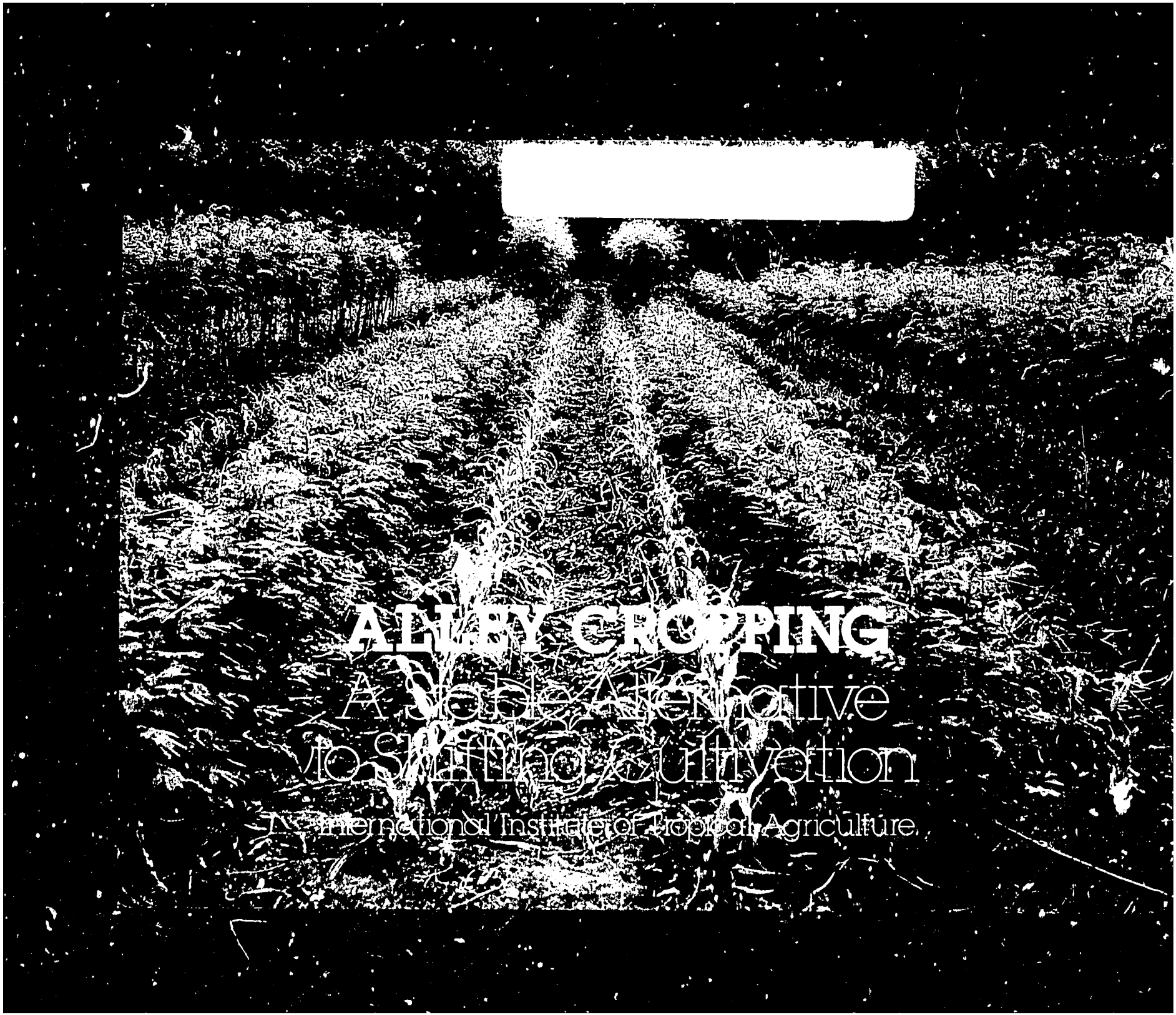
ALLEY CROPPING
A Viable Alternative
to Shifting Cultivation
International Institute of Tropical Agriculture

About IITA . . .

The International Institute of Tropical Agriculture (IITA) is an autonomous, nonprofit corporation governed by a 15-member board of trustees headed by Dr. John J. McKelvey Jr. of the United States of America. The Institute's chief executive officer is Director General Dr. Ermond H. Hartmans.

IITA seeks to develop alternatives to shifting cultivation that will maintain the productivity of the land under continuous cultivation in the humid and subhumid tropics; to develop higher yielding pest and disease resistant varieties of cowpeas, yams and sweet potatoes worldwide, and of maize, rice, cassava and soybeans in Africa, and to strengthen national agricultural research systems by a comprehensive training program and collaborative research.

IITA was established in 1967 by the Ford and Rockefeller Foundations, which provided the initial capital for buildings and development, and the Federal Military Government of Nigeria, who allotted 1,000 hectares of land for a headquarters site seven kilometers north of Ibadan.

IITA is one of 13 nonprofit international agricultural research and training centers supported by the Consultative Group for International Agricultural Research (CGIAR). The CGIAR is supported by the Food and Agriculture Organization of the United Nations (FAO), the International Bank for Reconstruction and Development (World Bank) and the United Nations Development Programme (UNDP). The CGIAR consists of about 50 donor countries, international and regional organizations and private foundations.

IITA receives support through the CGIAR from a number of donors including Australia, Belgium, Canada, Ford Foundation, France, Federal Republic of Germany, India, World Bank, International Fund for Agricultural Development (IFAD), Italy, Japan, The Netherlands, Nigeria, Norway, Organization of Petroleum Exporting Countries (OPEC) Fund for Agricultural Development, United Kingdom and the United States of America. In addition, other donors provide funds to IITA to support specific research and training programs.

Cover: Experimental field to study the effects of hedgerow height and time of pruning on crop yield.

ALLEY CROPPING
A Stable Alternative to Shifting Cultivation

By

B.T. Kang
Soil Scientist

G.F. Wilson
Agronomist

T.L. Lawson
Agroclimatologist

International Institute of Tropical Agriculture
Oyo Road, PMB 5320, Ibadan, Nigeria

Foreword

In most parts of the tropics, especially in tropical Africa, there is a critical need to increase food production to meet the demand of a rapidly increasing population.

One of the challenges presented to the International Institute of Tropical Agriculture from its beginning has been to develop alternatives to the centuries-old shifting cultivation and bush fallow production systems predominant in tropical regions. Such traditional systems are effective given an unlimited amount of land and labor. The fertility and productivity of tropical soils have been maintained by short periods (1 to 3 years) of cultivation followed by long periods of restorative fallow (bush).

Problems arise when the supply of land and labor are no longer unlimited; when rapidly growing and rapidly urbanizing populations put new and heavy demands on the food production system.

One obvious response is to increase the cropping period and decrease the fallow period, keeping more land under cultivation at a given time. But this is not as simple as it appears. The fragile tropical soils do not respond well to temperate climate farming methods based on the use of heavy machinery and expensive agrochemicals, which often leave the land in poorer condition than does a heavily used bush fallow system. In an attempt to incorporate the good features of bush fallow into a continuously productive farming system, scientists at IITA have developed a production system for tropical agriculture called alley cropping. This is an agroforestry system that involves growing food crops in alleys formed by hedgerows of leguminous trees or shrubs.

This exciting new development of integrating the art or knowledge developed over the centuries by the small tropical farmer with modern science or technology, we believe, has tremendous potential for feeding the increasing populations and simultaneously stabilizing tropical soils for future generations.

IITA scientists B.T. Kang, G.F. Wilson and T.L. Lawson, who pioneered this concept eight years ago and carefully researched its many phases, have prepared this technical bulletin for the information of scientists, teachers, technicians and farmers.

Ermond H. Hartmans
Director General
International Institute of Tropical Agriculture

Introduction

In many parts of the humid and subhumid tropics,[1] particularly in Africa, shifting cultivation with the related bush-fallow slash-and-burn cultivation is still the dominant food crop production system. In this system short (one to two years) cropping periods alternate with long (six or more years) fallow periods. This fallow restores soil fertility and rids the land of many noxious weeds, pests and diseases. A large area of the humid and subhumid region is dominated by low activity clay (LAC) soils. These soils are characterized by low effective cation exchange capacity, low available water and nutrient reserve, and are highly susceptible to soil erosion (Kang and Juo, 1981).

The restorative power of the bush fallow is linked to the regrowth of deep rooted trees and shrubs that recycle plant nutrients and build up soil organic matter (Nye and Greenland, 1965). During the fallow period plant cover and litter protect the soil from the impact of high intensity raindrops and the roots help to bind the soils, increase water infiltration and reduce runoff and soil erosion. Moreover, litter mulch and shading by tree and shrub canopies reduce soil temperature and maintain soil moisture conditions that are favorable for the growth of beneficial soil macro- and microorganisms.

[1]The humid zone is defined as areas with precipitation equal to or greater than potential evapotranspiration for six to eight months of the year. In the subhumid zone, precipitation is equal to or greater than potential evapotranspiration for four to five months of the year.

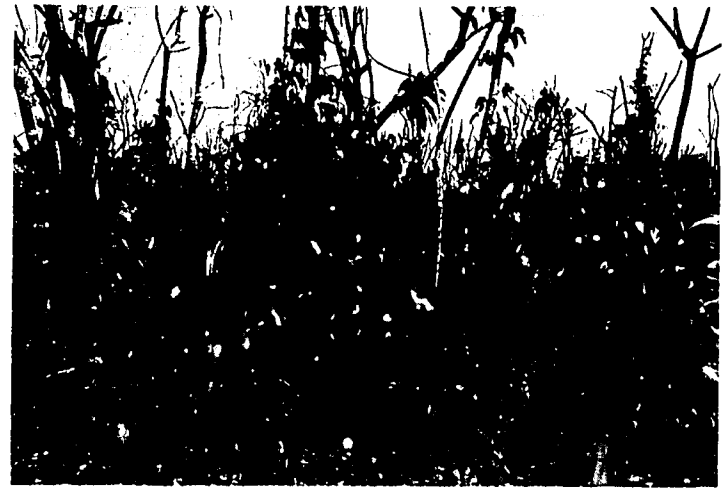

Figure 1. Traditional farm plot near Onne in southeastern Nigeria showing mixed cropping of maize and yam growing on newly cleared land after 7 years of bush fallow. In-situ grown *Anthonata macrophylla* stakes are used for staking yam.

This shading also reduces weed infestation.

In addition to restoring soil fertility, the bush fallow provides supplementary food, animal feed, staking material, firewood and herbal medicine (Okigbo, 1983).

Where land is abundant the bush fallow has been found to be a stable and efficient biological method for soil productivity restoration. Food crops grow well on newly cleared land following a long rest period under bush fallow, as illustrated in the example from south-

Figure 2. Alley cropping maize with *Leucaena leucocephala* at IITA.

eastern Nigeria shown in Figure 1.

Increasing land pressure, resulting from rapid population growth in many parts of the tropics, has resulted in a shortening of the fallow periods. Over-exploitation of land dominated by highly weathered kaolinitic soils can easily lead to soil degradation, a rapid decline in crop yield and invasion by noxious weeds, including difficult to control grass species.

Since farmers in many developing countries in the tropics cannot afford costly inputs, it is necessary to develop a low input soil management technology that can sustain crop production. One promising technique is alley cropping.

This bulletin describes the basic principles and results of six years of alley cropping research conducted mainly at the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria.

The Alley Cropping Food Production Method

Alley cropping is essentially an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees or shrubs (Kang *et al.*, 1981b; Wilson and Kang, 1981). The hedgerows are cut back at planting and kept pruned during cropping to prevent shading and to reduce competition with food crops (Fig. 2). When there are no crops, the hedgerows are allowed to grow freely to cover the land.

Alley cropping retains the basic features of bush fallow. It can easily be adopted by resource-poor farmers in the tropics. Trees and shrubs in the alley system:

- Provide green manure or mulch (Fig. 3) for companion food crops. In this way plant nutrients are recycled from deeper soil layers.
- Provide prunings, applied as mulch, and shade during the fallow to supress weeds.

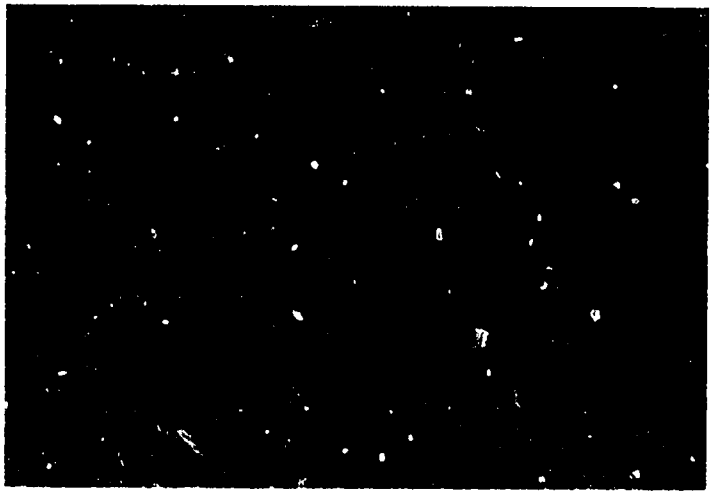

Figure 3. Mulch cover from *Acioa barterii* prunings.

- Provide favorable conditions for soil macro- and microorganisms.
- When planted along the contours of sloping land, provide a barrier to control soil erosion.
- Provide prunings for browse, staking material and firewood.
- Provide biologically fixed nitrogen to the companion crop.

The major advantage of alley cropping over the traditional shifting cultivation and bush fallow systems is that the cropping and fallow phases can take place concurrently on the same land, thus allowing the farmer to crop for an extended period without returning the land to bush fallow.

Tree and Shrub Species

A number of trees and shrubs are potentially suitable for alley cropping, but only a few have been tested. Trees and shrubs tested so far include the leguminous species *Leucaena leucocephala*, *Gliricidia sepium*, *Flemingia congesta* and the nonleguminous species, *Alchornea cordifolia*, *Acioa barterii* and *Gmelina arborea*. The importance of some species in soil fertility regeneration in the traditional bush fallow has been recognized by farmers in many parts of the tropics as evidenced by their selective retention of these species in the fallow. In areas of high population density, selective retention has resulted in fewer species being left in the bush fallow (Obi and Tuley, 1973). In several areas of southeastern Nigeria, for example, where there were normally many species in the natural fallow, only four species are now predominant, *Alchornea cordifolia*, *Acioa barterii*, *Anthonata macrophylla* and *Dialium guineense* (Table 1).

To evaluate and select suitable tree and shrub species for alley cropping, field testing is currently being

Table 1. Vegetation density of three- and seven-year-old bush fallow in southeastern Nigeria (Getahun *et al.*, 1982)

Species	AKWA 3-year	AKWA 7-year	IKOT-EKPENE 3-year	IKOT-EKPENE 7-year
	Density/ha (%)			
Dialium guineense	48.8	41.0	0.8	—
Anthonata macrophylla	27.0	34.6	53.4	33.7
Pentaclethra macrophylla	2.4	—	—	—
Acioa barterii	12.7	23.9	—	3.6
Alchornea cordifolia	9.5	0.5	15.3	51.2
Napeliona imperialis	—	—	—	3.6
Unknown	—	—	30.5	7.8
Total	100.0	100.0	100.0	99.9
Total plants/ha	1,008	1,504	1,048	1,328

conducted on Alfisols (pH- 5.6) at IITA in Ibadan (Fig. 4) and also on acid Ultisols (pH- 4.5) at IITA's high rainfall substation near Onne in southeastern Nigeria.

Trees and shrubs suitable for alley cropping should meet most of the following criteria:

- Can be established easily
- Grow rapidly
- Have a deep root system
- Produce heavy foliage
- Regenerate readily after pruning
- Have good coppicing ability

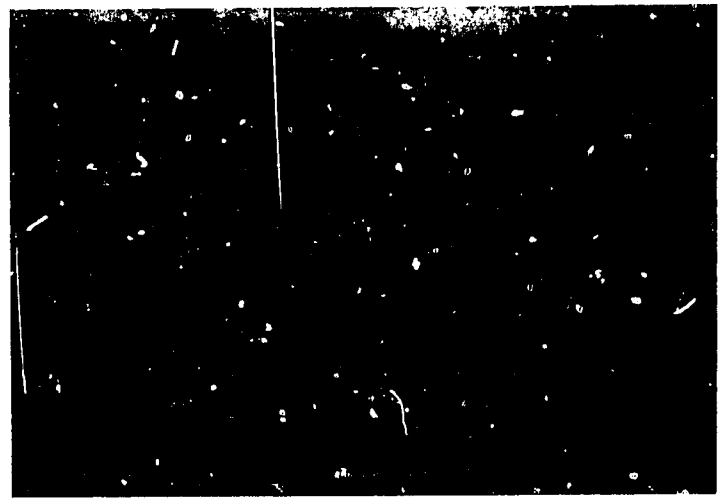

Figure 4. Field testing tree and shrub species for suitability for alley cropping with food crops at IITA.

- Are easy to eradicate
- Provide useful by-products

Leguminous trees and shrubs, because of their ability to fix atmospheric nitrogen, are preferred over non-legumes.

Few species meet all of the above-mentioned criteria and some have disadvantages that must be overcome. Leucaena, for example, has slow early growth, and its seedlings must be protected against weeds during early

establishment. But once established, leucaena seedlings grow vigorously.

Multipurpose species are generally preferable because they give the alley cropping system flexibility. Occasionally it may be necessary to choose a species that is excellent for a specific purpose – for example, *Acioa barterii* for its slow decomposing mulch or the fast growing *Calliandra calothyrsus* for its ability to produce a large amount of firewood within a short time (NAS, 1983).

Establishment of Trees and Shrubs

Direct seeding is the easiest and cheapest method of establishing hedgerows. Seeds carried in pockets or small bags can be planted by hand or with simple planters. However, seedlings from direct seeding are usually very small during early development and must be given extra care and protection.

A cheap and easy way of establishing leucaena hedgerows is by direct seeding in the same row with a crop such as maize (Fig. 5). With this method of establishment, there is no extra weeding cost for the leucaena during early growth. The slower growing leucaena can also benefit from residual fertilizer applied to the maize crop. At the time of maize harvest, the leucaena has normally reached a height of 750 cm (Table

Figure 5. *Leucaena leucocephala* **established with a maize crop at harvest time.**

Table 2. Height and diameter of *Leucaena leucocephala* established with maize and maize/cassava after maize harvest (G. F. Wilson, unpublished data).

Cropping system	Height (cm)	Girth (cm)
Maize/leucaena	375	2.72
Maize/leucaena/cassava	370	2.62
Leucaena	445	3.14
LSD 0.05	74	0.25

2) and is able to outgrow the weeds.

Seeds of certain legumes, such as leucaena, require scarification for good germination. Scarification can be done manually or by hot water or acid treatments. The hot water treatment is frequently used. This is done by immersing the seeds in four to ten times their volume of hot water (90 C) and allowing them to soak in the gradually cooling water for 12 to 24 hours. This treatment can give erratic results. Acid treatment is a more reliable method of scarification. Seeds are treated for 60 minutes with concentrated (commercial grade) sulphuric acid (98%, 36 *N*) at a seed to acid ratio of about 10:1 by volume. Following treatment the seeds are immediately rinsed in running water to remove traces of acid.

Transplanting is used when direct seeding does not give desirable results or for seeds that rapidly lose their viability during storage, as do the seeds of *Acioa barterii*. Seedlings grown in nursery beds are transplanted as bare root seedlings. Those grown in perforated plastic bags are transplanted with the bags, or the bags are removed at transplanting. Bagged seedlings, however, are bulky, difficult to transport and thus expensive to handle. Generally, the seedlings are tall enough to have a competitive edge over weeds and require less care and protection during early development.

Cutting is an alternative method for establishing some species, but it is only recommended when direct seeding is not feasible. For example, gliricidia can be established by direct seeding, but woody cuttings 50 cm or more in length often give better results.

Soil and climatic factors are important for successful establishment. Leucaena and gliricidia, for example, establish well in non-acid soils with adequate annual precipitation. On strongly acidic soils, soil amendments, particularly phosphorus and lime, are needed for good growth of these species. Inoculation with compatible rhizobium strains is sometimes necessary for rapid establishment.

Alley Width

Four meters between hedgerows is quite satisfactory for continuous food crop production with or without the use of a tractor. However, if the purpose of alley cropping is to provide in-situ staking material for a yam crop, the spacing should be adjusted to suit the yam

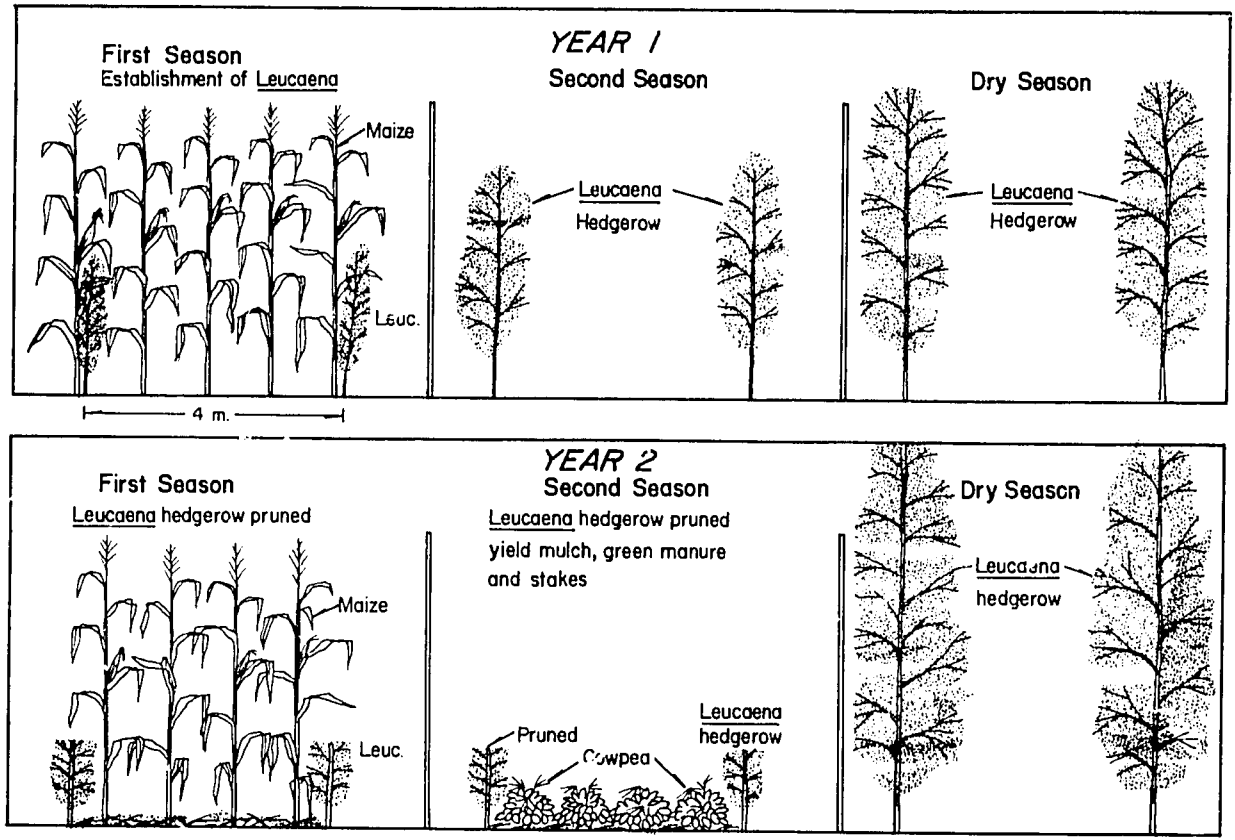

Figure 6. Cropping sequence diagram for establishing *Leucaena leucocephala* hedgerows (spaced 4 m) for alley cropping with sequentially cropped maize and cowpeas.

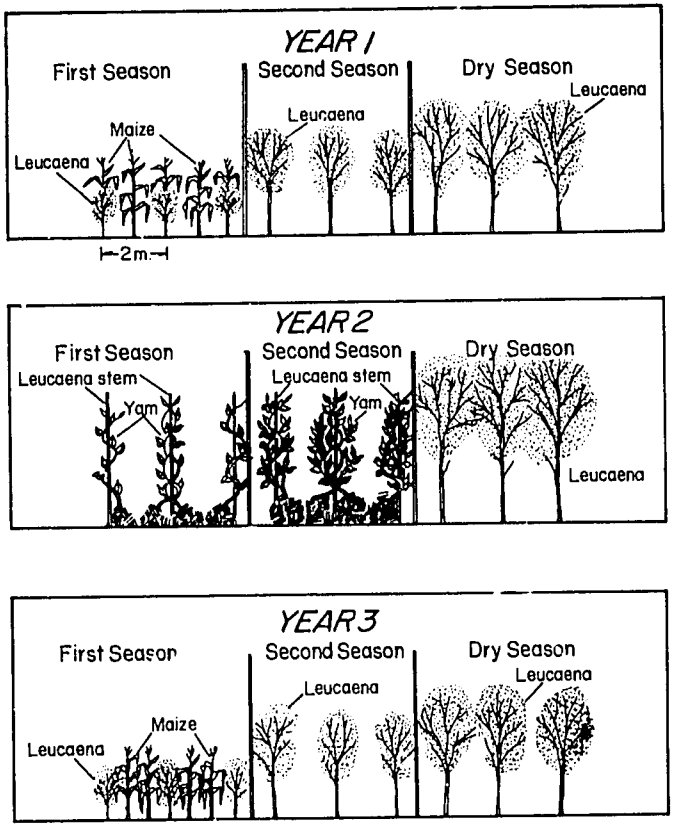

Figure 7. Cropping sequence diagram for establishing *Leucaena leucocephala* hedgerows (spaced 2 m) for alley cropping maize and for in-situ yam vine support.

spacing. Figures 6 and 7 show leucaena alleys with 4-m and 2-m interrow spacing. The latter has been used for in-situ yam staking.

Within the hedgerows, trees and shrubs can be spaced 25 to 100 cm apart depending on the species.

Pruning

During cropping, pruning of the hedgerow is necessary to avoid shading of the companion crop. Table 3 shows changes in the percentage of incoming light (global radiation) incident on alley cropped cowpeas before and after pruning of the leucaena hedgerows. Results of this and various other experiments carried out at IITA in Ibadan show that pruning heights of 25 to 75 cm are satisfactory. East-west orientation of the hedgerows also minimizes shading.

Table 3. Percentage of daily global radiation (RG) incident on cowpeas alley cropped with *Leucaena leucocephala* before and after the pruning of hedgerows (T.L. Lawson, unpublished data).

Season	Period/time	Percent radiation (RG) incident on the cowpea crop W*	M*	E*	Mean
2nd, 1982	Before pruning	41	82	49	57
	After pruning	89	98	90	92

*W and E refer to the west and east sides of the plots, close to the leucaena rows, which are 4 m apart and orientated north-south; M refers to the middle of the plot, midway between the leucaena rows.

Pruning can be done manually using a sharp cutlass or slasher (Fig. 8). A dull cutlass or slasher that strips the bark will delay coppicing and result in the death of the plants. For pruning large plots, Howard rotary blades have given good results. This implement can cut back one hectare of one-year-old leucaena hedgerows spaced 4 m apart in about one hour. Small, $2\frac{1}{2}$-horsepower backpack brush cutters have also given satisfactory results for pruning of uniform size plants with a diameter of less than 3 cm. It requires approximately eight hours to prune one hectare with brush cutters.

Pruning intensity varies with the shrub or tree species. As a general rule, the lower the hedgerows and the taller the crop, the less frequently is pruning needed. Fast growing plants, such as leucaena and gliricidia, require pruning every five to six weeks during cropping.

Too low and too frequent pruning of the hedgerows should be avoided as it may result in dieback.

Figure 8. Pruning *Leucaena leucocephala* **hedges.**

Staking for Vine Support

An added benefit of alley cropping is that stems produced by trees and shrubs grown in the hedgerows can be used for supporting climbing plants such as beans (Rachie, 1983) and yams (Wilson and Akapa, 1981). Major methods of using these stems are:

- In-situ live staking: Live stems serve to support nearby climbing plants. Figure 7 illustrates an alley cropping rotation between maize/leucaena and yam/leucaena. At the start of yam growth, the stems are cut back to a height of about 2.0 m to keep them within reach for pruning. A major disadvantage of this method is the difficulty of pruning the leucaena stem when the yam vines reach the top of the stem.
- In-situ dead staking: The stems are killed close to the ground either with fire or by girdling and used as support for the climbing crop planted close by.

A mechanized form of alley cropping with cowpeas and leucaena.

Cutting back is unnecessary, and the climbing plants can grow higher for better leaf exposure.

- Cut and carry staking: The stakes are cut and used outside the alley cropping area. This method is favored by farmers who are currently testing alley cropping in the yam growing area of east central Nigeria. This work has led to the development of stake lots in which a fast growing tree, such as leucaena, can be planted more densely than in alley cropping for the sole purpose of producing stakes. Stake lots can be established on marginal land.

Tillage

Conventional tillage involving plowing and harrowing is not required. Whether tillage is used or not makes only a small difference in the yield of the alley crop as long as there is adequate mulch from the prunings (Table 4). However, occasional shallow tillage between the hedgerows that will partially trim the surface roots of the shrubs or trees is recommended.

Weed Control

The control or suppression of noxious weeds, a major function of the bush fallow, is also a major attribute of alley cropping. Shading by trees or shrubs during the fallow suppresses most weeds. The prunings, applied as mulch, also suppress weeds. Weed growth after a rotation of maize followed by one year of naturally regenerated fallow compared with that after one year of leucaena (regrowth of hedgerows) fallow shows that most weed species are suppressed by leucaena (Table 5). Although volunteer leucaena became the major weed in leucaena fallow, its adverse effect on maize yield was less than that of weeds from the short natural fallow where weeds were not controlled (Table 6).

Prunings from *Acioa barterii* (Fig. 9) and *Alchornea cordifolia*, which decompose slowly, are effective when

Table 4. Effect of tillage and no-tillage on yields of sequentially cropped maize and cowpea grown on Apomu loamy sand (Psammentic Ustorthent) in alley cropping with *Leucaena leucocephala* (B.T. Kang, unpublished data).

Treatment	Maize yield (main season) (tons/ha)		Cowpea yield (minor season) (tons/ha)	
N rate* (kg N/ha)	1982	1983	1982	1983
		Tillage		
0	2.10	1.92	0.61	0.45
40	2.67	2.41	0.47	0.57
80	2.91	3.16	0.48	0.45
		No-Tillage		
0	1.57	2.17	0.53	0.50
40	2.29	3.03	0.54	0.51
80	2.42	3.97	0.49	0.49
LSD 0.05	0.44	0.79	0.15	0.09

*Nitrogen applied only to the main season maize and not to the minor season cowpea.

Table 5. Weed species under maize following one year of natural fallow regeneration or leucaena (alley cropping) fallow (G.F. Wilson, unpublished data).

Species	Natural regeneration Presence	Natural regeneration Percent	Leucaena alleys Presence	Leucaena alleys Percent
Leucaena leucocephala	–	–	+	92.60
Synedrella nodiflora	+	38.05	+	4.25
Rottboellia exaltata	+	22.85	–	–
Euphorbia heterophylla	+	15.69	+	–
Brachiaria deflexa	+	4.06	–	–
Commelina spp.	+	8.54	–	–
Talinum triangulare	+	4.26	+	2.10
Spigelia anthelmia	+	1.57	–	–

+ = Present
– = Not present

applied in sufficient quantities as mulch for suppressing weed growth. The suppression of weeds is therefore viewed as a major advantage of alley cropping, especially in small scale farming where weeding can take more than 30% of the labor used in crop production.

Biomass Production and Nutrient Recycling

The giant *Leucaena leucocephala* varieties are known to produce substantial biomass (Brewbaker and Hutton, 1979). This has been confirmed by observations at Ibadan. A well-established hedgerow of *Leucaena leucocephala* variety K-28 grown on a sandy Entisol at 4-m interrow spacing produced between 15 and 20 tons of fresh prunings (5.0 to 6.5 tons of dry matter) per hectare with five prunings per year. These prunings, excluding stakes, yielded over 160 kg N, 15 kg P, 150 kg K, 40 kg Ca and 15 kg Mg/ha/year. The high nitrogen yield from leucaena is well known (NAS, 1977). Guevarra *et al.* (1978) reported nitrogen fixation as high as 500 to 600 kg N/ha/year under favorable growing conditions in Hawaii. Rachie (1983) reported a nitrogen yield of 127 kg/ha from four-month-old leucaena plants grown in the Cauca valley of Colombia.

Table 6. The effects of chemical weed control on maize grain yield following one year of natural fallow regeneration or leucaena alley cropping fallow (G.F. Wilson, unpublished data).

	Atrazine (kg/ha) 0	2.5	3.0
	yield (tons/ha)		
1st Season			
Alley cropping	2.74 a	3.37 a	3.88 a
Natural fallow	0.95 b	4.53 a	4.53 a
2nd Season			
Alley cropping	1.48 b	2.43 a	2.56 a
Natural fallow	0.68 b	2.40 a	2.47 a

Values within columns followed by the same letter are not significantly different at 5% level according to Duncan's multiple range test.

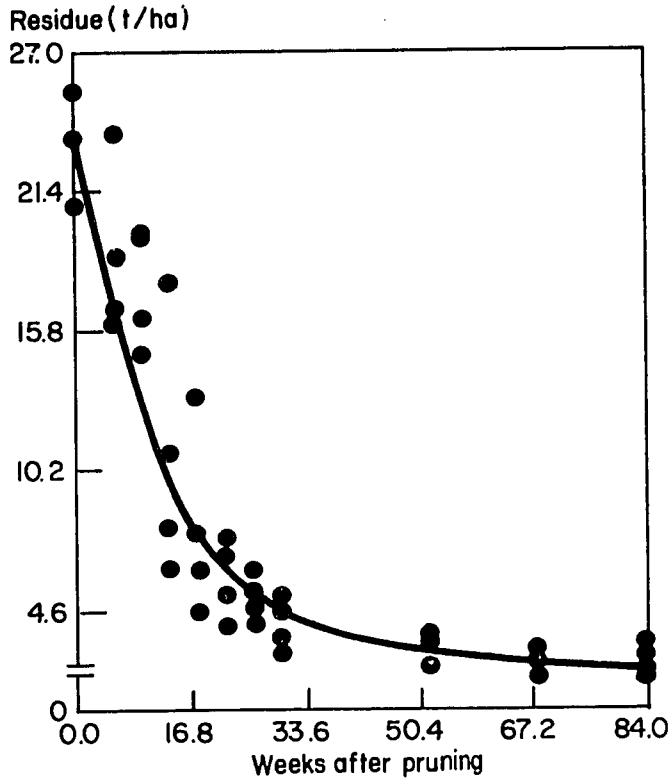

Figure 9. Change with time in amount of residual *Acioa barterii* prunings applied as mulch (IITA, 1982).

Biomass production and nutrient recycling depends on factors such as plant species, spacing, soil and climatic conditions (Guevarra *et al.*, 1978; Rachie, 1983). As shown in Table 7, prunings from different species exhibit large differences in nutrient composition. Among the four species studied, leucaena has the highest nutrient concentration.

Table 7. Nutrient composition of prunings of four tree and shrub species grown on Egbeda sandy loam (Oxic Paleustalf) (Koudoro, 1982).

	N	P	K	Ca	Mg
			(%)		
Gliricidia sepium	4.21	0.29	3.43	1.40	0.40
Leucaena leucocephala	4.33	0.28	2.50	1.49	0.36
Alchornea cordifolia	3.29	0.23	1.74	0.46	0.20
Acioa barterii	2.57	0.16	1.78	0.90	0.27

Depending on the species, prunings from the hedgerows can also produce substantial quantities of stakes. Fully grown leucaena and gliricidia hedges sequentially cropped with maize and cowpeas in the Ibadan area and periodically pruned back to a height of 75 cm produce over 5.7 and 1.4 tons/ha of dry weight of stakes, respectively (Table 8). At Ibadan many of the stakes were produced during the dry season (November to March) when there is no cropping and the hedgerows are not pruned. Utilizing subsoil moisture during the four-month dry season, leucaena and gliricidia hedgerows grew 4.0 m and 2.5 m, respectively. When allowed to grow uninhibited for one year, the leucaena

Table 8. Dry weight of usable stakes (> 2 m length) from prunings of *Leucaena leucocephala* and *Gliricidia sepium* alley cropped with maize and cowpea on Egbeda sandy loam (Oxic Paleustalf) (B.T. Kang, unpublished data).

Hedgerow spacing	Dry weight stakes Gliricidia (tons/ha/five prunings/year)	Leucaena
2 m	2.64	6.98
4 m	1.47	5.78
LSD 0.05	0.86	

hedgerow easily reached a height of over 7.5 m and produced more than 88 tons of wood per hectare (Fig. 10).

Effect on Soil Properties

Six years of alley cropping leucaena with maize and cowpeas on a low fertility Entisol has given very encouraging results. Periodic addition of leucaena prunings helped to maintain higher soil nutrient and organic matter content (Table 9). Plots receiving prunings contained twice the amount of soil organic matter as plots where prunings were removed. Repeated application of nitrogen fertilizer increased soil acidity, but the addition of leucaena prunings did not affect soil acidity.

Plots receiving leucaena prunings also maintained higher soil moisture status (Fig. 11). Mulch from

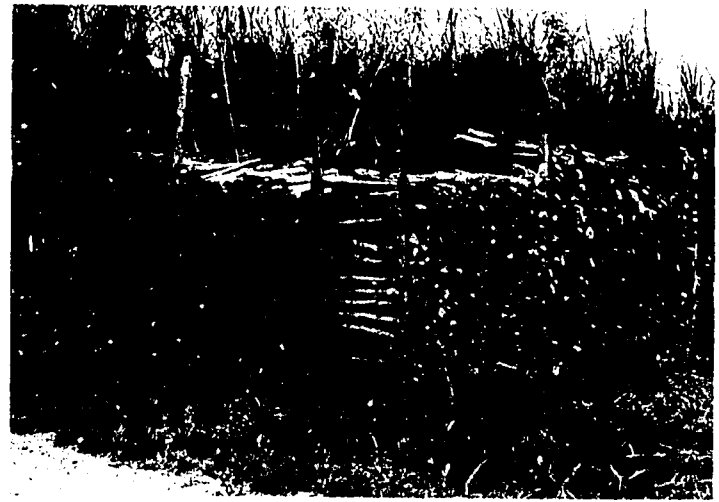

Figure 10. *Leucaena leucocephala* **prunings as source of firewood.**

Table 9. Effect of six years of alley cropping maize and cowpea with *Leucaena leucocephala* and nitrogen application on some chemical properties of surface soil of Apomu loamy sand (Psammentic Ustorthent) (B.T. Kang, unpublished data).

Treatments (kg N/ha)	Leucaena prunings	pH-H_2O	Org. C (%)	Exchangeable K (me/100g)	Ca	Mg	Bray p-1 (ppm)
0	Removed	6.0	0.65	0.19	2.90	0.35	27.0
0	Retained	6.0	1.07	0.28	3.45	0.50	26.2
80	Retained	5.8	1.19	0.26	2.80	0.45	25.6
LSD 0.05		0.2	0.14	0.05	0.55	0.11	5.3

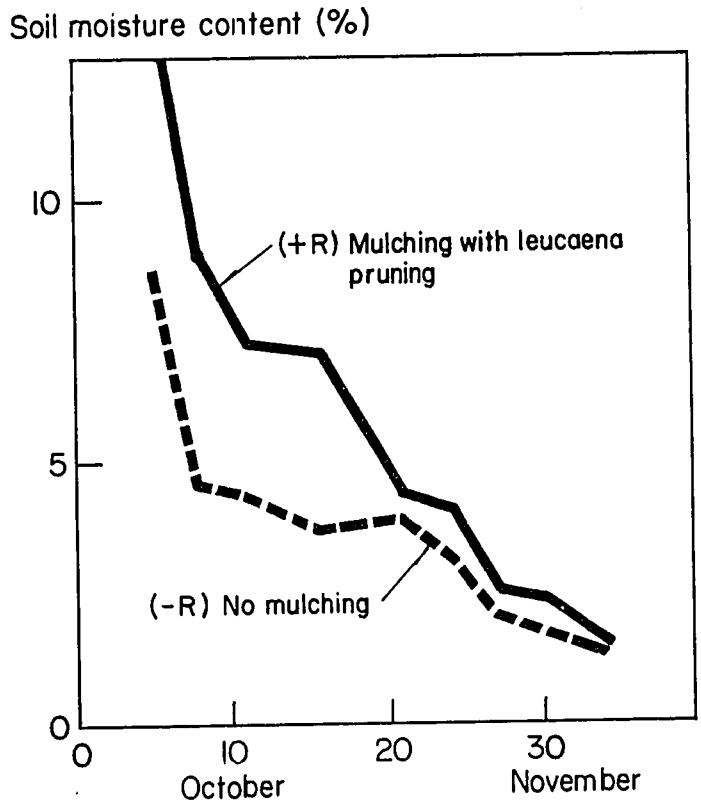

Figure 11. Soil moisture content of Apomu loamy sand (Psammentic Ustorthent) sampled at 5-15 cm depth from plots receiving leucaena prunings (+R) and no leucaena prunings (−R) (H. Grimme, unpublished data).

prunings lowered soil temperature and enhanced biological (particularly earthworm) activity.

Crop Performance

The recycling of nutrients to the surface soil is one of the basic assets of alley cropping. Where nitrogen-fixing leguminous trees or shrubs are used, some of the nitrogen fixed is eventually released to the companion crops through decomposition of prunings (leaves and twigs).

It has been observed (Kang *et al.*, 1981a) that leucaena prunings are a more effective nitrogen source when incorporated in the soil than when applied as mulch (Table 10). The better results obtained with incorporation may be due to faster decomposition and mineralization of prunings (Fig. 12). Buried in the soil, fresh leucaena prunings have a half-life of less than 10 days. The lower efficiency of surface applied prunings may be due to high losses from N volatilization during decomposition (A.D. Messan, personal communication). The high nitrogen efficiency obtained with incorporation may not always be desirable or practical, especially where other benefits can be obtained by applying the prunings as mulch.

Despite the high nitrogen yield from the prunings of leucaena hedgerows, the benefit from the nitrogen added with the prunings to the food crop was less than 50% (Guevarra *et al.*, 1978; Kang *et al.*, 1981a). Even

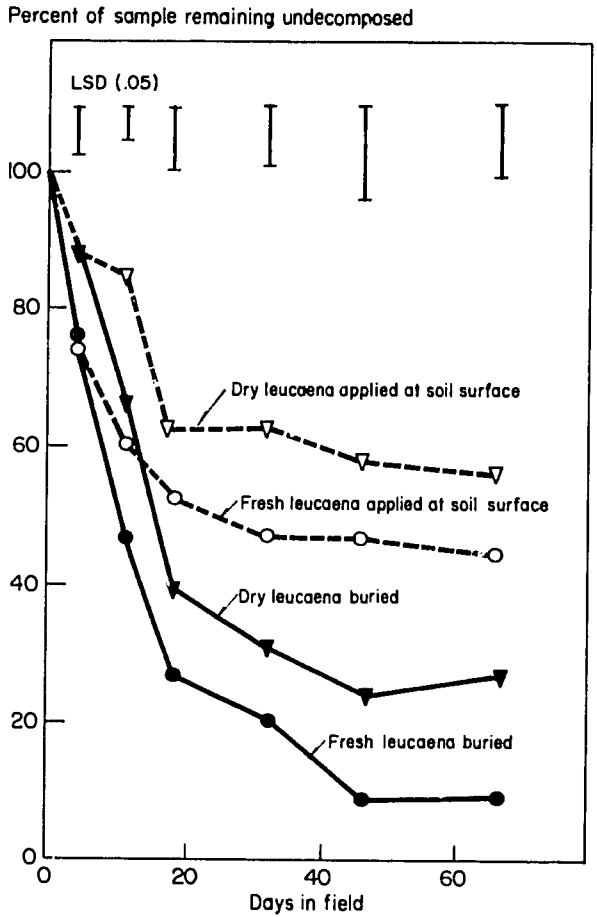

Figure 12. Decomposition of fresh and dry leucaena prunings applied as mulch or buried in soil (Read, 1982).

Table 10. Effect of applications of *Leucaena leucocephala* prunings and inorganic nitrogen on grain yield of maize grown on Apomu loamy sand (Psammentic Ustorthent) (Kang *et al.*, 1981a)

Leucaena rate (tons/ha)	N rate (kg N/ha)	Leucaena prunings Incorporated (grain yield/kg/ha)	Mulch
0	0	1283	1740
	50	2093	2218
	100	3315	3138
5	0	2313	2013
	50	3035	2300
	100	3453	3028
10	0	3213	1855
	50	2578	2338
	100	3068	3023
Mean		2705	2406

LSD 0.05 Between means of methods of leucaena placement, 688. Between treatments in different leucaena placement methods, 1146.

so, the amount of nitrogen utilized was a significant portion of the crop requirement (Fig. 13). For maize, relatively low rates of additional fertilizer nitrogen were required for obtaining optimum yield. On a sandy Entisol at Ibadan, yield of maize alley cropped continuously for six years has been maintained at about 2 tons/ha with the addition of leucaena prunings only (Table 11).

Table 11. Main season grain yield of maize variety TZPB alley cropped with *Leucaena leucocephala* on Apomu loamy sand (Psammentic Ustorthent) as affected by application of leucaena prunings and nitrogen (B.T. Kang, unpublished data)

N rate (kg N/ha)	Leucaena prunings	Year 1979	1980	1981*	1982	1983
				(tons ha)		
0	Removed	–	1.04	0.48	0.61	0.26
0	Retained	2.09	1.91	1.21	2.10	1.92
80	Retained	3.54	3.26	1.89	2.91	3.16
LSD 0.05		0.36	0.31	0.29	0.44	0.79

*Maize crop seriously affected by drought during early growth.

Table 12. Main season grain yield of maize variety TZPB and seed yield of minor season cowpea variety VITA-6 alley cropped with *Gliricidia sepium* grown on an Alagba sandy loam (Oxic Paleustalf) at Ikenne in southern Nigeria (B.T. Kang and G.F. Wilson, unpublished data).

Treatment N rate (kg N ha)	Gliricidia prunings	Maize[1]	Cowpea[2]
		(kg ha)	
0	Removed	2699	738
0	Retained	3037	818
40	Retained	3291	820
80	Retained	3125	994
LSD 0.05		427	187

[1]N applied to main season maize.

[2]Cowpea plantings following maize in minor season and received no N application.

With low intensity cropping on an Alfisol, in which maize was alley cropped with leucaena only in alternate years, maize grain yield exceeded 4.0 tons/ha with the addition of leucaena prunings only.

Investigations on Alfisols and Entisols in southern Nigeria have shown that cropping maize and cowpeas sequentially with either leucaena or gliricidia is a promising alley cropping system. Studies conducted on Alfisols at Ikenne (Table 12) and at Ibadan (Tables 13 and 14) with maize alley cropped with gliricidia showed that at both locations gliricidia prunings met the nitrogen requirement of maize. Cowpeas grown follow-

Table 13. Effects of alley cropping and fertilizer application on yield of maize and cowpea grown on Egbeda sandy loam (Oxic Paleustalf) (G.F. Wilson, unpublished data).

Species	Maize yield No F	+ F[1]	Mean	Cowpea yield No F	Res.F	Mean
			(tons ha)			
Natural regrowth (control)	2.8	4.4	3.6	0.84	0.81	0.83
Acioa barterii	3.2	4.5	3.9	0.63	0.62	0.63
Gliricidia sepium	4.4	5.2	4.8	0.63	0.78	0.71
Mean	3.5	4.7		0.70	0.74	

LSD 0.05 For maize yield: between species, 1.1; between fertilizer means, 0.8; between fertilizer within species, 1.4 and, between fertilizer among species, 1.5.
For cowpea yield: differences insignificant

[1] (+ F), fertilizer applied to maize only: 60 N-60P_2O_5-60K_2O in kg/ha

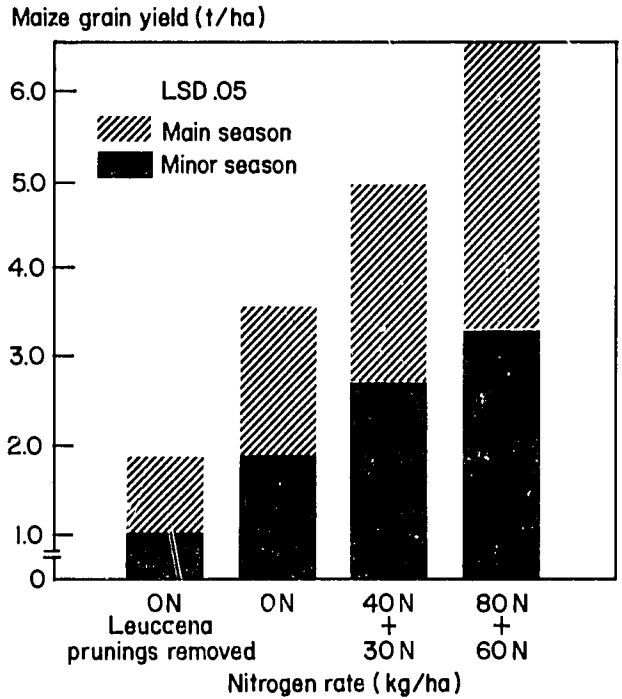

Figure 13. Grain yield of maize alley cropped with *Leucaena leucocephala* grown on Apomu loamy sand (Psammentic Ustorthent) as affected by application of leucaena prunings and nitrogen (main season variety TZPB; minor season variety TZE) (Kang *et al.*, 1981b).

Figure 14. Alley cropping with *Gliricidia sepium*.

ing maize in alley cropping with gliricidia (Figure 14 and Table 12) required no fertilizer application.

The potential of alley cropping pluvial rice and root and tuber crops with leucaena and gliricidia is currently being investigated. Very promising results were obtained from alley cropping cassava with gliricidia (Table 14) and also from alley cropping of pluvial rice and yams with leucaena on Alfisols.

Planting leucaena hedges along contours is reported to control soil erosion (Prussner, 1982). Thus, alley cropping may be a suitable food crop production

Table 14. Yield of maize and cassava alley cropped with *Gliricidia sepium* and grown on Egbeda sandy loam (Oxic Paleustalf) (G.F. Wilson, unpublished data).

Nitrogen rate (kg N/ha)	Control		Prunings applied as mulch		Prunings incorporated in soil	
	Maize	Cassava	Maize	Cassava	Maize	Cassava
	(tons/ha)					
0	2.11	23.04	2.36	25.46	2.76	22.79
45	2.69	24.37	2.70	29.67	2.82	23.26
90	2.91	25.18	3.01	31.62	3.03	29.07

LSD 0.05: Maize, 0.45; Cassava, 6.12

method on sloping land where soil erosion is a serious problem. The potential of using alley cropping for large scale food crop production on sloping land is currently being investigated.

Fodder

Alley cropping was originally developed to maintain soil fertility for food crops. However, where the hedgerow species are suitable for fodder, an animal component (e.g., small ruminants) could be introduced into the system. The hedgerow species are usually leguminous trees or shrubs which provide high protein fodder. For example, leucaena and gliricidia fodders are well known for their high protein content.

The Small Ruminant Programme of the International Livestock Centre for Africa (ILCA) has recognized the potential of this system. Collaborative research between IITA and ILCA on the integration of crops and small ruminants in a comprehensive alley farming system are being conducted (Sumberg, 1984). Leucaena and gliricidia used in such a system have produced sufficient fodder for dry season home feeding (Fig. 15).

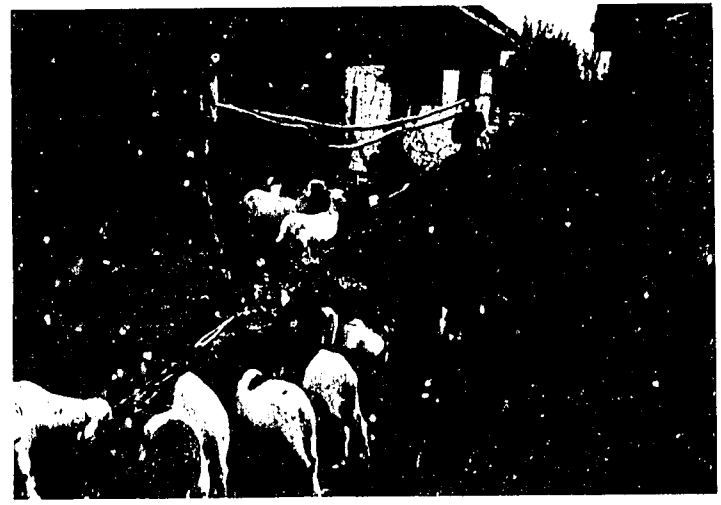

Figure 15. Feeding goats and sheep with leucaena prunings in a cut-and-carry system (Courtesy of Dr. A.N. Atta-Krah, ILCA).

Summary and Conclusions

Although bush fallow and shifting agriculture provides only a subsistence living, it is ecologically stable and therefore suited to the tropical environment. Unfortunately, most programs for improving agriculture in the tropics have tried to remove components of the bush fallow system, replacing them with destabilizing temperate climate farming methods.

Alley cropping is a stable alternative to the bush fallow system. It retains the basic principles and components of traditional agriculture while introducing important improvements. In the traditional system trees and shrubs are grown in a random mixture. But in alley cropping they are planted in an organized system, which makes possible continuous cultivation of food crops.

Biological recycling of nutrients and soil conservation, suppression of weeds and rapid production of by-products such as stakes and firewood are major advantages of alley cropping. Where firewood has become scarce as a result of increased demand for land for crops and livestock production, alley cropping or alley farming offers a means of combining crops and/or livestock with firewood production.

Research at IITA on alley cropping has led to the development of the following alley cropping systems:

- The leucaena/gliricidia maize-cowpea alley cropping system.
- The leucaena-maize-yam alley cropping system.
- By integrating leucaena and gliricidia alley cropping with livestock production, ILCA has developed alley farming, a promising small ruminant production system for the humid region of Africa.

Intensive work with alley cropping has been done on the high base status or less acidic Alfisols and associated Inceptisols and Entisols. More research is in progress on the low base status and acidic Ultisols. Suitable tree and shrub species (particularly legumes) have yet to be identified. Promising species such as *Gmelina arborea*, *Acioa barterii*, *Flemingia congesta*, *Alchornea cordifolia* and others are being tested on acid soils (Typic Paleudult) at IITA's high rainfall substation at Onne.

As a biological low input production system, alley cropping should be a preferred production technique in developing countries where shortages of foreign exchange prohibits the importation or use of large quantities of inputs such as fertilizers and pesticides.

References

Brewbaker, J.L., and Hutton, E.M. 1979. Leucaena – versatile tree legume. In *New Agricultural Crops, AAAS Selected Symposium*, ed. G.A. Ritchie, pp. 207–259. Boulder, Colorado: Westview Press.

Getahun, A., Wilson, G.F., and Kang, B.T. 1982. The role of trees in farming systems in the humid tropics. In *Agroforestry in the African Humid Tropics*, ed. L.H. MacDonald, pp. 28–35. Tokyo: United Nations University.

Guevarra, A.B., Whitney, A.S., and Thompson, J.R. 1978. Influence of intra-row spacing and cutting regimes on the growth and yield of leucaena. *Agron. J.* 70: 1033–1037.

International Institute of Tropical Agriculture. 1982. Use of *A. barterii* as a beneficial mulch in alley cropping. *Research Highlights*, pp. 32–33. Ibadan: IITA.

Kang, B.T., and Juo, A.S.R. 1981. Management of low activity clay soils in tropical Africa for food crop production. Paper read at Fourth International Soil Classification Workshop, 2–12 June 1981, Kigali, Rwanda.

Kang, B.T., Sipkens, L., Wilson, G.F., and Nangju, D. 1981a. Leucaena (*Leucaena leucocephala* (Lam) de Wit) prunings as nitrogen source for maize (*Zea mays* L). *Fert. Res.* 2: 279–287.

Kang, B.T., Wilson, G.F., and Sipkens, L. 1981b. Alley cropping maize (*Zea mays* L) and leucaena (*Leucaena leucocephala* Lam) in southern Nigeria. *Plant and Soil* 63: 165–179.

Koudoro, D. 1982. "Evaluation of four woody fallow species for alley cropping with maize and cowpeas." M.Sc. thesis, National University of Benin, Cotonou, Benin.

National Academy of Sciences. 1977. *Leucaena. Promising Forage and Tree Crop for the Tropics.* Washington, D.C.: National Academy Press.

National Academy of Sciences. 1983. *Calliandra. A Versatile Small Tree for the Humid Tropics.* Washington, D.C.: National Academy Press.

Nye, P.H., and Greenland, D.J. 1965. *The Soil Under Shifting Cultivation.* Technical Communication 51. Harpenden, England: Commonwealth Bureau of Soils.

Obi, J.K., and Tuley, P. 1973. *The Bush Fallow and Ley Farming in the Oil Palm Belt of Southern Nigeria.* Miscellaneous Report 161. London: Overseas Development Ministry.

Okigbo, B.N. 1983. Plants and agroforestry in land use systems of W. Africa. In *Plant Research in Agroforestry*, ed. P.A. Huxley, pp. 25–41. Nairobi, Kenya: International Council for Research in Agroforestry.

Prussner, K.A. 1982. Overcoming critical lands: examples in East Nusa Tenggara. National Leucaena Seminar I, 23–25 August 1982, Jakarta, Indonesia.

Rachie, K.O. 1983. Intercropping tree legumes with annual crops. In *Plant Research and Agroforestry*, ed. P.A. Huxley, pp. 103–116. Nairobi, Kenya: International Council for Research in Agroforestry.

Read, M.D. 1982. "Management alternatives for maize-bean and leucaena-based cropping systems." Ph.D. thesis, Colorado State University, Fort Collins, Colorado.

Sumberg, J.E. 1984. Small ruminant feed production in a farming systems context. Paper read at Workshop on Small Ruminants Production Systems in the Humid Zone of West Africa, 22–26 January 1984, International Institute of Tropical Agriculture, Ibadan, Nigeria.

Wilson, G.F., and Akapa, K. 1981. Improving the in-situ stem support systems for yams. In *Tropical Root Crops: Research Strategies for the 1980s*, ed. E.R. Terry *et al.*, pp. 195–197. Ottawa: International Development Research Centre.

Wilson, G.F., and Kang, B.T. 1981. Developing stable and productive biological cropping systems for the humid tropics. In *Biological Husbandry: a Scientific Approach to Organic Farming*, ed. B. Stonehouse, pp. 193–203. London: Butterworth.

For More Information . . .

● **Ibadan Headquarters**

Oyo Road
PMB 5320
Ibadan, Oyo State
Nigeria

Telephone: 413244/413315/413440

Telex: 31417 Tropib NG (or)
20311 TDS IBA NG (Attn: IITA, Box 015)

Cablegram: TROPFOUND, IKEJA

● **Lagos/Ikeja Office**

P.O. Box 145
Ikeja, Lagos State
Nigeria

Telephone: 933931

● **Onne Substation**

PMB 5433
Port Harcourt, Rivers State
Nigeria

● **Benin Substation**

B.P. 06-2523
Cotonou
People's Republic of Benin

Telephone: 300904
Telex: 5329 ITABEN

Acknowledgements

The authors wish to express their special thanks to Dr. A.S.R. Juo, Dr. P. Ay, Mr. J.E. Keyser, Mr. N. Russell, Dr. J. Sumberg, Mr. F.M. Gatmaitan Jr and Prof. W.B. Ward for their invaluable criticisms, suggestions and assistance in the preparation of this bulletin. Appreciation is also given to Ms. A. Ukasoanya for typing the manuscript.

Printed in England by Balding + Mansell Limited

December 1984/4,200/JEK

23