselves.

There are some reports on the population of nitrogen transforming bacteria in forest soils of different regions of the world. Ranjana and Nagaraj (1989) found that population of *Azotobacter* varied from 7 x $10^3$ to 7 x $10^8$/g in non-lateritic and dry deciduous forest soils**.** Zhang *et al.* (1988) found 14.41-x $10^4$/g *Azotobacter* sp. and 8.73 x $10^5$/g ammonifying bacteria in soils below *Pinus massoniana*. Chen *et al*. (1972) observed differences in population of nitrifying bacteria under pure *Casuarina* and mixed stands of Suhu coastal area of Taiwan. Lodhi and Ruess (1988) observed ammonifier and nitrifier populations and available N of associated soils in a forest community of red oak (*Quercus rubra*), hemlock (*Tsuga canadensis*), basswood (*Tilia americana*), sugar maple (*Acer saccharum*) and beech (*Fagus grandifolia*) near Ithaca, New York. Jones and Richards (1977) reported that nitrifying bacteria were more numerous in *Pinus elliottii* stands than in burned stands of *Eucalyptus micrantha* forest.

*Interrelationships among microorganisms*

The present study showed strong interrelationships among the soil microorganisms which may be apparent from the correlation coefficients

calculated on the basis of the overall population in all the study sites (Table 3). Ammonifying bacteria was positively and significantly correlated with *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria. In addition, *Nitrosomonas* was also correlated positively with ammonifying bacteria, *Nitrobacter* and denitrifying bacteria. Significant positive correlation at 0.01% level was again observed among ammonifying bacteria, *Nitrosomonas*, *Nitrobacter* and denitrifying bacteria. *Azotobacter* was only significantly related with denitrifying bacteria. Significant correlation between numbers of free-living cells of ammonia- and nitrite-oxidizing bacteria in a forest site was reported by Jha *et al.* (1996). Mai (1988) observed that *Nitrosomonas* and *Nitrobacter* in a forest soil were intercorrelated ($P<0.001$). The population of nitrifying bacteria is related to the supply of ammonia. Therefore, a relation between ammonifying bacteria and *Nitrosomonas*/*Nitrobacter* is evident.

TABLE 3: CORRELATION COEFFICIENTS AMONG MICROBIAL POPULATIONS IN SOILS

| | Azotobacter | Ammonifying Bacteria | Nitrosomonas | Nitrobacter | Denitrifying Bacteria |
|---|---|---|---|---|---|
| *Azotobacter* | 1.000 | 0.442 | 0.316 | 0.233 | 0.574* |
| Ammonifying Bacteria | 0.442 | 1.000 | 0.760** | 0.827** | 0.846** |
| *Nitrosomonas* | 0.316 | 0.760** | 1.000 | 0.892** | 0.627** |
| *Nitrobacter* | 0.233 | 0.892** | 0.892** | 1.000 | 0.630** |
| Denitrifying Bacteria | 0.574* | 0.846** | 0.627** | 0.630** | 1.000 |

*Significant at 0.05% level, **Significant at 0.01% level.

*Relationship of microbial population with soil properties*

The soils had appreciable differences in various physico-chemical and nutritional properties (Table 4). The overall effect of soil parameters on the population of the organisms is shown in Table 5. Soil pH was correlated positively and significantly with ammonifying bacteria, *Nitrobacter* and denitrifying bacteria at 0.01% level and with *Nitrosomonas* at 0.05% level. Ammonifying bacteria and *Nitrosomonas* were correlated with organic carbon at 0.05% level. All the nitrogen transforming bacteria are significantly and positively correlated with total nitrogen content of soils. Available phosphorus was positively correlated at 0.05% level only with *Nitrosomonas* bacteria.

TABLE 4: PHYSICO-CHEMICAL PROPERTIES OF SOILS IN SIX FOREST PLANTATIONS OF CHITTAGONG UNIVERSITY CAMPUS.

| Plantation | Location | Site Characteristics | Slope | Texture | pH | EC µs/cm | Org. C % | Org. matter % | C/N ratio | CEC me/ 100g | BSP | TEB meq / 100 g | **Total N %** | Available Pmg/ 100g | Total K% | Total Na% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Lagerstroemia speciosa* | Pump house of Chittagong University | Steep sloping, medium hill | Level | Clay loam | 5.6 | 0.82 | 0.77 | 1.32 | 11.00 | 3.90 | 33 | 1.29 | 0.07 | 0.25 | 0.05 | 0.07 |
| | | | Medium | Sandy clay loam | 5.7 | 1.23 | 1.14 | 1.96 | 14.25 | 5.60 | 38 | 2.13 | 0.08 | 0.79 | 0.06 | 0.08 |
| | | | Top | Silt loam | 5.6 | 1.23 | 1.10 | 1.89 | 15.71 | 4.58 | 36 | 1.63 | 0.07 | 0.75 | 0.09 | 0.09 |
| *Acacia auriculiformis* | East side of Godown | Very steep slope, medium hill | Level | Silt loam | 5.6 | 1.26 | 0.97 | 1.67 | 12.13 | 5.15 | 41 | 2.11 | 0.08 | 1.70 | 0.07 | 0.04 |
| | | | Medium | Clay loam | 5.7 | 1.27 | 1.07 | 1.84 | 9.73 | 6.25 | 43 | 2.69 | 0.11 | 1.80 | 0.06 | 0.02 |
| | | | Top | Sandy clay loam | 5.7 | 1.27 | 1.16 | 1.99 | 9.67 | 5.45 | 41 | 2.13 | 0.12 | 1.80 | 0.09 | 0.03 |
| *Dipterocarpus turbinatus* | South side of Shahjalal Hall | Steep sloping, medium hill | Level | Clay loam | 5.6 | 0.49 | 0.82 | 1.41 | 10.25 | 5.50 | 36 | 1.98 | 0.08 | 1.67 | 0.03 | 0.08 |
| | | | Medium | Sandy clay | 5.6 | 1.24 | 0.94 | 1.62 | 10.44 | 7.50 | 37 | 2.78 | 0.09 | 1.65 | 0.09 | 0.01 |
| | | | Top | Sandy clay loam | 5.6 | 0.42 | 0.84 | 1.44 | 9.33 | 7.00 | 36 | 2.52 | 0.09 | 1.52 | 0.04 | 0.02 |
| *Tectona grandis* | Science Cafeteria east | Flat top of very steep slope, high hill | Level | Silt loam | 5.6 | 1.25 | 1.09 | 1.87 | 13.63 | 5.50 | 36 | 1.98 | 0.08 | 0.32 | 0.32 | 0.03 |
| | | | Medium | Clay | 5.7 | 1.70 | 1.32 | 2.27 | 13.20 | 5.50 | 38 | 1.86 | 0.10 | 1.95 | 0.23 | 0.02 |
| | | | Top | Clay | 5.7 | 0.64 | 0.90 | 1.55 | 10.00 | 4.90 | 36 | 1.98 | 0.09 | 1.08 | 0.03 | 0.04 |
| *Acacia mangium* | West side of Institute of Forestry and Environmental Sciences | Gently sloping, low hill | Level | Clay loam | 5.7 | 0.56 | 0.78 | 1.34 | 9.75 | 3.00 | 31 | 0.93 | 0.08 | 0.07 | 0.10 | 0.04 |
| | | | Medium | Clay loam | 5.9 | 1.24 | 0.80 | 1.38 | 7.27 | 4.80 | 37 | 1.78 | 0.11 | 0.11 | 0.12 | 0.04 |
| | | | Top | Loam | 5.8 | 1.26 | 0.96 | 1.65 | 9.6 | 2.95 | 34 | 0.66 | 0.10 | 0.08 | 0.12 | 0.04 |
| *Eucalyptus camaldulensis* | Side of university play ground | Steep sloping, medium hill | Level | Loam | 5.6 | 0.57 | 0.75 | 1.29 | 10.71 | 1.95 | 34 | 0.66 | 0.07 | 0.09 | 0.07 | 0.08 |
| | | | Medium | Clay loam | 5.9 | 0.60 | 1.19 | 2.05 | 11.90 | 6.10 | 43 | 2.62 | 0.10 | 1.20 | 0.07 | 0.08 |
| | | | Top | Clay loam | 5.9 | 0.60 | 1.19 | 2.05 | 11.09 | 6.10 | 42 | 2.62 | 0.10 | 1.30 | 0.09 | 0.08 |
| Range | | | | Sandy Clay - Clay | 5.6-5.9 | 0.56-1.26 | 0.75-1.19 | 1.29-2.05 | 7.27-11.90 | 1.95-6.10 | 31-43 | 0.66 - 2.62 | 0.07-0.11 | 0.07-1.30 | 0.07-0.12 | 0.04-0.08 |
| Mean | | | | | 5.7 | 0.98 | 0.99 | 1.70 | 11.09 | 5.10 | 37.33 | 1.91 | 0.09 | 1.01 | 0.10 | 0.05 |

TABLE 5: CORRELATION COEFFICIENTS BETWEEN MICROORGANISMS AND SOIL PROPERTIES

| Microorganisms | pH | Organic Carbon | Total Nitrogen | Available Phosphorus |
|---|---|---|---|---|
| *Azotobacter* | 0.280 | 0.460 | 0.518* | 0.334 |
| Ammonifying Bacteria | 0.655** | 0.550* | 0.848** | 0.397 |
| *Nitrosomonas* | 0.578* | 0.560* | 0.706** | 0.548* |
| *Nitrobacter* | 0.610** | 0.445 | 0.660** | 0.410 |
| Denitrifying Bacteria | 0.681** | 0.345 | 0.940** | 0.300 |

**significant at 0.01% level, *significant at 0.05% level

Investigations on the distribution of nitrogen transforming organisms with properties of soils have been done to a limited extent. Most workers indicated that there was a relationship of decomposable organic matter in soil with the population of heterotrophic nitrogen transformers (Hegazi *et al.* 1979).

Nitrification is much more sensitive to pH than is ammonification and at both low and high pH ammonium will tend to accumulate during soil incubations**.** The accumulation of ammonium will tend to be offset by the volatilization of ammonia with the increase of pH above 9. In pure culture nitrifiers grow well only between pH 6 and 8.5. However, there are some strains of *Nitrobacter* which are acidophilic (Hankinson and Schmidt, 1988). In addition, active nitrification has been reported in soils of pH 4-5 (Belser 1979).

The rate of denitrification was found to be different in different soils, depending on the pH of the soil, content of organic matter, structure, moisture, etc (Nommik 1956). The potential for denitrification in soil is positively correlated with pH (Muller *et al.* 1980), having an optimum between 7 and 8 (Van Cleemput and Patgrick 1974). Jansson and Clark **(**1952) observed that denitrification was considerably suppressed under acid conditions. Addition of organic material to soils has been shown to have a stimulating effect on denitrification (Nommik 1956). The organic material acts both as a carbon source and as a hydrogen donor for the denitrifying bacteria (Bailey 1976). Rates of denitrification are highly correlated with amounts of water-extractable soil organic carbon (Burford and Bremner 1975).

## CONCLUSION

The hill soils distributed over the area within Chittagong University are poorly to moderately fertile. The cycling of nutrients and decomposition of forest litter is restricted due to removal of litter materials by the people of nearby areas. Organic matter and nitrogen content were relatively low. Population of nitrogen transforming microorganisms varied considerably and significantly with one another, with soil type and under different tree cover.

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