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Changes in the Nutrient Status of a Tropical Alfisol Following Application of Leaf Biomass of Some Agroforestry Species

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Abstract: This study was carried out to evaluate changes in the nutrient content of a tropical soil consequent upon application of leaf biomass of *Cajanus cajan, Tithonia diversifolia, Acacia mangium* and *Grevillea robusta*. Equivalent of 5 t ha^{-1} of fresh leaves of each of the woody species was applied to the soil surface. Soil chemical properties were determined prior to application of leaf biomass and at 2, 4, 6 and 8 weeks after. Total N, available P and exchangeable K, Ca and Mg contents of the soil increased with time and the rate of increase varied with the type of plant material applied. Eight weeks after application of the plant materials highest organic C (1.51%), K (0.77 cmol kg^{-1}) and Mg (1.55 cmol kg^{-1}) were observed in soils to which *C. cajan* was applied while soil contents of P and Ca were highest in soils to which *T. diversifolia* was applied. Values of K, Mg, P and Ca were however not significantly different between *C. cajan* and *T. diversifolia* soils. The rapid release of nutrients from *C. cajan* and *T. diversifolia* is an indication of their suitability for soil fertility amendment in arable crop fields where an immediate release of nutrients for crop uptake is required.

Key words: Biomass transfer, fresh leaves, soil, nutrients

INTRODUCTION

One of the major challenges of the tropical developing countries today is the production of sufficient food for the teeming population. The high population pressure and the shortened fallow period has made it very difficult to increase and sustain food production on the inherently erodible and infertile soils of the tropics[1]. Consequently, alternative methods of improving and sustaining soil fertility are being developed. One of these methods is biomass transfer, in which plant biomass produced outside the crop growing area is transferred to crops to provide an output of nutrients.

There is an increasing interest in the use of plant residues for improving soil productivity in agricultural systems in the tropics. According to Buresh and Tian[2], the addition of organic materials originating from outside the soil-plant system is a nutrient input and the effectiveness of this organic matter addition as nutrient sources depends on the composition[3]. The transfer of nutrients through tree biomass can contribute to micro variability in soil fertility and plant growth[4].

Jama *et al.*[5] reported that leaf biomass from *Calliandra calothyrsus* applied at 10 kg P ha^{-1} significantly increased maize yield and had a residual effect on the subsequent maize crop. Fresh leaf biomass of *Tithonia diversifolia* decomposes rapidly and is reported to be an effective source of N, P and K for maize and vegetables[6]. According to Mafongoya *et al.*[3] the potentials of tree biomass to supply nutrient depend on their resource quality. In addition to the resource quality of the organic material, the environment and the type of organisms present influence decomposition and rate of nutrient release. According to Salako and Tian[7] efficient conversion of plant biomass to soil humus by soil organisms depends largely on climatic factors and the selected species (plant tissue quality). Although there is no general agreement on any single plant tissue quality factor as the best predictor of decomposition rate of biomass and nutrient release, C:N ratio and lignin content could be among the best predictors.

Kaya and Nair[8] in an experiment to understand the effectiveness of application of imported high quality biomass on the improvement of soil fertility and maize crop production reported excess of soil N (relative to crop uptake) of 19, 11 and 18 kg ha^{-1} at 4 Weeks After Planting (WAP) and 8, 3 and 14 kg ha^{-1} at 6 WAP, respectively for *Gliricidia, Pterocarpus* and *Stylosanthes*; a result which was consistent with the biomass decomposition rates of the species. The present study was designed to evaluate the changes in the nutrient content of a humid tropical Alfisol consequent upon application of leaf biomass of selected agroforestry species.

MATERIALS AND METHODS

The study was carried out at the agroforestry site of the Teaching and Research farm, Federal University of Technology, Akure, Nigeria (latitude 7°17′N, longitude 5°10′E 350 m a.s.l.). The area has a bimodal rainfall pattern with an annual mean of 1500 mm and a mean annual temperature of 26°C. The main growing season is from April to August and a minor growing season is from August to October, followed by a long dry season from November to April. The experiment was conducted during the 2003 growing season. The soil of the experimental site is an Alfisol with sandy loam texture. Before the experiment the land was under natural fallow.

The experiment was laid out in a split-plot-in-time design. The main plot treatment was the sampling dates while the mulch materials constituted the sub-plot treatment. The whole experimental plot (6×6 m) was partitioned into 20 micro-plots of 1×1 m in dimension. Adjacent micro-plots were separated from each other by a buffer 0.25 m wide. Each treatment including a control (without mulch) was replicated four times and treatments were randomly allocated to the micro-plots.

Based on the facts obtained from the study of Mafongoya *et al.*[3] the following plant materials which have contrasting chemical and physical characteristics were chosen for the field study: *Tithonia diversifolia, Cajanus cajan, Grevillea robusta* and *Acacia mangium.* The leaf and litter characteristics of the selected species as presented in Table 1. Matured but not senescent leaves of the woody species were collected as mulch materials for the study. Fresh plant materials were applied at the rate of 0.5 kg μ^{-1} plot, an equivalent of 5 t ha^{-1}.

Soil sampling: Surface soil (0-15 cm) samples were collected with the aid of a 3.5 mm diameter soil auger. Three auger points were taken in each micro-plot. Soil samples from same micro-plot were bulked and homogenized and composite samples were taken to the laboratory for analyses. Soil samples were collected prior to application of leaf biomass and at 2, 4, 6 and 8 weeks after. The soil samples were kept in polythene bags.

Soil analysis: Soil pH was measured with an electronic pH meter in a 1:2.5 soil/water suspension. Soil organic carbon was determined by wet oxidation. Total nitrogen in the soil was determined using semi microKjeldahl method[9]. Soil samples were leached with ammonium acetate solution to obtain the extracts used in the determination of exchangeable cation. Ca and Mg in the leachate were determined by Ethylene Diamine Tetraacetic Acid (EDTA) titration while potassium was determined by flame photometry

Table 1: Concentration of carbon and nitrogen in the leaves of the selected agroforestry species

Species	C(%)	N(%)	C/N
G. robusta	49.92	1.72	29.02
A. mangium	48.87	1.96	24.93
C. cajan	44.46	3.84	11.58
T. diversifolia	42.34	4.13	10.20

Statistical analysis: A split plot experimental design was used with the main plots being the time soil of sampling and the sub plots, mulch type. Mean comparison were made according to the Duncan's Multiple Range Test (p = 0.05).

RESULTS AND DISCUSSION

Changes in soil chemical properties: A steady increase in soil nutrient elements was observed over the 8 week period of the study in soils to which application of fresh leaf biomass of selected agroforestry trees was made (Table 2). It was observed that the rate of increase varied with the agroforestry species and the nutrient element measured. The most rapid rate of soil increase of N was observed in soil to which leaf biomass of *C. cajan* was applied. Although N concentration in soil to which *A. mangium* leaf was applied was higher than that of *C. cajan* in weeks 2 and 4, this soon decreased and became less than that of *C. cajan* and *T. diversifolia* by week 6. Soil organic C, available P, K Ca and Mg were also observed to increase more rapidly in soils to which leaf biomass of *T. diversifolia* and *C. cajan* were applied. Although changes were also observed in the soil pH after application of the various plant materials this was very gradual with little inter-specific variations.

Statistical comparison of soil properties: Statistical comparison of soil chemical properties prior to the application of plant materials shows no significant difference.

Application of leaf biomass of the various species significantly influenced soil chemical properties (Table 3). Eight weeks after application of plant materials, highest organic C content was observed in soils to which leaf biomass of *C. cajan* was applied. The soil contents of K and Mg were also highest for *C. cajan* but these were not significantly different from the values obtained for *T. diversifolia.* Soil content of P and Ca were highest in soils to which leaves of *T. diversifolia* were applied.

The absence of significant differences in most of the measured soil parameters at the beginning of the

Table 2: Mean values of chemical properties of surface (0-15 cm) soil layer over the eight week period of assessment

					Exchangeable cations (cmol kg^{-1})		
Species	pH-$H_2$0	Organic C (%)	Total N (%)	P (mg kg^{-1})	K	Ca	Mg
Before mulching							
G. robusta	5.13	0.20	0.12	0.08	0.12	0.40	0.04
A. Mangium	5.11	0.21	0.15	0.07	0.13	0.53	0.04
C. cajan	5.11	0.23	0.15	0.09	0.14	0.50	0.06
T. diversifolia	5.13	0.21	0.13	0.08	0.13	0.58	0.04
Control	5.12	0.20	0.12	0.08	0.15	0.50	0.05
Week 2							
G. robusta	5.43	0.17	0.14	0.08	0.10	0.68	0.08
A. Mangium	5.36	0.19	0.29	0.07	0.15	0.38	0.20
C. cajan	5.83	0.24	0.24	0.09	0.22	1.63	0.33
T. diversifolia	5.90	0.22	0.19	0.09	0.24	1.68	0.58
Control	5.16	0.29	0.13	0.07	0.17	0.35	0.06
Week 4							
G. robusta	5.61	0.21	0.20	0.09	0.11	0.93	0.08
A. Mangium	5.32	0.22	0.37	0.09	0.20	0.70	0.32
C. cajan	6.06	0.35	0.29	0.41	0.33	2.55	0.49
T. diversifolia	6.19	0.28	0.25	0.75	0.49	3.23	1.15
Control	5.16	0.33	0.15	0.07	0.13	0.55	0.07
Week 6							
G. robusta	5.70	0.25	0.28	0.15	0.21	1.30	0.15
A. Mangium	5.57	0.27	0.38	0.36	0.39	1.30	0.45
C. cajan	6.05	0.49	0.45	1.12	0.67	2.63	1.30
T. diversifolia	6.18	0.51	0.39	1.59	0.76	3.40	1.55
Control	5.20	0.37	0.16	0.09	0.17	0.48	0.07
Week 8							
G. robusta	5.60	0.42	0.27	0.39	0.21	1.23	0.52
A. Mangium	5.77	0.33	0.34	0.59	0.36	1.30	0.55
C. cajan	5.96	1.51	0.45	1.42	0.77	2.65	1.55
T. diversifolia	6.11	0.64	0.40	1.69	0.69	3.35	1.30
Control	5.16	0.33	0.16	0.09	0.18	0.50	0.09

Table 3: Chemical properties of surface (0-15 cm) soil layer eight weeks after application of leaf biomass of selected agroforestry species

Chemical parameters	*G. robusta*	*A. mangium*	*C. cajan*	*T. diversifolia*	Control
pH-H_2O	5.60^{b}	5.77^{b}	5.96^{a}	6.11^{a}	5.16^{c}
Organic C (%)	0.42^{c}	0.33^{c}	1.51^{a}	0.64^{b}	0.33^{c}
Total N (%)	0.27^{c}	0.34^{b}	0.45^{a}	0.40^{a}	0.16^{d}
P (mg kg^{-1})	0.39^{b}	0.59^{b}	1.42^{a}	1.69^{a}	0.09^{c}
Exchangeable cations (cmol kg^{-1})					
K	0.21^{c}	0.36^{b}	0.77^{a}	0.69^{a}	0.18^{d}
Ca	1.23^{c}	1.30^{c}	2.65^{b}	3.35^{a}	0.50^{d}
Mg	0.52^{b}	0.55^{b}	1.55^{a}	1.30^{a}	0.09^{c}

Figures on the same row followed by the same superscripts are not significantly different ($p = 0.05$)

experiment is an indication of the relative homogeneity of the experimental soil

The results obtained after application of leaf biomass showed the potentials of some of the selected woody species to improve significantly the concentrations of N, P, K, Ca and Mg in the soil. *C. cajan* and *T. diversifolia* were outstanding in their effect. The variations in the effects of the various plant materials is in agreement with the reports of Palm *et al.*[10] who stated that the amount, ratio and release of nutrients added from different organic materials vary. Mugendi and Nair[11] stated that the rates of decomposition and nutrient release influence the ability to enhance soil fertility through addition of prunings. Scroth *et al.*[12] observed that *Cajanus* decomposed rapidly and its decomposition was accompanied by immediate release of N, P and K to the soil. It should be noted however that rapid biomass decomposition may not always be the desired quality in plant materials to be used for soil improvement. De Costa and Atapattu[13] recommended *Calliandra calothyrsus* and *Flemingia congesta* for tea plantations in Sri Lanka because of their high soil nutrient enrichment capacity and slower decomposition rates which minimize leaching losses.

The effects of *Tithonia* on soils may however not be for a long duration judging from the decline observed in the K, Ca and Mg of soils to which *Tithonia* was applied by 8 weeks. Its use may therefore be limited to soil fertility amendment for annual crops which require immediate release of nutrients.

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