Journal of Soil Science and Environmental Management Vol. 3(4), pp. 91-96, April 2012
Available online at http://www.academicjournals.org/JSSEM
DOI: 10.5897/JSSEM11.151

Full Length Research Paper

Assessment of soil quality improvement under Teak and Albizia

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Accepted 11 April, 2012

This study was conducted to assess the quality of soil in terms of soil nutrients and other physico-chemical properties under *Tectona grandis* and *Albizia lebbeck* plantations. Systematic sampling was used to collect soil samples diagonally at eight spots in each plantation and their adjacent non-tree fields as controls. The samples were collected from soil depth of 0 to 20 cm in both plantations and controls and analyzed for pH, % of Organic carbon (O-C), % of Nitrogen (N), available Phosphorus (P) and Bulk density (Db). The study revealed that the mean levels of N, O-C and P under the *T. grandis* plantation were higher than its control plot. However, there was no significant difference in the level of N except for the O-C and P. Also, the pH and Db under the *T. grandis* were lower than its control plot but there was no significant difference between them. There was significant difference in the levels of N, O-C and P under the *A. lebbeck* plantation and its control plot. The N, O-C and P were higher under the *A. lebbeck* plantation compared to its control plot. The pH and Db were lower under the *A. lebbeck* plantation compared to its control plot. However, the differences were not significant. In general, *A. lebbeck* added more N and O-C to the soil compared to *T. grandis*. Also, the *T. grandis* added more P to the soil when compared to the *A. lebbeck*; however, the difference was not significant. It is therefore, recommended that *A. lebbeck* and *T. grandis* should be used for agro forestry practices particularly, where the soil needs some level of improvement in nitrogen and phosphorus respectively.

Key words: *Tectona grandis*, *Albizia lebbeck*, soil nutrients, plantation, agro forestry.

INTRODUCTION

The industrialization of agriculture and the concurrent increase in societal concerns on environmental protections and food quality have put the focus on agricultural management and its impact on soil quality and involve the ability of the soil to provide an appropriate productivity, while simultaneously reducing the effect on the environment and contributing to human health (Schjonning et al., 2004). Young (1997) suggested that soil fertility is the capacity of the soil to support plant growth under given climatic conditions. The lands for agricultural production are under continuous cultivation as a result of population increase and the continuous dependency on the soil for cultivation without preserving the soil. This depletes it of its nutrients. The situation is further worsened by annual bush fires, erratic rainfall, poor agronomic practices and low return of organic residues into the soil leading to decline in crop yield and increased soil degradation. Measures of maintaining the soil nutrients such as shifting cultivation and bush following are now limited. The use of compost, farmyard manure, leguminous crops and alley cropping system had been tried. Other organic residues such as cow dung, crop residues, and household residues are also used as a source of manure for soil improvement. Supplies of animal manure are inadequate and farmers consider fertilizer to be too expensive (Young, 1991).

Agro forestry which is a land use system in which trees or shrubs are grown in association with agricultural crops has been introduced to address the soil fertility problems. Most economic studies have shown agro forestry in favorable light (Hoekstra, 1990). Agro forestry is a land-use system in which woody perennials are grown in

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association with herbaceous plants and/or livestock in a spatial arrangement, rotation or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system (Lundgren, 1982). It is the ecological interaction, that is, the most distinctive feature and differentiates agro forestry from social forestry, although, there is a large overlap (Nair, 1993). According to Young (1997), the greatest potential of agro forestry lies in its capacity to supply and maintain ground cover. The tree canopy supplies leafy materials through litter fall or pruning to maintain surface cover. With the presence of favorable climatic condition, the litter fall from the tree canopy will decompose to release plant nutrients. It was reported that higher yields are obtained from intercropping than sole cropping and this is as a result of the improved use of environmental resources (Tewari, 1995). Component crops in an agro forestry system often make a better use of resources and therefore complement each other than when crops are grown as sole crops. In addition, trees and their roots can play an important role in maintaining desirable soil physical properties (Young, 1989).

Tectona grandis and *Albizia lebbeck* are among the widely planted trees in the study area. These trees are grown for purposes such as fuel wood, wind belts, and rafters for building. Parts of these trees can also improve the fertility of the soil thereby, improving the soil quality. Currently, information on *in-situ* litter decomposition in tropical soils is limited (Dinakaran and Krishnayya, 2010). But limited research has been done to evaluate the nutrient status of soil under these tree plantations in the study area. The objectives of the study were; 1) to assess the quality of soils (pH, O-C, N, P and bulk density) under *T. grandis* and *A. lebbeck* plantations and 2) to suggest which of the two plantation species can greatly improve upon the pH, % organic carbon, % nitrogen, available phosphorus and bulk density of soil in agroforestry practices.

Soil pH

Soil pH refers to the soil's acidity or alkalinity. This property hinges on the concentration of hydrogen ions in solution. A greater concentration of hydrogen results in a lower pH, meaning greater acidity. The pH of a soil will often determine whether certain plants can be grown successfully (King, 2008). Soil pH largely controls plant nutrient availability and microbial reaction in the soil. It affects trees, shrubs and grass that dominate the landscape under natural condition and determine which cultivated crop will grow well or not in a given field (Brady and Weil, 2008).

Phosphorus

Phosphorus is an essential nutrient for all organisms and is added in large quantities to obtain enhanced crop yields. Secondary sewage effluent often has high phosphorus content, making it an important source of phosphorus for irrigated soils (Dahama, 2007). The total supply of phosphorus in moist soils is usually low, and its relative availability is low. The total phosphorus in an average arable soil is approximately 0.1% but only a small part of it at any one time is available to the plant. The nucleus of each plant cell contains phosphorus and for that reason, cell division and growth are not possible without adequate phosphorus (Donahue et al., 1983).

Nitrogen

Nitrogen is an essential nutrient element for living organisms. it is usually added in larger quantities to agricultural lands to obtain higher crop yields (Dahama, 2007). The atmosphere contains about 78% nitrogen gas (N_2), yet, nitrogen is one of the most required elements for plant's growth. The reason is that, plants cannot utilize nitrogen as a gas. It must first be combined to some stable form such as urea or ammonium nitrate fertilizer. Plants absorb nitrogen either as ammonium or nitrate ion. The only storehouse of any kind of nitrogen is soil organic matter which must decompose before the nitrogen can be absorbed by plants (Donahue et al., 1983).

Organic carbon

Forest soils can store large amounts of carbon that could be released to the atmosphere through deforestation (Houghton et al., 1983). There is ample evidence that when forests are converted to cultivated cropland, the organic layer is depleted, and soil carbon contents and cation exchange capacities can decrease (Detwiller, 1986). Soil organic matter (carbon) content is often related to soil fertility. Forests are distinct in that they develop an organic layer above the mineral soil. When cultivated lands or soils that previously were low in organic matter are afforested or reforested, there can be substantial increase in the amount of soil organic matter (Ovington, 1959). Managing agricultural soils to store more carbon is likely to have ancillary benefits by reducing soil erosion through the use of cover crops, crop rotations, nutrient management and organic amendments is likely to increase soil fertility and enhance food security for affected population (Robert et al., 2000).

Bulk density (Db)

According to Singer and Munns (2002), bulk density is the weight of soil per unit volume (gcm^{-3}). The term bulk density is used to describe how tightly soil particles are pressed together. The bulk density has direct bearing on

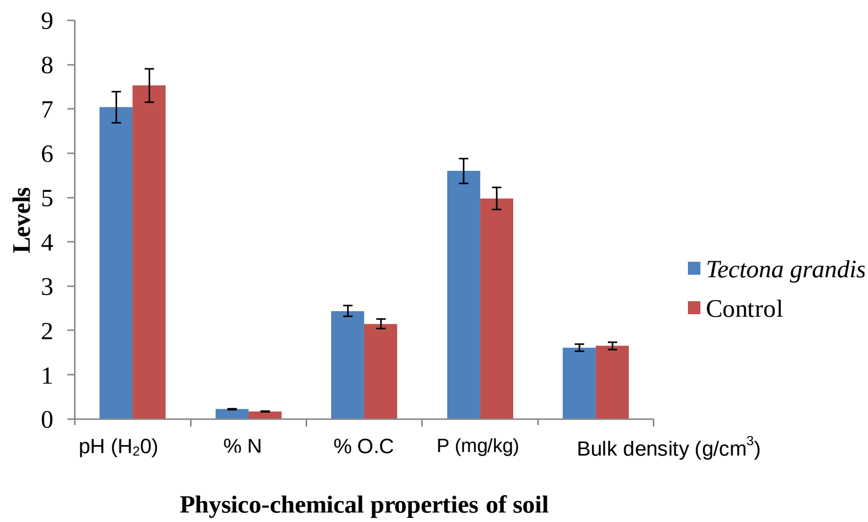

Figure 1. Comparison of the mean values of physico-chemical properties of soil under *Tectona grandis* plantation and its control plots.

the rate of water and water movement, the incidence of surface flooding, erosion, drought and soil temperature (Donahue, 1983). Soils with high densities inhibit water movement and root penetration (Singer and Munns, 2002). As soil become more and more compact, its bulk density increases (Buckman and Brady, 1952). The fine-textured soil such as silt loams, clay loams generally have lower bulk densities than sandy loam (Brady and Weil, 1999).

MATERIALS AND METHODS

Study area

The study was carried out at Yeji in the Pru District of the Brong Ahafo Region of Ghana. The study area lies between longitudes 1° 00' and 1° 05' West and latitudes 8° 00' and 8° 30' North. The area is bounded to North by the Black Volta; to the East is Sene District, West Gonja District to the West and Atebubu-Amantin District to the South. The main occupations of the people are farming and fishing. The vegetation of the area is Savanna woodland. It has however, changed to guinea savanna due to human activities such as clearing of land for farming purposes, cutting of trees for firewood and clearing some areas for settlements. The soils in the study area are dominated by sandy soil with some areas having sandy loam, clay, sandy clay and gravel. The topography of the study area is flat (Agyenim-Boateng, 1989).

Description of plantations

Both the *A. lebbeck* and *T. grandis* plantations under study were 10 years old as at the time of the research. Before planting, the ground was cleared using slash and burn method. The planting distance adopted was 3 by 3 m. Weeding had been done during 3 years from establishment. Pruning of the excess branches has been a practice in the plantations. Each plantation was approximately one acre in size. Different sites with different soil types within the plantation were selected for this study.

Soil sampling and analysis

Systematic sampling was used to collect soil samples diagonally at eight different spots in each plantation and their control plots using soil auger. The soil samples were taken at a depth of 0 to 20 cm at 15 m interval and 10 cm away from the tree base. The samples were air-dried, sieved with 2 mm mesh size and stored in sealed plastic bags for laboratory analysis. Soil samples from adjacent non-tree plot to the plantations were taken as control treatments. Bulk density was determined using the formula by Brady and Weil (2008). Soil pH was measured in 1:2.5 soil-water suspensions with glass electrode pH meter. Organic carbon (O-C) was determined using the Walkley and Black (1934) wet oxidation method. Total nitrogen (N) was determined by the Kjeldahl digestion procedure (Jackson, 1962; Black, 1965). Exchangeable bases were determined by extraction with neutral 1N NH_4OAC. Potassium in the extract was determined with flame photometer while available phosphorus (P) was extracted by Bray P1 method. The P concentration in the extract was determined calorimetrically using the spectronic 70 spectrophotometer.

Statistical analysis

The data was analyzed using Microsoft Office Excel for means and results presented in charts with error bars showing differences in the treatments.

RESULTS AND DISCUSSION

Physico-chemical properties of soil under the *T. grandis* plantation and its control plot

The comparison of the Physico-chemical properties of the soil under the *T. grandis* plantation and its control plot is shown in Figure 1. The mean pH values of the soil under the *T. grandis* plantation (pH = 7.04) was slightly lower than the mean pH of the soil under its control plot (pH = 7.53), however, the differences was not significant as

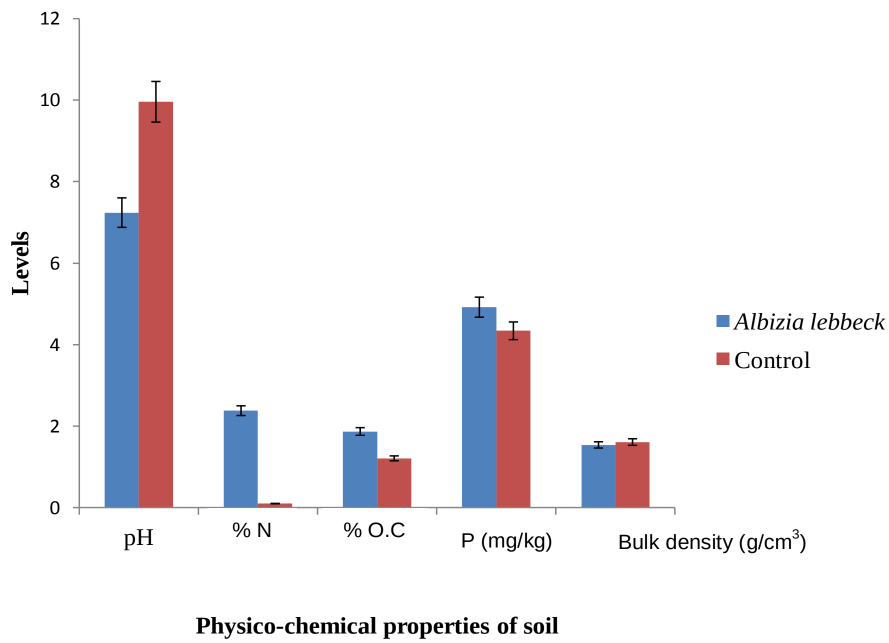

Figure 2. Comparison of the mean values of physico-chemical properties of soil under *Albizia lebbeck* plantation and its control plots.

shown by the error bars in Figure 1. However, Watanabe et al. (2009) recorded lower pH values (pH = 7.14) in the Afrensu Brohuma Forest Reserve in Ashanti region, Ghana. The mean level of nitrogen in the soil under the *T. grandis* plantation (N = 0.22) was slightly higher than the levels in its control plot (N = 0.17) but the difference was not significant. This is however, lesser than that recorded (N = 1.03) by Watanabe et al. (2009) and far lower (N = 2) than that recorded (Amponsah and Meyer, 2000). Also, the mean bulk density of soil under the *T. grandis* plantation (*Db* =1.61) was lower as compared to its control plot (*Db* =1.65). It assumes that *T. grandis* is able to loosen the soil creating more pore space and hence, easy penetration of water and also aeration but there is no significant difference between the bulk density levels of the *T. grandis* and its control plot.

There was significant ($p < 0.05$) difference in the percentage of organic carbon and available phosphorus in the soil under the *T. grandis* plantation as compared to the control plots. This could be attributed to the relatively high amount of organic materials that might have resulted from litter fall from the trees in the plantation than the control plot. Jones et al. (1996) stated that the level of plant material incorporated into the soil improves soil mineral status. Dinakaran and Krishnayya (2010) recorded increases in soil organic matter in afforested areas under Teak, Bamboo and mixed vegetation with increases being greatest under Teak plantations. The levels of N, P and O-C under the *T. grandis* plantation were higher than their controls; however, there was no significant difference in the levels of nitrogen. The pH and bulk density of soils under the *T. grandis* plantation were lower than their control but the differences were not significant.

Physico-chemical properties of soils under Albizia lebbeck plantation and its control

Figure 2 shows the comparison of the mean values of the physical-chemical properties of soils under *A. lebbeck* plantation and its control plot. There was significant ($p < 0.05$) difference in the level of pH in the soil under the *A. lebbeck* plantation and its control plot. The soil under the *A. lebbeck* control plot was highly alkaline (pH = 9.96) while, the soil under the *A. lebbeck* plantation was slightly above neutral (pH = 7.24). This could mean that *A. lebbeck* has the potential of reducing the pH of soils which are highly alkaline to slightly alkaline or neutral. There was significant ($p < 0.05$) difference in the nitrogen levels of the soil under the *A. lebbeck* plantation and its control plot. The soil under the *A. lebbeck* plantation (N = 2.38) had a high level of nitrogen compared to its control plot (N = 0.10). According to Pokhriyal et al. (1991), *A. lebbeck* fixes nitrogen into the soil and is therefore, of great interest especially, as a soil improver. Leguminous plant materials used as green manure and mulch provide an economical source of nitrogen. These could be attributed to the high levels of nitrogen in the soil under the *A. lebbeck* plantation as compared to its control plot.

There was also a significant ($p<0.05$) difference in the levels of organic carbon and available phosphorus in the soil under the *A. lebbeck* plantation and its control plot. Organic carbon and phosphorus were higher in the soil

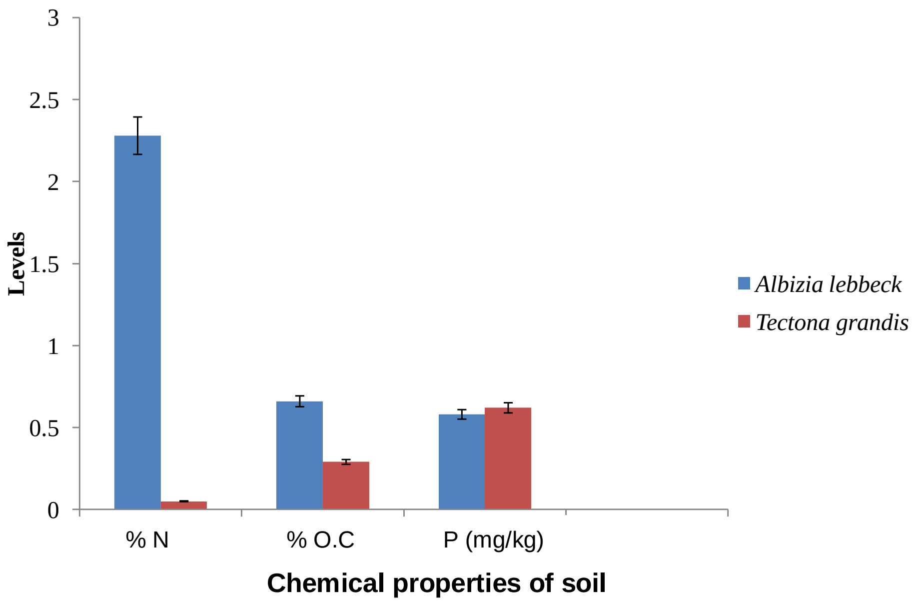

Figure 3. Differences in the mean levels of nitrogen, organic carbon and phosphorus between the soils under *Albizia lebbeck* and *Tectona grandis.*

under the *A. lebbeck* plantation (O-C = 1.87) compared to its control plot (O-C = 1.21). These could be as a result of the high litter fall from the *A. lebbeck* plantation as compared to its control plot. Robert et al. (2000) reported that managing agricultural soils to store more carbon is likely to have ancillary benefits as well as, reducing soil erosion and organic amendments which is likely to increase soil fetility. There was also a significant improvement in soil properties due to plantation of both species, but the organic C and kjeldahl N levels are higher in *A. lebbeck* plantation. According to Singh et al. (2004), the amounts of N and P deposition through leaf fall and release of these nutrients increased with the age of plantation in both *A. lebbeck* and *Albizia procera* species but are higher for *A. lebbeck* plantation. There was however, no significant difference in the bulk density of the soils under the *A. lebbeck* plantation and its control plot.

Differences in the mean levels of nitrogen, organic carbon and phosphorus between the soils under *Albizia lebbeck* and *Tectona grandis*

Comparing the differences in the mean levels of nitrogen, organic carbon and phosphorus of soil under the *A. lebbeck* and *T. grandis* plantation (Figure 3), it was realized that there was significant ($p < 0.05$) differences in the levels of nitrogen and organic carbon added by the *A. lebbeck* plantation to that added by the *T. grandis*. However, there was no significant difference in the levels of phosphorus though *T. grandis* added more phosphorus when compared to *A. lebbeck*. These could be attributed to the nitrogen fixing ability of the *A. lebbeck.* According to Tewari (1995), leguminous trees are capable of fixing nitrogen through the formation of root nodules. In addition, the high litter fall and the ease of decomposition of the *A. lebbeck* leaves may have contributed to the high organic carbon levels in the *A. lebbeck* plantation as compared to that of the *T. grandis* plantation. Ibraheem (2007) reported that nitrogen-fixing tree such as *A. lebbeck* could be incorporated into agro forestry system as its prunings in the form of green manure add nitrogen to the soil.

The N, P and O-G. levels of the soils under the *A. lebbeck* plantation were higher than that of their control plots and also, there was a significant difference in the levels. However, the pH and the bulk density levels of the soil under *A. lebbeck* plantation were lower compared to the soils on its control plot. However, the bulk density was lower under the *A. lebbeck* plantation as compared to its control plot but the difference was not significant. However, there was significant difference in the pH level of the soil under the *A. lebbeck* and its control plot.

Conclusions

In general, *A. lebbeck* added more N and O-C to the soil when compared to the *T. grandis*. Also, *T. grandis* added more phosphorus to the soil as compared to the *A. lebbeck*. However, the difference was not significant. The study also revealed that the pH of the soil under *T. grandis* was almost neutral while that under the pH of the soil under the *A. lebbeck* was slightly alkaline. The study indicated that there were higher differences in mean nutrient values between *A. lebbeck* and its control as compared to that of *T. grandis* and its control. This could mean that *A. lebbeck* contributes more to soil nutrient improvement than *T. grandis*. Based on the analyses of the aforementioned physico-chemical parameters, *A. lebbeck* is therefore, observed to contribute better when compared to *T. grandis*.

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