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Amelioration of a Degraded Alfisol by Planted Fallows in Ado – Ekiti, Southwestern Nigeria

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ABSTRACT

Knowledge of effects of fallow on soil fertility status is needed in order to be able to assess its contributions to sustainable land resources management and agricultural productivity, especially in Southwestern Nigeria, where the problem of land degradation is on the increase. To this effect, this study was designed to evaluate the influence of different planted fallows on the fertility status of a degraded Alfisol. The experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado –Ekiti, Ekiti State, Nigeria, between 2006 and 2011. The experiment was laid out in a randomized complete block design with three replications. The planted fallow treatments included: *Panicum maximum* fallow (PMF); *Chromolaena odorata* fallow (COF); *Centrosema pubescens* fallow (CPF); and continuous maize cultivation, which served as the control (C). The results indicated existence of significant ($P = 0.05$) differences among the planted fallows as regards their ameliorating effects on fertility status of a degraded Alfisol. Planted fallow treatments significantly ($P = 0.05$) increased soil organic carbon (SOC) from 0.23 g kg^{-1} for C to 2.86, 3.89 and 3.44 g kg^{-1} for PMF, COF, and CPF, respectively. Similarly, planted fallow treatments resulted in significant increases in total N from 0.10 g kg^{-1} for C to 0.78, 1.86 and 1.98 g kg^{-1} for the respective PMF, COF and CPF. Fallow treatments significantly increased available P from 0.21 mg kg^{-1} for C to 2.64, 2.73 and 2.56 mg kg^{-1} for PMF, COF and CPF, respectively.

Keywords: Alfisol, amelioration, degraded, fallow, southwestern Nigeria.

INTRODUCTION

Agricultural productivity of tropical soils is adversely affected by the inherently low fertility status of the soils, characterized by low level of activity clay, organic matter, nitrogen, phosphorus and exchangeable basic cations (Adenle, 2010; Pestov, 2012). The constraints or limitations for the utilization of the low activity clay tropical soils for continuous crop production have necessitated increasing search for efficient soil fertility improvement practices, which in recent time, have included adoption of appropriate and adequate fertilizer packages, involving the use of organic and/ or inorganic fertilizers (Atete, 2012, Lege, 2012).

The use of inorganic or mineral fertilizers in improving and maintain soil fertility has been reported to be ineffective, due to certain limitations. Some of these limitations include: low efficiency (due to loss through volatilization and leaching), declined soil organic matter content, nutrient imbalance, soil acidification, as well as soil physical degradation, with resultant increased incidence of soil erosion (Kader, 2012). Asides all these limitations, high cost and occasional scarcity of synthetic fertilizers, have posed a lot of problem to their use as nutrient sources in Nigeria (Guman, 2011).

The limitations of the use of mineral fertilizers to improve soil fertility has consequently informed shift of attention to the use of organic fertilizers for soil fertility improvement, especially, the highly weathered tropical soils (Ame, 2012; Kader, 2012). However, organic fertilization, too, has certain demerits of slow release and non – synchronization of nutrient release with period of growth for most short – season crops (Kiani *et al*., 2005).

The above enumerated problems, associated with the use of organic and/or inorganic fertilizers in restoring soil fertility or replenishing lost nutrients, have necessitated growing search for several other alternative techniques of restoring lost plant nutrients in the soil. Some of these alternative soil fertility restoration techniques include: rotational cropping, cover cropping, mulching, agro - forestry

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and bush fallow. Of all these options, bush fallow system has been recommended as the most effective method of restoring soil fertility (Aritoff, 2012; Lezz, 2013). Bush fallow helps in ameliorating degraded soils as the fallow vegetation helps in conserving the soil by minimizing incidence of erosion, run – off and leaching. This is because the fallow vegetation intercepts raindrops, thus, reducing the volume and erosive power of the falling rain, with resultant decreased soil loss or erosion (Aritoff, 2012). In addition, fallow vegetation protects the soil surface from the direct heat of the sun, thereby, ensuring water conservation in the soil, thus, providing a conducive environment for both soil macro – and micro - organisms, with resultant accelerated organic matter decomposition and earthworm casting activities in the soil system (Kapa, 2013). During fallow, there is always build – up of soil organic matter, resulting from decomposition of leaf litter, produced by the fallow vegetation. The build – up of organic matter, results in improvement of soil physical, chemical and biological properties (Galeb, 2012; Ito, 2012).

In Nigeria, one of the present – day principal constraints to agricultural production is the problem of land degradation and attendant declined soil fertility. In recent time, the problem had been addressed through adoption of appropriate and adequate fertilizer packages, involving the use of organic and/ inorganic fertilizers. Over the years, bush fallow had also been adopted as one of the practical options of ameliorating degraded land in Nigeria. However, there is dearth of published scientific data and research information on the comparative ameliorating effects of *Panicum maximum*, *Chromolaena odorata*, and *Centrosema pubescens* fallows on degraded land, especially in Southwestern Nigeria. To this end, this paper reports the results of a trial, aimed at evaluating ameliorating effects of planted fallows of *Panicum maximum*, *Chromolaena odorata*, and *Centrosema pubescens* on fertility status of a severely degraded Alfisol.

MATERIALS AND METHODS

Study Site

A field experiment was carried out at the Teaching and Research Farm of the Ekiti State University, Ado – Ekiti, Ekiti State, Nigeria, between 2006 and 2011. The soil of the study site belongs to the broad group Alfisol (SSS, 2003). The soil was strongly leached, with low to medium organic matter content. Prior to this investigation, the study site had earlier been under intensive and continuous cultivation of a variety of arable crops for many years.

Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with three replications. The planted fallow treatments included: *Panicum maximum* fallow (PMF); *Chromolaena odorata* fallow (COF); *Centrosema pubescens* fallow (CPF); and continuous maize cultivation, which served as the control (C). Each plot size was 6 m x 6 m.

Planting

The fallow plants: *Panicum maximum, Chromolaena odorata,* and *Centrosema pubescens* were planted in March 2006 at the commencement of the rainy season. Maize was planted at a spacing of 75 cm x 30 cm, with two seeds per stand (888,888 maize plants ha^{-1}).

Weeds, other than *Panicum maximum*, *Chromolaena odorata* and *Centrosema pubescens* (where they occurred), were completely hand - removed in all the treatment plots. In the maize plots, weeding was carried out at 3, 6 and 9 weeks after planting (WAP), using a hand hoe.

Collection and Analysis of Soil Samples

Prior to the establishment of the fallows in 2006, 35 core soil samples, randomly collected from 0 – 15 cm soil depth, were mixed inside a plastic bucket to form a composite sample, which was analyzed for chemical properties. Similarly, at the end of the experiment in 2011, another sets of soil samples were collected in each treatment plot and analyzed.

The soil samples were air – dried, ground, and passed through a 2 mm sieve. The processed soil samples were analyzed in accordance with the soil analytical procedures, as outlined by the International Institute of Tropical Agriculture (IITA) (1989).

Data Analysis

All the data collected on soil chemical properties were subjected to analysis of variance (ANOVA), and treatment means were compared, using the Duncan Multiple Range Test (DMRT) at 5% probability level.

RESULTS

Chemical Properties of Alfisol in the Study Site Prior To Investigation

Table1. *The chemical properties of Alfisol before investigation*

Soil properties	Values
pH	4.3
Organic carbon (g kg^{-1})	0.57
Total nitrogen (g kg^{-1})	0.37
Available phosphorus (mg kg^{-1})	0.40
Exchangeable bases (cmol kg^{-1})	
Potassium	0.38
Calcium	0. 33
Magnesium	0.29
Sodium	0.23
Exchangeable Acidity	0.19
Effective Cation Exchangeable Capacity (ECEC)	1.42
Micro – nutrients (mg kg^{-1})	
Cu	2.60
Zn	2.70
Fe	2.61
Mn	2.65

Chemical Properties of an Alfisol As Affected By Planted Fallows

Table 2 shows the influence of planted fallows on fertility status of a degraded Alfisol after the investigation. Planted fallows significantly increased pH of the soil from 3.2 for C to5.9, 6.5 and 5.1 for PMF, COF and CPF, respectively. Planted fallows significantly increased soil organic carbon (SOC) from 0.23 g kg^{-1} for C to 2.86, 3.89 and 3.44 g kg^{-1} for the respective PMF, COF and CPF. Fallow resulted in significant increases in total nitrogen from 0.10 g kg^{-1} for C to 0.78, 1.86 and 1.98 g kg^{-1} for PMF, COF and CPF, respectively. Fallow significantly increased available phosphorus from 0.21 mg kg for C to 2.64, 2.73 and 1.40 mg kg for the respective PMF, COF and CPF. Fallow significantly increased effective cation exchangeable capacity from 0.28 cmol kg^{-1} for C to 2.63, 2.88 and 2.49 cmol kg^{-1} for PMF, COF and CPF, respectively. Fallow significantly increased exchangeable K from 0.15 cmol kg^{-1} for C to 0.84, 0.92 and 0.68 cmol kg^{-1} for the respective PMF, COF and CPF.

Fallow significantly increased exchangeable Ca from 0.12 cmol kg^{-1} for C to 0.77, 0.84 and 0.61 cmol kg^{-1} for PMF, COF and CPF, respectively. Fallow significantly increased exchangeable Mg from 0.09 cmol kg^{-1} for C to 0.84, 0.91 and 0.58 cmol kg^{-1} for PMF, COF and CPF, respectively. Fallow significantly increased exchangeable Na from 0.13 cmol kg^{-1} for C to 0.71, 0.80 and 0.60 cmol kg^{-1} for the respective PMF, COF and CPF. Fallow resulted in significant decreases in Cu from 3.21 mg kg^{-1} for C to 2.77, 2.70 and 2.89 mg kg^{-1} for PMF, COF and CPF, respectively. Similarly, fallow significantly decreased Zn from 3.53 mg kg^{-1} for C to 2.85, 2.78 and 2.93 mg kg^{-1} for the respective PMF, COF and CPF. Fallow significantly decreased Fe from 2.94 mg kg^{-1} for C to 2.76, 2.68 and 2.84 mg kg^{-1} for PMF, COF and CPF, respectively. Fallow significantly decreased Mn from 3.67 mg kg for C to 2.88, 2.76 and 2.99 mg kg for the respective PMF, COF and CPF.

Table2. *Chemical properties of an Alfisol as affected by five - year - fallow period*

Treatments (Planted fallows)		Org. C	Total N	Av. P	ECEC	Exch. bases (cmol kg^{-1})				Micronutrients (mg kg^{-1})			
	pH	(g kg^{-1})	(g kg^{-1})	(mg kg^{-1})	(cmol kg^{-1})	K	Ca	Mg	Na	Cu	Zn	Fe	Mn
CMC	3.2d	0.23d	0.10d	0.21d	0.28d	0.15d	0.12d	0.09d	0.13d	3.21a	3.53a	2.94a	3.67a
PMF	5.9b	2.86c	0.78c	2.64b	2.63b	0.84b	0.77b	0.84b	0.71b	2.77c	2.85c	2.76c	2.88c
COF	6.5a	3.89a	1.86b	2.73a	2.88a	0.92a	0.84a	0.91a	0.80a	2.70d	2.78d	2.68d	2.76d
CPF	5.1c	3.44b	1.98a	1.40c	2.49c	0.68c	0.61c	0.58c	0.60c	2.89b	2.93b	2.84b	2.99b

Mean values in the same column followed by the same letter(s) are not significantly different at P = 0.05 (DMRT). ECEC, Effective cation exchangeable capacity; CMC, continuous maize cultivation; PMF, *Panicum maximum* fallow; COF, *Chromolaena odorata* fallow; CPF, *Centrosema pubescens* fallow.

DISCUSSION

The lowest pH value of soil under *Centrosema pubescens* fallow, compared to other planted fallows, agrees with the findings of Arit (2011); Orre (2012) and Lezz (2012), who noted higher acidity of soil under *Centrosema pubescens* and *Leucaena leucocephala* fallows, relative to *Panicum maximum* and *Chromolaena odorata* fallows. This observation can be ascribed to the release of hydrogen ions (H^+) from the roots of these legumes (*Centrosema pubescens* and *Leucaena leucocephala)* because of their high uptake of cations, in comparison to anions (Orre, 2012; Lezz, 2013). Asides, the acidification of soil under *Centrosema pubescens* fallow can be attributed to the release of hydrogen ions, due to rapid nitrification (i.e. microbial conversion) of soil organic nitrogen (SON), in the form of ammonium ions (NH_4^+) to nitrate – nitrogen (NO_3^- - N), as shown by the chemical equation below:

$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$. This suggests that, legumes, through their high nitrate concentration, have the potential to acidify and degrade soil in the same way as nitrogen – fertilizers, such as ammonium sulphate [(NH_4)2SO4], particularly, in soils of low action exchange capacity (CEC). So, in view of the potential problem of soil acidification, associated with nitrogen – fixing legumes, to avert the problem of soil acidity, and hence, achieve sustainability of farming systems, the addition of liming materials to soil that has been under legume fallows, is strongly recommended.

The lowest soil pH value for continuous maize cultivation can be ascribed to the lowest values of the exchangeable bases at the exchange sites of soil in the plots of continuous maize cultivation. The lowest concentration of the exchangeable bases, adduced to continuous maize cultivation, can be attributed to two reasons: First, the lowest concentration of the exchangeable bases can be attributed to their continuous uptake by maize during the five - year - cropping period. Second, the lowest concentration of the exchangeable bases can be adduced to leaching. This is because, the tillage operations, involved in the five – year – continuous maize cultivation may have rendered the soil porous, thus, increasing its vulnerability to leaching losses.

The significantly higher values of soil organic carbon (SOC), adduced to the planted fallows, compared to the control, are in conformity with the reports of Galeb (2012); Aritoff (2012); Liya (2013), who reported significantly higher SOC values under *Panicum maximum*, *Chromolaena odorata* and *Centrosema pubescens* fallows, as against what obtained under continuous maize cultivation (control). The significantly higher SOC values, adduced to the planted fallows, relative to the control treatment, can be explained in the light of higher soil organic matter (SOM) under planted fallows, resulting from decomposition of leaf litter, produced by the fallow vegetation. Asides, the significantly higher SOC values for the planted fallows, can be attributed to increased biological activities and nutrient recycling by the increased fine root network activities under the planted fallows (Moss, 2012). The significantly lower SOC value for *Centrosema pubescens* fallow than that of *Chromolaena odorata* fallow, support the findings of Liya (2013), who reported significantly higher SOC value under non – legume fallow vegetation than under planted fallows of leguminous species. This observation was probably due to higher build – up of SOM under the non – legume (*Chromolaena odorata*) fallow than its legume (*Centrosema pubescens*) counterpart. The lowest SOC value for *Panicum maximum* fallow, of all the three planted fallows, can be ascribed to the lowest rate of decomposition of *Panicum maximum* residues, due perhaps, to their higher lignin content (i.e. higher value of C/N ratio) (Arigbede, 2011; Moss, 2012).

The lowest SOC value for continuous maize cultivation, corroborates the findings of Heald (2009) and Ito (2012), who obtained lowest SOC value for continuous maize cultivation, as against what obtained under planted fallows of *Panicum maximum*, *Chromolaena odorata* and *Centrosema pubescens*. This observation is a further confirmation of the assertion of Galeb (2012), who opined that, soil organic matter decreased under continuous cultivation, with or without addition of organic and / or inorganic soil ammendments. The lowest SOC value that attended continuous maize cultivation treatment, compared to its planted fallow counterparts, was probably due to higher rate of oxidation of SOM in the continuous maize cultivation plots. This is because, the tillage that attended continuous maize cultivation, may have exposed the previously inaccessible and preserved SOM to action of the soil microbial biomass (Moss, 2012; Young, 2013; Zinsir, 2013). So, the higher rate of oxidation of SOM in the continuous maize cultivation plots can be implicated for the lowest SOC value, adduced to the continuous maize cultivation treatment. This is because part of the organic carbon content of the organic matter may have been oxidized or converted into CO_2 gas, and consequently, carbon is lost in the form of carbon dioxide – C emission from the soil system. This observation suggested that, the practice of continuous maize cultivation, especially on a long term basis, will consequently result in fast depletion of SOC or SOM, with resultant declined soil fertility and crop yields. Thus, to avert this kind of problem, and hence, achieving sustainability of crop production, the addition of organic manures to soil under continuous maize cultivation is strongly recommended.

The highest total N value for *Centrosema pubescens* fallow, is in conformity with the highest total N value for *Centrosema pubescens* fallow, reported by Arit (2011) and Galeb (2012). This observation points to the superiority of *Centrosema pubescens* fallow effects to those of the other two planted fallows, as regards improving the soil N status. The superiority can be attributed to the ability of *Centrosema pubescens*, like any other legumes, to symbiotically fix atmospheric nitrogen into the soil. The lowest cation exchange capacity (CEC) value of soil under *Centrosema pubescens* fallow, in comparison to other planted fallows, can be ascribed to the lowest pH value of soil under *Centrosema pubescens* fallow. This is because, the CEC and other cations are pH dependent, with the CEC decreasing with decrease in pH (i.e. increased acidity) (Willet, 2010; Odu, 2011; Kapa, 2013).

The significantly higher values of the exchangeable bases, available P, total N and CEC, adduced to the planted fallows, as against the continuous maize cultivation, can be attributed to the significantly higher SOC values for the planted fallows. This is because, previous studies (Aina, 2008; Arigbede, 2011; Abbet, 2012), had established positive and significant correlation between plant nutrients and SOM. That is, plant nutrients and CEC are integrally tied to SOM, and hence, the maintenance of SOM is paramount in sustaining other soil quality factors (Abbet, 2012). The significantly higher values of exchangeable Na, adduced to the planted fallows, suggest possibility of using planted fallows of *Panicum maximum*, *Chromolaena odorata* and *Centrosema pubescens* to increase sodication.

The lowest available P value, associated with continuous maize cultivation, can be attributed to the lowest pH value of soil in the continuous maize cultivation plots. This is because, the availability of P in the soil, depends on pH of the soil medium, with available P decreasing with decreasing pH (Zorok, 2012). The decreasing available P phenomenon, associated with increasing acidity or decreasing pH, is due to the conversion of P into unavailable forms under acid soil conditions, as a result of fixation by micro – nutrients, such as Fe and Al, which abound in acid soils (Zorok, 2012; Zynth, 2013).

The highest concentrations of the micronutrients (Cu, Zn, Mn and Fe), recorded in the continuous maize cultivation plots, can be attributed to the lowest pH value of soil in the continuous maize cultivation plots. This is because the availability of these micronutrients depends on their solubility, which in turn, is pH dependent, with their solubility, and hence, availability increasing with decreasing pH of the soil medium. Thus, the lowest pH value of soil in the continuous maize cultivation plots accounts for the observed highest concentrations of micronutrients of soil in the continuous maize cultivation plots (Aritoff, 2012; Kapa, 2013).

CONCLUSIONS

Chromolaena odorata gave the highest SOC values, followed by *Centrosema pubescens* and *Panicum maximum*. *Centrosema pubescens* gave the highest total N value, followed by *Chromolaena odorata* and *Panicum maximum*. *Chromolaena odorata* gave the highest values of available P and ECEC, followed by *Panicum maximum* and *Centrosema pubescens*. *Chromolaena odorata* gave the highest values of exchangeable K, Ca, Mg and Na, followed by *Panicum maximum* and *Centrosema pubescens*.

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