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EVALUATION OF SOIL QUALITY IN TEA PLANTATION UNDER PRESENT CLIMATIC CONDITION

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Abstract

To assess the impact of different plantation system of tea *Camellia sinensis* L. crops in soil quality in comparison with fallow land under the experimental Garden for Plantation Crop of the Department of Tea Husbandry and Technology, Assam Agricultural University situated at latitude 26°47′ N, Longitude 94°12′ E and altitude 86.5 m above the mean sea level. This study was conducted during 2014-16 aiming where there are any change in soil quality under different plantation. Soil samples were randomly collected in replicates of four for each of the tea based plantations *viz.* tea, tea-arecanut, tea-albizzia and fallow land. The experiment was laid out in Randomized Block Design (RBD) having 4 treatments and the meteorological data recorded during the period of experimentation at Meteorological Observatory of the department of Agro-Meteorology, Assam Agricultural University, Jorhat. From the different plantation, highest available N, P_2O_5, K_2O was recorded in Tea-albizzia plantation followed by tea-arecanut plantation, tea plantation as compared to fallow land respectively. Cation Excange Capacity, soil electrical conductivity, organic carbon content and soil microbial population was also found highest in tea-albizzia plantation suggested that tea-albizzia intercropping system were superior to other plantation system.

Key words: Cation exchange capacity, microbial population, nitrogen, organic carbon, plantation, tea.

Introduction

Tea (*Camellia sinensis*) is one of the most important perennial crops in the Assam, India. It is a significant cash crop used for domestic consumption and export. Because of its economic value, many farmers have replaced their traditional food crops with tea. Overall soil quality changes with the tea plantation system as evidenced by increase in soil organic carbon, available N, P and K, change in pH, CEC, electrical conductivity etc. Because these soil properties were sensitive to cultivation effects, they were considered to be good indicators of soil quality. A soil under monoculture over a long period of time often deteriorates with regard to its structure and nutrient status (Deyel at. 1968). The role of vegetation in processes associated with pedogenesis is well recognized. In this respect effects of tree species and plantation forestry on soil properties; soil fertility, soil acidification and productivity have been studied intensively and it has been argued that specific plantation species reduce soil fertility, increase soil acidification and hence reduce productivity (Noble *et al.,* 1996; Routley and Routley 1975; Dasman 1972; Hamilton 1965; Khanna and Ulrich 1984). Productivity of plantations depends strongly on soil nutrient supply and it may be malleable under the influence of management practices and species (Binkley 1997). Almost all the industrial plantations are monocultures, and questions are being raised about the sustainability of their growth and their effects on the site (Khanna 1997). Repeated harvesting of fast growing trees such as poplar plantations on short rotations may deplete site nutrients. Nitrogen losses are likely to be very important for future growth. It is therefore, appropriate to explore new systems of plantation management in which N may be added via fixation (Khanna 1997). Mixed plantation systems provide a broader range of options, such as production, protection, biodiversity conservation and restoration (Montagnini *et al.,* 1995; Keenan *et al.,* 1995; Guariguata *et al.,* 1995 and Parrotta and Knowles 1999). Mixed plantations yield more diverse forest products than mono specific stands, helping to diminish farmer's risks in unstable markets. If planned with consideration for each species' response to mixed conditions, mixed designs can be more productive than monospecific systems. In addition, a mixture of species, each with different nutrient requirements and

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different nutrient cycling properties, may be overall less demanding on site nutrient than monoculture stands (Montagnini 2000).

Competition among individuals is less and the site is used integrally in mix plantation hence more biomass per unit area can be produced (Montagnini *et al.,* 1995). The roots of different species may occupy different soil strata allowing more complete utilization of soil and water resources (Lamb and Lawrence 1993). More solar energy can be captured because different species have different light requirements and crowns are broadly distributed in the vertical plane (Guariguata *et al.,* 1995). However, the success of the establishment of mixed forest plantations depends on plantation design and an appropriate definition of the species to be used, taking into consideration ecological and silvicultural aspects (Wormald 1992).

Concerns about decline in soil fertility and long-term productivity of fast-growing plantations have promoted interest in using nitrogen fixing trees in mixed species plantations (Rhoades and Binkley 1996). Nitrogen-fixing trees, mainly leguminous species, have been widely extolled for their soil-improving characteristics related to their production of nitrogen-rich, often rapidly decomposing leaf litter (Parrotta 1999). Although there have been some documented cases of increased productivity in mixed-species plantations in both temperate and tropical regions, the collective results of such studies have been inconclusive and show that accurate species/site matching and choice of complementary species strongly influence mixed-species plantation productivity (FAO 1992). Many experiments has done in the world such as North America of growing of *Populus* spp. as an intercrop with *Alnus* L. spp. have shown enhanced growth of *Populus* spp. (FAO 1992; Coté and Camiré 1987; Hansen and Dawson 1982; Radwan and DeBell 1988). The comparison of crop plantations with that of natural forest ecosystem has attracted several scientific investigation (Evans 1982). In addition to ensuring a stable ecosystem the plantations also aim at an economic return to the planter (Bruning *et al.,* 1978 and Akrcoll 1979). The different types of canopy covers are known to influence the water movement in the soil and consequently the nutrient content. (Megahan *et al.,* 1962; Nazaror 1969). The litter added by different crops causes' difference in soil organic matter and nutrient content. (Jha *et al.,* 2000). the tillage and other crop management practices along with other biotic and abiotic factors influence the soil properties (Norris 1970). The objectives of the study were to assess soil quality and its relationship to the sustainability of tea cultivation in the different tea plantation.

Materials and Methods

Study Location

The study sites were located in the experimental Garden for Plantation Crop of the Department of Tea Husbandry and Technology, Assam Agricultural University situated at latitude 26°47′N, Longitude 94°12′ E and altitude 86.5 m above the mean sea level. The climate of Jorhat is subtropical humid where monsoon normally begins from June and extended up to September to October.

Meteorological Data Collection

These were recorded during the period of experimentation at Meteorological Observatory of the department of Agro-Meteorology, Assam Agricultural University, Jorhat. The average maximum and minimum temperature during were 29.7ºC and 19.4°C respectively, while in 2015 the average maximum and minimum temperature were recorded 29.2ºC and 18.9°C respectively. The total rainfall received were 1999.5 mm and 1679.9 mm during the year 2014 and 2015, respectively.

Experimental Design

The soils are well-drained, and have a sandy loam texture. Soil samples were randomly collected in replicates of four for each of the tea based plantations *viz.* tea, tea-arecanut , tea-albizzia and fallow land. The experiment was laid out in Randomized Block Design (RBD) having 4 treatments (3 plantation system and fallow land as control with five replications)

Table 1: Methods for soil analysis.

Soil characteristics	Methods	References
pH	Soil water suspension glass electrode pH meter	Jackson (1973)
Cation Exchange capacity	Distillation method	Jackson (1973)
Electrical conductivity	Systronics digital electrical conductivity meter	
Available nitrogen	Alkaline $KMnO_4$ method	Subbiah&Asija (1956)
Available phosphorus	Colorometric method	Dickman& Bray's (1940)
Available potassium	NH_4OAc extraction method	Mengel (1968)
Organic carbon	Walkey and Black's method	Walkley and Black, 1934

Soil Collection

Soils were sampled to a depth of 60 cm in all plantations and control plots using a 7.6 cm diameter core sampler taken at two 15 cm and a 30 cm interval. After air drying, soils were passed through a 2.0 mm (20 mesh) sieve to remove roots prior to chemical analyses.

Soil Characteristics

Soil pH was determined by using a digital pH meter. Cation Exchange capacity

Cation Exchange capacity was determined by Distillation method, Electrical conductivity by using Systronics digital electrical conductivity meter, Available nitrogen by Alkaline $KMnO_4$ method, Available phosphorus by Colorometric method, Available potassium by NH_4OAc extraction method, Organic carbon by Walkey and Black's method.

Determination microbial population

Determination of microbial population done by the classical serial dilution technique was used for total microbial population from the soil sample by spread plate technique on appropriate media.

Isolation and Identification

The classical serial dilution technique was used for total microbial population from the soil sample by spread plate technique on appropriate media. Initially the studied soil sample of 1 g each were suspended in 9 ml of sterile distilled water (water blank) and from this original suspension, further dilutions were made aseptically. For isolation total microbial population from soil, 10^{-5} dilution was finally selected. With the help of a sterile pipette, 0.1 ml of the soil suspension was transferred from the final dilution to the sterilized petriplate containing nutrient agar (NA) media. Then the plates were incubated at 28±2ºC for about 45 hours and the microbial population was estimated as colony forming unit (cfu) g^{-1}soil on dry weight basis.

Table 2: Potato Dextrose Agar.

Ingredients	Amount (g/lit)
Infusion from potato	200
Dextrose	20
Agar	15
pH	5.6±0.2

Composition of the Media

Results

Results describe the soil related parameters in different plantation *viz.* Tea, Tea-arecanut, Tea-albizzia comparing with Fallow land which influences the soil quality parameters.

Nutritional status

Available Nitrogen of different Tea plantations

A significant difference was recorded in the available nitrogen of different Tea plantations table 1. Highest available nitrogen was recorded in the Tea-albizzia plantation (233.91 kg ha^{-1}) followed by the tea-arecanut plantation (216.57 kg ha^{-1}). The lowest available nitrogen was recorded in tea plantation (203.54 kg ha^{-1}). Compared to fallow land, higher per cent of available nitrogen was observed in tea-albizzia plantation with (74.81) followed by tea-arecanut plantation (61.84).

Available P_2O_5 (Kg Ha^{-1}) of different Tea plantations

Among the different tea plantations, the available phosphorus in soil was significantly different table 1. The highest available phosphorus was recorded in tea-albizzia plantation (46.47kg ha^{-1}) followed by tea-arecanut plantation (44.42 kg ha^{-1}). The lowest available phosphorus was observed in tea plantation (41.03 kg ha^{-1}). Highest per cent in available phosphorus was recorded in Tea-albizzia plantation (47.24) followed by tea-arecanut plantation (40.75) as compared to fallow land.

Available K_2O (Kg Ha^{-1}) of different Tea plantations

Significant differences were recorded with respect to the available potassium in different tea plantations table 1. The maximum available potassium (153.4 kg ha^{-1}) was found in tea-albizzia plantation followed by tea-arecanut plantation (142.4 kg ha^{-1}) and minimum was recorded in tea plantation (120.8kg ha^{-1}). Percent in available potassium was found maximum in tea and albiziia plantation (31.79) followed by tea-arecanut plantation (22.22) as compared to fallow land.

Soil Ph of different Tea plantations

A significant difference was observed in soil pH of the different Tea plantations Fig. 1. In tea-allbizzia

Table 1: Soil characteristics under different tea plantation.

Plantation system	Tea	Tea-arecanut	Tea-albizzia	Fallow land	Mean	SEd±	CD 5%
Available Nitrogen (Kg ha^{-1})	203.54(52.63)	216.57(61.84)	233.91(74.81)	133.81	196.81	18.78	40.92
Available P_2O_5 (Kg ha^{-1})	41.03(30.00)	44.42(40.75)	46.47(47.24)	31.56	40.87	3.32	7.23
Available K_2O (Kg ha^{-1})	120.80(3.78)	142.40(22.35)	153.40(31.79)	116.40	133.25	3.25	7.06

*Data within parentheses are in per cent increase over fallow land.

plantation minimum (5.34) soil pH was recorded followed by tea-arecanut plantation (5.45). While, highest soil pH was recorded in tea plantation (5.51). Soil pH was recorded 8.54 percent low in tea-albizzia plantation followed by tea-arecanut plantation 6.38 percent with respect to the fallow land.

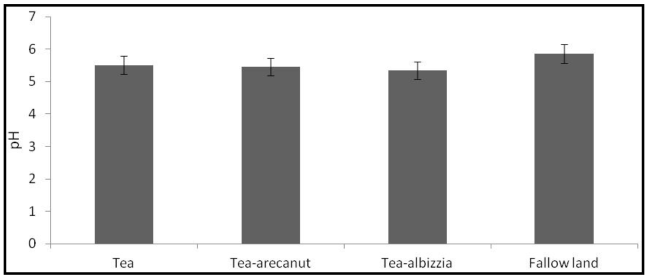

Fig. 1: P^H of soil under different tea plantation.

Cation exchange capacity of soil in different Tea plantations

A significant difference was noted in cation exchange capacity of soil in different Tea plantations Fig. 2. The cation exchange capacity of soil in tea-albizzia plantation was highest (6.53 cmol (p+)100 g soil^{-1}) followed by tea-arecanut (6.52 cmol (p+)100 g soil^{-1}). In the tea plantation the cation exchange capacity of soil showed lowest (6.51 cmol (p+)100 g) soil^{-1}). As compared to fallow land, tea-albizzia plantation showed highest with 3.37 percent in cation exchange capacity of soil followed by tea-arecanut plantation with 3.24 percent.

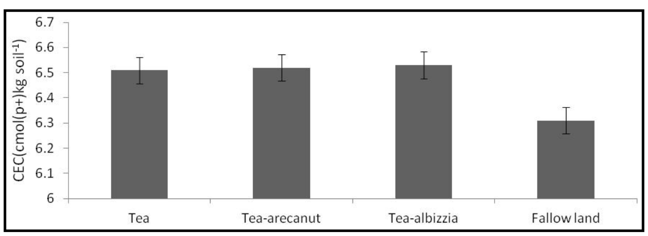

Fig. 2: Cation exchange capacity of soil under different tea plantation.

Soil electrical conductivity of different Tea plantations

There was a significant difference in electrical conductivity of different tea plantations table 4. The electrical conductivity of tea-allbizzia was found maximum (0.036 dsm^{-1}) followed by tea-arecanut plantations (0.03 dsm^{-1}) and lowest was recorded in tea plantation (0.016 dsm^{-1}). The per cent in electrical conductivity of tea-albizzia plantations was highest (157) followed by tea-arecanut plantations (114) as compared to fallow land.

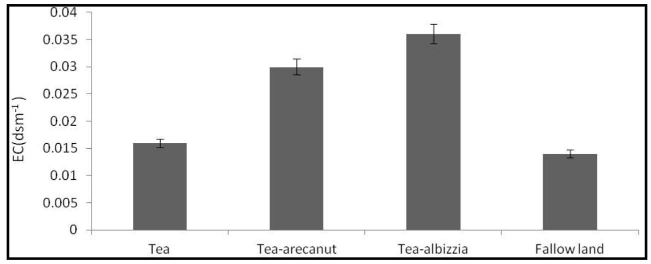

Fig. 3: Electrical conductivity of soil under different tea plantation.

Soil organic carbon of different Tea Plantations

There was significant difference in soil organic carbon of different plantations table 4. Among the different plantations the maximum soil organic carbon was recorded in tea-albizzia plantation (0.966%) followed by tea-arecanut plantation (0.950%) and minimum in tea plantation (0.871%). Among the different tea plantations, maximum percent in organic carbon was recorded in tea-albizzia plantation (26.27) followed by tea-arecanut plantation (24.18) as compared to fallow land.

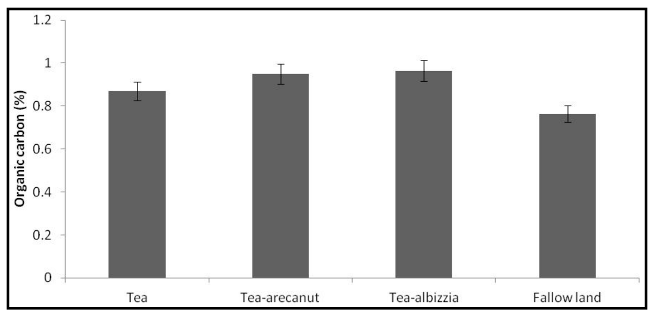

Fig. 4: Organic carbon of soil under different tea plantation.

Microbial Population in different Tea plantations

Among the different Tea plantations a significant difference was observed in terms of microbial populations table 4. Tea-albizzia plantation (146.53X 10^5cfu g^{-1}) have the highest microbial population followed by tea-arecanut plantation (134.48X 10^5cfu g^{-1}). In Tea plantation microbial population was found lowest (125.33 X 10^5cfu g^{-1}).

In tea-albizzia plantation (68.57) showed highest percent in the microbial population followed by the tea-arecanut plantation (54.70) as compared to the fallow land.

Table 1: Soil microbial characteristics under different tea plantation.

Plantation system	Tea	Tea-arecanut	Tea-albizzia	Fallow land	Mean	SEd±	CD 5%
Microbial population(cfu X 10^5)g^{-1}	125.33(44.18)	134.48(54.70)	146.53(68.57)	86.94	123.31	15.58	33.96
Organic carbon (%)	0.871(13.86)	0.950(24.18)	0.966(26.27)	0.765	0.890	0.15	0.33

*Data within parentheses are in per cent increase over fallow land.

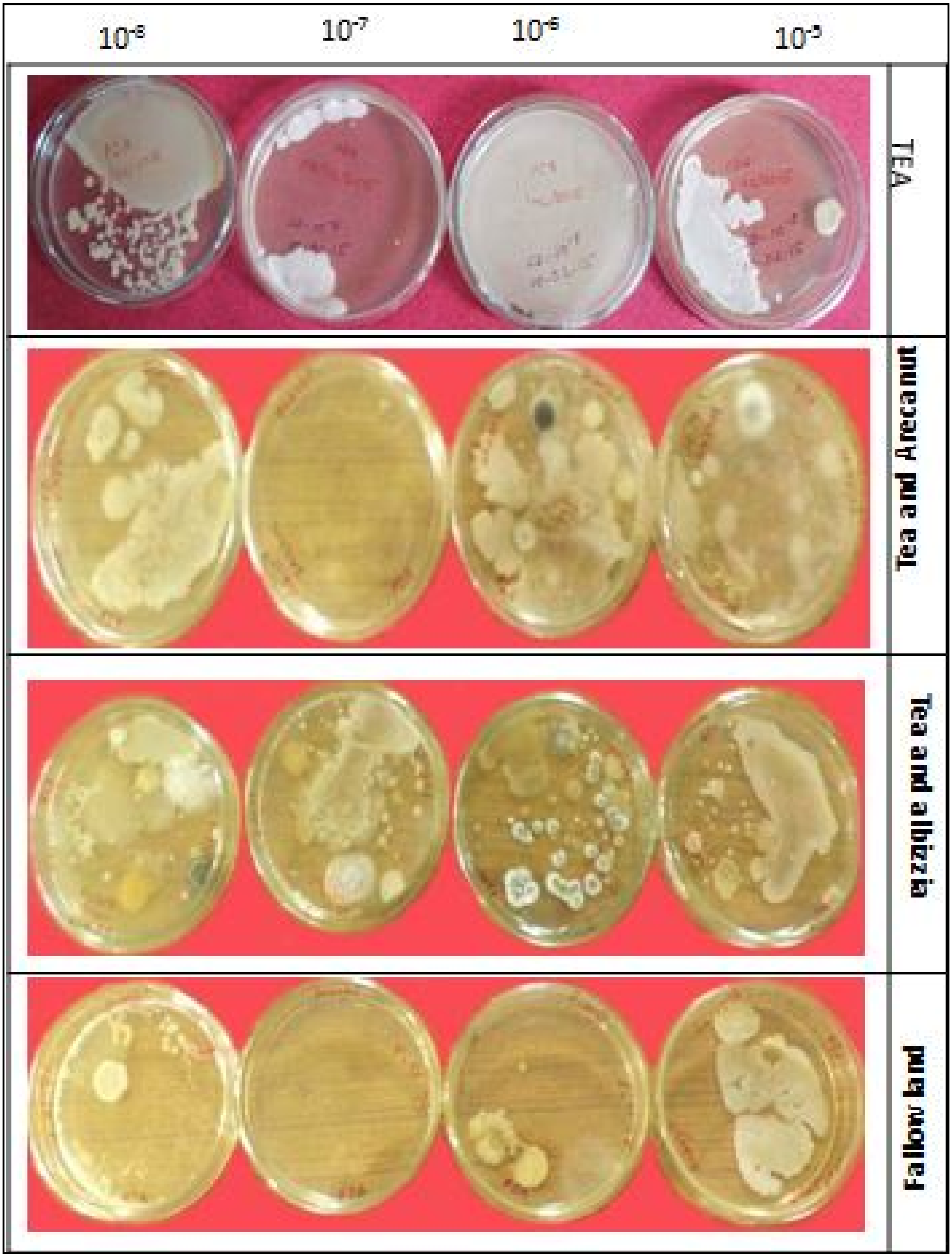

Plate 1: Soil microbial characteristics under different tea plantation.

Discussion

The different soil characteristics of different tea plantation were given in table 1. In tea-albizzia plantation, available nitrogen was 74.81 percent more compared to the fallow land. The highest nitrogen was recorded in tea-albizzia plantation (233.91 kg ha^{-1}) and lowest available nitrogen was recorded in tea plantation (203.54 kg ha^{-1}). Similarly available phosphorus was significantly different among the different tea plantations**.** The available phosphorus was also highest in the tea-albizzia plantation (46.47kg ha^{-1}) and lowest was in tea plantation (41.03 kg ha^{-1}). Significant variation with similar trend was also observed in available potassium content of the different tea plantations. According to Bernhard-Reversat (1986) and Belsky *et al.,* (1989) increase in soil fertility under or near the trees were reported to be related to tree litter. Apart from N fixation, other ways of increasing nutrients could be through precipitation (Kellman, 1979), redistribution of nutrients from lower to upper horizons and the droppings of domestic and wild animals resting under trees (Charley and Cowling 1986).

Treca *et al.,* (1996) noted that birds had recycled 12.8 kg of N and 0.9 kg of P ha^{-1}. Besides, albizzia being a leguminous tree, nitrogen is naturally fixed into the soil. In shaded coffee systems nutrients supplied for conventional fertilization were reported to be return to the system through litter form/or pruning residues of the shade trees (Aranguran *et al.,* 1982; Glover and Beer 1986). Significant effect of soil pH was observed in different plantations of tea. Among the different tea plantations, the pH was highest in the fallow land (5.85) followed by tea plantation (5.51) and it was lowest in tea-albizzia plantation. This tendency to decrease the soil pH in different plantations might be attributed to decomposition of pruning litters of tea plants and fallen leaves of shade trees. Another significant change found in the cation exchange capacity of the soil in different tea plantations. CEC was found to be higher in all the plantations as compared to fallow land. Increase in CEC can also be attributed to the leaf litter and pruned plant parts fallen in the soil. Noble *et al.,* (1996) reported that leaf litter of white cedar (*Melia azedarach*) was effective in significantly increasing effective cation exchange capacity in soil. There was significant variation in the organic carbon content of soil in different tea plantations. The highest organic carbon content was in tea-albizzia plantation (0.966%) and lowest in tea plantation (0.871%). Similarly microbial population in different tea plantations also showed significant variations. In tea-albizzia plantation maximum microbial population (146.53 X 10^5 $cfug^{-1}$ per g of soil) was observed and minimum was in tea plantation (125.33 X 10^5 $cfug^{-1}$ per g of soil) Plate 1.

More organic matter accumulation under plantation of tea with albizzia and arecanut trees was probably due to better stability of litter form the tree leaves. The same has been reported by Bernhard-Reversat (1982). Beer *et al.,* (1990) attributed increase of organic carbon in cacao plantation due to litter inputs. The leaf litter as well as the pruned decomposed pruned plant parts might have served as substrate for the growth of the soil microorganisms. Albizzia trees continuously shade leaves throughout the year (Edoh 1998), therefore higher littre mass in the tea-albizzia plantation might have contributed to higher organic carbon. Similarly, Nair *et al.,* (1977) reported that the association of cacao with coconuts increased the number of bacteria and fungi in the coconut rhizosphere. Increase in the soil microbial populations in different tea plantations is related to the increased organic carbon content of the soil. Similarly, Wang *et al.,* (2003) reported that in rubber plantation, rubber and tea plantation showed greater soil microorganism than pure rubber plantation.

In conclusion, present work are suggest that tea-albizzia intercropping followed by tea-arecanut system were not only superior to tea monoculture in sequestering atmospheric carbon dioxide both by increasing soil organic carbon level and reducing the turnover rates of Liable Organic Carbon (LOC) but also in both the system help to enhance the soil quality in terms of increasing the NPK in the soil as well as organic carbon.

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