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Does Forest Litterfall Nutrient Stocks Affect the Nutrient Supplying Capacity of Soils?

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Abstract

In order to understand nutrient stocks and dynamics of forest soils, the nutrient supplying capacity of forest soils and control soils were evaluated through greenhouse bioassay. Maize agronomy and nutrient uptake was assessed in 4 consecutive cycles, at 6 weeks/cycle. Results indicated that dry matter yield ranged from 4.25 to 10 g plant^{-1}. The mean plant height decreased from the 1st to the 3rd cycles. The organic carbon of the soils ranged from 0.61 to 1.80 % in soils from Leucaena leucocephala and Anogeissus leiocarpus, respectively. The soil total N ranged from 0.07 to 0.17 % while the maize N varied from 1.09 - 2.98 % in the 3rd and 1st cycle for soils under Treculia africana and Bambusa vulgaris. Bambusa vulgaris soil was better in nutrients supply considering the quantities of nutrients and their patterns of release to the soil.

Keywords: Agroforestry, maize, forest soils, soil nutrients, litter chemistry.

1. Introduction

The nutrient supplying capacity of a given soil type is essential for the growth and development of crops. High crop yield is partly dependent on the soil nutrient contents and its ability to supply these nutrients in adequate and available forms to the crops (Marschner, 2012). Many factors have, however, been recognised to influence the nutrient supplying capacity of soils. These factors include soil type, pH, organic matter content, soil cover or litter, and soil micro-organisms and the land-use system to which the soil is subjected to (Thiffault et al., 2011; Landon, 2014). Among these factors, soil cover or surface residues have been shown to contribute significantly both to the nutrient contents and to its supplying capacities particularly when under the same soil type (Meisner et al., 2012). The contributions of different soil surface residue to the soil nutrient supplying capacity are yet to be widely explored in research.

The capacity of trees to maintain and improve soil condition is shown by high soil fertility status and enriched nutrient cycling under natural forest, the restoration of fertility under forest fallow in shifting cultivation, and the experience of reclamation forestry and agroforestry (Attiwill et al., 1993). A range of properties have been identified which make tree species suited to soil improvement. These may include high biomass production, nitrogen fixation, a combination of fine feeder roots with tap roots and litter with high nutrient content (Attiwill et al., 1993).

It is recognized that forest trees contribute variable quantities of litters to the soil organic pool. This litter varies in their chemical compositions, the speed with which it breaks down in the soil and the diverse range of soil flora and fauna that inhabit it. The by-products of the litter breakdown are retained in the soil through chemical and biological processes (Ballard and Will, 1981). Nutrients, such as phosphorus, nitrogen, potassium, calcium, magnesium and trace elements, may be retained in a form that is not available for tree and plant growth (fixed pool), or may be in the plant available pool (Binkley et al., 2011).

Nutrients uptake in plants is influenced by the soil relative proportion of micro and macro-nutrients. Soil micro-nutrients are nutrients that are required by all plants for proper growth and productivity in minute amounts. They include copper, iron, manganese, and zinc. Each has several important and specific functions in plant cell metabolism and in photosynthesis. They are only rarely limiting to plant growth in soils because they are needed in trace amounts. A high proportion of these nutrients in the soil could lead to soil heavy metal pollution (Azeez et al., 2013). In contrast, macro-nutrients, such as nitrogen, phosphorus and potassium, are required in large quantity for optimum plant yield. These macronutrients, particularly, the NPK are highly limiting in most tropical soils. While it is clear that many tree litters could help supply these limiting nutrients and improve the soil chemical composition, the effects of different tree litters on the soil nutrient supplying capacity are yet to be effectively evaluated.

Similarly, the impact of trees on soil nutrients has been conventionally assessed by examining changes in soil nutrients (Baker, 1978) with fewer studies focusing on the nutrient concentrations of the crop grown in cycles on the forest soils. Different tree species could, however, differ in the quantity and quality of nutrients supplied to the soil. A good understanding of the impact of forest litters on the soil nutrient supplying capacity to subsequent crops grown on

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that soil is imperative and could help promote the practice of agroforestry among smallholder farmers. Therefore, it is in this context that the present study aims to evaluate the nutrient supplying capacity of soils from different forest species by evaluating, through greenhouse bioassay, the agronomic response and nutrient concentration of successive maize plants grown on soils collected from forest sites.

2. Materials and Methods

2.1. The Study Location

The plantations used for the present study was located at the Federal University of Agriculture Abeokuta Nigeria forestry arboretum. The site is located adjacent to the University's main entrance on latitude 7^0 58' N and on the longitude 3^0 25' E. The general topography of the present study area was an undulating land terrain. The annual temperature ranges from 22^0 C to 33^0 C. The annual rainfall is about 1400 mm with wet season from April to October while the dry season is from November to March

2.2. History of the Forest Sites

The trees used for the present study and the non-tree spp. soils were of the same soil type. Gmelina arborea was established in 2000 at an elevation of 159 m above sea level (ASL). The trees are located at 7.22738°N, 3.44742°E. Tectona grandis plantation was established in 1998 at an elevation of 156 m ASL; the trees are located at 7.22713°N; 3.44773°E; Leucaena leucocephala was established in 1998 at 159 m ASL and located at 7.22738°N, 3.44742°E. Bambusa vulgaris is probably the oldest plantation; estimates showed that it was established in 1990 at 150 m ASL at 7.22737°N, 3.44717°E. Treculia africana was established in 2001 at an elevation of 149 m ASL at 7.2263°N, 3.44909°E. Anogeissus leiocarpus was established in 2001 at an elevation of 149 m ASL and located at 7.2265°N, 3.44038°E.

2.3. Soil Sample Collection and Preparation

The soil samples were taken under the seven tree species which included: Gmelina arborea, Tectona grandis, Leucaena leucocephala, Bambusa vulgaris, Treculia africana, Anogeissus leiocarpus and fallow land (non tree spp.). Soil samples were collected at 0-15 cm depth with a shovel at the basement of each tree species. The trees established a continuous cluster of trees with litters of the same tree on the ground. Soil samples were collected from few meters from the base of trees randomly at depth of 0-15 cm (surface soil). The systematic sampling points were selected to fall at center points where at least four trees shoot-biomass interlock. Details of the sampling positions are shown in Figure (1). The soils were collected from the central dark spots on Figure (1). The samples were collected into well-labelled sampling bags. The samples were air dried and sieved with a 2 mm sieve. Routine soil analysis was carried out on those samples. Thirty-two experimental pots were prepared; 5 kg soil from each of the tree species was dispensed into the pots.

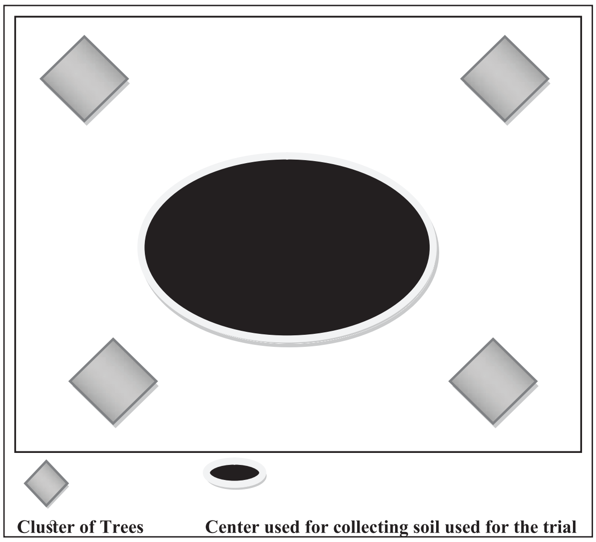

Figure 2. Sampling design of soil collection.

2.4. Soil Analysis

The soil pH was determined using glass electrode pH meter (McLean et al., 1982). Total nitrogen was determined using macro-Kjeldahl method (Bremner and Mulvaney, 1982). Phosphorus was determined by Bray 1 method (Nelson and Sommers, 1996). Organic carbon was determined using chromic acid oxidation procedure method (Nelson and Sommers, 1996). Exchangeable cations (potassium, calcium, sodium and magnesium) were extracted using 1N ammonium acetate. K and Na in the extract were read on a flame photometer while Ca and Mg were read on Atomic Absorption Spectrophotometer (AAS). The available Zn, Cu, Mn and Fe, extracted with HCl, were determined on an Atomic Absorption Spectrophotometer (Donisa et al., 2000).

2.5. Experimental Design, Planting and Data Collection

The experimental design was completely randomized design carried out in the screen house. Maize was planted in each of the thirty-two pots containing the soil samples from the tree species with no fertilizer or manure. Major soil nutrient, NPK (20-10-10) fertilizer (120 kg ha-^{1}), was added to the control soil samples taken from the non-tree spp). The vegetation of the non-tree spp was predominantly Chromolaena odorata. The maize was planted and thinned to one maize stand per pot after emergence. At the second, fourth and sixth weeks of planting, the plant height was measured with a meter rule.

2.6. Plant Sample Preparation and Analysis

At the end of four consecutive cycles, each cycle of six weeks, the maize plant was cut at ground level, oven-dried at 65^0 C to constant weight. The dry weight was recorded; this was immediately followed by milling. The plant samples were analyzed for total nutrient (N, P, K, Ca, Mg, Zn, Fe, Mn, Cu) concentrations at the end of each cycle after the samples were digested in ternary mixture of sulphuric, nitric and perchloric acids.

2.7. Statistical Analysis

The soil and plant data were subjected to the analysis of variance (ANOVA) using the SAS statistical package. The means were separated by Duncan's Multiple Range Test (DMRT) at 5 % probability level.

3. Results

3.1. The Oven Dried Weights of the Maize Plants under the Various Treatments

The maize plants oven dried weight is presented in Table (1). In the first and second cycles, the mean oven-dried weights of the maize plant varied from 4.25 to 6.25 kg and 6.5 to 8.5 kg in non-tree spp and Bambusa vulgaris; non-tree spp. and Gmelina arborea for the first and second cycles, respectively. At the 3rd planting cycle, Gmelina arborea also gave the highest mean oven-dried weight, while the lowest value was observed in non-tree spp. In most cases, Bambusa vulgaris soil, without fertilizer application, gave greater oven-dried weight, and in all, the non-tree spp recorded the least. It was observed that the maize plant oven dried weight increased from the first to the third cycles across the treatments. The cumulative mean weight of maize shows that the soils all enhanced the biomass accumulation in maize plant. However, the significant lowest yield was recorded in soil from Tectona grandis and the non-tree spp. without fertilizer application

3.2. The Effect of Tree Types on Maize Plant Height at 3 Cycles of Planting

The mean maize plant heights at different growth stages and at different cycles of planting are presented in Table (2). At the first cycle, the plant height, at 4 weeks of planting, varied from 58.88 cm to 74.38 cm with the tallest and lowest plants found in soil under Anogeissus leiocarpus and non-tree spp., respectively. At 6 weeks of planting, plant height ranges from 62.75 cm to 84.63 cm with non-tree spp. having the lowest (62.75 cm) and non-tree spp. + NPK fertilizer having the highest height (84.63 cm). In all, the Anogeissus leiocarpus and the non-tree spp. soils significantly produced the tallest and shortest plants, respectively. In the second planting cycle at 4 WAP, the non-tree spp. + NPK fertilizer soil gave the tallest plant (59.25 cm) while the lowest was in soil from Bambusa vulgaris (46.50 cm) but at 6 WAP, the tallest plant was found in Treculia africana (85.38 cm) soil while the lowest was in non-tree spp. (73.63 cm). At the third planting cycle during the 4 WAP, soil from the non-tree spp gave significantly ($P < 0.05$) higher taller plants than all other treatments. The soils from Bambusa vulgaris plantation produced the shortest maize plants both at the 4 and 6 WAP. The non –tree fertilizer gave the highest mean plant height of 78.50 cm at the 6 WAP.

Table 1. Effect of tree types on height and oven dried weight of maize plant

Plantation type	Dry weight (g pot^{-1})			
	Cycle 1	Cycle 2	Cycle 3	Mean
Bambusa vulgaris	6.25a	8.50a	8.50ab	7.75a
Tectona grandis	4.75a	8.00ab	6.50c	6.42c
Leucaena leucocephala	5.75a	8.00ab	8.00bc	7.25ab
Gmelina arborea	5.25a	8.25ab	8.75ab	7.42ab
Anogeissus leiocarpus	6.00a	8.00ab	10.00a	8.00a
Non-tree spp	4.25a	6.50b	7.50bc	6.08c
Treculia africana	5.50a	8.25ab	7.75bc	7.17abc
Non-tree spp + NPK fertilizer	5.75a	8.00ab	9.00ab	7.42ab

Means with the same alphabet(s) in a column are not significantly different from each other at $p < 0.05$

Table 2. Effect of soils under different tree species on maize plant height at 3 cycles of planting

	First cycle		Second cycle		Third cycle	
	4WAP	6WAP	4WAP cm	6 WAP	4WAP	6WAP
Bambusa vulgaris	63.63bc	67.75c	46.50b	77.75ab	37.00c	61.75c
Tectona grandis	62.63bc	66.88c	51.00ab	76.25ab	43.50b	63.25c
Leucena leucocephala	65.30bc	69.13bc	52.25ab	80.00ab	41.50bc	75.75a
Gmelina arborea	62.13bc	66.50c	56.25a	79.50ab	39.50bc	66.00bc
Anogenous spp	74.38a	78.55ab	58.50a	84.00a	44.25b	71.75ab
Non-tree spp	58.88c	62.75c	46.63b	73.63b	50.25a	73.25ab
Treculia Africana	68.88ab	72.75bc	58.50a	85.38a	40.50bc	66.00bc
Non-tree spp + NPK fertilizer	65.25bc	84.63a	59.25a	83.00ab	42.00bc	78.50a

Means with the same alphabet(s) in a column are not significantly different from each other at $p < 0.05$

3.3. Chemical Properties of Soils from Different Trees Species

The soil was characterized before planting and the result revealed that many of the soils under the different trees varied significantly in their nutrients concentrations (Table 3). Generally, the soil was moderately acidic and the pH ranged from 5.81 to 6.13 in the Gmelina arborea and non-tree spp., respectively. The organic carbon of the soils ranged from 0.61 to 1.80 % in soils from Leucaena leucocephala and Anogeissus leiocarpus, respectively. The total N varied from 0.07 to 0.17 %. The total N recorded in soils under the Bambusa vulgaris and Gmelina arborea was 143 % greater than that of Leucaena leucocephala and the non-tree spp. Gmelina arborea soil had a significantly higher available P of 19.46 mg kg^{-1} among the soils of the tree types; the lowest P (9.40 mg kg^{-1}) was obtained in soils under the Treculia africana and non-tree species. The exchangeable K slightly varied from 0.25 mg kg^{-1} in the soil from Bambusa vulgaris to 0.37 mg kg^{-1} in the Tectona grandis. The different tree species had no significant effect ($P>0.05$) on the soil exchangeable calcium. Tectona grandis, Treculia africana and non-tree species soils had significantly greater magnesium contents. The amount of sulphur varied from 0.05 to 0.41 %. Soils under Gmelina arborea had a significantly higher sulphur content. Some of the soil micronutrients in each of the forest soils also varied significantly. The non-tree species, Tectona grandis and Treculia africana had a significantly greater Cu content. The Mn content ranged from 1.68 mg kg^{-1} in the non-tree spp. to 14.36 mg kg^{-1} in the soils under Anogeissus leiocarpus. Anogeissus leiocarpus and Bambusa vulgaris recorded significantly high acid extractable Fe while Leucaena leucocephala had the least Fe content. The Zn content ranged from 0.02 to 5.82 mg kg^{-1} in the Bambusa vulgaris and Gmelina arborea, respectively.

Table 3. Chemical properties of soils from different trees species before the experiment

Tree types	pH	Org. C	Total N	S	P	K	Ca	Mg	Cu	Mn	Fe	Zn
		---------- % -----------			mg kg^{-1}	cmol kg^{-1}	------------------------- mg kg^{-1}---------------------------					
Anogeissus leiocarpus	5.89bc	1.80a	0.11a	0.11b	14.37b	0.26b	1.15a	0.38abc	3.29ab	14.36a	123.38a	0.93b
Bambusa vulgaris	6.12a	0.72ab	0.17a	0.21ab	15.93ab	0.25b	0.82a	0.43abc	2.56bc	19.02b	118.38ab	0.02b
Gmelina arborea	5.81 c	0.97ab	0.17a	0.41a	19.46a	0.30ab	0.98a	0.42abc	1.93c	5.81c	5.65c	5.82a
Leucaena leucaephala	5.95abc	0.61b	0.07a	0.05b	3.18d	0.35a	1.05a	0.33bc	2.25c	2.79d	0.29c	0.05b
Tectona grandis	6.08ab	0.84ab	0.09a	0.09b	5.11dc	0.37a	0.85a	0.53a	3.66a	1.86d	89.00b	2.31b
Treculia africana	5.82c	1.07ab	0.11a	0.05b	9.40 c	0.35a	1.18a	0.51ab	3.70a	1.84d	1.06c	0.38b
Non tree specie	6.13a	0.68b	0.07a	0.05b	9.40c	0.35a	1.17a	0.51ab	4.13a	1.68d	1.39c	1.40b

Means with the same alphabet(s) in a column are not significantly different from each other at $p < 0.05$

3.4. Effect of Tree Types on Maize Nutrient Concentrations in the First Cycle

The maize plant nutrient concentrations, under the different treatments in the first cycle, are presented in Table (4). The mean total N concentration ranged from 2.04 to 2.98 % in the soil from non-tree spp. + NPK fertilizer and Bambusa vulgaris, respectively. Total N in the maize plants, under the Bambusa vulgaris soil, was significantly ($P < 0.05$) higher than all the other treatments with the exception of those under Tectona grandis. The N concentration was in the order: Bambusa vulgaris > Tectona grandis > Leucaena leucocephala > Gmelina arborea > Anogeissus leiocarpus > non-tree spp. > Treculia africana > non-tree spp. + NPK fertilizer. The P concentration in maize varied from 0.05 to 0.40 mg kg^{-1}. Maize plants in the Gmelina arborea soil had higher P concentrations, though not significantly different from the other treatments. The non-tree spp. + NPK fertilizer was significantly higher ($P < 0.05$) in K and Ca concentrations of the maize plants than all other treatments. The Mg concentration of the maize plants, with different treatments, ranged from 0.49 to 1.45 mg kg^{-1}. Treatment with non-tree spp has the highest Mg value of 1.45 mg kg^{-1}, though not significantly ($P < 0.05$) different from other treatments except for the plants in Bambusa vulgaris, Leucaena leucocephala and non-tree spp. + NPK fertilizer soils.

The Zn concentration of the maize plant under the Treculia africana soil was significantly ($P < 0.05$) higher than all the other treatments. The Fe and Mn concentrations of maize plants in the Bambusa vulgaris soil were significantly ($P < 0.05$) higher than all the other treatments except for plants in Anogeissus leiocarpus soil. The Fe and Mn concentrations varied from 413 mg kg^{-1} to 881 mg kg^{-1} and 153 to 253 mg kg^{-1}, respectively. Maize plants in the non-tree spp soil had the highest concentration of Cu (29.25 mg kg^{-1}) with the least of 19.75 mg kg^{-1} in Bambusa vulgaris. Maize Cu concentrations under the non-tree spp was not significantly ($P > 0.05$) different from that of Leucaena leucocephala, Gmelina arborea and Anogeissus leiocarpus. Other differences were, however, significant ($P < 0.05$).

Table 4. Effect of tree types on Maize nutrient concentrations in the first and second cycles

Plantation type	N (%)	P	K	Ca	Mg	Zn (mgkg^{-1})	Fe	Mn	Cu
First Cycle									
Bambusa vulgaris	2.98a	0.18a	0.20b	0.22c	0.87bc	73.25b	881.25a	252.75a	19.75c
Tectona grandis	2.81ab	0.08a	0.23b	0.26bc	0.94abc	48.00b	498.75cd	134.50bcd	21.25bc
Leucaena leucocephala	2.59bc	0.05a	0.30b	0.25bc	0.84bc	45.00b	415.00d	96.25cd	23.75abc
Gmelina arborea	2.48cd	0.40a	0.28b	0.31b	1.27ab	58.75b	396.25d	137.50bc	26.25ab
Anogeissus leiocarpus	2.36cd	0.25a	0.25b	0.26bc	0.92abc	117.75b	871.25a	175.25b	27.25ab
Non-tree spp	2.34cd	0.22a	0.31b	0.21c	1.45a	68.00b	542.50bc	134.25bcd	29.25a
Treculia Africana	2.27de	0.22a	0.28b	0.24bc	0.96abc	336.50a	625.25b	152.50bc	20.00c
Non-tree spp + NPK fertilizer	2.04e	0.18a	0.67a	0.40a	0.49c	43.38b	413.63d	70.88d	20.00c
Second Cycle									
Bambusa vulgaris	2.57a	1.59ab	0.89b	0.68a	0.68b	69.94b	435.88a	81.56c	13.95abc
Tectona grandis	2.18b	2.69a	0.73c	0.68a	0.60b	49.25de	377.00ab	88.00bc	13.00abc
Leucaena leucocephala	2.07bc	0.90bc	1.02a	0.53bc	0.81a	56.75cd	393.13ab	104.88bc	10.81cd
Gmelina arborea	2.23b	1.48b	1.05a	0.68a	0.89a	84,31a	382.94ab	110.50ab	12.63bcd
Anogeissus leiocarpus	2.00bc	1.38bc	0.81bc	0.70a	0.85a	48.38e	311.00bc	133.75a	11.63cd
Non-tree spp	2.01bc	0.74bc	1.03a	0.64ab	0.85a	60.00c	360.00ab	109.25ab	17.56ab
Treculia Africana	1.76d	0.52bc	0.59d	0.44cd	0.65b	48.88e	256.13c	87.63bc	7.88d
Non-tree spp + NPK fertilizer	1.93cd	0.33c	0.72c	0.40d	0.41c	31.77f	346.55abc	55.17d	17.98a

Means with the same alphabet(s) in a column are not significantly different from each other at $p < 0.05$

3.5. Effect of Tree Types on Maize Nutrient Concentrations in the Second Planting Cycle

The concentration of maize nutrients, with different treatments in the second planting cycle, is presented in Table (4). The result indicated the nutrient concentrations in maize plant varied significantly under the various treatments. The N concentration of maize plant with different treatments ranged from 1.76 % to 2.57 % in the Bambusa vulgaris and Treculia Africana, respectively. Maize plants on the Bambusa vulgaris soil were significantly higher ($P < 0.05$) in their N and P concentrations than all the other treatments except for P with Tectona grandis. The K concentration of maize plant, treated in the non-tree spp. soil without fertilizer, was significantly higher ($P < 0.05$) than all the other treatments except for those in Leucaena leucocephala and Gmelina arborea soil. The mean Ca concentration of maize plants with different treatments ranged from 0.40 mg kg^{-1} to 0.70 mg kg^{-1} in non-tree spp. + NPK fertilizer and Anogeissus leiocarpus, respectively. The Mg concentration of maize plants under non-tree spp. + NPK fertilizer was significantly lower ($P < 0.05$) than all other treatments.

Maize plants, treated with Gmelina arborea soil, were found to be significantly higher ($P < 0.05$) in Zn concentrations than all the other treatments. The Fe concentration of maize plants in the Bambusa vulgaris was not significantly different ($P > 0.05$) from the other treatments except for Anogeissus leiocarpus and Treculia africana. The Mn concentration of maize plants with different treatments ranged from 55.17 to 133.75 mg kg^{-1} for non-tree spp and Anogeissus leiocarpus, respectively. The concentrations of Cu varied from the lowest value in Leucaena leucocephala to the highest in non-tree spp. + NPK fertilizer soils. The differences were statistically significant at $P < 0.05$.

3.6. Effect of Tree Types on Maize Nutrient Concentrations in the Third Cycle

Table (5) shows the mean concentration of maize nutrients under the different treatments at the third planting cycle. The N concentrations of maize plants differ significantly under the various treatments and this varied from 1.09 to 2.23 % in the Treculia africana and Bambusa vulgaris, respectively. Phosphorus concentration was not significant under the different treatments ($P > 0.05$). The treatment had a significant impact on K concentrations in the maize plant and it varied from 0.47 mg kg^{-1} to 1.08 mg kg^{-1} in the non-tree spp. + NPK fertilizer and Gmelina arborea, respectively. Maize plants in the Leucaena leucocephala and Anogeissus leiocarpus recorded the lowest Ca concentrations of 0.36 mg kg^{-1} and 0.64 mg kg^{-1}, respectively. Non-tree spp. + NPK fertilizer and non-tree spp. recorded the least and highest Mg concentrations in the maize plant.

Table 5. Effect of tree types on Maize nutrient concentrations in the third and fourth cycles

Plantation type	N (%)	P	K	Ca	Mg	Zn(mgkg^{-1})	Fe	Mn	Cu
Third Cycle									
Bambusa vulgaris	2.23a	1.33a	0.87abc	0.60a	0.63abc	60.13b	299.97a	69.98cd	12.63b
Tectona grandis	2.01ab	1.22a	0.62bc	0.54ab	0.42d	41.61cd	330.07a	77.92bc	10.14bc
Leucena leucocephala	1.86b	0.58a	0.61bc	0.36b	0.55cd	46.24c	324.13a	83.25bc	9.41c
Gmelina arborea	2.04ab	1.13a	1.08a	0.56ab	0.74ab	72.58a	325.35a	97.45ab	10.71bc
Anogeissus leiocarpus	1.73b	1.24a	0.91ab	0.64a	0.74ab	39.68cd	152.73b	121.36a	9.88bc
Non-tree spp	1.79b	0.54a	0.89ab	0.42ab	0.76a	47.53c	272.54a	99.43ab	12.90b
Treculia Africana	1.09c	0.46a	0.83abc	0.59ab	0.56bcd	32.20d	134.09b	59.09cd	5.29d
Non-tree spp + NPK fertilizer	1.75b	0.42a	0.47c	0.44ab	0.40d	29.98d	315.43a	48.51d	18.05a
Fourth Cycle									
Bambusa vulgaris	2.93a	0.40de	1.58ab	0.68ab	0.61bc	40.75c	411.90a	70.75b	Data not available
Tectona grandis	0.98cd	0.33e	1.56ab	0.71ab	0.40d	61.13a	315.20a	75.80b	
Leucena leucocephala	2.47ab	0.49cd	2.16a	0.68ab	0.81a	40.75c	556.90a	52.50c	
Gmelina arborea	1.60bc	0.51cd	1.94ab	0.63ab	0.73ab	62.75a	315.80a	82.44ab	
Anogeissus leiocarpus	0.54d	0.57bc	1.43b	0.62ab	0.84a	47.13bc	501.40a	82.38ab	
Non-tree spp	0.92cd	0.65b	1.86ab	1.14a	0.52cd	69.13a	498.80a	38.38d	
Treculia Africana	1.69bc	0.43de	1.44b	0.38b	0.46cd	61.13a	511.10a	90.15a	
Non-tree spp + NPK fertilizer	2.69a	0.87a	1.56ab	0.57b	0.50cd	70.00a	390.00a	52.50c	

Means with the same alphabet(s) in a column are not significantly different from each other at $p < 0.05$.

3.7. Effect of Tree Types on Maize Nutrient Concentrations in the Fourth Cycle

The mean concentration of maize nutrients under the different treatments at the fourth planting cycle is shown in Table (5). The total N concentrations in the maize plants ranged from 0.54 to 2.93 % in the Anogeissus leiocarpus and Bambusa vulgaris soils, respectively. Differences in N concentrations of maize plants found under the Bambusa vulgaris, Leucaena leucocephala and non-tree spp. with NPK fertilizer soils were not significant (P>0.05). The non-tree spp. recorded significantly the highest P concentrations of 0.87 mg kg^{-1} among the various treatments. The lowest P value of 0.33 mg kg^{-1} was observed in maize plants in the Tectona grandis soil. Differences in K concentrations of the maize plants were not significant (P>0.05) under the Leucaena leucocephala, Gmelia arborea, Bambusa vulgaris, Tectona grandis, non-tree spp. and the non-tree spp. with NPK fertilizer. Anogeissus leiocarpus, however, recorded the least K concentration which was significantly lower than that obtained under the Leucaena leucocephala. Calcium concentrations varied slightly under the different treatments and ranged from 0.38 to 1.14 mg kg^{-1} in maize plants under the Treculia Africana and the non-tree spp. Higher Mg concentration (0.84 mg kg^{-1}) was observed in Anogeissus leiocarpus soil. Tectona grandis gave the least mean Mg concentration of 0.40 mg kg^{-1} in the maize plants.

The mean zinc concentrations varied from 40.75 to70 mg kg^{-1} in Bambusa vulgaris and non-tree spp. with NPK fertilizer soils. Maize Zn concentrations grown on soils from non-tree spp with NPK fertilizer, non-tree spp., Gmelina arborea, Treculia Africana and Tectona grandis were not significantly different at 5 % probability level. The iron concentration ranged from 315.20 to 556.90 mg kg^{-1} in the Tectona grandis and Leucaena leucocephala soils. These differences were, however, not significant (P>0.05). The non-tree spp. gave the lowest mean Mn concentration of 38.38 mg kg^{-1} while Treculia africana gave the highest Mn concentration (90.15 mg kg^{-1}) in the maize plants.

4. Discussion

The present study shows that there is a positive synchrony between the soil chemical composition and maize nutrients concentrations grown on soils taken under different trees and non-tree species. The present study used nutrient concentrations in maize plants and maize›s oven-dried weight under the various treatments as a proxy for the nutrient supplying capacity of soils under different tree spp. The soils from each of the tree spp. varied in their nutrient supplying capacities. Kumar (2008) noted that different trees had different effects on soil nutrients. There exist significant differences between the quantities of each nutrient released due to the different forest spp. It was also observed that planting cycles affected the nutrient release. The nutrients release varied depending on the number of planting cycles. The mean oven-dried weight of the maize plant increased steadily from the first to the third planting cycles in all the treatments while the plant›s height followed the reverse order.

The total N decreased as the number of planting cycles increased from the first to the fourth cycle in most of the treatments. The N supplied by Gmelina arborea soil to the maize plants declined steadily from the 1st to the 4th planting cycle, though initially had a relatively high total N. This confirms earlier reports that in low-input farming system N deficient is a challenge due to the N removed in crops, season after seasons without replenishment (Scow et al., 1994; Ledgard, 2001). This system of agriculture is, however, not encouraged in the view of the need to promote sustainable use of soil resources and the urgent need to achieve food security in Sub-saharan Africa. In all the four planting cycles, N declined in the different tree soils with the exception of Bambusa vulgaris and non-tree spp. with NPK fertilizer. In most cases, the different forest soils supplied more N than the non-tree spp. This implies that forest soils are better N suppliers than non-tree soils. Soils taken under the Bambusa vulgaris plantation gave a higher total N during all the planting cycles among the different treatments even greater than the non-tree spp amended with NPK fertilizer. This demonstrates that soils obtained under the Bambusa vulgaris plantation are better N supplier and could maintain their N supply for at least 4 planting cycles without any mineral amendments than other tree spp. investigated in the present study. This could perhaps be due to the old age of the Bambusa vulgaris plantation and the several years of litter deposition. Anand and Anand (1999) reported nutrient build up from litters of Bambusa vulgaris.

The P concentration in the maize plants did not vary significantly with respect to the number of planting cycles and tree spp., while the second planting cycle and Tectona grandis appeared to give a slightly higher P in the maize plants. Since the amount of P, absorbed in the plant, is proportionate to the amount of soil available P; this could explain why the different tree spp. did not have a visible effect on the P concentration of the tested maize crop. The amount of P in the maize declined with increasing cropping cycles with the exception of those in Bambusa vulgaris and Tectona grandis soils. This indicates a decline in soil available P under the different forest soils. This is an expected trend because previous research has shown that soil nutrients decline in low input agriculture as cropping intensifies (Bommarco et al., 2013). Conversely, the stability in the amount of P supplied by the Bambusa vulgaris and Tectona grandis after four planting cycles was a demonstration of their ability to improve to soil phosphorus fertility under low input farming system or in degraded soils.

The supply of K did not follow any particular trend among the tree spp. In addition, the planting cycle did not exact significant impact on the K concentrations in the maize crop. It was observed that K supplied in all the tree and non-tree soils was slightly higher at the 4th planting cycle. In all, Bambusa vulgaris proved to be a better supplier of NPK than the other tree species. This is in agreement with the earlier findings of improved nutrient status under Bambusa vulgaris plantations (Rahangdale et al., 2014). Calcium concentration in the maize plants was very high both in the Anogeissus leiocarpus and at the second cycle, compared to the other treatments and planting cycles. Similar results were obtained by Casals et al. (2013). In all, the first cycle gave the least Ca concentrations in each of the treatments. It was interesting to note that soils from the Treculia africana gave increased Ca concentrations in the maize plants from the first to the third cycle. This shows that Treculia africana has the potential to be a sustainable supplier of cations both for proper plant growth and for neutralizing acid soils. Such tree species are, thus, desirable in sustainable soil fertility strategies. The non-tree spp., amended with NPK fertilizers, had no influence on the Ca concentrations in the maize plant as calcium concentrations in the maize plant did not follow a particular pattern under the different treatments. The supply of Mg from the soils under the different trees decreased steadily from the first cycle to the 4th cycle. The non-tree spp. had greater Mg concentrations particularly in the first cycle and slightly higher when amended with NPK fertilizer at the 4th planting cycle. Considering all the treatments as soil nutrient suppliers, the non-tree spp. amended with NPK was found to be the poorest irrespective of the number of planting cycles.

The micro-nutrients of the maize plants decreased at the 4th cycle compared to the 1st planting cycle. Soils from different trees do not have profound influence on the Zn concentrations in the maize plant. The non-tree spp., however, had a significantly greater Zn release at the first and fourth planting cycles. There was a decrease in the amount of Zn supplied from the 1st to the 3rd cycle with a slight increase in the 4th cycle under the non-tree spp. soil. The least Fe concentration occurred in the third cycle and in the Leucaena leucocephala. Bambusa vulgaris and Anogeissus leiocarpus soils were better in supplying Fe to the maize plant particularly in the first planting cycle. The Fe supplying capacity of the different tree spp. dropped with increasing number of planting cycles. Soils from Bambusa vulgaris had a significantly greater Mn concentration in the first cycle than the other tree and non-tree spp. which were found not to be significantly different from each other. The maize Cu concentrations under both the tree and non-tree spp. followed the same pattern. The amount of Cu was significantly higher in the first cycle than the 2nd and 3rd cycles under the various treatments. In most cases, the non-tree spp. was a better Cu supplier than the tree spp. It was recognized that the soils from each tree and non-tree spp. supplied sufficient quantities of micro-nutrients to the maize plant for proper growth and development. Quantities higher than those supplied may result in heavy metal bioaccumulation in the plant tissues which could be dangerous to human health.

Conclusions

The present study demonstrates that different soils under different tree species have varying effects on the dry matter yield and nutrient concentrations of maize plant. The maize dry matter weights, plant height and the nutrients concentrations varied depending on the type of tree species. In all, soils from Bambusa vulgaris and Anogeissus leiocarpus were found to be better nutrient suppliers in considering the quantities of nutrients and their patterns of release. It was observed, and must be emphasized, that agroforestry or farming systems with no or low external input result in declining yields through nutrients mining and chemical degradation. A higher crop yield was observed in the first planting cycle, and more nutrients were extracted. However, in subsequent cropping cycles, both the yield and nutrient concentrations could be significantly reduced. Farmers are, therefore, advised to supplement their agroforestry practices with other soil fertility management options, like nutrients addition, to maintain and increase their yield sustainably.

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