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Soil Fertility Regeneration of Impoverished Ultisols of Edo State Using *Gliricidia sepium* Jacq Walp.

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Abstract: Improved fallow involving short-rotation woody and/or other perennial species are increasingly being tried as a means of sustaining crop productivity in impoverished farming systems of sub-saharian Africa. The contributions of nitrogen fixation and leaf litter of *Gliricidia sepium* Jacq Walp. to soil fertility regeneration of an impoverished ultisol during a two year fallow was assessed after continuous cropping for four consecutive years. One of the plots used in this investigation contained *Gliricidia sepium* as part of the fallow vegetation while the second plot did not. At the end of the two year fallow period, higher levels of exchangeable cations, available phosphorus and total nitrogen were recorded for the plot with gliricidia compared to the control plot. Litter from the gliricidia treated plot recorded higher nitrogen (23.5%), phosphorus (0.31%), potassium (1.3%) calcium (0.9%), lipid (10.85%) and crude fiber (4.28%) compared to control fallow plot occupied by diverse plant population, excluding gliricidia species, which recorded lower levels of nitrogen (12.31%), calcium (0.63%), potassium (1.7%), phosphorus (0.27% and lipid (9.92%) but higher crude fiber (6.18%).The incorporation of ground leaf litter into the post-fallow soil resulted in up to two fold increases in soil nutrients such as total nitrogen, available phosphorus and exchangeable cations (magnesium and calcium) in the gliricidia treated plot compared to the control plot.

Key words: *Gliricidia sepium*, soil fertility, impoverished soil, improved fallow

INTRODUCTION

The quality of soil is pivotal to sustain cropping, however after cropping on a piece of land for a long time, the soil nutrients are depleted. The maintenance of soil fertility and therefore of crop productivity is crucial to the development of sustainable agriculture. Modern agriculture relies heavily on inputs of chemical fertilizers for the maintenance of crop productivity. However, environment friendly systems based on the use of nitrogen fixing trees such as *Gliricidia sepium* have been reported to bring about favourable changes in soil properties by enhancing soil conservation and fertility regeneration thereby achieving sustainable production (Hartemink, 2004; Schwendener *et al*., 2005; Vanlauwe *et al*., 2005; WAC, 2006).

Gliricidia and *Leucaena* species are among the most widely studied of the many tropical woody legumes. *Gliricidia sepium* (commonly referred to as gliricidia) is the most widely used tree legume in Edo Stateof Nigeria because of its ability to establish well on acid soils prevalent in this region. In the agroforestry practices of Edo State of Nigeria, *Gliricidia sepium*, used as stakes for yams or climbing beans are left on the farms during the fallow period to enhance the soil fertility regeneration process through nitrogen fixation and litter accumulation. According to earlier reports (Yamoah and Ay, 1986; Zaharah and Bah, 1999; Elevitch and Francis, 2006), the ability of *Gliricidia sepium* to improve soil fertility is due to its high litter production and nitrogen fixation, leading to substantial increases in the amounts of nitrogen, phosphorus, potassium and calcium in the soil during alley cropping or bush fallow.

According to Vlek *et al.* (1997), nitrogen is an important plant nutrient; however it is a limiting factor especially in tropical soils. Therefore the strategy of integrating soil fertility management using legume trees in the farming practices of indigenous communities is essential. The aim of the present study was to assess the contributions of *Gliricidia sepium* in soil fertility regeneration during a two-year fallow on an impoverished Ultisol as a result of nitrogen fixation; litter production and decomposition.

MATERIALS AND METHODS

The experiment was conducted at the Faculty of Agriculture Experimental Farm, Ambrose Alli University,

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Ekpoma Nigeria (6.44° N; 6.04°E). The mean annual rainfall at the Experimental site is 1520 mm, bimodal in distribution and starts from late March and ends early November, with a short dry spell in August. The site is classified locally as Kulfo series (Moss, 1957) and into the soil order of Ultisols.

An area of two hectares was hand cleared of its six year- old secondary thicket in April, 1999. The cleared plant material was burnt and the unburnt material removed from the plot. The area was divided into two equal parts. The two farmlands were then cropped continuously for four years until the crop showed signs of decreased productivity as a result of soil impoverishment. Both farms had yam, maize and melon planted for the four years, during the main cropping season of February to November. Gliricidia was used as stakes for the yams at a spacing of three meters apart on the first plot (Plot 1), while bamboo was used as stakes for the second plot (Plot 2) at the same spacing. Soil samples were collected at 10 spots on each plot at depths of 0-15 and 15-30 cm using a calibrated core auger of 6 cm diameter. Large roots and pieces of organic matter were removed from the soil samples prior to laboratory analyses, which were conducted following the techniques of Anderson and Ingram (1993) and Okalebo *et al.* (2002). The sites were then subjected to a two-year fallow (2003-2005), at the end of which ground litter was sampled and analysed. Using the same techniques as outlined above, the post-fallow soils were also sampled and analyzed.

The plots were then ploughed to incorporate the litter into the soil and sampled again for analysis of soil nutrients after a four-week post-plough period, to enable decomposition of the litter into the soil. Present study was done to evaluate the combined effects of the litter and nitrogen fixation of the gliricidia compared to the plot which used bamboo for staking and served as the control.

RESULTS AND DISCUSSION

Table 1 gives the details of the soil characteristics prior to the two year fallow period imposed on the two selected plots used in the present study. The soils had a colour range of red to rusty red of 5R3/2 to 5R2.5/1. The pH of the nutrient depleted soils ranged from 4.66 to 5.05 indicating that the soils are acidic in reaction.

The bulk density varied from 1.48 to 1.54 g cm^{-3} while the total nitrogen content varied from 0.09-0.14%. The available phosphorus concentrations were also low (4.35-5.32 ppm) compared to the critical range of 7.0-20 ppm recommended by Sobulo and Adepetu (1987) for agricultural soils.

Table 1: Soil characteristics of degraded ultisols prior to fallow period

	Depths (cm)			
	Gliricidia fallow		Non-Gliciridia fallow	
Parameters	0-15	15-30	0-15	15-30
BD (g cm^{-3})	1.48	1.52	1.48	1.54
pH	5.05	4.72	5.15	4.66
Total N %	0.14	0.12	0.11	0.09
Av. P (ppm)	5.32	5.26	4.89	4.35
Org. carbon (%)	0.60	0.51	0.55	0.48
Na*	0.06	0.04	0.07	0.03
K*	0.22	0.17	0.22	0.10
Ca*	1.38	1.34	1.42	0.98
Mg*	0.56	0.53	0.58	0.56
Al +H*	1.95	2.00	1.98	1.96
ECEC*	4.17	4.07	4.27	3.63
B sat %	53.20	50.10	53.63	46.00

*cmol kg^{-1}; BD = Bulk Density; Av. P = Available Phosphorus; Total N = Total Nitrogen

Table 2: Characteristics of soil samples under 2-year fallow for the gliricidia and control (non-gliricidia) treatment

	Depths (cm)			
	Gliricidia fallow		Non-Gliciridia fallow	
Parameters	0-15	15-30	0-15	15-30
BD (g cm^{-3})	1.38	1.42	1.31	1.48
pH	5.77	5.52	5.28	5.25
Total N (%)	0.43	0.38	0.15	0.17
Av. P (ppm)	7.94	6.01	7.10	6.77
Org. carbon (%)	2.36	1.10	1.30	0.95
Na*	0.07	0.06	0.09	0.05
K*	0.50	0.40	0.42	0.22
Ca*	1.98	1.92	1.79	1.65
Mg*	1.36	1.30	1.42	1.25
Al +H*	2.20	2.20	1.80	1.83
ECEC*	6.06	5.88	5.52	5.00
B Sat %	63.70	62.58	67.39	63.40

*cmol kg^{-1}; BD = Bulk Density; Av. P = Available Phosphorus; Total N = Total Nitrogen

The organic carbon content was low (0.48-0.60%) as a result of the four years of continuous farming. The effective cation exchange capacity was low to moderate (3.63-4.27 cmol kg^{-1}) and dominated by calcium (0.98-1.42 cmol kg^{-1}) and magnesium (0.53-0.58 cmol kg^{-1}). The exchangeable acidity recorded moderate values (H^+ + Al^{3+}) compared to the effective cation exchange capacity. Consequently, the recorded base saturation was low with values ranging from 46.0-53.63%.

The characteristics of the soils of the two plots at the end of the two year fallow period are indicated in Table 2. There were considerable improvements in the physical and chemical properties of the soil compared to that of the pre- fallow soil. The results revealed that the soils were still acidic (pH 5.25 -5.77) with the gliricidia treated soils being more acidic than the control plot. Ganessan (1994) has reported that gliricidia grows well in acidic soils. The organic carbon content increased from 0.95 to 2.36% compared to the pre-fallow values of 0.48 to 0.60%.

Thus at the end of fallow period the organic carbon content was adequate to support agriculture (Aweto, 1981). The major contributor to the soil organic matter was decomposition of dead plant parts and leaf litter. Nonetheless the plot with gliricidia recorded higher values compared to the control.

The total nitrogen content of the gliricidia plot varied from 0.38-0.42% compared to the control (0.15-0.17%). The increase in nitrogen in the gliricidia treated plot confirmed the efficient nitrogen fixing ability of the plant (Allen and Allen, 1981; Trinick, 1986; Kang and Mulongoy, 1987; Thangata and Alavalapati, 2003). Nitrogen is one of the macro-nutrients which plants require in large quantities for their growth. However, it is in short supply in most tropical soils (Vlek *et al*., 1997). The control plot without gliricidia accumulated less nitrogen during the fallow period compared to the gliricidia treated plot.

Although gliricidia biologically fixes nitrogen in its nodules below the ground, it is the tree's leaves that are valued by farmers as source of nitrogen and other plant nutrients. The nitrogen content of the litter from the gliricidia treated plot averaged 23.5% compared to the control (12.1%; Table 3). Gliricidia provides high quality nutrients that are easily utilized by crops (Sanchez, 1999; WAC, 2006). In the present study litter from gliricidia was also a good source of other nutrients such as calcium (0.96%), phosphorus (0.31%) and organic carbon (52.7%) as shown in Table 3.

Ploughing the ground litter into the top 30 cm of the soil resulted in considerable improvement in its chemical and physical properties. The results indicated that the soils of the two experimental plots are acidic with a pH range of 5.95-6.66. The organic carbon content increased from the post -fallow values of 0.95-2.36% to post-plough values of 6.45-10.46%. The plot with gliricidia recorded higher values compare to the control plot. Thus the gliricidia plot had better potentials to sustain longer period of cropping than the control plot. The total nitrogen content of the gliricidia treated plots varied from 1.63-1.81% compared to the control plot (0.42-0.48%).

The total exchangeable cation decreased down the profile and was in agreement with Aiboni (1985). The critical effective cation exchange capacity value of 4.0 cmol kg^{-1} soil for tropical soils (Sanchez, 1996) was exceeded on the two plots. Calcium dominated the exchangeable bases at the two sites and ranged from 2.35-3.10 cmol kg^{-1}. Taylor and Pholen (1966) had reported calcium concentrations for a wide range of soils as 2.00-5.00 cmol kg^{-1}. Lower concentrations were recorded at the control site (1.94-1.95 cmol kg^{-1}) compared to gliricidia treated plots for magnesium (1.98-2.13 cmol kg^{-1}). The concentrations of potassium

Table 3: Percentage composition of leaf litter from two-year gliricidia and non-gliricidia bush fallow

Parameters	Gliricidia fallow	Non-gliricidia fallow
Nitrogen (%)	23.50	12.10
Calcium (ppm)	0.96	0.63
Potassium (ppm)	1.08	1.07
Phosphorus (%)	0.31	0.27
Sulphate (ppm)	2.10	2.20
Crude fiber (%)	4.28	6.18
Lipid (%)	10.85	9.92
Organic carbon (%)	52.70	47.96

Table 4: Characteristics of soil four weeks after ploughing/incorporation of litter from 2-years fallow under gliricidia and non-gliricidia treatment

	Depths (cm)			
	Gliricidia fallow		Non-Gliciridia fallow	
Parameters	0-15	15-30	0-15	15-30
BD (g cm^{-3})	0.95	1.25	1.30	1.45
pH	6.65	5.95	6.66	6.25
Total N %	1.81	1.63	0.48	0.42
Av.P (ppm)	22.38	15.88	10.44	9.10
Org. carbon (%)	10.46	10.35	7.37	6.45
Na*	0.08	0.08	0.06	0.05
K*	0.60	0.50	0.38	0.28
Ca*	3.10	2.90	2.70	2.35
Mg*	2.13	1.98	1.95	1.94
Al +H*	2.05	2.04	2.08	2.13
ECEC*	7.96	7.50	7.17	6.75
B Sat %	74.25	72.80	71.00	68.44

*cmol kg^{-1}; BD = Bulk Density; Av. P = Available Phosphorus; Total N = Total Nitrogen

in the experimental plots were higher than the critical level of 0.10 cmol kg^{-1} reported earlier by Doll and Lucas (1973).

The results revealed that ploughing in the litter improved the soil fertility at the end of the two-year fallow period in terms of bulk density; total nitrogen, available phosphorus, organic carbon content and calcium concentrations.

Reports of improved soil fertility after bush fallow from gliricidia and non-gliricidia plots have earlier been recorded (Snoeck, 1996; Thaman and Whistler, 1996; Kaya and Nair, 2001).

The present results (Table 2 and 4) clearly indicate that during the fallow period, the presence of leguminous plants such as gliricidia and the nature of fallow vegetation contributed to the regeneration of soil fertility. The practice of using gliricidia as part of the fallow by indigenous farmers is therefore commendable as it enhances faster regeneration of soil fertility.

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