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Impact of *Albizia lebbeck* Benth (rattle tree) on soil nutrient status and crop yield under agroforestry system (Alley cropping)

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This experiment was conducted to evaluate the impact of *Albizia lebbeck* Benth (its green manure and N_2 fixing ability of its tree rows) on soil nutrient status (physical and chemical properties) under alley cropping (an agro-forestry system) with Irish potato (*Solanum tuberosum* L). The experimental design was a randomized complete block design (RCBD) comprising five treatments and three replicates. Soil sample analyses (pre and post experiment) were done. Tending operations and data collection on apparent growth and yield parameters throughout the five cropping seasons were carried out. Results on the soil physical properties indicated that the nine samples from the three soil depths of T_4 (with the highest rate of green manure application at 10 ton ha^{-1} and *A. lebbeck* tree rows) were predominantly sandy loam probably because of the rate of green manure application which had increased the ratio of smooth to coarse fragment in favor of smooth. Three of the samples of T_1, T_2 and T_3 were sandy clay loam as opposed to T_4 with only two. Though T_0 also had only two of its nine samples being sandy clay loam which could be attributed to the initial textural class of T_0 ($T_{0:}$ control experiment). Thus, a non-significant difference between the pre and post planting soil texture was observed (sandy clay loam, clay loam and sandy loam constituted the dominant textural classes). Regarding the soil chemical properties, the organic matter and nitrogen were very low and the values decreased from pre planting to after planting (no significant difference between treatments/blocks) due to crop removal, leaching and high rates of decomposition/mineralization but the treatments applied (*A. lebbeck* green manure and its tree rows) significantly influenced the available P at 0 to 10 cm depth and K at three soil depths. Block effects were observed at significant level on the pH at 10 to 25 cm and 25 to 40 cm depths and on Mg at 0 to 10 cm depth. The available P decreased generally from the surface soil (down wards) to the subsoil in the study site owing to absorption by the plants and crop removal. The values of exchangeable acidity and effective cation exchange capacity increased generally from surface soil to the sub-soil probably due to leaching or infiltration of the exchangeable cations. The morphological growth parameters (plant height, leaf count and collar girth) except stem count were highly influenced by the different levels of *A. lebbeck* green manure application and its tree rows (sequel to N_2-fixation) at $P \leq 0.1$ which subsequently brought about significant differences in yield, tuber count ($P \leq 0.5$) and tuber weight ($P \leq 0.01$) of the crop (Irish potato) in all the 5 treatments and throughout the 5 cropping seasons due to improvement on the nutrient status in the agro-forestry farm.

Key words: Albizia lebbeck, Alley cropping, soil physical and chemical properties, nutrient status, crop yield.

INTRODUCTION

The essence of improving the nutrient status of our impoverished soils cannot be overemphasized. The

organic matter content on the soil surface is being destroyed by wildfire/bush burning in the forest and savanna ecosystems annually (Okonkwo and Kareem, 1999) coupled with the consumption of much of the organic matter by termites most especially in the semi-arid areas (Gachene and Kimaru, 2003). Even, the nitrogen that is abundantly available in the atmosphere (about 79%) is very deficient in most soils. Several tons of chemical (nitrogenous) fertilizers are purchased yearly to remedy soil nitrogen deficiencies and besides its exorbitance, its application could adversely affect the ozone layer thereby causing increase in skin cancer and rates of mutation in organisms due to harmful radiation (Alexander, 1982). Integration of non-nitrogen and nitrogen fixing trees into agro-forestry systems has been identified as one of the ways of increasing the organic matter and nitrogen content in most savanna soils. These are soils which Alasiri (1997) described as being low in nutrients and of poor structure due to continuous cultivation. In soil fertility improvement and land reclamation, nitrogen fixing trees can play significant roles particularly under alley cropping system which has been known to enhance both nutrient and structural characteristics of soils (Osunde, 1995).

Most tropical soils are highly weathered and leached, some of which are typical Ultisols that are usually characterized by low levels of organic matter and nitrogen content of about 0.3 to 0.6% and 0.03 to 0.05%, respectively (D'Hoore, 1964). In the past, organic matter build-up was achieved under bush fallow system or shifting cultivation or land rotation as a means of fertility maintenance (Greenland and Nye, 1959). But owing to rapidly increasing population, these systems are no more practicable due to pressure on land by other sectors of the economy (Yayock et al., 1988). The vital role played by organic matter in the soil cannot be over-emphasized as Nye (1961) had earlier described it as a vital component of soil exchange complex. This can be increased through ample supply of organic residues such as litter and compost. These inputs can be achieved under alley cropping with trees that are characterized by profuse litter deposition and nitrogen fixing capacity especially in the long run on sustainable basis. Also, Adepetu et al. (1979) reported a 58% drop in the organic matter content of the low soil series in a virgin forest site at Ile-Ife, South Western Nigeria during a seven-year continuous cropping. High cost and inadequate supply of inorganic fertilizer at the right time are among the major constraints to sustainable soil management and cropping and even some of the available ones are adulterated. The use of farmyard manure is limited to small area of land since the demand by large scale farmers or the numerous small scale farmers cannot be met owing to major constraints such as unavailability/scarcity or insufficient quantities of animal wastes, transportation and labor costs (Yayock et al., 1988).

An alternative and inexpensive technique of improving soil nutrient status is alley cropping (an agro-forestry system), where trees help in improving soil fertility (Famuyide and Kareem, 2006). Also, greater erosion resistance, litter deposition, better microclimate and improved rate of mineralization are feasible. Under alley cropping farm, effective timing of nutrient release through decision on when to prune the hedge or tree rows for mulching or as green manure is easily determined (Young, 1985; Adebagbo, 1997) in addition to N_2 fixation activities. Saginga and Mulongoy (1995) reported that more than 3000 kg N ha^{-1} $year^{-1}$ was realized when *Gliricidia*/*Leucaena* hedge rows were pruned and their nitrogen content in the range of 40 to 70 $kgNha^{-1}$ per season was released to crops. With *Albizia lebbeck* which is capable of fixing high amount of nitrogen (Dommergues, 1987) because most soils in the tropics harbor the *Bradyrhizobium* strains of nitrogen fixing bacteria needed for nodulation which is present in this species (*A. lebbeck*). Coupled with its profuse litter deposition in the dry season (being deciduous) the soil physical and chemical properties are eventually modified thereby leading to higher nutrient status. The objective of this study is to evaluate the impact of *A. lebbeck* on the soil nutrient status (physical and chemical properties) and potato (*Solanum tuberosum*) yield under agro-forestry.

MATERIALS AND METHODS

Study area

The experiment was carried out in the Teaching and Research Farm of the Department of Agricultural Extension and Management, Federal College of Forestry, Bauchi Road, Jos, Plateau State, Nigeria in the north-eastern part of the Jos city. The Jos Plateau is located in the Northern Guinea Savanna but owing to its distinctive features, it has been mapped out separately from the rest of the Northern Guinea Savanna Zone (Keay, 1959). The Jos Plateau lies between latitude 8° 50[1]N and 10° 10[1]N and longitude 8° 22[1]E and 9° 30[1]E (Udo, 1978). The average elevation is about 1250 m above sea level while it is height above the surrounding plains is about 600 m and the highest point is about 1777 m above mean sea level which is about 20 km eastwards from Shere Hill. Also, a number of relatively low plains are found at the boundaries of the Jos Plateau, at the north-east, it is surrounded by the Bauchi plains, Jama'-Kaduna plains to the north-west and the Benue lowlands to the South. The Jos Plateau is about 8,600 km^2, its north to south length is about 105 and 81 km from east to west and almost occupies the center of the Nigeria's physical space (Keay, 1951, 1959; Hill, 1978; Davis, 1973; Morgan, 1979; Eziashi, 1995).

Pre-experimental soil analysis

In order to assess the initial nutrient status of the experimental site

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Table 1. Particle size distribution (%) and textural classes* (TC) of the pre and post experimental soil samples.

Soil Depth (cm)		Replicate 1				Replicate 2				Replicate 3			
		Sand	Silt	Clay	TC	Sand	Silt	Clay	TC	Sand	Silt	Clay	TC
Before planting													
0-10		61	26	13	SL	47	18	35	SCL	61	22	17	SL
10-25		59	18	23	SCL	61	14	25	SCL	61	14	25	SCL
25-40		51	16	33	SCL	53	16	31	SCL	49	16	35	SCL
After planting													
	0-10	75	12	13	SL	65	18	17	SL	67	18	15	SL
T_0	10-25	71	14	15	SL	61	18	21	SCL	63	18	19	SL
	25-40	65	16	19	SL	61	16	23	SL	61	16	23	SCL
	0-10	75	12	13	SL	67	20	13	SL	63	22	15	SCL
T_1	10-25	71	12	17	SL	65	18	17	SL	49	24	27	SCL
	25-40	69	12	19	SL	61	16	23	SCL	63	22	15	SL
	0-10	69	16	15	SL	63	16	21	SCL	61	18	21	SCL
T_2	10-25	69	14	17	SL	67	18	15	SL	59	16	25	SCL
	25-40	63	18	19	SL	71	18	11	SL	63	22	15	SL
T_3	0-10	75	12	13	SL	77	20	03	SL	67	20	13	SL
	10-25	71	12	17	SL	67	20	13	SL	65	16	19	SL
	25-40	59	24	17	SL	61	16	23	SCL	61	16	23	SCL
	0-10	61	22	17	SL	61	16	23	SCL	61	22	17	SL
T_4	10-25	65	16	19	SL	65	16	19	SL	59	20	21	SL
	25-40	63	14	23	SCL	63	20	17	SL	67	22	11	SL

TC: Textural Class, SL: sandy loam, SCL: sand clay loam (see section 2.2 for what To- T4 denote).

and use the result of the laboratory analysis as basis for the block design, soil nutrient analysis was carried out. Prior to blocking of the experimental site into three parts to represent the three blocks, three portions or locations were randomly selected (as major locations/portions). This was followed by random selection of four sub-locations from each major location. Subsequently, from each sub-location, soil samples were collected at three depths: 0-10, 10-25, and 25-40 cm. Composite samples from each major location were used for analysis (that is, the three major locations were assigned Arabic numerals 1, 2, and 3, their corresponding sub-locations were 1a, 1b, 1c, 1d; 2a, 2b, 2c, 2d, 3a, 3b, 3c, 3d). Each sub-location was at 3 soil depths represented in Roman numerals i, ii, and iii. To make composite samples, combinations of ai, + bi + ci, di; aii + bii + cii, dii and aiii + biii + ciii, and diii were produced. Thus, a total number of 9 samples (3 from each of the major locations) were analyzed and taken as pre-experimental site nutrient status (Tables 1 and 2).

Furthermore, each sample was meticulously put in polythene bags separately, labeled and taken to the laboratory, removed from the polythene bags, air dried, ground, sieved with 2 mm sieve, smooth and coarse samples weighed separately, the percentage of the coarse portion determined and smooth portion subjected to laboratory analysis. Also, a soil profile was dug at a suitable place in the experiment site. This paved way to have the knowledge of the different horizons in the soil profile, ensured proper identification and classification of the different soil types (for example, Entisols, Inceptisols, Alfisols and Ultisols). It is pertinent to mention here that the same soil sample analytical procedures were employed before (pre) and after (post) the experiment. Determination of the particle size distribution of the soil samples was done by using the hydrometer method (Day, 1965) and separated into sand, silt and clay and expressed in percentages, while the pH (1:2:5) in water and KCl was determined electronically by using a functional pH meter. Flame photometer was employed in the determination of the exchangeable cations (bases) such as Na and K while estimation of the Ca and Mg was done by means of atomic absorption spectrometer (AAS). Effective cation exchange capacity (ECEC) was determined by summation method, following the extraction of exchangeable acidity with the aid of IN KCL. Coleman in Kamprath (1984) suggested that the determination of CEC through the summation of exchangeable bases plus KCL exchangeable acidity serves as a more realistic method of evaluating the actual amount of bases experienced by plants. The percentage organic carbon content was determined with the aid of potassium dichromate method of Walkey and Black (1974), available phosphorus by Bray and Kurtz (1945) method and total nitrogen by Kjeldal method (Jackson, 1962). The results obtained are shown in Table 2.

The experimental design employed was randomized complete block design (RCBD) consisting of five treatments and three replicates. A table of random numbers was employed in assigning treatments to each block. The five treatments used are as follows: T_o, Potato planted on flat bed without tree rows and green manure

Table 2. Some chemical properties of the pre-experimental soil samples as influenced by the treatments after planting at three soil depths.

Treatment		pH		OM	TN	Avail. P	Ca	Mg	K	Na	E.A	ECEC
		H_2O	KCl	(%)	(%)	(ppm)	cmol (+) kg^{-1}					
Before planting (0 - 10 cm Depth)		4.5^{b}	4.2^{ab}	1.94^{a}	0.10^{ab}	23.45^{a}	4.07^{a}	0.78^{b}	0.22^{a}	0.18^{ab}	0.87^{a}	6.12^{a}
	T_0	5.2^{a}	4.5^{a}	1.22^{b}	0.06^{b}	15.52^{b}	2.06^{c}	0.61^{c}	0.17^{ab}	0.15^{b}	0.73^{a}	3.72^{b}
	T_1	4.5^{b}	4.3^{ab}	1.29^{b}	0.06^{b}	16.40^{b}	2.07^{c}	0.63^{c}	0.11^{ab}	0.19^{ab}	0.54^{a}	3.54^{c}
After planting (0 - 10 cm)	T_2	5.2^{a}	4.5^{a}	1.38^{b}	0.06^{b}	24.62^{a}	3.00^{ab}	0.72^{b}	0.14^{ab}	0.23^{a}	0.80^{a}	4.89^{ab}
	T_3	5.1^{a}	4.0^{b}	1.45^{b}	0.08^{b}	6.45^{c}	2.67^{b}	0.69^{c}	0.20^{a}	0.19^{ab}	0.73^{a}	4.48^{ab}
	T_4	4.7^{ab}	4.1^{b}	1.69^{a}	0.33^{a}	18.90^{b}	3.07^{ab}	0.93^{a}	0.17^{ab}	0.20^{a}	0.60^{a}	4.97^{ab}
Before planting (10 - 25 cm)		4.3^{b}	3.9	1.15^{b}	0.07^{a}	3.79^{c}	3.93^{a}	0.80^{b}	0.15^{a}	0.20^{a}	1.20^{a}	6.28^{a}
	T_0	4.9^{b}	4.5^{a}	1.03^{c}	0.05^{a}	10.92^{b}	2.40^{b}	0.46^{c}	0.14^{a}	0.17^{ab}	1.13^{a}	4.30^{b}
	T_1	4.8^{b}	4.2^{ab}	1.24^{b}	0.07^{a}	18.22^{a}	3.07^{ab}	1.16^{a}	0.11^{a}	0.20^{a}	0.73^{b}	5.27^{ab}
After planting (10 - 25 cm)	T_2	5.1^{ab}	4.4^{a}	1.26^{b}	0.08^{a}	13.79^{ab}	1.81^{c}	0.34^{c}	0.17^{a}	0.26^{a}	1.07^{a}	3.65^{b}
	T_3	5.4^{a}	4.4^{a}	1.57^{a}	0.08^{a}	7.29^{c}	2.87^{b}	0.81^{b}	0.19^{a}	0.20^{a}	1.47^{a}	5.54^{ab}
	T_4	5.1^{ab}	4.5^{a}	1.38^{a}	0.08^{a}	10.38^{b}	3.27^{a}	0.99^{b}	0.17^{a}	0.18^{a}	1.07^{a}	5.68^{ab}
Before planting (25 - 40 cm)		4.3^{b}	3.7^{a}	0.79^{c}	0.07^{a}	3.04^{b}	3.60^{a}	0.52^{c}	0.18^{b}	0.27^{a}	1.87^{a}	6.44^{a}
	T_0	5.1^{a}	4.6^{a}	0.95^{c}	0.06^{a}	4.46^{b}	2.87^{b}	1.19^{a}	0.16^{b}	0.18^{ab}	1.40^{ab}	5.80^{ab}
	T_1	5.3^{a}	4.4^{a}	1.05^{b}	0.07^{a}	3.90^{b}	2.73^{b}	0.66^{b}	0.14^{b}	0.21^{ab}	1.13^{b}	4.87^{b}
After planting (25 - 40 cm)	T_2	4.8^{b}	4.4^{a}	1.14^{a}	0.31^{b}	4.43^{b}	2.20^{c}	0.76^{b}	0.47^{a}	0.16^{ab}	1.33^{b}	4.92^{b}
	T_3	5.4^{a}	4.4^{a}	1.15^{a}	0.07^{a}	5.02^{a}	2.53^{b}	1.07^{a}	0.16^{b}	0.16^{ab}	1.53^{a}	5.45^{b}
	T_4	4.9^{b}	4.5^{a}	1.03^{b}	0.27^{b}	6.88^{a}	1.93^{c}	0.29^{c}	0.13^{b}	0.15^{ab}	1.13^{b}	3.63^{ab}

OM: Organic matter, TN: total nitrogen, E.A.: exchangeable acidity, ECEC: effective cation exchange capacity. Each value represents mean value from three replicates from a treatment. Mean values with the same letters are not significantly different at 5% Probability level by DMRT.

of *A. lebbeck*. T_1, Potato planted in the alleys of *A. lebbeck* without green manure. T_2, Potato planted with green manure of *A. lebbeck* at 5 ton ha^{-1} without its tree rows. T_3, Potato planted in alleys of *A. lebbeck* tree rows with its green manure at 5 ton ha^{-1}. T_4, Potato planted in alleys of *A. lebbeck* tree rows with its green manure at 10 ton ha^{-1}. Each plot/replicate in a block was 3 m × 2 m, the green manure was single application two weeks before planting the pre-sprouted potato tubers (bertita variety). *A. lebbeck* tree seedlings had early been raised prior to planting (seedlings were 6 months old before planting (0.60 and 2.0 m) within and between rows, respectively). All necessary tending operations were carried out. Analysis of variance (ANOVA) was employed in analyzing the data collected on the soil samples, apparent growth parameters (plant height, number of leaves, stem count, collar girth) and yield parameters (tuber count and tuber weight) in order to find out if there were significant differences among treatments and blocks owing to the possible influence of the green manure of A. lebbeck and its tree rows. Duncan's Multiple Range Test (DMRT) was used where significant differences were recorded in separating the mean values of the variables so as to help in giving appropriate recommendations(Table 3).

Post-experimental soil sample collection and analysis

Immediately after final harvest at the 5th planting season, soil samples were collected for laboratory analysis by employing the same method of analysis earlier described (in pre-experimental soil sample analysis). Samples from the five treatments (T0, T1, T2, T3 and T4) were analyzed (three replications per treatment). A comparison between the results from composite samples of pre and post (final) experiment soil nutrient analysis was made using the analysis of variance technique (ANOVA). Thus, improvement or effect on the nutrient status of the soil due to the nitrogen fixing activities of A. lebbeck tree rows and incorporated green manure (of this tree species) was evaluated and all the soil samples were analyzed by the same analyst and with the same sets of chemicals (reagents) at the Soil Science Department of Faculty of Agriculture, Ahmadu Bello University, Zaria and Institute of Agricultural Research, ABU, Zaria, Nigeria.

RESULTS AND DISCUSSION

Soil physical properties

Particle size analysis of the three randomly selected locations at the experimental site (prior to planting which served as three replicates) indicated that the soils in the granite area were predominantly sandy clay loam (Table 1). The 0 to 10 cm depth indicated that the soil had a very high percentage of sand (61%). The silt and clay contents were 26 and 13%, respectively. This agrees with Olowolafe (2007) who observed that the soil in the study area was an Alfisol which was characterized by increase in clay content with increase in soil depth. For the 10 to 25 cm and 25 to 40 soil depths, the soil texture was sandy clay loam due to the fact that the sand had the highest percentage and this was followed by clay. It was observed that the sand and silt proportions decreased with increasing depth (from 0 to 10, 10 to 25, 25 to 40 cm depth) while the clay content increased with depth. For instance, the 0 to 10 cm depth had 13% clay which increased to 23 and 33%, respectively and at 10 to 25 cm and 25 to 40 cm depths. This supports the classification as Alfisol owing to increase in clay content with depth which is an important property of Alfisol. However, ANOVA indicated no significant difference in the % clay at the three soil depths (Table 1 and Figure2).The nine samples from the three soil depths of T_4 were predominantly sandy loam (except two samples) probably because T_4 received the highest rate of green manure application (10 ton ha^{-1}). This must have increased the ratio of smooth to coarse fragment in favor of smooth. T_1, T_2 and T_3 had three of their replicates (samples) being sandy clay loam as opposed to T_4 with only two. Though T_0 also had only two of its nine samples being sandy clay loam which could be attributed to the initial textural class of T_0 and probably little fertility gradient as no green manure was applied to the treatment (that is T_0). There was little (non-significant) difference between the pre and post planting soil texture which was probably the reason why analysis of variance on the clay content indicated no significant difference in the soil texture before and after planting. This agrees with Olowolafe (2003) who had earlier observed that soils developed from granites are mainly loamy textured with sandy clay loam, clay loam and sandy loam constituting the dominant textural classes.

Chemical properties of the soil samples (before and after planting)

The significant difference in block effect with regard to pH at 10 to 25 cm and 25 to 40 cm soil depths ($P \leq 0.01$ and $P \leq 0.05$, respectively) was observed and this could be attributed to addition of organic matter in form of green manure from *A. lebbeck.* Since the pH (H_2O) was initially low (4.5) before planting which made the soil very strongly acid (Troug, 1948; Olowolafe, 2003) but rose to a range of 5.1 to 5.4 in T_2-T_4 which indicates the influence of the green manure application (Table 2). Kunishi (1982) had earlier observed that organic matter raises the soil pH, helps in ameliorating phyto-toxicity in acid soils, decreases soluble manganese and exchangeable aluminium (Al) and increases calcium and available phosphorus. Olowolafe (2003) had also reported that the addition of more organic matter could lead to the release of more basic cations that resulted in the improvement of base saturation and soil pH indicated no significant difference at 0 to 10 cm depth was probably as result of crop/plant absorption or leaching.

The soil structure also could have been improved probably owing to the application of the organic manure in T_2, T_3 and T_4 which could have probably improved infiltration and porosity of the soil. Thus, the green manure applied and the tree rows of *A. lebbeck* might have contributed in reducing the acidity of the soil, which brought about better yield of potato in T_1-T_4 over that of T_0. This agrees with Kunishi (1982) who observed that the pH range of 5.5-8.5 is within the pH range of tolerance for crop production and that soil acidity does result to low agricultural productivity. The organic matter (OM) in T_0-T_4 (after planting) was lower than the value before planting (Tp) due to crop removal and leaching and those of T_2-T_4 are higher than T_0 and T_1 probably because of the addition of green manure. The OM of the T_P and T_0-T_4 are generally low (Table 2) below 2% (0.79 to 1.94%) which could be attributed to the fact that the soils are of granite origin (Olowolafe, 2003) and is characteristic of tropical soils (Landon, 1991). This low level of OM was as a result of the high temperature experienced in larger period of the year which brought about high decomposition, mineralization rates and subsequent disappearance of organic matter which are detrimental to the practice of sustainable agriculture in the tropics (Mulongoy and Merckx, 1993; Olowolafe, 2003).

Lack of significant effect of blocks and treatments at all depths on the total nitrogen (TN) could be due to the generally low level of TN in the site. This is a characteristic feature of tropical soils/environment with high temperature that results to fast loss of nitrogen owing volatilization, crop removal, erosion and leaching

(Landon, 1991; Olowolafe, 2003). Only the effect of block and treatment at 0 to 10 cm depth on available phosphorus (available Phosphorus) was significant probably because of reasonable differences in the values before planting and those of the treatments. For instance, the values in T_P, T_1, T_2 and T_4 are relatively higher (16.40 to 23.45 ppm) as opposed to T_0 and T_3 (which are 6.45 and 15.52 ppm, respectively), thus, a significant difference among the blocks and treatments was observed (Table 2). As earlier stated by Olowolafe (2003), soils that were derived from granites contain relatively high available phosphorus and there is high P-fixation in acid tropical soils (Courley, 1987). This could be the reason why available P values were higher before panting (23.45 pp at 0 to 10 cm depth, increased to 24.62 pp in T2 but decreased to a range of 3.7 to 18.90 pp in T0, T1, T3 and T4) and those treatments with fairly low values could be as a result of lower fixation rate and higher rate of absorption by plants (*A. lebbeck* and potato) in the treatments. The exchangeable cations, there was no significant effect of treatments on Ca levels. This could be attributed to the nature of the parent material, fairly uniform levels of Ca before planting (Tp) and the respective treatments (T_0-T_4), different rates of Ca intake by plants and the dominant nature of Ca at the exchange site. The low levels of Ca (Table 1) in some of the treatments could also be due to leaching as a result of the high rainfall pattern which is about 1371 mm per annum (Alford et al., 1979; Eziashi, 1995) on the Plateau and the generally low pH values of the soils from the site (granite) which favours the formation of kaolinite. Kaolinite is the main silicate clay mineral in the major soil types on the Plateau (Inceptisols, Alfisols and Ultisols) which is a contributory factor to the low Ca and Mg (Olowolafe, 2003).

Magnesium (Mg) is one of the exchangeable cations that dominates the exchange site of the soils (Table 1). The significant effect of blocks on Mg content at 0 to 10 cm depth could be attributed to the influence of fertility gradient (in respect of block) at the experimental site. Generally, soils derived from granites are low or very low in exchangeable Ca and Mg (Olowolafe, 2003). Similarly, the significant effect of the treatments on K levels at 0 to 10 cm and 10 to 25 cm could be as a result of the application of green manure which might have influenced the K content in the soil samples from the treatments ((Table 2). The generally low K levels which could be as result of leaching and the low K content of the soil parent material as earlier reported by Olowolafe and Dung (2000). The non-significant effect of the treatments on Na observed at all soil depths could be attributed to the low level of variations among the mean values of the treatment which ranged from 0.15 to 0.26 cmol (+) kg^{-1} which is not enough to bring about significant differences (Table 2).

However, the low level of sodium (Na) at the exchange site might not be unconnected with the nature of the parent material, leaching, intake by plants and treatments applied (Table 2). The generally low exchangeable acidity is as a result of the low pH and organic matter of the soil. This phenomenon had earlier been observed by Nyle and Ray (1996) in respect of soils with low pH and organic matter. The generally low levels of the exchangeable cations in the study site (which has been under continuous cultivation is traceable to nutrient removal by crops and grazing (by the cattle in the College). This further indicates that the amount of nutrients (cations) removed from the soil exceeds what was added to the soil through manuring or nitrogen fixation activities of the *A. lebbeck* trees, hence, the increasing value of exchangeable bases and accompanying decline in soil pH in the experimental site (Olowolafe, 2007).The differences among the mean values of exchangeable acidity could be attributed to possible effect of clay content in the soils.

The values of subsoil are higher than that of the surface soil which could be due to leaching or higher infiltration rates of the exchangeable cations at the exchange site. For instance, the values of the exchangeable acidity before planting (0.87 to 1.87) decreased profoundly (0.54 to 0.80) in the surface soil (0 to 10 cm depth) but to a little extent in the deeper strata (10 to 40 cm) with mean values of 0.73 to 1.53 cmol (+) kg^{-1} soil. This is due to leaching of nutrients or their uptake by the crop (potato) and *A. lebbeck,* as more H^+ and Al^+ replaced the exchange site and thereby making the soil more acidic. This phenomenon had earlier been reported by Fomba (1998) on the effects of *Gliricidia sepium* leaf mulching on okra growth and yield. Also, low organic matter contents normally adversely affect exchangeable acidity since soil organic matter plays a vital role in the supply of plant nutrients and enhancement of exchangeable acidity. The low organic carbon in the site is traceable to the influence of high temperature which is a prominent feature of tropical environment which leads to fast rates of decomposition, mineralization and subsequent disappearance of soil organic matter (Nye and Ray, 1996; Olowolafe and Dung, 2000). The observed decrease in the effective cation exchange capacity (ECEC) from a range of 6.12 to 6.62 downwards the soil strata (0 to 40 cm depth) before planting to a range of 3.65 to 5.79 (Table 2) down the strata (0 to 40 cm depth) after planting could be due to absorption by plants, crop removal. Also, the values of the ECEC reduced because of the reduction in the values of exchangeable cations and exchangeable acidity since ECEC is the summation (addition) of the exchangeable cations and exchangeable acidity (Table 2). Therefore, the increase in exchangeable acidity and ECEC from the surface soil to the deeper strata of the soil (subsoil) in the study site could be as a result of infiltration of the exchangeable cations or their absorption by the potato crops for growth and yield. This is in line with the earlier observation made by Olowolafe and Dung (2000) in

Table 3. Seedling emergence, growth and yield parameters of Irish potato in the 1st, 2nd, 3rd, 4th and 5th cropping seasons.

Treatment	Germination		Growth Parameters				Yield Parameters	
	%S.E. (7 DAP)	%S.E. (14 DAP)	Plant height (cm)	Leaf count	Stem count	Collar girth (cm)	Tuber count	Tuber yield (t/ha)
1st Season								
T_0	70.0[a]	97.0[a]	44.7[d]	24.7[d]	3.0[a]	2.2[e]	112.3[c]	5.03[d]
T_1	52.06[b]	98.0[a]	51.3[c]	27.0[d]	2.7[ab]	2.8[d]	109.0[c]	5.08[d]
T_2	41.0[c]	97.0[a]	53.7[c]	41.3[b]	2.3[ab]	3.07[c]	139.0[b]	8.36[b]
T_3	62.0[ab]	97.7[a]	55.7[b]	35.7[c]	2.3[ab]	3.4[b]	113.0[c]	7.98[c]
T_4	57.3[b]	99.0[a]	66.3[a]	56.7[a]	2.0[b]	4.5[a]	160.7[a]	9.36[a]
2nd Season								
T_0	29.7[b]	92.7[ab]	48.0[e]	30.0[c]	2.3[b]	2.3[e]	79.7[d]	5.19[e]
T_1	24.3[c]	90.0[ab]	55.7[d]	35.0[c]	2.7[a]	3.0[d]	111.0[c]	5.43[d]
T_2	24.0[c]	87.0[b]	58.7[c]	53.0[b]	3.0[a]	3.4[c]	153.7[a]	9.72[b]
T_3	33.7[a]	87.7[b]	62.3[b]	52.0[b]	2.3[b]	3.5[b]	127.7[b]	8.90[c]
T_4	24.7[c]	95.0[a]	68.3[a]	67.3[a]	3.0[a]	4.7[a]	160.7[a]	10.41[a]
3rd Season								
T_0	58.3[b]	94.7[b]	62.0[c]	36.7[d]	3.0[a]	2.4[e]	92.3[c]	5.30[e]
T_1	54.7[b]	98.3[a]	65.0[bc]	52.3[c]	3.0[a]	3.3[d]	94.7[c]	5.40[d]
T_2	43.7[c]	98.0[a]	67.7[b]	61.7[b]	3.0[a]	3.6[c]	151.7[a]	9.13[b]
T_3	71.7[a]	97.7[ab]	63.7[c]	64.0[b]	2.7[a]	3.5[b]	118.0[b]	8.61[c]
T_4	56.7[b]	97.0[ab]	75.3[a]	70.3[a]	2.7[a]	4.9[a]	93.7[c]	9.80[a]
4th Season								
T_0	36.3[b]	93.0[ab]	64.7[d]	44.0[e]	3.0[a]	2.5[e]	95.7[bc]	5.22[d]
T_1	31.0[c]	92.0[b]	70.3[c]	60.0[d]	3.0[a]	3.5[d]	93.7[c]	5.74[c]
T_2	29.0[c]	95.0[ab]	76.3[b]	66.0[c]	2.0[b]	4.3[b]	142.7[a]	9.61[a]
T_3	33.0[bc]	84.0[c]	74.3[b]	72.3[b]	2.3[b]	4.1[c]	103.3[b]	8.90[b]
T_4	41.0[a]	97.0[a]	80.7[a]	77.7[a]	2.3[b]	5.3[a]	87.0[d]	9.73[a]
5th Season								
T_0	61.0[a]	93.0[a]	63.7[d]	46.0[c]	2.7[a]	3.1[e]	97.0[c]	5.28[e]
T_1	55.3[a]	91.7[a]	70.7[c]	72.3[b]	2.7[a]	3.5[d]	91.0[c]	5.85[d]
T_2	59.0[a]	92.3[a]	77.3[b]	71.0[b]	2.3[a]	4.4[b]	160.7[a]	9.63[b]
T_3	59.3[a]	94.0[a]	71.3[c]	70.3[b]	2.7[a]	4.2[c]	142.7[b]	9.02[c]
T_4	63.0[a]	94.0[a]	82.3[a]	78.7[a]	2.3[b]	5.3[a]	161.7[a]	11.96[a]

S.E.: Seedlings' emergence. Mean values with the same letters were not significantly different at 5% level by Duncan's Multiple Range Test (DMRT). To-T_4 were explained in the work.

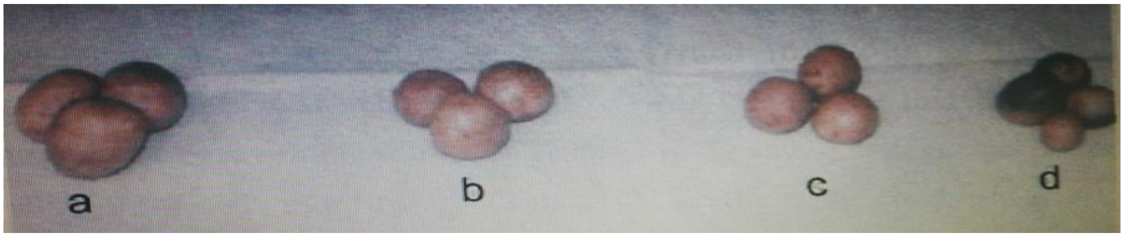

Plate 1. Different sizes of harvested potato tubers (a: > 50 mm, b: 40-50 mm c: 30-40 mm, d: < 30 mm in diameter).

respect of soils derived from the biotite-granite on the Jos Plateau (Nigeria) with regard to their nutrient status and management for sustainable agriculture. Apart from factors such as infiltration, absorption by crops (crop removal), mini- erosion could also be a contributory factor for the decline in exchangeable acidity and ECEC in the surface soil. This agrees with the reports by Lal (1981) and Olowolafe (2007) who observed that considerable or substantial proportion of topsoil nutrients are lost as a result of erosion.

With regard to the yield, it was obvious from the data collected that T4 had the highest values in growth and yield (tuber count, tuber size, tuber weight) values in all the five cropping seasons owing to the fact that it was the treatment that received the highest level of green manure application (10 ton/ha) with tree rows of *A. lebbeck..* Also, significant differences were observed at 1% probability level (Table 3, Plate 1).

Conclusion

Indubitably, reasonable impact/effect of the *A. lebbeck* trees on the soil physical and chemical properties at the experimental site within the five cropping seasons (3 years) had been observed. This is not unconnected with the green manure application, litter from the *A. lebbeck* trees and its N_2 fixation activities. Also, better positive effects are expected in the long run in terms of the soil physical characteristics (structure, texture, bulk density, porosity, water holding capacity, permeability/hydraulic conductivity) and chemical properties (pH, organic matter, total nitrogen, available phosphorus, K, Ca, Mg, S, Zn, Mn, Bo, Mo, Cl, exchangeable acidity, cation exchange capacity). Thus, a reasonable improvement/ modification on the soil nutrient status (fertility) in the agroforestry farm will be achieved which will concomitantly lead to increased yield of crops in the alley cropping farm, reduced/lesser cost of production and better microclimatic condition on sustainable basis.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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