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Growth of Short Rotation *Cajanus Cajan* Fallow and Its Impact on a Degraded Tropical Alfisol

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Abstract

Cajanus cajan (L) Millsp. has been reported to improve soil fertility in many areas of the humid tropics. Although this woody species is widely cultivated in the South-western Nigeria usually in association with other agricultural crops, reports of its successful use as a fallow species are scanty. To determine the extent of the beneficial effects of *C.cajan* fallow on soil, experimental plots were established on an extensively cultivated soil using *C. cajan* fallow and natural bush fallow. Soil chemical properties to a depth of 30 cm were measured prior to the establishment of the fallow species and 12 and 25 months after. The type of fallow species affected soil nutrient content. Organic carbon (OC) and phosphorus (P) were observed to be significantly lower under *C. cajan* fallow compared to the natural fallow at 12 weeks after fallowing. However, by the 25th month after fallowing there had been significant improvement in soils under cajanus fallow with organic carbon, total nitrogen (TN) and P being 19.9%, 37.5% and 38.3% respectively higher than in the natural fallow.

Keywords: improved fallow, *Cajanus cajan*, soil chemical properties

INTRODUCTION

One of the greatest challenges facing the developing world today is production of sufficient food to meet the needs of the rapidly growing population. Maintenance of soil fertility is one of the major factors affecting agricultural production in Nigeria. The traditional farming system which relies on bush fallowing to maintain soil fertility used to be the backbone of agricultural production. This sustainable practice is however collapsing under the increasing population pressures which have led to shortened fallow lengths. In some areas of Ondo State, Nigeria where the farmers still maintain sufficiently long fallow, it is at the expense of the reserved natural forest which is now being converted to agricultural use at an alarming rate. This trend if not checked portends great danger to the environment and biodiversity. The need for a sustainable alternative to shifting cultivation has become more pressing than ever before.

While mineral fertilizers have been used with great successes in many of the developed temperate countries, a lot of factors ranging from high cost of fertilizers to 'fragile' nature of tropical soils have constrained continuous use of the product in the developing tropical countries like Nigeria. Several low input agroforestry technologies have been designed as alternatives to bush fallow system. These include biomass transfer [1], improved fallow [2] and alley cropping [3].

Short term improved fallow technology which is characterized by deliberate planting of fast growing nitrogen fixing leguminous species in rotation with crops is currently being promoted for soil fertility replenishment in the small holder farms in the tropics [4]. Fast growing nitrogen fixing tree/shrub species are used in improved fallow because of their ability to rapidly enhance soil fertility through litter-fall, retrieve nutrient from deep soil layers and fix atmospheric nitrogen.

Several fast growing leguminous species have been investigated for their role in improved fallow technology. These include *Sesbania sesban* [2, 5], *Tithonia diversifolia, Cajanus cajan, Teprosia candida* [4], *Acacia leptocarpa, Leucaena leucocehala, Acacia auriculiformis* [6]. Improved fallows of one to three-year duration have been reported to increase N-availability to subsequent crops on N-deficient soil. Barrios et al [7] reported increases in soil organic nitrogen (ON), N in light fraction soil organic matter (OM) and N mineralization in Sesbania fallows in Eastern Zambia. Similar results were reported by Maroko et al [8] in Western Kenya. Siriri and Rausen [9] after an experiment conducted to assess the potentials of improved fallow in the South-western Uganda concluded that the system shows potential to double returns to land and labour. In Malawi, an increase in yield was achieved by having a controlled 3-year fallow with *Cajanus cajan* as compared with bush fallow [10].

Although *Cajanus cajan* has been widely grown as an agricultural crop in the South-western Nigeria, there has been little or no reports of efforts at tapping the soil rejuvenation potentials of this woody species. This study was carried out to assess the growth of *Cajanus cajan* in the study area and examine its impact on soil characteristics.

MATERIALS AND METHOD

Study Site

The study was conducted at the Agroforestry plots, Teaching and Research Farm, Federal University of Technology, Akure (Latitude 7^{o} 17' N, Longitude 5^{o} 10' E, 350 m a.s.l.) The experimental site had well-drained, moderately-weathered, and granular- structured soil which is classified as Alfisol in the USDA system of classification. The area has a bimodal rainfall pattern with an annual mean of 1500 mm and a mean annual temperature of 26^{o}C. The main growing season is from April to August and a minor growing season from August to October.

The study was conducted using the Cajanus improved fallow plots established in April 2004. At inception, the experimental area was partitioned into nine 10 m x 10 m plots. Three of these were randomly selected for improved fallow, three for continuous maize cropping and the remaining three were left to re-grow as natural fallow. The experiment was established on a land that had been continuously cropped with maize and cassava for six years.

Soil sampling and analysis

Soil samples were collected and analyzed prior to the establishment of plots in 2004. In April 2005, twelve months after establishment of the *Cajanus cajan* fallow, soil samples were collected from the cajanus plots and the natural fallow to assess the impacts of the two fallow types on soil properties. The fallow vegetation was cleared in June 2006 and soil samples were again collected for analysis after the plant materials had partially decomposed on the spot. Soil samples were collected at 0-10, 10-20, and 20-30 cm depths with the aid of a 3.5 cm diameter soil auger. Five auger points were taken along the diagonals of each plot. Samples from the same plot and the same soil depth were bulked and homogenized and composite samples were taken to the laboratory for analyses.

Soil pH was measured with an electronic pH meter in a 1:2.5 soil/water suspension. Soil OC was determined by Walkley Black wet oxidation method. TN was determined using semi microKjeldahl method [11]. Soil samples were leached with ammonium acetate solution to obtain extracts used in the determination of exchangeable cations. Ca and Mg in the leachate were determined by Ethylene Diamine Tetraacetic Acid (EDTA) titration while potassium was determined by flame photometry.

Determination of biomass production in Cajanus fallow

In April 2005, twelve months after planting, three plants with collar diameter closest to the mean were selected in each of the three Cajanus fallow plots for above- and below ground biomass determination. The selected plants were carefully dug out and separated into leaves twig, stem, coarse root (> 2mm diameter) and fine roots (< 2 mm diameter. The plant materials were weighed fresh and sub-sampled. The sub-samples were oven-dried at 65^{o}C to constant weight. Samples of fresh plant materials were also collected and air dried for chemical analysis.

Plant analysis

Samples of plant biomass were analyzed for N, P, K, Ca and Mg. Air-dried plant samples were milled in a Willey mill to pass through a 1 mm sieve. 0.2 g of the milled plant material was digested and analysed as described by Anderson and Ingram [12]. TN in each digest was determined by semi-micro Kjeldahl procedure while available P was determined by Bray l method. For determination of K, Ca, and Mg, each plant sample was dry ashed at 550^{o}C. K was measured by flame photometry and Ca and Mg by atomic absorption spectrophotometry.

RESULTS

Growth and nutrient accumulation in *Cajanus cajan*

Cajanus cajan plants in the established fallow grew rapidly within the first twelve months. Total dry matter production was 5.05t/ha with the highest proportion (26.23%) in the coarse root and the lowest in the fine roots (Table 1). Nutrient concentrations (N,P,K, Ca and Mg) varied considerably between plant tissues and were highest in the leaves (Table 2). The highest concentration of N (1.59%) was found in the leaves, followed by fine root (1.03%) and the lowest (0.81%) was in the stem. The pattern of P, K, Ca and Mg concentrations in plant parts were similar with the highest concentrations in the leaves.

Effects of Cajanus fallow on soil nutrients

Table 3 shows the chemical properties of the experimental soil prior to fallowing. The pH values ranged between 5.99 for 0-10 cm soil depth and 5.09 for the 20 – 30 cm depth indicating

Table 1. Dry matter production of *Cajanus cajan* 12 months after planting

Plant part	Biomass(t/ha)	% of total
Leaves	0.73	14.46
Stems	1.20	23.76
Twigs	0.71	14.06
Branches	1.02	20.20
Fine root	0.03	0.59
Coarse root	1.36	26.23
Total	5.05	100.00

Table 2. Nutrient concentration in different tissues of 12-month-old *Cajanus cajan*

Plant part	N(%)	P(%)	K(%)	Ca(%)	Mg(%)
Leaf	1.59	0.50	1.09	0.72	0.61
Stem	0.81	0.13	0.63	0.32	0.43
Twig	0.92	0.37	0.73	0.54	0.42
Branch	0.83	0.17	0.68	0.72	0.29
Fine root	1.03	0.16	0.65	0.40	0.51
Coarse root	0.90	0.22	0.67	0.34	0.33

Table 3. Chemical characteristics of experimental soil prior to fallowing

Soil depth	pH (H_2O)	OC (%)	TN (%)	P (mg/kg)	Exchangeable (Cmol/kg)		
					K	Ca	Mg
0-10	5.99	1.23	0.17	9.50	0.41	0.15	0.27
10-20	5.21	1.19	0.15	8.65	0.26	0.19	0.26
20-30	5.09	0.95	0.15	7.55	0.28	0.21	0.22

Table 4. Chemical characteristics of experimental soil 12 months after fallowing

Fallow type	pH (H_2O)	OC (%)	TN (%)	P (mg/kg)	Exchangeable (cmol/kg)		
					K	Ca	Mg
0 – 10 cm depth							
Cajanus	5.13	1.16	0.14	7.85	0.37	0.16	0.26
Natural	5.11	1.56	0.15	10.40	0.53	0.19	0.30
t-test	NS	*	NS	*	NS	NS	NS
10 – 20 cm depth							
Cajanus	5.60	1.54	0.14	7.60	0.46	0.15	0.22
Natural	5.36	1.13	0.14	10.55	0.43	0.17	0.21
t-test	NS	*	NS	*	NS	NS	NS
20 – 30 cm depth							
Cajanus	5.87	1.29	0.14	6.50	0.55	0.10	0.23
Natural	5.26	0.92	0.14	7.85	0.44	0.13	0.22
t-test	NS	*	NS	NS	NS	NS	NS

NS – not significant; * - significant at $p < 0.05$

that the soil was slightly acidic. The OC and TN contents of the soil were moderate while the P content was low. The exchangeable cations were in low to moderate concentrations. There was a general decline in soil nutrients with depth.

The results of soil chemical analysis 12 months after fallowing (Table 4) indicated that the type of fallow species affected the soil nutrient content. Slight differences were observed in the pH, TN and the exchangeable K, Ca and Mg between *Cajanus* fallow and the natural fallow although these were not statistically significant. OC content was significantly lower at 0-10 cm depth and higher at 10-20 and 20-30 cm depths under *C.cajan* fallow while P was significantly lower at 0-10 and 10-20 soil depths. When compared with soil properties prior to fallowing, most of the measured soil parameters were lower under *Cajanus cajan* at 0-10 cm depth while only pH and TN were slightly lower in the natural fallow.

The chemical characteristics of the experimental soil after 25 months of fallowing (Table 5) shows significant differences between soil OC, TN, P and exchangeable K between *C. cajan* fallow and natural fallow. Higher values were recorded for *C. cajan* at 0-10 cm depth. Although the pH was lower under *C.cajan* 25 months after fallowing, all the other measured parameters were higher than they were prior to fallowing.

DISCUSSION

Soil pH did not show marked differences with the type of fallow. The slight reduction in the pH values 12 months after fallowing may be attributed to the exposure of the experimental soil during land preparation. Yeboah et. al. [13] who made similar observations on an Ultisol in Ghana attributed it to erosion of the exposed soil prior to the closure of *C. cajan* canopy.

Table 5. Chemical characteristics of experimental soil 25 months after fallowing (2 weeks after clearing and in situ decomposition of cleared debris).

Fallow type	pH (H_2O)	OC (%)	TN (%)	P (mg/kg)	Exchangeable (cmol/kg)		
					K	Ca	Mg
0 – 10 cm depth							
Cajanus	5.90	2.83	0.22	16.05	1.03	0.21	0.27
Natural	5.61	2.36	0.16	11.60	0.82	0.16	0.28
t-test	NS	*	*	*	*	NS	NS
10 – 20 cm depth							
Cajanus	5.30	1.93	0.16	15.80	0.99	0.19	0.24
Natural	5.42	1.79	0.16	10.65	0.76	0.12	0.22
t-test	NS	NS	NS	*	*	NS	NS
20 – 30 cm depth							
Cajanus	5.50	1.33	0.15	15.60	0.69	0.19	0.23
Natural	5.40	1.47	0.16	8.60	0.82	0.12	0.24
t-test	NS	NS	NS	*	*	NS	NS

NS – not significant; * - significant at $p < 0.05$

OC and nutrient levels tend to decline under *C.cajan* fallow at 12 months after fallowing. This may not be unconnected with the vigorous growth of the fallow plants and the rapid nutrient uptake from the topsoil as the canopy and root system of the fallow plants develop. The significantly low P content under *C. cajan* at week 12 may be attributed to high P uptake by the woody species. Cajanus like other leguminous plant species has high phosphorus need and this could be responsible for the mining of P under the plants. Moreover the amount of litter fall from the plants during this period was not sufficient to provide enough nutrients to completely offset that taken up by the young vigorous plant. Yemefack et al [14] attributed a reduction in the availability of P in an ageing natural fallow to P absorption by plants and storage in vegetative biomass. The significant improvement in soil nutrients in *C. cajan* plots after 25 months of fallowing may be attributed to biological fixation and the return of nutrients that accumulates in the above-ground biomass of the fallow species to the soil upon clearing and *in situ* decomposition. Abunyewa and Karbo [15] reported a 30.5% increase in soil OC content and 48.5% increase in TN after a 2-year fallow period in *C.cajan* fallow compared with the natural fallow.

CONCLUSION

The potentials of *Cajanus cajan* as an improved fallow species for the amelioration of a degraded tropical Alfisol has been demonstrated by this study. It is very clear however, from the study that a minimum fallow period of two years is needed for the species to make a reasonable positive impact on the soil.

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