GROWTH OF *GLIRICIDIA AND LEUCAENA* AS AFFECTED BY RHIZOBIUM INOCULATION AND N AND P FERTILIZER APPLICATION IN NIGERIA

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Abstract: *Six field trials to determine the effects of rhizobium inoculation, and N and P fertilizer applications on the early growth of Gliricidia sepium and Leucaena leucocephala were conducted in farmers' fields at three sites: Alabata and Ajaawa located in the derived savanna of southwestern Nigeria and Zakibiam located in the southern Guinea zone of east central Nigeria. At Alabata and Ajaawa the soils are Entisols and mean annual rainfall was 1300 mm; at Zakibiam, the soils belonged to the Alfisol group with a mean annual rainfall of 1070 mm. By 15 MAP Gliricidia responded significantly to inoculation in four fields and to fertilization in two fields. Leucaena responded significantly to inoculation in three fields and to fertilizer application in one field. The performance of the two species was better at Alabata and Ajaawa than at Zakibiam. The better performance may be related to soil fertility and rainfall. Gliricidia showed better early growth than Leucaena. The faster growing Gliricidia responded better to inoculation and fertilization. The mean response to rhizobium inoculation was higher in the control than in plots fertilized with N. The N response was more pronounced than P response in spite of the low available P level of the fields. Inoculation, and N and P fertilization increased the N and P uptake of the two species. To ensure the early establishment of both species, inoculation with rhizobium and starter applications of N and P fertilizers is highly recommended.*

1. Introduction

Alley cropping is an agroforestry system in which food crops are grown between hedgerows of woody shrubs and trees [Kang et al. 1984]. The use of N_2 fixing leguminous hedgerow species can contribute nitrogen to the system. Periodic pruning to minimize shading by the hedgerows on the companion crop can provide mulch and green manure.

The success of the alley cropping system greatly depends on rapid and efficient establishment of the hedgerows. For the less acid soils, *Leucaena* [*Leucaena leucocephala* (Lam.) de Wit] and *Gliricidia* [*Gliricidia sepium* (Jacq.) Stud] have been found suitable for alley cropping. Although *Leucaena* and *Gliricidia* can be established by direct seeding at the time of planting food crops [Kang et al. 1984], information, however, is needed on the fertilizer and rhizobium inoculation requirements for consistent and rapid establishment for the various agroecological zones. It was found that the early growth of *Leucaena* and *Gliricidia* in farmers' fields in southwestern Nigeria is better in fields where the soil nitrogen is higher [Cobbina et al. 1989, Onafeko 1992]. The beneficial effects of N fertilizer on the growth of *Leucaena* has also been reported [Roshoki et al. 1982, Sanginga et al. 1988a and 1988b]. It was also found that starter N satisfies the demand of the plants during the initial N hunger period, although nodulation was inhibited with high use of N. *Gliricidia* is reported to have a lower N-fixing potential [Roskoki et al. 1982] than *Leucaena* [Cobbina et al. 1989, Mulongoy and van der Meersch 1988, Sanginga et al. 1989]. The optimum N fertilization level for the growth of *Leucaena* in Nigeria [Sanginga et al. 1988a] and the critical N fertilization levels for the early growth of *Leucaena* and *Gliricidia* [Onafeko 1992] have been measured. Phosphorus is considered to be necessary for the successful establishment of forage legumes in sub-Saharan Africa [Haque and Jutzi 1984]. *Leucaena* needs adequate P for vigorous growth and N fixation [NAS 1984]. Phosphorus deficiency affects N fixation and plant growth. As soils in the tropics are usually deficient in P, crops usually respond to moderate amounts of P application [Le Mare 1984]. Although some workers [Onafeko 1992, Sanginga et al. 1988a] have reported that P fertilizer is required for the good growth of *Leucaena* and *Gliricidia*, information on P requirements of both species under farmers' field conditions is still lacking.

This study was conducted (i) to determine the effects of N and P applications and rhizobium inoculation on the growth of *Leucaena* and *Gliricidia*, and (ii) to compare the relative effects on both species.

2. Materials and Methods

The experiments were conducted on farmers fields' at the following three sites in Nigeria; Alabata (7°35'N, 3°54'E), Ajaawa (7°57'N and 4°9'E) and Zakibiam (7°1'N and 7°3'E). At each site, two trials were established. Mean annual rainfall is about 1300 mm for Alabata and Ajaawa sites, and 1070 mm for Zakibiam site, with bimodal distribution pattern at all three location. The mean daily temperature is about 25°C at all sites.

The soils at all three locations have a sandy loam texture at the surface soil and are classified as Entisol (Psammentic usthortent) for Alabata and Ajaawa sites and as Alfisol (Plinthic paleustalf) for Zakibiam. Composite soil samples were collected from each site and air-dried, sieved (2mm) and analysed for chemical properties according to procedures described by Juo [1979].

The experimental design used for the field trial was a split-plot with three replications for each of the species. The sub-plot treatments were N, P, NP and no fertilizer control (0). Nitrogen was applied at the rate of 60 kgN/ha as calcium ammonium nitrate and P at the rate of 20 kgP/ha as a single superphosphate. The observation sub-plot size was 2 x 2 m^2. The main plot treatments were; no inoculation (I_o) and inoculation (I_1). *Leucaena* inoculant LX 382 from Nitragin company USA, and *Gliricidia* peat-based rhizobium inoculum from the University of Hawaii, Honolulu, Hawaii were used for seed treatments. Scarified *Leucaena* var.

K-28 and local *Gliricidia* seeds were used in the trials. Seeds were sown at intrarow spacing of 5 cm with interrow spacing of 50 cm.

Plant height, leaf area, leaf, stem, and root dry weight were determined at 12 months after planting (MAP). Dry weight was measured, after the planted materials were oven-dried at 65°C. Plant samples were analysed for N and P content by procedures described by Juo [1979]. Above ground biomass was also determined at 15 MAP. Data were statistically analyzed using Genstat, and compared at P.05 level for differences.

3. Experimental Results

3.1 Soil properties

Chemical characteristics of the surface soils from the three sites are shown in table 1. At the three sites, soil pH was adequate for optimum growth of both species. Except for Ajaawa site I, the soil organic carbon level was generally low on all the plots. The Ajaawa site had the highest Org. C level followed by the Alabata and Zakibiam sites. Phosphorus levels were also low for all the sites except for the Ajaawa II plots. Exchangeable cations at all the sites were more than adequate for the healthy growth of both species.

Table 1. Some chemical properties of surface soils from the six fields

Fields	pH-H_2O	Org.C (%)	Avail. P (ug\g)	..... Exchangeable .... Ca	Mg	K	ECEC
				...... (me/100g)			
Alabata I	6.2	0.76	6.7	1.56	0.33	0.31	2.20
Alabata II	6.0	0.69	3.8	1.42	0.36	0.41	2.19
Ajaawa I	6.0	1.21	6.5	0.87	0.40	0.54	1.81
Ajaawa	6.5	0.90	11.9	1.27	0.47	0.28	2.02
Zakibiam	6.0	0.42	2.7	1.15	0.16	0.18	1.49
Zakibiam	6.1	0.48	6.3	1.45	0.22	0.26	1.93

4. Plant Growth and Biomass Yield

Comparison on the mean effects of fertilizer application and inoculation on some plant growth parameters are shown in table 2. The height of both species was improved by N and P fertilization. The response to nitrogen was higher than that to P. Combined NP applications resulted in taller plants. Fertilizer application increased the plant leaf area of *Gliricidia*, but not of *Leucaena*. Only *Leucaena* showed a significant response in plant height with inoculation. Inoculation had a significant effect on the leaf area of *Leucaena* but not on that of *Gliricidia*.

Fertilizer significantly increased leaf, stem and root dry weight of *Gliricidia* and *Leucaena*. With *Gliricidia*, the stem dry weight responded more to N than P. Leaf and root dry weight of *Gliricidia* was more effected by P application. On *Leucaena*, the effect of P application on leaf, stem and root dry weight was less than that of N application (table 2). Although inoculation increased all growth parameters, its effects were significant only on the root dry weight of *Gliricidia* and on plant height, leaf dry weight and leaf area of *Leucaena*

The effect of fertilizer and inoculation on plant biomass yield at 15 MAP are shown in tables 3 and 4. Highest plant biomass yield was observed at Alabata followed by Ajaawa and Zakibiam with the least. *Gliricidia* showed a significant response to inoculation at Alabata II, Ajaawa I and Ajaawa II, and Zakibiam I (table 3). There were similar responses to inoculation on *Leucaena* at Alabata II, Ajaawa II and Zakibiam I (table 4). Without inoculation there were significant differences in biomass yield between fertilized and unfertilized *Gliricidia* at Alabata and Ajawaa II, and for *Leucaena* only at Ajaawa II.

Table 2. Mean (across sites) values of growth parameters measured at 12 MAP for *G. sepium* and *L. Leucocephala* as affected by inoculation, N, and P fertilizer applications.

Fertilizer treatments/ inoculation	Plant height (m)	Leaf area (m^2/plant)	.... Dry matter yield (g/tree) .... Leaf	Stem	Root
		Gliricidia sepium			
O (Control)	1.20	0.95	42	64	92
N	2.47	1.10	70	120	168
P	1.60	1.30	77	96	176
NP	2.62	1.34	70	151	158
LSD. 05	0.28	0.36	27	50	55
I_0	1.82	1.04	55	90	94
I_1	2.12	1.31	74	126	202
LSD .05	NS	NS	NS	NS	102
		Leucaena Leucocephala			
O (Control)	1.23	0.77	29	46	36
N	2.12	0.63	35	66	74
P	1.53	0.64	39	61	62
NP	2.18	0.75	46	91	137
LSD. 05	0.16	NS	11	20	70
I_0	1.65	0.56	32	56	57
I_1	1.88	0.83	42	76	97
LSD .05	0.17	0.18	9	NS	NS

Notes: NS = Not significantly different (P.05)

I_0 = Uninoculated; I_1 Inoculated

Table 3. Above ground dry biomass yield of *Gliricidia* (kg tree^{-1}) at 15 MAP as affected by fertilizers application and rhizobium inoculation

	.... Fertilizer treatment				
Site/Inoculation	O	N	P	NP	LSD. 05
Alabata I					
Uninoculated	1.49	2.12	1.94	1.79	0.34
Inoculated	1.76	2.16	2.10	1.97	
Alabata II					
Uninoculated	0.12	0.54	0.27	0.66	0.44
Inoculated	1.12	1.09	1.28	1.27	
Site mean	1.12	1.48	1.40	1.42	
Ajaawa I					
Uninoculated	0.88	0.90	0.93	0.95	0.17
Inoculated	1.26	1.38	1.30	1.47	
Ajaawa II					
Uninoculated	0.62	2.26	1.12	0.97	0.24
Inoculated	1.78	1.99	1.81	1.94	
Site mean	1.14	1.63	1.29	1.33	
Zakibiam I					
Uninoculated	0.14	0.37	0.23	0.29	0.21
Inoculated	0.44	0.44	0.42	0.46	
Zakibiam II					
Uninoculated	0.54	0.64	0.54	0.77	0.16
Inoculated	0.55	0.68	0.56	0.58	
Site mean	0.42	0.53	0.44	0.53	

Comparing the mean treatment effect of the three sites for both species (table 5), the highest response was observed at the Alabata and Ajaawa sites. There was a small but insignificant effect of inoculation at the Zakibiam site.

The mean effects of inoculation and fertilizer at the three sites are shown in table 6. *Gliricidia* grew better than *Leucaena*. The effects of inoculation and fertilizer were more pronounced on the faster growing *Gliricidia* than on *Leucaena*. There was a higher response to inoculation in both species when there was no N fertilizer. Both species responded more to N than to P.

Table 4. Above ground dry biomass yield of *Leucaena* (kg tree^{-1}) at 15 MAP as affected by fertilizers application and rhizobium inoculation

	.... Fertilizer treatment				
Site/Inoculation	O	N	P	NP	LSD. 05
Alabata I					
Uninoculated	1.03	1.32	1.36	1.29	0.38
Inoculated	1.19	1.46	1.43	1.41	
Alabata II					
Uninoculated	0.75	0.78	0.75	0.75	0.30
Inoculated	1.15	1.32	0.93	0.93	
Site mean	1.12	1.22	1.12	1.12	
Ajaawa I					
Uninoculated	0.40	0.59	0.42	0.67	0.24
Inoculated	1.41	1.62	1.54	0.93	
Ajaawa II					
Uninoculated	0.81	1.87	0.84	0.97	0.24
Inoculated	1.21	1.70	0.90	1.94	
Site mean	0.71	1.20	0.68	1.27	
Zakibiam I					
Uninoculated	0.15	0.26	0.17	0.23	0.08
Inoculated	0.20	0.24	0.27	0.28	
Zakibiam II					
Uninoculated	0.36	0.45	0.40	0.47	0.02
Inoculated	0.59	0.50	0.45	0.45	
Site mean	0.28	0.36	0.32	0.36	

5. Nutrient Uptake

The effects of fertilizer application and inoculation on nutrient content in both species is shown in table 7. The nutrient content of *Gliricidia* was higher than that of *Leucaena*. In both species, inoculation increased N and P uptake but the differences were not significant (table 7). Nitrogen and P fertilization also increased N and P assimilation in both species. However, the increase in N assimilation with N fertilization was only significant in *Gliricidia*. Fertilization with P significantly increased the assimilation of N in both species.

6. Discussion

There were significant differences in the performance of both species at the three test sites. *Gliricidia* and *Leucaena* yielded more biomass and showed better growth at Alabata and Ajaawa than at Zakibiam (tables 3 and 4). This may reflect the more fertile soils and higher rainfall there (table 1). No distinct relationship was observed between the soil organic matter and available P status with the response to N and P in this study.

Table 5. Above ground dry biomass (g/plant) of *G. sepium* and *L. leucocephala* at 15 MAP as affected by rhizobium inoculation at the three sites

Sites	Uninoculated	Inoculated	Mean
	Gliricidia sepium		
Alabata	1117	1595	1356
Ajaawa	1077	1614	1346
Zakibiam	439	516	478
Mean	878	1242	
LSD.05			
Between site means, 518			
Between inoculation means, 145			
Between inoculation means for same site, 252			
Between inoculation means for different sites, 547			
	Leucaena leucocephala		
Alabata	1043	1304	1174
Ajaawa	901	1021	961
Zakibiam	312	347	330
Mean	752	890	
LSD.05			
Between site means, 351			
Between inoculation means, 62			
Between inoculation means for same site, 108			
Between inoculation means for different sites, 359			

Table 6. Mean plant dry biomass yield (g/plant) of *G. sepium* and *L. leucocephala* at 15 MAP as affected by rhizobium inoculation and fertilizer application

Inoculation	O	N	P	NP	Mean
		Gliricidia sepium			
I_0	631	1138	838	904	878
I_1	1149	1291	1247	1281	1242
Mean	890	1215	1043	1093	
LSD.05					

Between inoculation means, NS
Between fertilizer means, 159
Between fertilizer for same inoculation treatment, 225
Between fertilizer for different inoculation treatments, 631

Inoculation	O	N	P	NP	Mean
		Leucaena leucocephala			
I_0	584	877	657	890	752
I_1	759	972	755	1078	891
Mean	672	925	706	984	
LSD .05					

Between inoculation means, NS
Between fertilizer means, 197
Between fertilizer for same inoculation treatment, 278
Between fertilizer for different inoculation treatments, 352

Note: *I_0 = Uninoculated; I_1 = Inoculated

Table 7. Mean effects of rhizobium inoculation and fertilizer application on N and P uptakes by *G. sepium* and *L. leucocephala* at 12 MAP

Species	Fertilizer treatment				LSD 0.05	Inoculation*		LSD 0.05
	O	N	P	NP		I_0	I_1	
				(kg N/ha)				
G. Sepium	36	81	83	83	37	64	77	NS
L. leucocephala	23	36	39	52	16	32	42	NS
				(kg P/ha)				
G. Sepium	2.0	4.4	4.9	5.5	2.6	3.7	4.6	NS
L. leucocephala	1.3	1.9	2.8	3.6	1.7	1.8	2.9	NS

Note: *I_0 = Uninoculated; I_1 = Inoculated

Comparing the effects of the treatments on the two species, the faster growing *Gliricidia* benefited more from inoculation and fertilizer application (table 5). rhizobium inoculation increased biomass yield without N application in both species as earlier reported by Sanginga et al.[1988b]. For both species N improved growth more than P despite the low P status of the soils used (table 1). The low response to P may result from a high level of VA mycorrhizal infection in these soils [Ayanaba and Sanders 1981]. The latter can aid in P uptake.

It was recommended that for rapid early establishment of both species, inoculation with rhizobium and the application of small amounts of starter N and P should be administered in the humid/subhumid tropical zones.

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