EFFECTS OF LEGUMINOUS TREE SPECIES ON SOILS' NUTRIENT STATUS AND HIGH YIELD PERFORMANCE OF *GNETUM AFRICANUM* INTERCROPPED

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Abstract: The study aimed at determining the effect of leguminous tree species on nutrient and yield performance of *Gnetum africanum*. The leguminous tree species intercropped with *Gnetum* were *Leucaena leucocephala* and *Gliricidia sepium*. A land area of 0.081 ha was cleared with machete, demarcated and manually tilled. Three replicated plots were randomly selected for planting *Gnetum* with *Leucaena* (T_1), *Gnetum* intercropped with *Gliricidia* (T_2) and plot planted with only *Gnetum* (T_3) serve as Control. Soil analyses were carried out before and after planting, to ascertain the baseline nutrient statues and treatment effects. The seedling of *Leucaena* already potted, were obtained from Forestry Department Arboretum, University of Uyo, while that of *Gliricidia* was obtained from the State Ministry of Agriculture (AKADEP). The height of *Leucaena* and *Gliricidia* was approximately 30 cm while that of *Gnetum* averaged 20 cm. Pruning leguminous tree species was done three times a year and data on plant height and *Gnetum* number of leaves were obtained at four-month intervals. Data were analyzed using Randomized Complete Block Design (RCBD) and significant means were compared by using Fisher's LSD test**.** The result showed a significant increase in the number of leaves and height of *Gnetum africanum* intercropped with *Leucaena*, followed by *Gnetum* with *Gliricidia*, while the least was obtained from the Control (T_3) ($p \leq 0.05$). The result also revealed that there was a remarkable improvement in the nutrient status of the soil. The saturated exchangeable bases on the absorption site of the soil micelle increased by 20 % in soils receiving. Improvement in soil fertility came as a result of incorporating pruned leguminous tree species especially in the subsurface layers where nodulation had taken place. Therefore, farmers are encouraged to intercrop their arable crops with leguminous tree species for high yield and improvement of soil fertility.

Keywords: *Gnetum*, high yield, improved fertility, leguminous trees, Taungya farming.

Introduction:

Gnetum africanum is one of the most important staple agroforestry vegetables found in the rainforest ecosystem of Nigeria. It belongs to the family: Gnetaceae, order Gnetales (Dutta 1979). *Gnetum africanum* is an African indigenous crop mainly grown for its leaves. *Gnetum* can be classified as a climber because it produces vines which can wind round the stake in a clockwise direction (Etuk et al. 2010a). Gnetum is predominantly grown in the dry season than in rainy season. Locally, it has as many names as there are ethnic groups that consume it. Efik and

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Ibibio call it “Afang” and in Ikom, it is called “Nkani”, while the Igbos call it “Ogazi” or “Okasi” (Ekanem 1998; Etukudo 2003).

Gnetum africanum is a terrestrial flora species which mostly survives in the high forest and in a well conserved ecosystem. It survives well in a very rich soil with plant nutrients especially soils rich in Nitrogen (N), Phosphorus (P) and Potassium (K). It requires a very large quantity of sunlight for photosynthesis (Nwoboshi 2000; Isong et al. 1999). *Gnetum africanum* is a seed bearing forest vegetable (Etukudo 2000). It is more popular and a very important leafy agroforestry vegetable mostly sought after by the inhabitants of the South Eastern zone of Nigeria. It is an all-season agroforestry vegetable which is consumed in the area (Etuk et al. 2010a). *Gnetum* holds an important place in the diet of many people in the zone and the high nutritional value of its leaves is a significant source of protein, 30 % amino acids (Udah and Echebiri 1997; Eyo et al. 1983). The high performance of this valuable forest vegetable can be achieved if grown/intercropped with some selected leguminous tree species capable of fixing nitrogen and other vital nutrients in the soil (Etuk et al. 2010b).

Taunya system is a system whereby agricultural and forestry crops can be raised in combination with forest trees able to fix nitrogen and other nutrients in the soil in the same piece of land in alleys (Handayanto et al. 1994). Alley cropping or alley farming is essentially an agroforestry system in which food crops, such as *Gnetum africanum*, are grown in alleys formed by the hedgerows of fast growing leguminous tree species or shrubs such as *Leucaena leucocephala*, *Gliricidia sepium*, *Anthonotha macrophylla*, *Longocarpus griffonianus* etc. (King and Eka 1995).

Hedgerows are trimmed during the planting period and kept pruned to prevent shading and reduce competition among crops. *Leucaena leucocephala* and *Gliricidia sepium* have been known to be intercropped with both agronomic and forest crops in alleys because of their effective supply of free nitrogen in the soil. This enhances the nitrogen fixing bacteria such as *Clostridium* and *Asotobacta* which taps free N from the atmosphere and stores it in the root nodules of leguminous tree species (Giller and Wilson 1991). When they die, the nitrogen is released into the soil for plant growth (Etuk, et al. 2010b). This process and its benefits are accomplished through the symbiotic association between the nitrogen fixing bacteria and the leguminous tree species in alleys, intercropped in hedgerows with agronomic crops which are obtained through leaf pruning, stems and roots. (Etukudo 2000).

During the fallow period, the hedges are allowed to grow freely, and are handled to provide staking materials, firewood, and forage, thereby enabling integration of crops, livestock and wood production in perpetuity. Therefore, for the growth performance of *Gnetum africanum* and other crops to be enhanced, it is important to intercrop them with some fast grown species of leguminous tree species which can enrich the soil with required plant nutrients through their pruning and nodulation process.

Materials and methods:

Experimental Site

This research was carried out near the Department of Forestry Arboretum in University of Uyo, Annex Campus, Uyo, Akwa Ibom State. It lies between latitude 4^{o} 52' and 5^{o} 3' N and longitude 7^{o} 51' and 8^{o} 20' E in Nigeria, (Eko et al. 2014). As with every Nigerian coastal area, the state experiences two main seasons, the wet season and the dry one. The wet or rainy season lasts for nine months, from April through October; the dry season spans from November until March. The annual rainfall ranges from 2000-3000 mm. The mean annual temperature of the state varies between 26 °C and 28 °C, featuring a high relative humidity ranging from 75-95 % with

the highest and lowest values in July and January respectively (Eko et al. 2014).

Despite the seasonal variations, by the nature and location of the area along the coast which exposes it to hot maritime air mass, rainfall is expected every month of the year.

Methods of Data Collection

Land Preparation: The land was cleared manually using machete, the debris was packed out making the land available for pegging and planting. Manual tillage and stumping were done using spade and the land was mulched immediately after tillage. The land was divided into three randomly selected plots each being planted with *Gnetum* and *Leucaena* (T_1), *Gnetum* with *Gliricidia* (T_2) and *Gnetum* with neither *Leucaena* nor *Gliricidia* (T_3) (Control).

Soil sampling and analyses

Soil sampling and analyses were conducted before and after planting to ascertain the improvement in soil nutrient status by the leguminous tree species. Soil samples were collected at two depths of a 15- centimeter interval (0-15 and 15-30 cm) in diagonal grid per plot using soil auger. The samples were air dried and put through a 2 mm mesh sieve for physico-chemical analyses using standard methods (Agbede 2009).

Sources of planting material and agronomic practices

The total area of land under cultivation was 0.081 ha. The planting distance for *Leucaena* and *Gliricidia* was 1 x 1 m^2, while that of *Gnetum* was planted at 0.25 x 0.25 m around the leguminous tree species. The population density of *Gnetum africanum* was 40,000 stands ha^{-1}. The seedlings of *Leucaena* were obtained from the forest arboretum of the Department of Forestry and Wildlife, University of Uyo, whereas those of *Gliricidia* were obtained from the State Ministry of Agriculture (AKADEP). As at the time of transplanting, the plants' height of *Leucaena* and *Gliricidia* averaged 30 cm, while that of *Gnetum* was 20 cm obtained from the wild.

The transplanting of *Leucaena*, *Gliricidia* and *Gnetum* was performed in March, therefore the regular supply of water was imminent until the plants were fully established in the field. Weeding was routinely done every two weeks, whilst pruning, three times per year. Data were collected at four-month intervals after planting (MAP) up to thirty six (36) months.

Data Analysis

Data on plant heights and number of leaves for *Gnetum* collected from each plot were subjected to analysis of variance (ANOVA) in the Randomized Complete Block layout (RCBD). Fisher's least significant difference (LSD) was employ separate significant means at $p \leq 0.05$ level of significance.

Results and discussion:

General performance of *Gnetum africanum* intercropped with leguminous tree species

General performance of *Gnetum africanum* intercropped with leguminous tree species and control during the experimentation (Tab. 1) shows that the number of leaves of *Gnetum africanum* cropped with *Leucaena* and *Gliricidia* consistently and significantly yielded the control. The highest leaf number was obtained from the span between the 32nd and 36th month after planting, on plots with *Leucaena* x *Gnetum* (T_1); the leaf number averaged 40.15, followed by T_2, the plots with *Gliricidia* x *Gnetum* (38.0). The lowest leaf number was obtained from plot T_3 with *Gnetum* only (Control) (30.05).

The leguminous tree species significantly affected the height (cm) of *Gnetum africanum* (Tab. 2). There was a progressive increase in the height of *Gnetum* intercropped with leguminous trees. *Gnetum* intercropped with *Leucaena* showed the

highest performance in height, followed by its intercropping with *Gliricidia*, while the least was obtained from the Control. T_1 yielded 80 cm, which was significantly different from the 61.02 cm obtained from T_2. T_3 yielded 32.46 cm exhibiting 146 % and 87 % height reduction in response to *Leucaena* and *Gliricidia*, respectively.

Table no. 1 Effect of leguminous tree species on the number of leaves of *Gnetum africanum*.

MAP	Treatments		
	T1	T2	T3
4	11.00	12.00	10.00
8	14.00	15.00	13.00
12	19.00	15.00	14.00
16	21.00	18.00	16.00
20	23.00	22.00	19.00
24	26.00	29.00	21.00
28	32.00	32.00	26.00
32	40.00	38.00	29.00
36	43.00	38.00	32.00
Treatments total	229.00	219.00	180.00
Mean	25.44	24.33	20.00
Least significant difference (0.05)	2.18		

Note: MAP - months after planting; T1 - *Leucaena* x *Gnetum*; T2 - *Gliricidia* x *Gnetum*; T3 - *Gnetum* only (control).

The results further revealed that, there was a progressive increase in the number of leaves and height of *Gnetum africanum*. At the initial stage up to the 20th month after planting, there was no notable increase in the number of leaves, but the height of *Gnetum* significantly increased from the 12th month after planting with plots receiving treatments of both *Leucaena* and *Gliricidia*, intercropped with *Gnetum*.

Although, the highest number of leaves was obtained from *Gnetum* with *Leucaena* (T_1). At the earlier stage of growth, *Leucaena* and *Gliricidia* were at par in fixing N to the soil, but after 12 months of planting, the fixation potential of *Leucaena* outweighed *Gliricidia*. This indicated on the significant foliage yield and height of *Gnetum* intercropped with *Leucaena* in the 16th month after planting (MAP) and above. This also showed that the production capacity in terms of foliage yield and heights were low in the control plots. This was owing to the fact that there was no leguminous tree species intercropped to rejuvenate the loss nutrients, thereby improving the fertility of the soil. This explained the high foliage yield and height obtained from plots containing *Gnetum* x *Leucaena* and *Gnetum* x *Gliricidia*.

Table no. 2 Effect of leguminous tree species on the heights (cm) of *Gnetum africanum*.

MAP	Treatments		
	T1	T2	T3
4	26.33	20.67	15.67
8	35.00	32.00	16.94
12	50.67	42.17	18.17
16	65.270	52.120	27.250
20	80.10	71.21	31.63
24	97.20	84.20	39.47
28	110.00	99.00	45.00
32	125.00	104.00	48.10
36	131.00	115.00	50.940
Treatments total	720.57	549.16	292.17
Mean	80.00	61.02	32.46
Least significant difference (0.05)	15.06		

Note: MAP - months after planting; T1 - *Leucaena* x *Gnetum*; T2 - *Gliricidia* x *Gnetum*; T3 - *Gnetum* only (control).

Changes in soil properties as affected by incorporation of prunes from leguminous tree species

Changes in soil characteristics after incorporating pruned materials from *Leucaena* and *Gliricidia* in the soil as shown in Table 3 revealed the following: there was no alteration in the textural characteristics of the soil in both depths examined. This report is in agreement with the report of Edem and Udoinyang (2012), that soil management technique cannot easily alter the textural characteristic of the soil. The pH of the surface soil increased by 12 % due to

incorporated pruning of *Leucaena,* which showed a slight enhancement over the 4.1 unit on the acid soils. Soil organic matter increased respectively by 43.6 and 3 % on the surface soil with incorporation of *Leucaena* and *Gliricidia* and in the subsurface soils, a 51 and 31 % increase was respectively observed. Significant changes in the soil nutrients: Ca, Mg, P and total N were noticed mostly on the surface layer where *Leucaena* was applied, increased by 33, 4, 11 and 60 %, respectively. Leafy legume incorporation improved the nutrient cations without depleting the exchangeable acidity. Exchangeable acidity (EA) saturation fostered the surface layer by 10, and 6 %, and in the subsurface it increased by 12 and 0.7 % for *Leucaena* and *Gliricidia* respectively.

Table no. 3 Soil analysis before application of (treatments) prunes from leguminous tree species.

Soil parameters	Units	Surface soil			Subsurface soil		
		Control	*Leucaena*	*Gliricidia*	Control	*Leucaena*	*Gliricidia*
Sand	%	86.40	88.80	88.40	89.40	79.80	84.40
Silt	%	5.40	4.20	5.20	4.40	6.20	5.20
Clay	%	8.20	7.00	6.40	6.20	84.40	10.40
pH		4.10	4.60	4.10	4.10	4.20	4.10
Organic matter	%	2.20	3.16	2.89	1.98	2.99	2.61
Total N	%	0.05	0.08	0.06	0.04	0.07	0.06
Available P	mg kg^{-1}	89.66	99.99	96.66	88.66	99.66	93.99
Ca	cmol kg^{-1}	2.10	2.80	2.10	2.14	2.90	2.10
Mg	cmol kg^{-1}	1.00	1.40	0.90	0.80	1.20	0.90
Na	cmol kg^{-1}	0.06	0.08	0.06	0.05	0.09	0.07
K	cmol kg^{-1}	0.07	0.10	0.09	0.07	0.11	0.08
EA	cmol kg^{-1}	2.80	3.10	2.99	2.84	3.20	2.86
ECEC	cmol kg^{-1}	6.03	7.48	6.14	5.90	7.50	6.01
BS	%	53.56	58.56	51.30	51.86	57.33	52.41

Note: EA - exchangeable acidity; ECEC - effective cation exchange capacity; BS - base saturation.

Conclusions:

The intercropping of leguminous tree species of *Leucaena leucocephala, Gliricidia sepium* and other species of legumes play a fundamental role in the enrichment and improvement of soil nutrient elements. The practice of leguminous trees intercropped with *Gnetum* plant on acid sand showed significant changes in plant height and number of leaves yield. Low yield of *Gnetum*'s leaves and plant height in the control plots signified that the nodulation process between the roots of leguminous tree species and the soil which enhanced the activities of nitrogen fixing bacteria in the treated soil lacked. Hence, the soil nutrients such as N, P, K and Mg were not enriched. Changes on soil properties resulted in the improvement of soil fertility by fresh leafy pruning of *Leucaena* and *Gliricidia* species. Application of pruning of leguminous tree was not sufficient to correct soil acidity during the experimentation. Therefore long term application of pruning leguminous trees intercropped with *Gnetum* and any other plants is necessary as a measure to cope with the soil acidity effect on arable crops that prevails on the coastal plain sand of the study site. To this end, this will engender food security and fight against hunger and poverty in our society. It will also help to reduce the rate at which chemical fertilizers are applied to the farm which in the extreme, may cause serious environmental hazards especially during this era of climate change.

Rezumat:

EFECTELE CULTIVĂRII SPECIILOR DE LEGUMINOASE LEMNOASE ASUPRA NIVELULUI NUTRIENȚILOR DIN SOL ȘI A RANDAMENTULUI ÎNALT LA *GNETUM AFRICANUM* ÎN CULTURILE MIXTE

Studiul are în vedere determinarea efectului speciilor de leguminoase lemnoase asupra nutrienților și a randamentului la *Gnetum africanum*. Speciile de leguminoase lemnoase în culturi mixte cu *Gnetum* au fost *Leucaena leucocephala* și *Gliricidia sepium*. O arie de pământ de 0,081ha a fost curățată cu maceta, marcată și arată manual. Trei loturi identice au fost selectate aleator pentru a fi plantate cu *Gnetum* și *Leucaena* (T_1), *Gnetum* și *Gliricidia* (T_2) și un lot a fost cultivat doar cu *Gnetum* (T_3) pentru Control. Analizele de sol au fost realizate înainte și după plantare, pentru a se stabili nivelul de bază al nutrienților și efectele apărute în urma tratamentelor. Răsadurile de *Leucaena* inițial păstrate în ghivece, au fost obținute de la Departamentul Silvic Arboretum, Universitatea Uyo, în timp ce răsadurile de *Gliricidia* au fost obținute de la Ministerul de Stat al Agriculturii (AKADEP). Înălțimea tulpinii la *Leucaena* și *Gliricidia* a fost de aproximativ 30 cm, în timp ce la *Gnetum* a fost în medie de 20 cm. Toaletarea speciilor de leguminoase lemnoase s-a realizat de trei ori pe an, iar datele despre înălțimea tulpinii și numărul frunzelor la *Gnetum* au fost obținute la intervale de patru luni. Informațiile au fost analizate folosind Randomized Complete Block Design (RCBD), iar datele semnificative au fost comparate prin utilizarea testului Fischer LSD. Rezultatul a demonstrat o creștere semnificativă a numărului de frunze și a înălțimii tulpinii la *Gnetum africanum* din cultura mixtă cu *Leucaena*, urmată de *Gnetum* cu *Gliricidia*, în timp ce cele mai mici valori au fost obținute pe lotul de Control (T_3) ($p \leq 0.05$). Rezultatul a arătat, de asemenea, că există o remarcabilă îmbunătățire a nivelului nutrienților din sol. Bazele de schimb saturate din zona de absorbție a solului au crescut cu 20 % în culturile mixte. Îmbunătățirea fertilității solului a apărut datorită încorporării tăierilor de la speciile de leguminoase lemnoase cu precădere în straturile de suprafață, unde au apărut nodozitățile. În consecință, fermierii sunt încurajați să practice culturile mixte cu speciile de leguminoase lemnoase pe terenurile lor, pentru un randament mare și îmbunătățirea feritilității solului.

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