Economic and On-Farm Evaluation of Alley Cropping with *Leucaena* Leucocephala

1980 - 1983 Activity Consolidated Report

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I. INTRODUCTION

Frequent and extensive forest clearing for wood, cultivation, grazing and other human activities in the humid tropics, has led to progressively shorter traditional fallow periods, thus making their primary function of soil fertility restoration less effective (Okigbo,1974, 1982). In these regions, the R*-value of rotational systems, which is a measure of land use intensity (Ruthenberg, 1976), is also becoming progressively smaller. The result being soil nutrient depletion poor crop yields and shortage of food and firewood. For many of the countries in the tropics that lack the necessary foreign exchange to import sufficient inorganic fertilizers and fossil-fuel energy to increase agricultural productivity. In this case, developing efficient low-input technologies based on biological recycling nutrients and energy and on principles of the existing 'bush fallow' systems is of great interest (Benneh, 1972).

Some farmers in the tropics have recognized the need of using certain plant species for regeneration and maintenance of soil fertility of their land. For instance, in parts of eastern Nigeria, farmers retain woody species such as _Acioa baterii_ and _Anthonata macrophylla_ after land

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* $R = \frac{C}{C+F} \times 100$, where C = duration of cropping and F = duration of fallow period.

clearing and encourage them in the bush fallow (Benneh, 1972, Okigbo, 1976). In parts of Western Nigeria, Glyricidia sepium established from stakes used for yam support has become the recognized fallow species (Wilson and Kang, 1981). The Chinese use leguminous crops such as Sesbania cannabina, Astragalus sinicus, Vicia faba etc... for their green manuring national programme which increased from 1.3 million hectares in 1960 to 6.6 million hectares in 1975 (FAO soils Bulletin, 1977). Under this programme, green manure crops are either sown and ploughed under the same field; or harvested and incorporated in other fields, or cut, mixed with grasses and mud and put in pits in corners of fields for compost making or interplanted with summer rice crops. In some other parts of Asia, Leucaena leucocephala and Sesbania granliflora are among the legumes recognized as efficient soil restorers (Guevarra, 1976, NAS, 1979). Some researchers in the tropics, are therefore investigating alternative systems such as alley cropping, planted fallow and agroforestry; that are biologically stable, soil conserving and productive (Wilson and Kang, 1981, Kang et al 1981, Vergara 1982).

Alley Cropping

Alley cropping is an alternative land use system in which arable crops are grown in the spaces between rows of established leguminous shrubs or tree species whose tops or branches are periodically pruned during the cropping season to prevent shading as well as to minimize tree-crop competition for moisture and nutrients (Kang et al, 1981). The prunings are left on the soil surface as mulch or incorporated in the soil as green manure for the companion crops. The alley cropping concept is an adaptation and a refinement of the bush fallow system commonly practised by small farmers in Africa (Wilson and Kang, 1981).

Promising alley cropping leguminous or tree species being evaluated by IITA are: Leucaena leucocephala, Gliricidia sepium, Acioa barteri, Anthonatha macrophylla, Alchornea cordifolia, Cassia siamea, Sesbenia grandiflora and Flemingia congesta (IITA Anual Report 1980). Species selected for alley cropping must be easy to establish, fast growing, deep rooted, coppicious, have the ability to withstand frequent prunings and be able to produce heavy foliage (Wilson and Kang, 1981).

Purpose

The "Alley Cropping" concept emerged from IITA's work in early 1970s on legumes, including woody perennials such as Cajanus cajan and Leucaena leucocephala, as soil conserving and/or improvement crops (IITA Annual reports 1974, 1980, 1981, (Wilson and Kang 1981). Since then, a number of agronomic and soil fertility studies on alley cropping leucaena with maize have been carried out mainly at IITA, Ikenne and Onne sites (IITA reports 1980, 1981). This work has shown that leucaena can contribute nitrogen of over 200kg/ha/year and increase significantly the yields of the associated maize crop (Kang et al 1981). With this system, maximum yields of maize were obtained when the leucaena tops were incorporated and/or supplemented with nitrogeneous fertilizers at planting. The system was designed with an alley width of 2m for hand tools and 4m for tractor oriented maize production (Wilson and Kang 1981). Also using leucaena to support yam vines gave 12 to 15t/ha of yams and planting leucaena with spacing of 150cm by 50cm produced about 13,000 plants/ha in the first year and 13,330 stems/ha in the second year which could be used as stakes or other purposes (Wilson, 1980, Wilson and Kang 1981).

The Leucaena leucocephala is a fast growing tree species and has a range of varieties that are either tall and slender (20m) or are bushy (5m) with deep roots of 2 to 5m (Dijkman, 1950). Leucaena can fit a wide range of environments ranging from semi-arid with low rainfall to forest with high rainfall, heavy clay and alkaline soils. It has the ability to restore woody bushes in derived grasslands (NAS 1980). Once the leucaena is established in hedgerows, it has several advantages such as: (a) the leucaena hedgerows can help to maintain soil fertility which will allow continuous cultivation as they fix atmospheric nitrogen, (b) recycle leached nutrients from the subsoils, (c) protect against soil erosion (d) provide an inexpensive source of stakes to support yam vines, provide fuel, wood, fodder and its seeds are sometimes used for human food.

Alley cropping leucaena with maize and or yams is of great interest in the predominant yam producing areas of the mid-belt (Guinea savannah) of Nigeria where almost all trees and shrubs are fast disappearing. The predominantly grown white yams require staking to prevent leaf diseases and for good yields, but due to large area under yam cultivation and the scarcity of staking materials, many farmers in Guinea savannah of Benue state choose not to stake yams. In the neighbouring Kwara state, some farmers make trellises (of 0.5m to 1m) woven from sorghum stalks to support yam vines; while others use one stake to support five to nine yam vines which climb on strings running from the surrounding yam heaps to top of the stake (tent staking). One question that arises therefore is:

How attractive is alley cropping leucaena with maize and/or yams to small scale farmers under such or similar conditions? This report presents an economic and on-farm evaluation from agro-economic experiments at IITA site and on-farm trials of alley cropping with leucaena in Western and mid-belt of Nigeria.

II OBJECTIVES

As a new technology alley cropping must be technically and economically feasible and superior to some existing technology it is designed to replace. The overall objective of this study was therefore to ascertain the economic feasibility of alley cropping within the context of small scale farmers. The specific objectives of both station-based and on-farm tests were:

(a) to monitor labour inputs and assess the economic benefits from leucaena alley cropping with maize, yams or cowpeas;

(b) to check the applicability of leucaena in different ecological zones and observe the problems that farmers have with the establishment, growth and management of leucaena alley cropping system under farm conditions, and

(c) to obtain farmers' assessment and any other feedback for further improvement and adaptation of the alley cropping system.

It is important to examine the economic implications regarding the amount of land occupied by leucaena rows the extra demand for labour needed for cutting and pruning leucaena during the cropping season, vis-a-vis the question of profitability and the farmers' reactions to leucaena alley cropping system.

III ECONOMIC EVALUATION

Methods

The agro-economic experiments carried out at IITA, were on alley cropping leucaena with maize followed by maize in 1981 and with maize followed by cowpeas in 1982. To assess whether leucaena is compatible with nitrogen and herbicides, a 2x2x2 factorial design was used comprising leucaena, herbicide and nitrogen at two levels each. A plot of about 0.23ha which had been left under fallow in 1980 was planted to maize followed by maize in 1981 and the maize followed by cowpea in 1982. The trial had 4 replicates along the contours with each of the replicates subdivided into 8 plots of 6 by 10 meters and 3 of the plots in a replicate already established with leucaena. Leucaena, herbicide and leucaena/herbicide were the main plot treatments in maize. A sub plot nitrogen treatment at 80kg/ha was superimposed on these. In the leucaena plots, leucaena trees were cut in April 1981, prunings left in the plots as mulch and the stems removed. During the cropping seasons at planting, weeding and flowering, leucaena tops were pruned, weighed and returned as mulch to the crop.

The herbicide plots were sprayed with paraquat at 3 litres active ingredient/ha before planting and atrazine at 2.5 litres active ingredient/ha after planting maize, or paraquat and dual at 2.5 active ingredient/ha for cowpea. The cowpea crop received four insecticide applications to control thrips, aphids, maruca and pod bugs. The control plots were weeded each season with a hoe two weeks after planting. All plots were planted to maize or cowpeas without tillage and were top-dressed with P and K fertilizers at 60kg/ha and 30kg/ha respectively for maize only. To obtain realistic labour input data, casual workers with some farming experience were hired on daily task work basis. This resulted in more efficient labour inputs than with regular workers. Leucaena stands occupy 20 to 26 percent of the land which is regarded as a cost. Data on all inputs and crop yields were carefully recorded. The analyses used included analysis of variance for factorial experiments to separate treatment effects, plant tissue of maize ear leat for nitrogen content and input-output budgeting to determine various economic indicators.

IV RESULTS AND DISCUSSION

Labour Utilization in Alley Cropping with Leucaena

From the agro-economic experiments of 1981 and 1982 at IITA, cutting leucaena, including shredding the leaflets, at about 15,000 trees/ha took 185 man-hours/ha or 30.8 man-days/ha (6 man-hours being equal to one man-day) in 1981 when the plots had been put under fallow during the previous year. The pruning of leucaena tops took 145.9 man-hours/ha or 24.23 man-days/ha for first season and 113.89 man-hours/ha or 19 man-days/ha for second season 1981. In first season 1982, cutting leucaena regrowth took 16.46 man-days/ha, and two prunings took respectively 14.6 and 7.5 man-days/ha making a total of 38.56 man-days/ha for the management of leucaena for that cropping season. In the second season of 1982, cutting leucaena regrowth took 16.2 man-days/ha and two prunings took respectively 7.5 and 6.9 man-days/ha or a total of 30.6 man-days/ha for management of leucaena in second season.

Considering the labour inputs for various treatments in the agro-economic experiments on alley cropping leucaena with maize or cowpeas, the leucaena treatment doubled the labour inputs in 1981 first season maize, but increased them by (154 man-hrs/ha) 25% in 1981 second season maize and (148 man-hours/ha) 37% in 1982 first season maize as compared to those of the control. The leucaena-nitrogen treatment which took the highest amount of labour, took in man-hours/ha 921 and 895 in 1981 first and second season maize, and 565 in 1982 first season maize compared to 424, 652 and 400 man-hours/ha used in the control plots for the respective seasons (Table 1). Thus increasing labour inputs by 117, 37 and 41 percent in the respective seasons. The herbicide treatments however reduced the labour inputs by about 30 percent per season. Table 2 shows average labour inputs per season by treatments for the production of maize or cowpeas. On the average, with maize crop leucaena treatment increased labour inputs by 52%, leucaena-nitrogen 61% leucaena-herbicide 31% and leucaena-nitrogen-herbicide by 40%. Whereas herbicide reduced labour inputs by 35% and herbicide-nitrogen reduced it by 26%. With the cowpea crop, leucaena treatment increased labour inputs by 28% and herbicides reduced them by 27%.

The Main and interaction Effects of Leucaena, Herbicides and Nitrogen on Crop Yields

From the agro-economic experiment of 1981 and 1982 first and second seasons, the leucaena treatment increased maize grain yields by (1832kg/ha)

Table 1: Labour inputs per treatment for maize and cowpeas. IITA 1981/1982 seasons

Treatment	Labour inputs man-hours/ha					
	1981 1st season maize	1981 2nd season maize	% increase 1st + 2nd season	1982 1st season maize	1982 2nd season cowpeas*	% increase 1st + 2nd season
Control++	424	652	-	400	442	-
Leucaena++	890	816	58	548	565	32%
Nitrogen++	466	731	11	417	442	2
Herbicide	422+	280	-35	245	321	-33
Leucaena-nitrogen	921	895	68	565	565	34
Leucaena-herbicide	788+	705	38	440	505	12
Leucaena-nitrogen-herbicide	830+	785	50	457	505	14
Herbicide-nitrogen	465	360	-23	271	321	-30

\+ Herbicide failed due to weather conditions.

++ Hand weeded.

* No fertilizers were applied to the cowpea crop.

Table 2: Average Labour inputs per season by treatments for maize or cowpea. IITA 1981/82

	Labour input for maize			Labour input for cowpeas		
	man-hours/ha	increase over control		man-hours/ha	increase over control	
		man-hrs/ha	%		man hrs/ha	%
Control	492	-	-	442	-	-
Leucaena	751	259	52	565	123	28
Nitrogen	538	46	9.3			
Herbicide	319	-173	-35	321	-121	-27
Leucaena-nitrogen	794	302	61			
Leucaena-herbicide	644	152	31	505	63	14
Leucaena-nitrogen-herbicide	691	199	40			
Herbicide-nitrogen	365	-127	-26			

95% and (1728kg/ha) 228% in 1981 first and second seasons and by 984kg/ha) 45% in 1982 first season as compared to the control. Leucaena-nitrogen increased maize yields by (1670kg/ha) 85%, (1938kg/ha) 229% and (1047kg/ha) 48% in the respective seasons. Leucaena-herbicide on its part, increased maize yields by (1401kg/ha) 72%, (927kg/ha) 122% and (1501kg/ha) 69% and leucaena-nitrogen-herbicide increased them by (1235kg/ha) 63%, (1395kg/ha) 184% and (2549kg/ha) 116% as compared to maize yields of 1957, 758 and 2159kg/ha obtained from the control plots. The treatments of nitrogen and herbicide-nitrogen increased yields by 33 to 40 percent whereas the treatment of herbicide alone tended to depress the maize yields.

Table 3 shows maize and cowpea yield responses to various treatments for 1981 and 1982 first and second seasons. Using an average of three seasons for maize and one season for cowpeas, the leucaena treatment gave an average increase for maize yields of (1407kg/ha) 68% leucaena-nitrogen (1358kg/ha) 66%, leucaena-herbicide (1451kg/ha) 70% and leucaena-nitrogen-herbicide (1892kg/ha) 90%. As for the cowpea crop, the treatment of herbicide and leucaena-herbicide respectively gave yields of 745 and 730kg/ha which is an increase of 19.58 and 17.17 percent as compared to cowpea yields of 623kg/ha obtained from the control plots. Although no fertilizers were applied to the cowpea crop, the herbicide-nitrogen and leucaena-nitrogen-herbicide plots increased cowpea yields by (147kg/ha) 23.59% and (143kg/ha) 22.9% respectively. But the leucaena treatment by itself lowered cowpea yields by (47kg/ha) 7.54%.

Table 3: Maize and Cowpea yield response to treatment in alley cropping experiment at IITA in 1981 and 1982

Treatment	1981		1982		Increases/Decreases in yield			
	1st season maize	2nd season* maize	1st season maize	2nd season cowpeas	Maize		Cowpeas	
	kg/ha		kg/ha		kg/ha	%	kg/ha	%
Control+	1957	758	2159	523	-	-	-	-
Leucaena+	3789	2486	3141	576	1407	66	-47	-7.54
Nitrogen +	2749	998	2872	628	752	36	5	0.8
Herbicide	3094	616	1929	745	453	22	122	19.58
Leucaena-nitrogen +	3627	2496	3206	572	1358	66	-51	-8.18
Leucaena-herbicide	3358	1685	3660	730	1451	70	107	17.17
Leuceana-nitrogen-herbicide	3192	2153	4708	766	1692	90	143	22.9
Herbicide-nitrogen	3342	1049	3021	770	1123	45	147	23.59
Stand. dev.	211.5	744.46	662.78	151.08				
LSD	575.07	761	564.71	174.85				

* 1981 Second season crop was badly hit by drought.

\+ Hand weeded

Table 4: Maize ear leaf of Nitrogen content from 1st season maize leucaena alley cropping. IITA 1981 and 1982

Treatment	Maize ear leaf % Nitrogen	
	1981	1982
Control	2.11	2.67
Leucaena	2.74	2.95
Nitrogen	2.36	2.97
Herbicide	1.96	2.41
Leucaena-nitrogen	2.97	3.16
Leucaena-herbicide	2.31	2.74
Leucaena-nitrogen-herbicide	3.03	3.16
Herbicide-nitrogen	2.48	2.82
St. dev.	0.11	0.31
LSD	0.45	0.27

Maize ear leaf nitrogen content for first season both in 1981 and 1982, ranged from 1.96% of N for herbicide in 1981 to 3.16% of N for leucaena-nitrogen-herbicide and leucaena-nitrogen in 1982 (Table 4). This suggests that the herbicide plots had less nitrogen uptake, being 0.2% of N less than that of the control. While the leucaena treatment had a man effect of over 20 percent on ear leaf nitrogen content as compared to the control, suggesting a more efficient uptake of N, there was a negative interaction between leucaena and herbicide in 1981. Thus suggesting that herbicide application tends to depress N status in maize ear leaf.

Table 5: The Main effects and interactions[+] of treatments on maize and cowpea yields in an alley cropping experiment. IITA 1981 and 1982

Treatment	Main effects and interactions					
	1981			1982		
	1st Season Maize ear leaf N %	1st Season Maize yield kg/ha	2nd season Maize yield kg/ha	1st season Maize ear leaf N %	1st season Maize yield kg/ha	2nd season Cowpea yield kg/ha
Leucaena	0.64**	1760**	1610**	0.28**	1163.37**	-19.03
Nitrogen	0.25**	807	240**	0.34**	729.57**	
Herbicide	-0.15	1279	-142*	-0.15**	485*	140.09**
Leucaena-Nitrogen	0.03	-303	70	-0.02	-172.69	
Leucaena-Herbicide	-0.07	-629*	-717	0.05	239.61	18.66
Leucaena-Nitrogen-Herbicide	0.04	151	-149	0.03	150.8	
Herbicide-Nitrogen	0.17	-215	-1319	0.08*	340.6*	

** F ratio significant at 1 percent.

* F ratio significant at 5 percent, but the actual F ratio statistics are not presented in this table.

\+ The statistical analysis used a 3 by 2 factorial experiment and figures in the table indicate additive responses resulting from either a single or combination of factors in a treatment.

Table 5 shows the main effects and interactions of the various treatments in 1981 and 1982. Calculations of main effects and interactions were done using a statistical analysis of a 2x2x2 factorial experiment (Cochran and Cox, 1957, Friedman and Savage 1947, Yates 1937). The analysis shows that leucaena had additive main effects of about 1.6 t/ha maize grain yields and 30 to 60% maize ear leaf nitrogen which were consistantly statistically significant at 1 percent level and greater than those of nitrogen and herbicide in the two seasons of 1981 and 1982 first season. The main effects of nitrogen had additive effects of about 0.8t/ha on maize yields and 25 to 34% of maize ear leaf N. They were also consistently statistically significant except in 1981 second season when they were insignificant. However, the herbicide treatment had negative main effects, except in 1982 first season when its effects on maize yields were positive and significant at 5 percent level.

The interaction effects between leucaena and nitrogen on maize for ear leaf nitrogen and grain yield both tended to be negative but insignificant reducing maize yields by 0.2 to 0.3t/ha. The interaction effects between leucaena and herbicide on maize, were negative in 1981 but positive though insignificant in 1982 first season. Whereas the interaction effects between leucaena, nitorgen and herbicide on both maize ear leaf nitrogen and grain yield, were mostly positive but insignificant except in 1981 when they gave negative though insignificant effects on maize yields. The negative interaction between leucaena and nitrogen though not significant and the significant negative interaction between leucaena and herbicides in 1981, suggest that application of herbicides, or certain level of nitrogen to maize-leucaena alley cropping reduces the effects of leucaena on maize grain yield, thus constituting an economic waste of resources.

It therefore appears that the negative interaction between leucaena and nitrogen on maize crop yield is due to the fact that application of the nitrogen supplied by leucaena leaflets, increases the level of soil nitrogen content beyond the optimal level, thus reaching a point where any additional nitrogen brings about diminishing returns in the response of maize crop yield to total soil nitrogen. As for the negative and/or insignificant effects between leucaena and herbicides, it appears that atrazine in particular depresses the growth of leucaena shoots, thus reducing the amount of leucaena prunings for mulch and nitrogen suppliable by it.

In contrast of maize with cowpea, herbicide is the only treatment that had statistically significant additive main effects on cowpea yields (Table 5). The main effects of leucaena treatment on cowpea yields was negative but insignificant. While the interaction effects between leucaena and herbicide on cowpea yield were not significant. Both the negative increase caused by leucaena treatment on cowpea yields, Table 3, and the negative main effect of leucaena on cowpea yields, Table 5, suggests that leucaena alley cropping system alone does not benefit the cowpea crop as much as it does with the maize crop probably due to shading effects of leucaena shoots on cowpea and/or the additional nitrogen supplied by leucaena especially considering that the interaction effect between leucaena and herbicide on cowpea, is less than the main effects of herbicides on cowpea.

Economic Contributions of Leucaena vis-a-vis those of Herbicide and Nitrogen

Three economic indicators namely net ruturn/ha, marginal rate of return and benefit-cost ratio (Table 6), were calculated to determine the economic contributions of each treatment for 1981 and 1982. In all the analysis for 1981, the leucaena treatment gave highest economic returns. Leucaena plots gave a net return of 496 U.S. dollars/ha, equivalent to a marginal rate of return of 2.33 per ha, per additional unit cost and a benefit-cost ratio of 1.32. This was followed by herbicide which gave a net return of 480 U.S. dollars/ha equivalent to a benefit cost ratio of 1.18, then leucaena-herbicide which gave a net return of 139 U.S. dollars/ha equivalent to a marginal rate of return of 1.97 per ha, per additional unit cost and a benefit-cost ratio of 1.07. The leucaena-nitrogen treatment gave net returns of 130 U.S. dollars/ha equivalent to a marginal rate of return of 1.56 per unit additional cost and a benefit cost ratio of 1.05. In that year (1981), all treatment suffered a loss during the second season due to severe drought. But the leucaena treatment suffered only 6% loss as compared to leucaena-nitrogen or leucaena-herbicide which suffered over 20% loss each and compared to nitrogen or herbicide each of which had a loss of 60%.

In 1982 however, the treatment of leucaena-nitrogen-herbicide in absolute terms gave the highest net return of 1108 U.S. dollars/ha, followed by the treatment of herbicide-nitrogen at 992 U.S. dollars/ha then the treatment of leucaena-herbicide at 765 U.S. dollars/ha. But the treatments of herbicide-nitrogen and herbicide alone gave highest marginal rate of return being respectively 3.9 and 2.6 per additional unit cost.

Table 6: The economic contribution of various treatment in agro-economic alley cropping experiment, IITA 1981 and 1982

Treatment	1981 Maize-Maize			1982 Maize-Cowpeas		
	Net returns US Dollars/ ha	Marginal rate of return/ha	Benefit cost ratio/ha	Net return US Dollars/ ha	Marginal rate of return/ha +	Benefit cost ratio/ha
Control	-438	-	-	491	-	1.39
Leucaena	496	2.33	1.32	396	-0.21 (1.58)	1.23
Nitrogen	-371	loss	0.79	669	1.69 (2.9)	1.49
Herbicide	480		1.18	650	2.6 (1.25)	1.51
Leucaena-nitrogen	130	1.56	1.09	302	0.34 (1.16)	1.17
Leucaena-herbicide	139	1.97	1.07	765	0.63 (2.81)	1.44
Leucaena-nitrogen-herbicide	-58	loss	0.97	1108	1.01 (2.8)	1.59
Herbicide-nitrogen	146		1.1	992	3.9 (3.1)	1.76

\+ Figures in parentheses represent marginal rate of return from 1981 first season mmaize alone.

Considering the benefit-cost ratio, again the treatment of herbicide-nitrogen gave the highest ratio of 1.7, followed by that of leucaena-nitrogen-herbicide, then that of herbicide alone being 1.59 and 1.51. The leucaena treatment gave negative marginal rate of return of 0.21 units per additional unit cost per ha based on maize and cowpea crops but for maize alone it yielded a relatively higher marginal rate of return of 1.58 per unit additional cost.

When costs of fertilizers are calculated at subsidized* prices, the combination of herbicide-nitrogen gives the highest marginal rate of return of 10 per additional unit cost and benefit-cost ratio of 2 followed by nitrogen at 8 marginal rate of return per additional unit cost. Generally, the three economic indicators, show that with a crop sequence of maize-maize, the treatment of leucaena gives the best economic returns, followed by herbicide-nitrogen and leucaena-herbicide. But with a crop sequence of maize-cowpea, the treatment of herbicide-nitrogen gives the best economic returns followed by leucaena-nitrogen-herbicide, nitrogen and leucaena-herbicide, in that order. In all cases the treatment of leucaena, gives better economic returns than that of leucaena-nitrogen. Also, leucaena stands produce about 9 to 15.5 t/ha fresh weight of leucaena wood or 5 to 8.6t/ha dry weight and about 6 to 12t/ha fresh weight of leucaena tops for mulch equivalent to between 60 and 70 N kg/ha at 3.2 per cent dry leaf N content.

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* In 1981/82 farmers in Nigeria received 75% subsidy on fertilizers and the price was 13.5 US dollars/50kg of nitrogeneous fertilizers.

V. ON-FARM EVALUATION OF LEUCAENA

On-Farm Trials of Alley Cropping with Leucaena in Western and Mid-belt Nigeria.

In order to assess whether alley cropping with leucaena is applicable under different climatic, soil and farmer conditions two types of on-farm trials with leucaena were conducted in Western and mid-belt Nigeria. These are: (1) long term on-farm trials of alley cropping leucaena with maize and yam and (2) cut and carry leucaena stakes for yam production. Aims of the long term trials were to check the establishment, growth and management of leucaena under farmers' conditions in different ecological zones and to obtain farmers' assessment and other feedback for further improvement of alley cropping system. The cut and carry staking on-farm trials evaluated the economics of staking yam in this area, and assessed the suitability of cut leucaena stakes for yam vines support.

Selection of sites and participating farmers.

Areas for leucaena/maize/yam on-farm testing in Nigeria were selected to include forest, derived and Guinea savannah ecological zones. Within each zone, the selection was based on high probability of success, as indicated by the information from previous surveys and other secondary sources.

Previous surveys indicate that the yam producing belt of Nigeria stretches from the Delta to Kaduna, covering part of the forest, derived, southern and Northern Guinea savannahs (Gosden, 1978). The dominant systems in these ecological zones are: yam/maize-cassava in forest Zone, yam/cassava in the derived savannah, yam/sorghum in Benue State and sorghum/yam in Kwara State both of which are mainly in southern Guinea savannah and sorghum/maize/yam in Kaduna State in the Nothern Guinea savannah. These surveys also indicated that in the Guinea savannah, maize and cowpeas are important food and cash crops in addition to yams. The surveys also indicated that the major constraints to production in the Guinea savannah are shortage of labour, fertilizers and scarcity of water. Bachmann (1981) identified the constraints to yam production in the savannah as scarcity of both planting and staking materials.

In each area, the criteria used for site selection were therefore: (1) a yam/maize producing area, (2) size of the active farming community, (3) shortage of staking material and/or soil fertility problem(s), (4) existence of marketing facilities for yam and maize and (5) accessability. The selected locations for the trials were Ekiti-Akoko in the forest zone, Ijaiye in the derived savannah (transitional zone), Osara, Tawari and Ayangba in the forest savannah mosaic, Yandev, Tyowanye and Zakibiam in the Guinea savannah (Fig. 1).

The major soil types in the selected areas are ferralsols covering Benue and ferruginous tropical soils covering Ogun, Oyo and Kwara States (Agboola, 1979, Murdoch et al. 1976). Generally, the ferruginous tropical soils have a sandy surface horizon underlain by a weakly-developed clayey, mottled and occasionally concretionary sub-soil (FAO,1966).

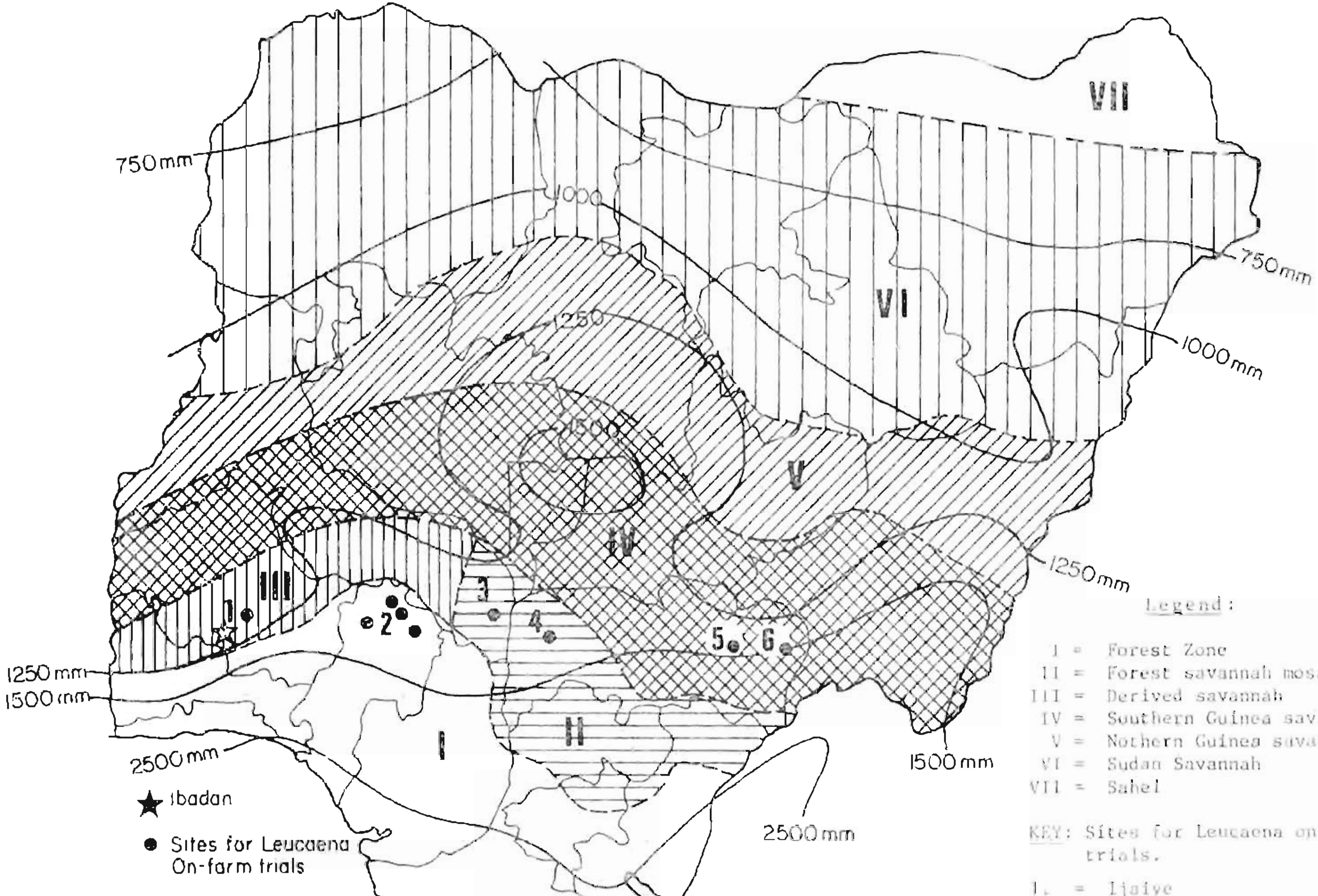

Fig 1 Nigeria vegetation zones: Sites of Leucaena-Maize-Yam on-farm trials.

Legend:

I = Forest Zone
II = Forest savannah mosaic
III = Derived savannah
IV = Southern Guinea savannah
V = Nothern Guinea savannah
VI = Sudan Savannah
VII = Sahel

KEY: Sites for Leucaena on-farm trials.

1. = Ijaiye
2. = Ekiti-Akoko (Ikole, Ikare, Ado, Omuo)
3. = Osara
4. = Ayangba
5. = Yandev.
6. = Zakibiam.

They are sensitive to erosion, have low water-holding capacity and are susceptible to drought (Agboola, 1979). The ferralsols have limited reserves of weatherable minerals in the B horizon, are susceptible to leaching and considered to be of low fertility (Bridges, 1970). The colours of the soils are dark grey in Ijaiye, vary from dark grey to blackish in Ekiti-Akoko, redish yellow in Osara and Ayangba and greyish sandy in Yandev-Zakibiam area.

Researchers conducted informal exploratory surveys at each site and with the help of local extension personnel selected cooperating farmers. The criteria for selecting farmers were: farmers growing at least one hectare of white yams (Dioscorea rotundata) that normally requires staking, farmers' willingness to cooperate and accessability of his farm. Before the trials were set, researchers explained to farmers wihout making promises, the concept and possible benefits of alley cropping leucaena with maize or yams. If a farmer showed interest and offered to set up leucaena trial, he was given seeds of Leucaena leucocephala Var K 28 Hawaiian giant already scarified by soaking them in hot water and innoculated with Rhyzobium bacteria and shown how to plant them.

Supervision and Organisation of the trials

For all the trials, planting of leucaena was carried out by the farmer(s) under the supervision of the researcher(s). The farmers took care of their trials with occassional advice from the researchers. Regular visits to each trial were made every three to five weeks by the researchers to take records, observations and measurements. At Osara, Ayangba and Ekiti-Akoko sites, interested extension agents identified as contact persons were also involved in data recording.

For the initial establishment, leucaena was interplanted with maize, rice, sorghum or soybeans according to the farmers' preferences. The earlier leucaena plots were planted at the spacing of 2m by 0.5 m and the latter ones planted at 4m by 0.5 m spacing. These trials used a simple experimental design of maize/yam/leucaena plot versus farmers' practice as the control. The sizes of leucaena plots varied from 0.25 to 0.8 ha, with each farmer serving as a replicate.

Each farmer had been taught to prune the leucaena trees at the height of about 1.5 meters after planting yams and to prune the live leucaena stakes regularly, leaving the leucaena tops as mulch for the yam crop. When the leucaena trees became established with 2.5 to 4 meters high, the leucaena plot with its control were put under yam production with a rotation of yam-maize. For the yam phase farmers made heaps between the leucaena rows in their traditional way. Local varieties of white yams (Dioscorea rotundata) were planted. For the maize phase variety Farz 7 was planted in Ekiti-Akoko sites and elsewhere TZSRW was used. In case of maize, the pruning height of leucaena was 0.5 m. For yam production, farmers supplied all the inputs including labour and seed-yam. For maize production, the farmers supplied labour inputs in addition to land while the researcher(s) supplied seeds.

Farmers were made to feel that the trials were their own and that researchers were cooperating to get at insight of the nature and range of modifications needed to enhance the potentials of the alley cropping system. At each visit, informal discussions were held with farmers. In many cases, the discussions centered on various aspects of the trials including farm operations, management and benefits from leucaena.

Farmers planned and carried out farm operations according to their schedules and were given the freedom to modify the system where necessary; while researcher(s) took note of the nature and reasons behind the modifications.

In case of on-farm cut and carry staking trials which were included in 1982 and 1983, selected farmers were encouraged to establish small leucaena stake lots for providing yam stakes. Others who were not convinced of the benefit of staking and were reluctant to establish lots were given leucaena stakes of 2m length. Farmers who had access to nearby bush fallow where stakes from naturally regenerated plants were available were encouraged to use these stakes. In each case, a plot-size of 50 by 20 yam heaps (0.14 ha) was laid out jointly by the researcher(s) and farmer but staked by the farmer. The trials which also had a simple design of a staked plot versus non-staked with a single replicate per farmer, were superimposed on the farmers' fields. The farmers supplied all the inputs including labour with exception of gathering stakes in a few cases. Researchers only monitored the operations and took records of yields.

FEEDBACK FROM ON-FARM TESTS

Establishment of Leucaena

A total of 15 leucaena trials were successfully established between 1980 and 1983. Four were established in 1980, four in 1981, five in 1982 and two in 1983. Of these trials, four are in the forest zone, one in the transitional zone, three in the forest savannah mosaic and seven in the Guinea savannah (Table 7). Percentage of the leucaena stands at established trials ranged from 25% at Tawari and Ayangba, 30% at Osara to 95% at Zakibiam and Ikole, Ekiti-Akoko. The height attained by the leucaena after one year of establishment ranged from 0.5 - 1.8 m at Osara and Ayangba to 3-4 meters at Ikole (Ekiti-Akoko) and Zakibiam (Table 7). Some seven other trials had establishment problems especially those in the forest savannah mosaic. At Osara, Tawari, Tyowanye, Yandev and Ado, the initial trials had to be replanted or abandoned. Some of the observed problems with leucaena establishment were uneven germination at Osara, Tawari, Tyonwanye and Ijaiye; and retarded growth at Osara, Tawari, Ayangba and Isherev either due to poor soils, prolonged drought or chlorofic of the leucaena seedlings. Other problems included accidental uprooting of seedlings during weeding, herbicide damage and termite attacks. Some farmers could not carry out the required two weedings for the establishment of leucaena. For instance eupatorium, imperata and gramineae weeds affected some of the trials in the forest zone, derived savannah and Guinea savannah. Bush burning during the dry season affected at least seven of the trials. Although the leucaena seeds were scarified with hot water and innoculated, the germination on farmers' fields tended to be low.

Table 7. Establishment of leucaena on-farm trials in Western and Mid-belt of Nigeria, 1980 to 1983.

Location/zone	Date planted	Crop at establishment	Leucaena trials established	Height after one year meters
Forest Zone				
Ekiti-Akoko: Ikole, Ikare, Omuo, Oka, Ado	1982 1983	Maize	4	2.6-4.0
Derived Savanna (Transitional)				
Ijaiye	1981	Maize	1	0.9-2.0
Forest Savanna Mosaic				
Osara	1981	Maize	1	0.5-1.8
Tawari	1981	Sorghum	Few trees	0.6-1.8
Ayangba	1982	Rice	Few trees	0.6-1.9
Southern Guinea Savannah				
Yandev	1980	Maize,	1	2.5-3.0
Tyowange	1982	Soybeans	Few trees	0.6-2.0
Zakibiam (Ninga)	1980	Maize	1	2.8-3.0
Zakibiam (Wombo)	1980	Maize	1	0.9-2.5
Abari (Zakibiam)	1981,1982	none	2	2.0-3.0
Isherev (Zakibiam)	1981	Maize	1	1.2-2.5
Kwa hlaade (Zakibiam)	1982	None	Few trees	0.6-2.0

Leucaena establishment tended to be poor where leucaena seeds were interplanted with soybeans, rice or sorghum. At some sites in Kwara State, leucaena trees were either stunted, dwarfish or feeble with few leaves and branches. It was observed that optimal planting time, effective weed control and some fertilization helped establishment of the leucaena.

EFFECTS OF LEUCAENA ON SOILS AND CROP YIELDS

Soil samples taken from the plots in November 1982, indicate that one year under leucaena changed certain soil chemical properties (Tables 8). For instance soil pH, percentage organic carbon and total nitrogen increased with averages of 4, 51 and 88 percent respectively. Analysis of dry leucaena leaves from the on-farm trials (Table 9) show higher proportion of potassium and zinc than those found in the top soils, suggesting that the leucaena trees probably extracted some of the leached minerals from the sub-soils.

Of the leucaena trials started in 1980, only one at Zakibiam (Ninga) was fully established ready for yam cultivation in early 1981. By 1982, five trials were ready for yam cultivation and in 1983 a total of ten leucaena trials were planted to yam or maize depending on the previous crop. There were also ten cut and carry staking trials in 1983.

The leucaena trial at Yandev together with its control was planted to yam in May 1982 and to maize in May 1983. During the growing seasons, the farmer maintained the plot well, pruned the leucaena shoots regularly at 1.5m high for yams and 0.6m for maize. Yam vines grew vigorously as he guided them to climb up the leucaena live stakes.

Table 8 Chemical Properties of soils in leucaena on-farm trials in Nigeria - June 1981 and November 1982. (soil samples taken (0-15cm)

Location	1981						1982					
	pH H_2O	Organic C%	Total N %	P (ppm)	Echangeable cations Ca	k	pH H_2O	Organic C%	Total N %	P (ppm)	Echangeable cations Ca	k
Osara	6.0	0.92	0.06	2.6	5.78	0.16	6.3	0.81	0.12	1.19	4.04	0.23
Tawari	6.0	1.09	0.05	6.6	2.70	0.13	-	-	-	-	-	-
Abari-Zakibiam	6.2	1.25	0.05	10.0	4.05	0.16	6.3	1.27	0.08	4.06	2.77	0.15
Hinga-Zakibaam	6.9	0.78	0.09	219	18.0	0.16	6.4	2.12	0.16	-	6.28	0.15
Wombo-Zakibiam	5.9	0.34	0.04	2.3	2.18	0.10	6.4	0.99	0.15	2.45	1.79	0.38
Isherev-Zakibiam	5.8	1.02	0.04	1.4	1.3	0.06	6.2	0.70	0.1	1.54	2.47	0.15
Yandev	6.0	0.86	0.05	1.4	2.1	0.10	6.5	1.94	0.12	1.54	3.36	0.27
Ahwe-Ahugh-Kusu	-	-	-	-	-	-	6.2	1.08	0.07	2.80	2.77	0.27
Ochaje-Ayangba	-	-	-	-	-	-	5.9	0.98	0.09	13.3	1.79	0.04
Gliricidia trial IITA	6.8	0.71	0.10	20.9	5.63	0.31						

Table 9 Analysis of dry leucaena leaves taken from on-farm trials in Nigeria: November 1982.

Location	N	P	Ca	Mg	K	Zn
	(%)					(ppm)
Osara	3.49	0.23	2.30	0.66	2.09	51.7
Abari - Zakibiam	3.73	0.21	0.98	0.43	2.14	36.8
Ninga - Zakibiam	5.14	0.30	1.4	0.38	3.08	46.0
Wombo - Zakibiam	4.22	0.25	0.79	0.32	2.77	40.2
Isherev - Zakibiam	3.96	0.17	1.07	0.48	2.22	34.1
Yandev	5.07	0.42	0.91	0.35	3.20	51.0
Tyowanye	3.31	0.50	1.7	0.62	2.77	62.1
BN1 - IITA Site	4.82	0.29	1.73	0.39	2.69	24.4

Table 10 The effects of leucaena alley cropping on maize yields under farm conditions in Nigeria, 1982 and 1983.

Location	Maize yield (t/ha)		Yield increases	
	Leucaena plot	Control	t/ha	%
Zakibiam (Wombo)	1.3	1.0	0.3	30
Abari	1.5	1.0	0.5	50
Yandev	3	1.5	1.5	100
Ijaiye	1.9	1.3	0.6	46
Ekiti-Akoko	4.7	4.3	0.4	9
Osara	3	1.5	1.5	100
Average	2.5	1.8	0.8	44

Planted Farz 27 maize variety. Others planted TZSRW maize variety

The leucaena plot yielded 4.9 t/ha (18%) more yam (Table 11) and 1.5 t/ha (100%) more maize (Table 10) than the control.

Four of the leucaena trials under production were located around Zakibiam in Ukum Local Government Area. One of the farmers at Abari, Zakibiam, after planting yam in March 1982, he pruned the leucaena live stakes regularly and maintained the trial as well as that of Yandev in the early season. But later in the season, the farmer became irregular in pruning leucaena live stakes. Consequently the leucaena shoots overgrew and shaded the yam vines between pruning. This overgrown live stakes gave 2.6 t/ha (16%) less yam yields than the control. With maize production however, the farmer pruned the leucaena at 0.5 m and maintained the plot very well. In spite of the drought during the season, the farmer obtained 1 t/ha (50%) more maize yields than in the control (Table 10).

In the second trial at Zakibiam (Wombo) the leucaena trees were burnt down by bush fire in January 1982 and at the time of making yam heaps the soil had become so hard that wide spacing of yam mounds were used. The yam was then planted to make use of dry leucaena stems as stakes. However, the stakes sprouted during the heavy rains of June/July. The farmer was not regular in the pruning of this regrowth and the the yam leaf production was not as much as in the other trials and the process of pruning overgrown leucaena shoots appeared to disturb the yam vines. The shading resulted in 1.6 t/ha (8%) less yam yields than that of the control. For the maize crop in the subsequent season, the leucaena plot was better managed by the farmer and he obtained 1 t/ha (30%) higher yields than the control plot.

Table 11: The effects of leucaena stakes on yam yields in Benue state 1982 and 1983

Location	In-situ live leucaena stakes				* Cut and carry leucaena stakes			
	Live stakes t/ha	Control t/ha	Yield increases t/ha	Yield increases %	Cut stakes t/ha	Control t/ha	Yield increases t/ha	Yield increases %
Zakibiam	22.3	20.8	1.5	7.2	22.8	18.9	3.9	20.6
Isherev	9.2	24.3	-15.1	-62	30.5	23	7.5	33
Abari	13.8	16.4	-2.6	-16	19.4	10.5	8.9	85
Yandev	32.7	25	4.9	18	18.8	10.3	8.5	82
Amaladu	-	-	-	-	20	11	9	81
Nyikwagh	-	-	-	-	33.5	17.7	15.8	85
Average	20	21	-1	-5	23.3	15	8.3	55
Stand dev.	6.31				7.51			
LSD	22.86				7.34			

* Cut and carry staking trials were conducted with separate set of farmers.

For the trial at Isherev, in Zakibiam, the farmer missed planting yam in 1982 growing season due to sickness and planted it in February 1983. After initial pruning, he also became irregular in subsequent prunings and the overgrown leucaena live stakes depressed yam yields by 15.2 t/ha (62%) (Table 11). The fourth trial at Zakibiam (Ninga) had the best established leucaena trees. The farmer planted late yam in the leucaena plot along with the control in 1981. He maintained the plot fairly well and obtained good yields with increases of 4.6 t/ha (20%) over the control. The farmer attributed the low yield increases of yams from the leucaena plot to shading because of irregular pruning and late planting. He expected significantly better yields during subsequent crops. The farmer put this leucaena plot under fallow for one year and has since adjusted the leucaena spacing from 2m by 0.5m to 4m by 0.5m and put the plot under continuous cultivation.

Although the maize was hit by drought at most of the locations, yields from the leucaena plots were substantially better than those from the control plots. Maize yield increases from the leucaena plots over the control varied from 0.4t/ha (9%) in Ekiti-Akoko sites to 1.5 t/ha (100%) at Yandev and Osara sites (Table 10). The in-situ live leucaena stakes gave on the average, yam yields that were 1 t/ha (5%)lower than that of the control (Table 11). However, yam yield response to staking with the cut and carry system (Table 11, Columns 6 to 9) was significantly positive. It gave yield increases over the control, ranging from 1 t/ha (5.8%) at Zakibiam (Agba) to 15.8 t/ha (89%) at Nyikwah in Abwa Local Government Area. On the whole, cut and carry staking system gave an average increase of 8.3 t/ha (55%) over the control.

In the cut and carry trials conducted in the Guinea savannah of Benue State, two sources of staking materials were considered to assess the economic benefits of staking yam in the area. When gathering stakes from grassland bushes was compared with cutting stakes from planted leucaena stake lots, the labour requirement for stake lots was 16 man-days/ha being 45% lower than that of 31 man-days/ha for grassland bush.

Returns per unit cost of yam staking were calculated for the two sources of stakes in the area. Farmers who used stakes from leucaena lots obtained an average marginal rate of return of 5.13, ranging from 1 to 11.5 per additional unit cost of staking. But farmers who used stakes from grassland bushes obtained an average marginal* rate of return of 0.53, ranging from -0.8 to 2.1 per additional unit cost of staking. This suggests that gathering scarce stakes from the nearby grassland bushes is uneconomical for the local farmer. But the results of cut and carry system in Table 11, suggest that substantial yam yield increases can be achieved at economic levels if staking of yam is reintroduced by establishing leucaena lots as inexpensive source of stakes. Also the relatively high maize yield increases at farm level in Table 10, suggest that leucaena alley cropping can be economically attractive to farmers.

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* Here marginal rate of return is given by value of additional yields due to staking divided by additional cost due to staking.

FARMERS' ASSESSMENT, MANAGEMENT PROBLEMS AND ADAPTATION OF LEUCAENA ALLEY CROPPING.

The farmers assessment of alley cropping was generally positive. Farmers were out spoken of both the alley cropping and cut and carry leucaena stakes from established leucaena lots. They commented that leucaena/yam alley cropping has definite benefits. Leucaena provides inexpensive staking materials for yams. The yam or maize crop in leucaena plots looked much better than those in the control plots. For instance farmers at Zakibiam explained that when leucaena was first introduced to them, they were not convinced that trees could be interplanted with and be useful to crops. Nevertheless, they have been impressed by leucaena and have noted other benefits from it.

Most farmers commented that leucaena controls weeds, especially *Imperata cylindrica* and helps to maintain better soil structure and moisture. That is it keeps the soils moister and more friable. During heap making, farmers found the soil in the leucaena plots softer and easier to dig than that in the control plots. Farmers in the Guinea Savannah were particularly impressed by the cut and carry leucaena stakes system for yam production. Besides the significant increases in yam yields from staked plots, they observed that staked yam vines grew more vigorously and were the last ones to wither during the dry season. They also observed that leucaena trees provide firewood and fencing materials especially in the Guinea Savannah.

Table 12 Farmers' reasons for interest in leucaena alley cropping; Nigeria, 1982 and 1983

Location/Zone	Number of Leucaena trials				Neighbouring farmers' interested			
					No. of farmers	Reasons		
	Established	Alley cropped		Cut* Leucaena stakes for yams		Stakes	Soil improvement	Weed Control
		maize	yams					
Forest Zone								
Ekiti-Akoko: Ikole, Ikare, Omuo Oka, Ado, Oke	4	3						
Derived Savannah								
Ijaiye	1	1			3		x	x
Forest savannah mosaic								
Osara	1				2		x	
Ayangba	1				2		x	
Guinea Savannah								
Yandev	1	1	1	4	5	x	x	
Tyowanye	1			1	4	x	x	
Zakibiam	2	1	2	3	3	x	x	x
Abari (Zakibiam)	2	1	1	1	4	x	x	
Isherev (Zakibiam)	2		1	1	3	x	x	
Total	15	7	5	10	26			

* Cut and carry staking trials were conducted with separate set of farmers.

Live leucaena stem for yam vine support (background) and unsupported control (foreground) at yam emergence. Pruning of leucaena stem was done later after emergence was complete.

Cut leucaena stakes for supporting yam vine (background) and unstaked control (foreground) at yam emergence.

Plate 1. Yam staking with in-situ live and/or cut and carry leucaena stakes in Guinea savannah, Nigeria.

The most significant observation was the positive reaction of the farmers involved in the trials and some of their neighbours. Generally, three major reasons, namely: inexpensive source of stakes, soil fertility improvement and weed control, were given by farmers for their interest in leucaena (Table 12). Two of the farmers have indicated that they plan to increase the land under leucaena to 2ha each. Some of the neighbouring farmers who have also been impressed by these trials have requested for leucaena seeds, mainly to establish leucaena lots for cut and carry stakes. The largest number of interested farmers are in yandev-Zakibiam area of Benue state.

Observations of trials and comments by farmers indicate that further research is needed to adapt the system to farmers' conditions and capabilities. One problem is proper and easy establishment of leucaena on farmers' fields. Uneven germination of the leucaena seeds, retarded growth of seedlings, reaction to soil type, sensitivity to weed competition and bush fires pose problems to farmers at the establishment stage. At least two weedings and two year growth period for leucaena are expected before yam cultivation.

A second problem is that of proper management of the system by farmers. The live in-situ staking of yam require regular pruning to prevent competition for sunlight. The yam is an eight-month crop, lasting through both growing seasons, so about six prunings are required. If labour shortage or sickness cause delay of pruning, the leucaena shoots are likely to depress both the vegetative growth and yield of yams (Table 11, columns 2 to 5). Late pruning, when the leaflets are already large, tend to damage the yam vines. It therefore appears that the use of dead stake in-situ or in cut and carry system is more efficient for yam vine support.

Tabale 13 Labour inputs for the management of leucaena in an alley cropping system in Nigeria, 1982 and 1983. (Man-days+ ha)

Operation	Alley Cropping with maize	Yam Staking
<u>Establishment (1st year)</u>		
Planting leucaena seeds	6	6
Weeding (twice)	20.8	20.8
<u>Alley cropping with maize</u>		
Cutting and shredding of leucaena stems after 1 to 2 year fallow	24.3	-
Carrying leucaena stems from field cut after fallow	14.5	-
Two prunings of leucaena shoots for maize	22	-
Harvesting leucaena stakes	-	10
Staking and training yam vines	-	14
Total	87.6	50.8

+ One man-day is equivalent to 6 man-hours.

Third problem is that of mechanization to speed up pruning of the leucaena bushes at labour peak periods, especially with medium scale farms. A farmer at Yandev commented that although he was impressed by the yam and maize yields from the leucaena, the leucaena plot demanded too much attention and took too much labour to maintain. Both the farmers at Zakibiam and Ijaiye while cutting the leucaena trees after a two year fallow, complained that the leucaena trees were too many and too hard for their traditional cutlass and causing blistering of their hands. The farmers in the forest zone were reluctant to crop their leucaena plots and their neighbouring farmers feared that alley cropping might cost a lot of labour to manage the leucaena trees.

Data of labour inputs for the management of leucaena in an alley cropping system were collected from the on-farm trials in 1982 and 1983(Table 13). On the average, planting and weeding of leucaena at establishment took respectively 6 and 20.8 man-days/ha. For alley cropping with maize cutting and shredding of leucaena stems after 1 to 2 years fallow took 24.3 man-days/ha and carrying leucaena stems from the field took 14.5 man-days/ha, and two prunings of leucaena shoots took 22man-days/ha. Harvesting of leucaena stakes and staking took respectively 10 and 14 man-days/ha. So there is need to find suitable tools to reduce the labour requirements for the management of leucaena.

A fourth problem is that of optimal spacing between and within rows of the leucaena plants. The early trials were planted at 2m x 0.5m and the latter ones at 4m x 0.5m. In the former, farmers could make only one row of mounds, and even then some farmers complained that 2m spacing is too narrow for their yam heaps. The 4m row spacing seems more reasonable, although some farmers think it still gives too high a proportion of trees per unit land. Some of the farmers also wonder whether 4m row spacing is wide enough for efficient operation of a tractor in the alleys.

A fifth problem requiring attention is the development of an improved alley cropping system for continuous cultivation and at the same time for production of staking materials and/or browses for animal feed. In the Guinea savannah where there is both the problem of soil fertility and scarcity of stakes for yams, farmers' traditional rotation is that of yam, (without staking) sorghum/guinea corn-soybeans/groundnuts followed by two to three year fallow. If alley cropping is to improve such traditional system, then farmers expect it to (a) extend the period of cultivation and (b) provide sufficient mulch and/or stakes. While farmers were impressed by maize/leucaena - yam/leucaena rotation, there were some who wondered whether the system could be extended to cover rotation of yam-maize-cowpeas or soybeans or groundnuts - back to yam. Another prominent question asked again and again was: How many years should a farmer using alley cropping expect to cultivate the same piece of land without being forced to put his land to fallow?

CONCLUSIONS

From the results of the agro-economic experiments at IITA, four conclusions can be drawn:

(a) The consistently significant increases in maize yields under leucaena and the small negative interactions between leucaena and nitrogen from three successive seasons, suggest that the maize-leucaena alley cropping system can give high maize yields without nitrogeneous fertilizers. The use of nitrogeneous fertilizers at full rate with leucaena, even at subsidized prices, is an economic waste.

(b) Although leucaena stands occupy about 20 percent of the land, cutting and pruning leucaena increases labour costs by about 52 percent; the economic contributions of leucaena are greater than those from leucaena-nitrogen or those from herbicide-nitrogen or those from herbicide.

(c) The highest level of technological input, leucaena-nitrogen-herbicide, gave on average the highest increase of 90% on maize yields followed by leucaena-herbicide and leucaena alone with respectively 70 and 69% increases on maize yields, its economic contributions are not necessarily better than those of herbicide-nitrogen, or those of leucaena-herbicide.

(d) With a crop sequence of maize-maize, leucaena gave the best economic returns followed by herbicide-nitrogen and leucaena-herbicide. But with a crop sequence of maize-cowpea, herbicide-nitrogen gave the best economic returns followed by leucaena-herbicide. However, leucaena was observed to have depressing effects on cowpea yields unlike the case with maize. This needs to be investigated even further. In all cases, the leucaena treatment gave better economic contributions than leucaena-nitrogen.

Results obtained from the on-farm trials so far, suggest that leucaena-maize-yam alley cropping has definite benefits for small scale farmers particularly in areas where soil fertility problem and scarcity of staking materials exist. The farmers recognize the benefits of using leucaena in an alley cropping system, but there are a number of questions that require further research. These are: (a) problem of establishing leucaena on farmers' field (b) farmers management of leucaena live in-situ stakes for yams (c) need for better tools (or mechanization) for pruning of leucaena bushes to reduce labour requirements at peak periods and (d) evolving a strategy for the management of the leucaena trees in the alley cropping system that allows continuous cultivation of the land, covers a wide range of crops and provides sufficient bio-mass production for mulch (and/or animal fodder) plus sufficient wood for stakes and firewood. In spite of some management problems, farmers reacted favourably to alley cropping and are interested in leucaena as an inexpensive source of stakes.

References

Agboola, S. A. (1979). An Agricultural Atlas of Nigeria. Oxford University Press.

Bachmann , (1981). Yam Holdings in Southern Nigeria: Economic assessment of Problems and trends. IITA Agric. Econs. Discussion Paper 2/81.

Benneh, G. (1972). Systems of Agriculture in Tropical Africa. Econ. Geog., 48, 244-257

Bridges, E. M. (1970). World Soils. Cambridge.

Cochran, W. G. and G. M. Cox (1957). Experimental Designs. John Wiley and Sons.

Dijkman, M. J. (1950). Leucaena, a promising soil-erosion control plant. Econ. Bot. 4, 337-349.

Friedman, M. and L. J. Savage (1947). Planning experiments seeking maxima. In Techniques of statistical analysis. McGraw-Hill.

FAO Soils Bulletin, 40 (1977). China: recycling of organic wastes in agriculture.

FAO(1966) Agricultural Development in Nigeria 1965-1980 Rome.

Gosden, P. N. (1978). Land resources of Central Nigeria. Present farming systems, vol.3, Descriptions of sample villages 51-101.
Land Resource Development Centre, Tolworth Tower, Surbiton, Surrey England KT6 7Dy.

Gueverra, A. B. (1976). Management of Leucaena Leucocephala (Lam) de wit for maximum yield and nitrogen contribution to intercropped corn. Ph.D. Thesis, University of Hawaii.

IITA annual reports 1974, 1980, 1981.

Kang, B. T., G. F. Wilson and L. Sipkens (1981).
Alley Cropping Maize (Zea maysl.) and Leucaena (Leucaena Leucocephala) in Southern Nigeria. Plant and soil 63, 165-79.

Kang, B. T., L. Sipkens, G. F. Wilson and D. Nangju (1981).
Leucaena (Leucaena leucocephala (Lam) de Wit) prunings as nitrogen source for maize (Zea mysl.)

Murdoch, G. <u>et al</u> (1976).
Soils of the Western State Savannah in Nigeria. vol.1, 2 and 3.
Land Resource Division, Min. overseas Development,England.

NAS (1979). Tropical Legumes: Resources for the Future. Washington, D.C.; National Academy of sciences.

NAS (1980). Firewood Crops: Shurb and Tree species for Energy Production. Washington, D.C.; National Academy of sciences.

Okigbo, B. N. (1974). Fitting research to farming systems. In Proc. Second Int. Seminar on change in Agriculture, Reading, England.

Okigbo, B. N. (1976). Role of legumes in small holdings of the humid Tropics of Africa. In Proc. of a Workshop on Exploiting the legume-Rhizobium symbiosis in Tropical Agriculture. University of Hawaii, College of Tropical agriculture. Misc. Publications 145.

Okigbo B. N. (1982). Impact of agricultural systems and rural Development on Nigeria forests. In Agro-forestry in the African humid tropics ed. by L. H. Macdonald, the United Nations University.

Ruthenberg, N. (1976). Farming Systems in the Tropics, London, Oxford University Press.

Vergara, N. T. (1982), New directions in Agroforestry: The potential Legume trees improving Agroforestry in the Asia-Pacific tropics. East-West Center and United Nations University.

Wilson, G. F. (1980). Providing stakes, for supporting yams and other climbing crops. IITA Research Briefs Vol.1, Blo.3.

Wilson, G. F. and B. T. Kang (1981). Developing stable and productive biological cropping systems for the humid tropics. In stonehouse, B. (1981). Biological Husbandary: A scientific approach to organic farming. Butterworth, London.

Yates, F. (1937). The design and analysis of factorial experiments. Imp. Bur. soil. Sci. tech. comm. 35.