IITA Resource and Crop Management Technologies – An Annotated Bibliography

S.O. Oikeh

About IITA

The International Institute of Tropical Agriculture (IITA) was founded in 1967 as an international agricultural research institute with a mandate for improving food production in the humid tropics and to develop sustainable production systems. It became the first African link in the worldwide network of agricultural research centers known as the Consultative Group on International Agricultural Research (CGIAR), formed in 1971.

IITA is governed by an international board of trustees and is staffed by approximately 80 scientists and other professionals from over 30 countries, and approximately 1300 support staff. Staff are located at the Ibadan campus, and also at stations in other parts of Nigeria, and in Benin, Cameroon, Côte d'Ivoire, and Uganda. Others are located at work sites in several countries throughout sub-Saharan Africa. Funding for IITA comes from the CGIAR and bilaterally from national and private donor agencies.

IITA's mission is to enhance the food security, income, and well-being of resource-poor people primarily in the humid and subhumid zones of sub-Saharan Africa by conducting research and related activities to increase agricultural production, improve food systems, and sustainably manage natural resources, in partnership with national and international stakeholders.

To this end, IITA conducts research, germplasm conservation, training, and information exchange activities in partnership with regional bodies and national programs including universities, NGOs, and the private sector. The research agenda addresses crop improvement, plant health, and resource and crop management within a food systems framework and targetted at the identified needs of three major agroecological zones: the savannas, the humid forests, and the mid-altitudes. Research focuses on smallholder cropping and postharvest systems and on the following food crops: cassava, cowpea, maize, plantain and banana, soybean, and yam.

Cosponsored by the World Bank, the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP), the CGIAR is an informal association of over 40 governments and about 15 international organizations and private foundations. The CGIAR provides the main financial support for IITA and 15 other international centers around the world, whose collective goal is to improve food security, eradicate poverty, and protect the environment in developing countries.

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Preface

Since the 1970s, the International Institute of Tropical Agriculture, through the Resource and Crop Management Division/Farming Systems Program, has developed various prototype technologies to increase food production while conserving the natural resource base in sub-Saharan Africa. The technologies can be classified broadly into three: (1) those on cropping systems based on improved fallow management, including agroforestry (alley farming and multistrata systems), legume cover crops (live-mulch and *in-situ* cover crops), and crop rotation; (2) those on cropping systems based on crops and agroecological zones, including cassava-based for the humid forest, maize-based for the moist savanna, and rice-based for inland valleys, and (3) land and soil management technologies including zero/minimum-tillage.

The bibliography has a summary for each technology that includes a definition and concept of the technology, a brief history of its development, major research results, adoption of the technology, lessons from the adoption, and the future of the technology. It also has an executive summary of abstracts of documented studies in refereed journals, proceedings, book chapters, and Annual Reports. In the case of alley-farming systems, the most researched technology, the literature has been categorized into different components lettered A to F for ease of identification. Each bibliographic entry has letter(s) to identify the components of this technology covered in the study.

This publication is intended to provide scientists with first-hand information on the resource and crop management technologies developed by the Institute. It also provides baseline information for newly recruited scientists who want to have an overview of the research done on resource and crop management to date to avoid duplication of studies. Research managers will find this publication useful as a basis for future research planning.

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Chapter One

1 Technologies on cropping systems based on improved fallow management

1.1 Agroforestry

1.1.1 Alley farming systems

Alley farming is a farming system for food and animal production involving the growing of arable crops in spaces (alleys) between hedgerows of planted fallows of woody shrubs or trees, preferably leguminous species. The fallow species are periodically pruned during the cropping season to prevent shading and to provide mulch and green manure for the companion crops. The browse produced from the hedgerows on a cut-carry basis is used for supplementary feeding of small ruminants. Alley farming is a modified *taungya* (agroforestry) – modified to suit smallholder farmers. It enables cropping and fallow phases of production to take place concurrently on the same land, thus allowing the farmer to crop the land for an extended period without returning it to natural fallow.

The need to find improved alternatives to the traditional bush fallow, slash-and-burn cultivation system produced the concept of alley farming. It was designed to solve the problem of maintaining sustained food production, conserving soil resources, expanding forests, and improving the socioeconomic level of smallholder farmers in the humid tropics. Alley farming can sustain food crop production through the recycling of nutrients and weed suppression when the hedgerow species are applied to the companion crops as green manure and mulch, and by rapid production of staking material. Better soil conservation through erosion control is achieved from alley farming when the hedgerow species are planted along contour lines.

Development of alley farming technology started at IITA in the late 1970s with the screening of a wide range of tree/shrub species under different soil types to be intercropped, alley cropped, or to be grown as planted fallows. Characteristics of a candidate hedgerow species included ease of establishment, a deep root system, fast growth and high foliage productivity, tolerance to pruning, ability to coppice vigorously, and good fodder value of foliage. Long-term alley cropping on-farm trials began in the early 1980s with the following objectives: to identify and enlist the cooperation of farmers from different locations across the yam belt of Nigeria. Secondly, to educate farmers on the agronomy of the prototype *Leucaena*-maize-yam alley-cropping system and *Leucaena*/*Gliricidia*/maize/cowpea alley-cropping system. Thirdly, to establish *Leucaena* hedgerows as an understorey intercrop with first season maize and for use as *in-situ* yam vine stakes the following year.

Further screening of different hedgerow species for adaptation to different soil types and agroecologies and testing of prototype alley-cropping systems continued into the 1980s. Some problems associated with components of the technology were identified and effectively addressed through research. These included seed viability problems and poor growth and chlorosis observed with *Leucaena* and *Gliricidia* in some locations due to the absence of nodulation.

Initially the technology was called alley-cropping systems. By the mid-1980s, when *Leucaena* and *Gliricidia* alley-cropping systems were integrated with livestock (small ruminants) production systems by the International Livestock Centre for Africa (ILCA, now the International Livestock Research Institute [ILRI]), the technology was called alley farming systems. Alley farming systems were developed for the humid region of Africa. Supplementary browse produced from hedgerow species is used to feed small ruminants.

In the 1990s, most studies on the components of the technology were aimed at generating process-level knowledge needed to explain the results obtained from technology testing, and to refine the technology. Studies on adoption of the technology were also carried out to identify where the technology had been successfully adopted and reasons for adoption and for non-adoption.

Major results from on-station experimentation indicated that on Alfisols and associated soils of the humid and subhumid lowland of the forest-savanna transition zone of southwestern Nigeria, *Leucaena leucocephala* and *Gliricidia sepium* were the most promising woody hedgerow species for alley farming. On the more acid soils of southeastern Nigeria, *Dactyladenia* (*Acioa*) *barteri* and *Senna* (*Cassia*) *siamea* were better adapted. The establishment of multipurpose trees (MTPs) for alley farming is by direct seeding or by stem cuttings, depending on the species being used. Direct seeding is more cost effective considering the high tree population needed to establish an alley farm. However, seed treatment using hot water or acid is required to break seed coat dormancy for some species. Depth of planting can play an important role with certain MPTs species. Some nitrogen-fixing trees require seed inoculation with compatible and fast growing strains of *Rhizobium* to facilitate rapid establishment. *Rhizobium* strains IRc 1045 and IRc 1050 have been shown to be quite effective for *Leucaena* inoculation. Studies on hedgerow management showed that an interrow spacing of 4 m is recommended for most MPTs. Intrarow spacing varies with ecoregions. Intrarow spacing of 50 cm is recommended for the humid and subhumid region, and 100 cm for the drier regions, to offset competition for moisture. Growth and biomass yield of plants grown in hedgerows is affected by the pruning regime. With some species including *Leucaena*, *Gliricidia*, and *Sesbania grandiflora*, biomass and wood yield increased with a decrease in pruning frequency and an increase in pruning height up to 1 m. Use of foliage for animal feed is done without jeopardizing the goal of sustainable crop production. It is recommended that 25% of tree foliage be used for animal feed and the rest for mulch.

Annual nitrogen yield for MPTs varies with hedgerow spacing, pruning regime, and

soil type. In southwestern Nigeria, a wide range of N yields of about 150–560 kg N ha^{-1} yr^{-1} was reported for alley-farmed *Leucaena*.

Studies on the performance of various crops, including maize, cassava, and vegetables, grown in alleys formed by *L. leucocephala* and *G. sepium* showed that all gave greater yields than in the control plots. In contrast, cowpea showed either no yield increase or reduction in yield when alley cropped with these tree species. *Leucaena* can contribute as much as 40 kg N ha^{-1} to the companion maize. Long-term studies have shown that alley farming can sustain higher crop yields for an extended period. Significantly greater maize yields were obtained from long-term *Leucaena* alley-cropping experiments conducted on sandy soils and on degraded Alfisols with or without nitrogen fertilizer than from the control. The alley farming system, however, has only a limited advantage for maize yield on acid soils.

Most of the benefits of the alley farming system come from its contribution to soil conservation and to the maintenance of soil fertility. When hedgerow species are established on sloping land, they can form a solid barrier that helps soil and water conservation, thus, alley farming can reduce runoff and erosion and permit greater crop yields than conventional tillage or no-tillage. Furthermore, a continuous supply of prunings from hedgerow species provides sufficient surface soil cover (organic mulch) which, under conditions of erosive rains, can effectively reduce runoff and soil erosion. Organic mulching also lowers soil temperature and reduces temperature fluctuation, and increases moisture infiltration and retention.

Results of long-term studies indicate that the addition of prunings from hedgerows of *L. leucocephala* and *G. sepium* maintained higher soil organic matter and nutrient status, particularly of N, K, Ca, and Mg, than the control treatments. When legumes are used as hedgerow species in alley farming, they have significant potential for reducing the nitrogen requirement of companion crops. They can fix between 134 and 274 kg N ha^{-1} yr^{-1} under field conditions, representing an average of 45% of the total N contribution. The increase in soil organic matter level under alley farming, resulting from the addition of prunings, litter fall, and crop residues, has been shown to enhance soil biotic activities, particularly the production of earthworm (*Hyperiodrilus africanus*) casts.

The efficiency with which companion crops utilize the nitrogen in the applied prunings is strongly influenced by time of application of prunings. Results showed that the application of prunings close to the time of maize planting permits more efficient use of the nitrogen they provide and gives greater maize yields. It does not, however, matter whether prunings were incorporated into the soil or not. This practice makes little difference to the contribution of nitrogen from prunings to the companion crops. The quantity of prunings can greatly influence nitrogen-use efficiency. Application of the entire amount of prunings (6 Mg ha^{-1}) produced by hedgerow of *G. sepium* and *S. siamia*, as opposed to the application of only a quarter or half this amount, enabled the associated maize to recover a greater quantity of nitrogen, thus increasing its yield.

Another benefit of alley farming is weed suppression through partial or full shading of

the undergrowth by the hedgerow species and the addition of prunings. Studies have shown that weed infestation, in particular of speargrass (*Imperata cylindrica*), was reduced in the forest zone under two-year of uncut hedgerows of *G. sepium, S. siamea*, and *Flemingia macrophylla*.

Just as hedgerow species can suppress weed growth, they can also have adverse effects on the associated crops and on soil properties. On nonacid soils of the forest-savanna transition zone of Nigeria, it was observed that when hedgerows are not pruned frequently enough, they hinder crop growth through shading. The problem of allelopathic effects in alley farming with the addition of prunings of certain woody species has been reported.

The adoption of alley farming technology by farmers in Africa has not been completely successful. Some important success stories have, however, been reported. Recent studies conducted in Benin, Cameroon, and Nigeria, to assess the adoption of the technology and farmers' current management practices, ten years after the introduction of the technology revealed that farmers are adopting the technology in villages with the following characterics. (a) high land-use pressure, (b) soil fertility decline, (c) erosion problems, and (d) firewood and fodder scarcity. Farm-level adoption patterns varied across the three case-study countries.

In Nigeria, of the 223 farmers surveyed, 93% had heard about the technology, of which 66% had either initially adopted or experimented with it. Some of the initial adopters abandon it, but 53% of the farmers continue to use it. In Cameroon, of the 820 farmers surveyed, 256 (31%) had either initially experimented or adopted the technology. Of this group, 93% continue to use it. In Benin, of the 288 farmers surveyed, 78% of the farmers had heard about the technology. Of the latter, only 32% had either experimented or initially adopted it. Currently, 93% of this group continue to use the technology.

Farmers have made some important modifications to alley farming technology based on their resources and preferences. For example, in Nigeria, of the sample farmers currently using the technology, 83% had added a fallow phase to the technology.

The slow adoption of alley farming systems could possibly be attributed to the stringent labor requirements of the technology. It is a complex technology that requires fairly intensive training of farmers and continued interaction with them as they explore the possibilities and limitations of the system. Another reason for slow adoption could be linked to the approach by which the technology was transferred, – a top-down approach. The researchers started with a solution (alley farming) and then went in search of suitable niches for it among the farmers. The farmers often had little or no input in the technology. Other factors limiting adoption include tree-crop competition, population pressure on land, hard-to-get leguminous trees and shrubs, and the marketability of tree produce.

Future research on the technology should concentrate attention more on adaptive on-farm research that employs a stakeholder-approach to technology testing. Rural appraisals should indicate that problems, such as land-use pressure, soil fertility decline, erosion, and fuelwood and fodder scarcity, exist in the farming system that can be addressed by

the use of leguminous crops in which the alley-cropping system using leguminous hedgerows might be an attractive option among others. When the alley-farming system is included as an option to address the problems identified, purposeful extension services must be in place to train farmers. Testing should extend over a number years to allow the benefits of the alley-farming system to accrue for the farmers to observe, and also to identify the shortcomings within the technology. Such shortcomings or problems may be addressed preferably through on-station experimentation. Furthermore, impact studies are needed in areas where the technology has been successfully adopted.

Abstracts

0001
A
International Institute of Tropical Agriculture. 1981.
Pages 36–43 *in* Annual Report for 1980. Ibadan , Nigeria.

Studies on alley cropping systems in the forest zone in 1980 were on the effects of N application, legume species, and alley width on maize/*Leucaena* alley cropping, selection and the evaluation of woody species for alley cropping systems, and light regimes in potential tree-shrub species for alley cropping. Results showed total annual N yield from *Leucaena* was over 180 kg N ha^{-1}. Despite this high N yield, the application of additional low N rates was needed to obtain a high maize yield. The addition of *Leucaena* prunings had a distinct effect on soil organic matter and N levels. From a one-year study it was too early to observe the effect of alley width or legume species on the alley cropping system.

Results of screening and evaluation of woody species on the Alfisols at IITA and on the strongly acid Ultisols at Onne, Nigeria, showed that in general, the establishment and growth performance of shrub species were better at IITA, while tree species were better at Onne. Because competition for light is a major factor in the suitability of different species for mixed stands, species such as *Albizia falcataria* and *Gmelina arborea* that showed a strong depletion of incident light when fully established were incompatible with alley cropping and could best be maintained only as planted fallow. For most species, cutting back after the first year of growth was a practical way of using them for alley cropping.

On-farm trials of *Leucaena*-maize systems conducted at six different locations across the yam belt of Nigeria, showed that *Leucaena* was a very hardy plant that established well even under extremely adverse conditions. Furthermore, a linear programming model was developed to evaluate the economic effectiveness of the experimental *Leucaena*-rice alley cropping system under West African smallholder conditions. Results indicate that it was consistently more profitable to grow rice with N from *Leucaena* hedgerows than from either urea or ammonium sulphate.

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International Institute of Tropical Agriculture. 1982.
Pages 27–33 *in* Annual Report for 1981. Ibadan, Nigeria.

This publication presents results of trials measuring crop performance in alleys formed by various trees and shrub species, the potential contributions from the alley species, and techniques for measuring the system. In the fourth year of the establishment of four alley species, *Gliricidia sepium*, *Leucaena leucocephala*, *Tephrosia candida*, and *Cajanus cajan*, yields of first season maize planted at 30 000 plants per ha were similar among the

four species from a range of 2 to 4 Mg ha^{-1}. Earthworm activity, an important factor in maintaining good tilth, was also similar in all the plots. Biological activities associated with soil restoration were maintained mainly by leaf fall. Evaluation of the quantitative contribution of leaf fall from the four species during the dry season (Dec – Mar), showed that *T. candida* had the highest leaf fall with a peak early in Jan, and *L. leucocephala* the lowest with a peak in mid-Feb. From a pot experiment in which N from fresh and dry *Leucaena* leaves was evaluated by maize dry weight accumulation, N at 100 ppm from fresh leaves was as effective as 50 ppm N from calcium ammonium nitrate.

The potential of a non-leguminous shrub, *Acioa barteri* for alley cropping was tested in comparison with *Gliricidia sepium* and natural regrowth. The leaves and twigs of the alley species were spread on the plot with or without fertilizer, before maize planting. Results showed that maize yields from fertilized plots were greater than from unfertilized plots. *A. barteri* and *G. sepium* with fertilizer were also superior to natural regrowth. But there was no difference between treatments for a second season cowpea seed yield. In a study on the N contribution from *Leucaena leucocephala* alley-cropped with maize, cowpea, and pluvial rice on a low fertility Apomu soil (Psammentic ustorthent) at IITA, Ibadan, the addition of *Leucaena* with N application almost tripled grain yields compared to the treatment with no prunings added. The minor-season cowpea seed yield, however, was not affected by the addition of prunings.

The effectiveness of *Gliricidia sepium* tops as an N source for maize was also studied on a sandy Apomu soil series. The treatments were two *Gliricidia* rates and three methods of application in a randomized complete block design with four replications. *Gliricidia* tops applied at 5 and 10 Mg ha^{-1}, equivalent to 53 and 106 kg N ha^{-1}, respectively, significantly increased maize grain and stover yields. Banding and incorporation of *Gliricidia* tops was more effective than banding or broadcasting over the entire plot without incorporation. *Gliricidia* tops, as an N source were less effective than urea. Drying may affect the effectiveness of *Leucaena* as an N source in alley cropping.

A field experiment was conducted to determine the decomposition of rate of *Leucaena* following drying and its effectiveness as N source. The decomposition rate of fresh and dried *Leucaena* tops and maize stover was faster when the material was buried in the soil. When buried, the half-life of the fresh material was estimated at 6 d, compared to 11 d for dried *Leucaena* tops and 30 d for dried maize stover. Dried material was therefore, less effective as an N source because of the slower decomposition rate.

0003
D
Kang, B.T., G.F. Wilson, and L.E. Sipkens. 1981.
Alley cropping maize (*Zea mays* L.) and Leucaena (*Leucaena leucocephala* Lam) in southern Nigeria. Plant and Soil 63: 165–179.

A maize-leucaena alley cropping system was studied on an N-deficient sandy Apomu soil series (Psammentic Ustorthent) at Ibadan in the forest zone of southern Nigeria from 1976 to 1980. Maize was grown in 4-m width alleys between leucaena hedgerows. Five to six annual prunings of leucaena hedgerows yielded between 5 and 8 Mg of dry tops ha^{-1} yr^{-1} with N-yield of between 180 and 250 kg N ha^{-1} yr^{-1}. The addition of leucaena prunings from full grown hedgerows sustained maize grain yield at about 3.8 Mg ha^{-1} yr^{-1} for two consecutive years with no N addition, while higher yields were obtained with supplementation with low N rates of 20 to 80 kg N ha^{-1}. The maize-leucaena alley cropping system has the potential for development as a stable alternative to the traditional bush fallow system.

0004
D
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 mays* L.). Fertilizer Research 2: 279–287.

The effectiveness of *Leucaena leucocephala* (Lam) de Wit pruning as an N source for maize (*Zea mays* L.) was evaluated in pot trials in an N deficient, sandy Apomu soil (Psammentic Ustorthent) at Ibadan, southern Nigeria. The prunings significantly increased N uptake of seedlings and ear leaf N concentration of maize; and a high maize grain yield was obtained with application of 10 Mg fresh prunings or a combination of 5 Mg fresh prunings and 50 kg N ha^{-1}. The prunings as an N source, appeared more effective when incorporated in the soil than when applied as mulch. From the pot trial, prunings applied two weeks before planting were more effective than when applied at the time of planting maize, and the apparent N recovery from the prunings with early incorporation was about equal to that of fertilizer N.

0005
A
Getahun, A., G.F. Wilson, and B.T. Kang. 1982.
The role of trees in farming systems in the humid tropics. Pages 28–35 *in* Agroforestry in the African humid tropics, edited by L.H. MacDonald. The United Nations University, Tokyo, Japan.

The bush fallow-food crop rotation system has been the most popular and stable arable cropping system in the humid tropics of Africa, because of the presence in the fallow of deep-rooted woody plant species that are essential to soil fertility restoration. The stability and productivity of the system is threatened by pressure on land due to rapid population growth. As more land is brought into production, the fallow period is shortened and woody species are eliminated or become ineffective. The role of trees in nutrient recycling, soil organic matter buildup, and erosion control has been recognized by traditional farmers, who have identified and have been encouraging the most effective tree species in the fallow. With these selected species the fallow period can be effectively shortened. To exploit the potential of selected tree species in land and soil management a system called alley cropping was developed. The system embodies agroforestry concept of combining crops and tress and ensures the dominance of effective tree species during the fallow period.

0006
A
International Institute of Tropical Agriculture. 1983.
Agroforestry. Pages 153–159 *in* Annual Report for 1982. Ibadan, Nigeria.

As part of a continuous effort to find an improved alternative to the traditional bush fallow system, studies on alley cropping in 1982, were centred on the following: selection and evaluation of tree species for use in alleys; influence of alley cropping on microclimates; management of the system; and the potential contribution from alley species in on-station and on-farm studies. In 1981, a trial was started on an eroded Egbeda soil series (Oxic Paleustalf) with low N and P status to compare *Gliricidia sepium*, *Leucaena leucocephala*, *Acioa barteri*, and *Alchornea cordifolia* for soil improvement and suitability for alley cropping, and to test the effects of alley width and fertilizer application. The experiment was a split plot design with three replications. Results showed that a higher biomass was produced per unit area with 2-m than with 4-m alley width because of a higher population; and with 4-m spacing leucaena produced more biomass than gliricidia, while with 2-m spacing, gliricidia produced more. Gliricidia and leucaena prunings had higher contents of N, P, K, Ca, and Mg than those of alchornea and acioa even though, the later two species are widely grown as natural fallow by the traditional farmers on the strongly acid soils in the humid zone. Because the fallow

hedges were not pruned in the first year of establishment, the 1981 minor season cowpea seed yield was lowered more with the 2-m alley width than with the 4-m alley as a result of shading. Gliricidia depressed yield the most, while acioa the least, in proportion to the size and leafiness of the trees. Yields of 1982 main season maize (TZPB) was significantly increased with both the 2-m and the 4-m alley when fertilizer was applied, than it was when without fertilizer, but alley width had no effect on yield when hedges were periodically pruned during the season. With fertilizer application, alley cropped maize produced greater yields than monocropped maize, indicating the beneficial effects of alley cropping with these species, and in particular, with gliricidia, within two years of establishment in this eroded Alfisol.

To improve the efficiency of alley cropping systems, the use of physical resources and competition for these resources in an alley cropping system, light and moisture distribution were measured in an alley cropping system to analyze their characteristics and effects on crop yields. The incidence of light on crops close to the leucaena rows and those farthest away, in the middle of the 4-m alleys, was measured with long-tube solarimeters before and after each pruning of the leucaena. Soil moisture was monitored once a week gravimetrically and with tentiometers and resistance moisture blocks. Soil moisture content varied according to the position between the leucaena rows, but no consistent trends could be detected through regular sampling in the middle of the rows and at both edges. The global radiation incident on crops indicated that shading was a serious problem in the early stages of growth and on the side of the plot (east of the north-south oriented leucaena rows). Thus, timely pruning during this phase may be very important. In the latter stages, the increase in maize height relative to that of leucaena regrowth considerably reduced shading. But because shorter statured crops such as cowpea (second season crop) do not have this advantage, regular pruning may have to be done when these crops are included in the system. Results point out the advantages of reducing pruning height to the lowest level possible and show that a wider distance between leucaena rows decreases the area of excessive shading relative to the cropped area, and should therefore, improve crop performance.

In a screenhouse experiment to determine the suitability of certain tree species for alley cropping on acid soils, lime and phosphorus responses of three wooded species, *Calliandra calothyrsus*, *Leucaena leucocephala*, and *Sesbania grandiflora* were tested in an Ultisol collected from Amakawa in eastern Nigeria. All the three species responded significantly to lime and P applications with calliandra responding best to P and sesbania showing the highest response to lime. Among the three tree species, leucaena variety K-26 appeared to have the best response with low or high P and lime inputs.

The effects of leaves and twigs pruned from *Gliricidia sepium* on a first season maize yield were tested in an alley cropping system with 3.75-m spacing between rows. The main treatments were NPK fertilizer (applied at 60 kg ha^{-1} at planting plus 30 kg N ha^{-1} as a side dressing 4 week later) and no fertilizer, and subtreatments were leaves and twigs used as mulch or incorporated as green manure. Results showed that the fertilizer

treatment significantly gave a higher grain yield than the no fertilizer treatment, but using leaves as mulch or as green manure did not show any appreciable effects on yield. The trial was to continue for several seasons and years to determine the cumulative effects of the leaves as mulch and as green manure.

A good fallow system is expected to reduce the effects of diseases and pests, in particular, weeds in succeeding crops, in addition to restoring the physicochemical properties of the soil. Even though *Leucaena leucocephala* fallow reduces the population of many common weeds, it can itself become the major weed after the fallow. The effect of leucaena as a weed on maize yield was compared to the effect of weeds after natural fallow during a one-yr period in a split plot with tillage (rotovation and no tillage) in the main plots and three levels of atrazine in the subplots. After leucaena fallow, the plot was alley cropped. Leucaena was pruned, leaves and twigs were left as mulch or as green manure in which the prunings were incorporated during rotovation. In the tillage with mulch treatment, the land was rotovated before mulch was added. With natural fallow, the plant cover, mostly grasses, was killed with glyphosate and the residue was used as mulch or green manure. No fertilizer was applied to either case. After leucaena fallow, tillage and plant residue management had no effect on weed control. But atrazine at 3.0 kg a.i ha^{-1} controlled weeds significantly better than the control or 2.5 kg a.i ha^{-1} level. With natural fallow, tillage was slightly better than no-tillage, and both levels of atrazine were significantly better than the control. There was less weed competition after leucaena fallow than after natural fallow. In reducing weed competition, leucaena fallow had an advantage over natural fallow dominated by grasses, when maize is grown after the fallow.

A major problem with the use of *Leucaena leucocephala* for soil restoration is seed viability. A series of studies were conducted on leucaena seed germination using freshly harvested (untreated) leucaena seeds stored up to six months under various conditions: cold storage (< -1 °C), ambient room temperature (22–28 °C), dry soil (25–40 °C, in a glass-top screenhouse), and drying oven (40–45 °C). Germination tests were conducted monthly using moist sterile soil in clay pots each containing 100 seeds, in a completely randomized block design with six replications. Results showed that dry soil storage was the most effective germination stimulator. Neither cold storage nor ambient room temperature storage had a marked effect on germination over the six months period. Dry soil, a common field condition in the tropics, should be the most effective in stimulating germination of leucaena seeds, and may explain the large number of volunteer seedlings observed where a dry period of three or more months precedes the beginning of the rains.

To determine the effect of temperature on germination, seeds were sown in moist sterile soil in clay plots and kept at 10 °C, 20 °C, 25 °C, and 30 °C for 28 d. One set of seeds was treated with hot water to break dormancy, while the other was untreated. The experiment was a split plot, with seed treatments as main plots and temperature as subplots (100 leucaena seeds) with six replications. Results showed there was no

germination at 10 °C, but from 15 °C germination rate increased until 25 °C, and decreased significantly at 35 °C.

The effectiveness of *Gliricidia sepium* tops as a nitrogen source compared to urea fertilizer was tested with maize on a sandy Apomu soil series (Psammentic Ustorthent). The urea nitrogen and gliricidia tops were applied with one-third of the N at planting and two-third at 2 weeks after sowing, in bands and then covered. All plots received basal P and K dressings. The addition of urea and fresh gliricidia tops as fresh and dried materials at rates equivalent to 40 kg N ha^{-1} and 80 kg N ha^{-1} significantly increased maize yield. At the lower rate of 40 kg N ha^{-1}, gliricidia tops were less effective than urea. The fresh tops appeared to be more effective as an N source than the dry tops, although the latter is easier to handle because it is less bulky.

In 1976 a trial was initiated on low fertility Apomu soil series in (Psammentic Ustorthent) at IITA, Ibadan, using a continuous function design with four replications. The leucaena hedgerows were regularly pruned to a height of about 1.5 m. In 1982, the main season maize (TZPB) responded significantly to the addition of leucaena prunings. The addition of prunings and nitrogen kept yields at previous years' levels (2.3-2.9 Mg ha^{-1}), but in treatments where prunings were removed and no nitrogen was applied, yields were lower than the previous years'. The minor season cowpea (VITA-6) grew better in treatments receiving leucaena prunings, but this was not reflected in the yields. *Talinum triangulare* weed was a serious problem in cowpea plots, particularly the no-till plots, receiving leucaena prunings.

In 1981, a trial with rice was set up on an Alagba soil series (Oxic Paleustalf) at Ikenne, Nigeria. The leucaena hedgerows were pruned to a height of 0.6 m, and during 1982 a large amount of leucaena prunings and a high N yield were obtained. Addition of leucaena prunings and N had a striking effect on the growth and nitrogen status of the rice crop.

Long-term on-farm trials of maize/yam alley cropping with *Leucaena leucocephala* continued in 1982 across the yam belt zone of Nigeria. The following objectives were evaluated: to check the suitability of leucaena stems as live in-situ stakes for yam vines under farm conditions; to assess farmers' perceptions of the system, and to obtain other feedback for further improvement of the system. At the end of 1982, ten on-farm trials of leucaena/maize/yam alley cropping had been established across the zone. The experimental design consisted of a single replicate of yam/leucaena plot per farmer (with a control). Farmers were trained that once the leucaena trees were established, they should make heaps for yam cultivation between the leucaena rows, and prune the trees at a height of about 1.5 m after planting yam. Farmers were to guide the vines to climb up the leucaena stem and to prune the live leucaena stakes regularly, using the tops and leaves as mulch for the yam crop. Observations of the trials and comments by the farmers indicate that leucaena/yam alley cropping had definite benefits including, the provision of inexpensive staking materials for yam. Secondly, yam in the leucaena plots looked much better than those in the control plots. Farmers also observed that leucaena controls weeds,

especially *Imperata cylindrica*, and it keeps the soil more moist and friable, thereby making plowing in leucaena plots softer and easier than in the control plots. Furthermore, leucaena improves soil fertility, as indicated by the significant increase in some soil chemical properties including, total nitrogen, organic carbon, and soil pH in luecaena plots compared with the control plots. Another benefit recognized by the farmers was that leucaena trees provide firewood and fencing materials. One major problem, however, identified was management of the system. The shoots of live leuceana stems used as *in situ* yam stakes require pruning at regular intervals to prevent competition with the yam leaves for sunlight. But, because of labor shortage and sometimes illness, the farmer may be forced to delay the pruning, which may result in leucaena shoots depressing both the vegetative growth and yield of the yam. Another problem indicated by the medium-scale farmers was mechanization of the alley cropping system for plouwing and pruning of the leucaena bushes to reduce labor requirements at peak periods.

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International Institute of Tropical Agriculture. 1984.
Alley cropping. Pages 176–184 *in* Annual Report for 1983. Ibadan, Nigeria.

This reports progress in alley cropping system research involving the selection and evaluation of tree species for use in alleys, the management of the system, and potential contribution from alley species. In a trial started in 1981 on an eroded Egbeda soil series (Oxic Paleustalf) at IITA, Ibadan, to compare the performance of *Gliricidia sepium*, *Leucaena leucocephala*, *Acioa barteri*, and *Alchornea cordifolia* in alley cropping, results showed that all the species, except acioa were fully developed by the third year. In 1983 leucaena produced the highest dry weight of prunings (8.64 Mg ha^{-1}), yielded the highest dry weight of stakes (6.62 Mg ha^{-1}), and the highest amount of nitrogen (233 kg ha^{-1}) in five prunings, while acioa produced only a negligible amount of prunings, stakes, and nitrogen. The amount of N in the prunings of the two nonleguminous species, alchornea and acioa, was 84 and 29 kg ha^{-1}. Higher amounts of prunings were obtained with the 2-m hedgerow spacing than with the 4-m spacing. Maize yields were significantly lower with gliricidia and leucaena than with the much slower growing acioa and alchornea. Because gliricidia and leucaena grew much faster in the Egbeda soil series, adequate timing of prunings was apparently needed to avoid partial shading of the maize. A study of the root distribution of the four species showed that all the species had taproots deeper than 1 m, and gliricidia appeared to have the most taproots after three years of growth. Leucaena appeared to have the most lateral roots.

Leucaena leucocephala and *Gliricidia sepium* are the major hedgerow species used in alley cropping at IITA, Ibadan, but they may not fit all environments and systems. In 1981 *Cassia siamea*, *Flemingia congesta*, and *Gliricidia sepium*, the latter serving as a standard, were planted in 30- × 28-m plots with alleys 4 m wide, to evaluate their

suitability for use as alley species. Results showed that the erect branching of *G. sepium* and *F. congesta* allowed a higher percentage of solar radiation to reach the ground, resulting in more weeds under these species than under *C. siamea*; while, the lateral branching of *C. siamea* shaded even the centre of the alley and limited weed growth in the centre and the sides of the alley. The two species, *C. siamea and F. congesta,* seemed to have good potential for alley cropping. *C. siamea* had the following advantages: good shading that prevented weed growth during fallow; its high biomass production compensated for its low nutrient content; its leaves decomposed slowly and formed a good mulch, and it produced a large amount of wood. Some of the disadvantages, however, included its thick wood that requires much labor to prune, and its low leaf nutrient content. The advantages of *F. congesta* were that its small stems are easy to cut back and prune, and its residue decomposed slowly and formed a good mulch. But *F. congesta* does not shade the alleys enough to suppress weed growth during fallow, and its nutrient contribution potential is much lower than that of *G. sepium.*

The success of alley cropping greatly depends on simple and quick establishment of the tree and shrub species. This can be accomplished by seed scarification using hot water or sulphuric acid treatment to improve seed germination. Soaking the seeds with concentrated sulphuric acid gives good results, but the acid is scarce and costly. Tests were carried out to determine how the use of sulphuric acid could be minimized. The treatments were five levels of sulphuric acid concentration, four levels of acid: seed ratio and a control, and four levels of treatment periods. Diluted acid was less effective for seed treatment, particularly at low concentration of 25% or less. Use of low acid: seed ratio of 1:10 for a treatment period of one hour gave a higher germination of 88%. Results showed that the amount of sulphuric acid required for effective seed treatment could be considerably reduced.

Poor growth of *Leucaena leucocephala* in some areas has been attributed to the absence of root nodules. Because the rhizobia that effectively nodulate this legume are few or absent in many tropical soils, inoculation may be necessary. Two rhizobial strains were isolated, LeII from leucaena grown in IITA soil and the other, IRc 1045, from leucaena grown in Fashola soil in southwestern Nigeria. Both strains were tested in the field at IITA and at Fashola in comparison with urea (150 kg N ha^{-1}) and soil N without inoculation, to determine their influence on nodulation, nitrogen fixation, and growth of leucaena. To identify strains and compare the competitive ability of inoculant strains with that of indigenous rhizobia, nodules were typed using the enzyme linked immunosorbent assay (ELISA) technique for Rhizobium Le II and the intrinsic resistance of IRc 1045 to 500 mg ml^{-1} of streptomycin. At IITA, only the inoculated plants nodulated, and all the nodules were produced by the inoculant strains, while at Fashola, nodules were found in all the treatments. A high percentage (about 75%) of nodules containing introduced strains were found in the inoculated plots at Fashola, indicating that the indigenous rhizobia was a poor competitor. At Fashola, strain Le II performed better than IRc 1045 on the basis of nodule number, nodule mass, plant height, and acetylene reduction assay;

but dry matter and total N of the plants inoculated with this elite strain were superior only to those of uninoculated and unfertilized plants. The amount of biologically fixed nitrogen estimated at IITA by the N difference method ranged between 224 to 274 kg N ha^{-1}, about 52 to 61% of the total N in the leucaena plant. Thus, when a well nodulated leucaena is used in alley cropping system or in planted fallow, more than 50% of its N contribution is derived from atmospheric N.

In the Guinea savanna of Nigeria, particularly Benue State, where yam is extensively cultivated, farmers recoganize the value of staking yams; but because of the large area planted to yam and the enormous amount of labor required to obtain stakes, they chose not to stake their yams. In 1983, ten on-farm yam-staking trials were conducted in Benue State, to evaluate the economics of yam staking and to assess the suitability of leucaena stakes for yam vines. Farmers with at least 1 ha of yam varieties (*Dioscorea rotundata*) that usually require staking, whose farms were readily accessible and who were willing to participate in the study were selected. Each trial was a simple comparison of staked and unstaked plot with single replicate per farmer. The leucaena stakes were 2-m long, and were either cut from the leucaena plots previously established by the farmers or were brought in by the researchers. Results showed that at seven out of ten sites, yield increases ranged between 33 and 89% and exceeded 200% in one of the sites, because most staked mounds gave two to three tubers and the tubers where bigger and longer than those from the unstaked plants. If farmers obtained stakes from their own leucaena plots, the economic returns ranged from 3 to 11 times the cost. With an inexpensive source of wood such as leucaena that appeared to resist rotting and termite attack, yam staking is economically very attractive to farmers.

In 1983, further evaluation was done on the potential contribution of leucaena in a leucaena and maize/cowpea alley cropping system established in 1976 on a low fertility Apomu soil (Psammentic Ustorthent) at IITA, Ibadan. Dry matter and N yields from the prunings in 1983 were just as high as in the previous years and responded significantly to nitrogen applied to the main season maize crop. Even without the addition of nitrogen, the leucaena rows still fixed and recycled substantial amounts of nitrogen from the prunings. Without leucaena prunings and nitrogen, yields of maize (TZPB) continued to decline in 1983 to 0.26 Mg ha^{-1} or about one-half the yield in 1982. But the addition of leucaena prunings gave yields of about 2.0 Mg ha^{-1} in 1983, the same as 1982. The no-till treatments with surface applied prunings (mulch) showed better establishment, earlier growth, and a better yield than the tilled treatments. As in 1982, the dry matter yield of the minor season cowpea crop increased with the addition of leucaena prunings, but this had no effect on seed yields. The effect of six years of alley cropping on some of the chemical properties of the soil profile of Apomu soil series showed that the organic matter, K, Ca, and Mg levels were higher in plots where leucaena prunings were added than in plots without prunings. Repeated removal of prunings resulted in a generally low nutrient status, except for P.

Furthermore, in 1983, evaluation was done on the potential of gliricidia in a gliricidia

and maize/cowpea/cassava/rice alley cropping system established in 1982 in Alagba soil series (Oxic Paleustalf) at Ikenne, Nigeria. Maize yields benefited from the addition of gliricidia prunings with no nitrogen. When gliricidia prunings were added, nitrogen application had no effect on maize yield. Cowpea seed yield also increased with the addition of gliricidia prunings and benefited significantly from the residual nitrogen applied to the maize. The rice crop was severely damaged by drought, while the cassava crop was not ready for harvest in 1983.

The long-term on-farm trials of leucaena and maize/yam alley cropping established in the yam belt zone of Nigeria continued in 1983. The objectives were to evaluate the suitability of leucaena as live stakes for yam vines and to test the effects of alley cropping with leucaena on maize and yam yields under farmers' conditions, and to assess farmers' perception of the alley cropping system. The ten trials that had been established in 1982 were used. In 1983 five plots were planted to local varieties of yam (*Dioscorea rotundata*) and six to maize varieties (TZSR-W and FARZ7) in a rotation. Farmers made heaps between alleys in Jan/Feb, planted yams in Mar and pruned the leucaena live stakes at a height of 2 m in Apr. They were advised to prune shoots off the leucaena live stakes regularly until yam harvest in Nov/Dec. In plots were farmers pruned the leucaena live stakes regularly, the yams grew vigorously and yields increased by 18 to 20%. But in plots where farmers pruned only two to three times, the leucaena shoots on the live stakes overgrew the yam vines and caused yield depression of 8 to 60%. Farmers who planted maize in the alleys cut the leucaena at 0.6 m and pruned again three weeks later, leaving the cuttings in the plots as mulch. Cutting and pruning increased labor cost by about 58%, but halved the use of nitrogenous fertilizers and increased maize yields by 30 to 50%. After three years of alley cropping leucaena with maize and/or yam and of contact with researchers, farmers had gained an interest in the technology, because the leucaena served as an inexpensive source of wood for yam staking, building material, and firewood. They also recorganized the value of leucaena for improving soil fertility. Four of the farmers, however, said if they were to establish new leucaena plots for alley cropping, they would prefer wider spacing and a system of cut and carry (or cut and stake) to *in-situ* live stakes.

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Kang, B.T., G.F. Wilson, and T.L. Lawson. 1984.
Alley cropping: a stable alternative to shifting cultivation. International Institute of Tropical Agriculture, Ibadan, Nigeria. 22 pp. (French and Spanish editions available).

Bush fallow and shifting agriculture, even though they provide only subsistence living, are ecologically stable and therefore, suited for the tropics. 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 that allows for continuous cultivation of food crops. Major advantages of alley cropping include biological recycling of nutrients, soil conservation, suppression of weeds, and rapid production of by-products such as stakes and firewood. Research at IITA on alley cropping has led to the development of three alley cropping systems. They include, the *Leucaena/Gliricidia*/maize/cowpea alley cropping system; the *Leucaena*/maize/yam alley cropping system; and by integrating *Leucaena* and *Gliricidia* alley cropping with livestock production, the international Livestock Centre for Africa (ILCA) has developed alley farming, a promising small-ruminant production system for the humid region of Africa. Intensive work on alley cropping has been done on the low acidic Alfisols and the associated Inceptisols and Entisols. Research is in progress on the low base status and acidic Ultisols, and on identification of suitable tree and shrub species, particularly legumes. As a biologically low input production system, alley cropping should be a preferred production technique in developing countries where there is limited use of inputs such as fertilizers and pesticides.

0009
A
International Institute of Tropical Agriculture. 1985.
Farming Systems Program. Pages 155–207 *in* Annual Report for 1984. Ibadan, Nigeria.

In 1984, decomposition studies were carried out in a field under alley cropping with *Gliricidia sepium, Flemingia congesta*, and *Cassia siamea* as hedgerow plants, to estimate the decomposition rates and N contribution of the prunings from these alley species. Fresh leaves and small twigs from legume cutbacks and prunings were sealed in mesh bags, weighed, and distributed in a maize field. For each species, three samples each of prunings were collected on days 7, 14, 28, 60, and 120 after cutback and bagged. Content of the bags were oven dried, weighed, ground, and analyzed. Results showed that in 120 days, *Gliricidia* prunings decomposed completely, *Cassia* lost 85%, and *Flemingia* 73% of their dry matter. The rapid decomposition rate of *Gliricidia* prunings may have been due to their succulent nature and high N contents. Cutbacks and prunings of *Gliricidia*, *Cassia*, and *Flemingia* released 252, 120, and 75 kg N ha^{-1}, respectively, during decomposition, and increased maize grain yield by 15% for *Gliricidia*, 22% for *Flemingia*, and 50% for *Cassia*. The mulch effect of the persistent *Cassia* leaves, perhaps through moisture conservation and weed control, may have been more beneficial than the high N content released by *Gliricidia*.

Microbial biomass is an indicator of soil life and soil fertility. In 1984, microbial biomass of prunings from *Gliricidia sepium, Flemingia congesta, and Cassia siamea* were evaluated using the fumigation method. Cassia maintained a relatively high biomass C, probably because it decomposed slowly. Nitrogen applied at 90 kg N ha^{-1} promoted

soil biomass C, essentially by increasing leguminous dry matter production. Biomass C correlated with soil N (r = 0.77) and organic C (r = 0.70).

Nitrogen fixation by *Leucaena leucocephala* was estimated by the ^{15}N dilution technique to compare values with those obtained by the N difference method in 1983. Nitrogen fixation in six months ranged from 112 to 146 kg N ha^{-1}, and represented 43, 45, and 40 of N in leaves, stems, and roots, respectively. The estimated values were less than a range of 224 to 274 kg N ha^{-1} obtained by the N difference technique in 1983. The underestimation was because uninoculated plants were nodulated by indigenous rhizobia (35% of the nodules) and from inoculated plots (65% of the nodules).

The benefit of *Leucaena-Rhizobium* symbiosis on a subsequent maize crop was assessed at IITA. Plots were effects of inoculation with rhizobia and applied nitrogen on *Leucaena* were studied in the previous year were used for the study. At 24 weeks after planting (WAP), *Leucaena* was cut at soil level and Glyphosate was sprayed unto the stumps at 3 kg a.i. ha^{-1} to retard its regrowth. The main plots of the previous experiment: uninoculated, inoculation with *Rhizobium* IRc 1045 and IRc 1050, and 105 kg ha^{-1} (urea), were divided into two subplots with *Leucaena* either removed or broadcast unto the plots. Maize was sown two weeks later in all plots, and in an adjacent field where urea was applied at 0, 40, and 80 kg N ha^{-1} for comparison. Prunings from inoculated plants added 2.5 times more N than those from uninoculated plants and maize yield increases were 1.4 to 2.4 Mg ha^{-1}. In plots were prunings were removed, N contribution of *Leucaena* roots, nodules, and litter to maize grain yield was equivalent to an average of 36 kg urea N ha^{-1}, representing about 61% of inorganic N equivalent in plots with the prunings added. The highest inorganic N equivalents were in plots that received prunings from previously inoculated or N fertilized *Leucaena* plots, but they represent only 32% of the N in the prunings, indicating that maize did not use *Leucaena* N efficiently.

In 1982, six legume species (*Vigna unguiculata, Arachis hypogaea, Cajanus cajan, Centrosema pubescens, Leucaena leucocephala*, and *Psophocarpus palustris*) were inoculated with rhizobia strains of different origin at IITA, Ibadan and Fashola, Nigeria. The populations of introduced rhizobia were assessed at planting and 10 months after inoculation. At both locations and sampling periods, the number of cowpea and *Leucaena* rhizobia in uninoculated soils were 2.5 x 10^3 and < 10 rhizobia per gram soil, respectively; while the populations of inoculated soils at 10 months after planting increased to an average of 2.5 x 10^3 for cowpea rhizobia and 2.5 x 10^3 for *Leucaena* rhizobia per gram of soil. To evaluate the ineffective ability of inoculant strains, 10 months after inoculation, soil samples were collected to 20 cm depth from both fields in plots where legumes had been inoculated with *Rhizobium* strains IRc 1050 and Vi F2. The treatments were 12 legume-*Rhizobium* combinations and were set out in each field in a randomized complete block design with three replications. Surface-sterilized seeds of *Leucaena* and cowpea VITA 6 were used. Results indicated that nodulation was generally improved by increased rhizobial populations in the soil after inoculation and legume cultivation. Nodulation due to IRc 1050 was improved, particularly in Fashola soils where

it averaged 89% at 10 months after introduction. The *Rhizobium* IRc 1050, isolated from IITA, established well in Fashola and was more infective than the indigenous rhizobia. The strain is being used successfully as inoculant for *Leucaena*.

Maize (TZB) was sown in plots inoculated 10 months earlier with six rhizobia strains, to evaluate the residual effects of inoculation and legume cultivation. In adjacent plots maize was also sown and fertilized with urea at 0, 25, 50, or 75 kg N ha^{-1} for reference. The experiment was irrigated. At 7 weeks after planting, in legume plots where urea was not applied, N equivalents of the legumes ranged from 42 to 64 kg ha^{-1} and were not affected by inoculation. In plots where the legumes had been fertilized with 150 kg N ha^{-1}, N equivalent averaged 68 kg ha^{-1}. This implies that legumes improved soil fertility, and introduced rhizobia persisted, multiplied, and ensured proper nodulation of subsequent legume crops.

In alley cropping trials started at Karama and Kibungo in Rwanda, four leguminous shrubs, *Leucaena leucocephala, Calliandra calothyrsus, Cassia spectabilis* and *Sesbania sesban*, were evaluated for their ability to improve soil fertility in a semi-arid environment with poor soils and termite problems. Preliminary results showed that *Sesbania* was best for early growth and green matter production. At 9 months after planting at Karama, mean heights were 2.15, 1.06, and 1.01 m for *Sesbania, Leucaena*, and *Cassia*, respectively. *Cassia* resisted drought and termites better than the other species.

0010
B
Kang, B. T. and B. Duguma. 1985.
Nitrogen management in alley cropping systems. Pages 269–284 *in* Nitrogen management in farming systems in humid and subhumid tropics, edited by B.T. Kang and J. van de Heide. Haren. The Netherlands, Institute for Soil Fertility and IITA, Ibadan, Nigeria.

In order to reduce the dependency on commercial fertilizer N for crop production, there is much interest in using woody leguminous species as potential N sources. Woody legumes grown in hedgerows can be successfully intercropped with food crops in alley cropping systems. Regular prunings produced large quantities of green manure for the companion food crops. *Leucaena leucocephala* and *Gliricidia sepium* grown in 4 m spaced hedgerows on an Alfisol, can produce over 200 and 100 kg N ha^{-1} yr^{-1} with five prunings, respectively. The use of woody legumes in alley cropping with food crops needs, therefore, to be recommended for adaptation by farmers in the tropics as a low input, but stable method of farming.

0011
CD
Kang, B.T., H. Grimme, and T.L. Lawson. 1985.
Alley cropping sequentially cropped maize and cowpea with *Leucaena* on a sandy soil in Southern Nigeria. Plant and Soil 85: 267–277.

The potential of alley cropping maize and cowpea with giant Leucaena (*Leucaena leucocephala* (Lam) de Wit) was studied on an Entisol (Psammentic Ustorthent) in Southern Nigeria. The effect of application of leucaena prunings, nitrogen fertilizer, and tillage on maize and cowpea grown in 4 m alleys was studied. Despite the intensive pruning regime (five prunings/year) for a six-year period, the leucaena hedgerows continue to produce substantial amounts of prunings, nitrogen yield, and stakes. Even though high nitrogen yield was obtained from the prunings, the application of low nitrogen rates was still needed to obtain a high maize yield, whereas cowpea grain yield was not affected either by leucaena prunings or by residual nitrogen. Application of leucaena prunings resulted in higher soil moisture retention, organic matter, exchangeable K, Ca, Mg, and nitrate levels in the soil solution. Tillage (rototilling) resulted in either higher or the same maize and cowpea yields when compared with no-tillage. Timely pruning of hedgerows is necessary to minimize shading.

0012
F
Ngambeki, D.S. 1985.
Economic evaluation of alley cropping *Leucaena* with maize-maize and maize-cowpea in southern Nigeria. Agricultural Systems 17: 243–258.

Alley cropping is an aspect of agroforestry being developed for small farmers in the tropics. It consists of establishing fast-growing leguminous shrubs or tree species in rows, then controlling the shading from the trees during cropping by pruning the branches that can be used as mulch or green manure to benefit the companion crops planted between the alleys. The study assessed the economic implications on labor utilization for the management of the leucaena hedgerows, on crop yields and the overall benefits from alley cropping with leucaena. Results showed that even though the management of leucaena trees increased labor requirements by about 50%, the system can sustain and increase maize yields by over 60%, reduce the use of nitrogenous fertilizers and give an attractive net income and marginal rate of return per unit cost. It gave a reasonable benefit-cost ratio of 1.23 to 1.32 and looks promising, especially for maize production in tropical areas.

0013
D
Read, M.D., B.T. Kang, and G.F. Wilson. 1985.
Use of *Leucaena leucocephala* (Lam. de Wit) leaves as a nitrogen source for crop production. Fertilizer Research 8: 107–116.

Field and pot trials were conducted to determine the optimum management practices for using *Leucaena leucocephala* (Lam. de Wit) as a nitrogen source for crop production. From field trials with maize there was no benefit from a split application of leucaena leaves or from the application of fresh as against dry material, and also no difference between incorporation and surface application of leucaena leaves, possibly because of the low nitrogen response observed. Pot trials, however, showed that soil incorporation of leucaena leaves was more effective in increasing plant dry weight than surface application. *Leucaena* leaves were not as effective as inorganic nitrogen in increasing maize grain yield or dry matter production, but they had a significant residual effect on the succeeding maize crop compared with organic nitrogen. Decomposition studies indicated that buried leucaena leaves decomposed more rapidly than surface-applied leaves and fresh leaves decomposed more rapidly than dried leaves.

0014
B
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1985.
Effect of inoculation and mineral nutrients on nodulation and growth of *Leucaena leucocephala*. Pages 419–427 *in* Biological nitrogen fixation in Africa, edited by H. Ssali and S.O. Keya. Proceedings of the First Conference of the African Association for Biological Nitrogen Fixation (AABNF), 23–27 Jul, 1995, MIRCEN, Nairobi, Kenya.

Experiments were carried out at the International Institute of Tropical Agriculture (IITA) and at Fashola, southwestern Nigeria, to identify and characterize indigenous rhizobia nodulating *Leucaena leucocephala* (Lam.) de Wit, and to monitor the influence of some mineral nutrients on the effectiveness, survival, and competitive ability of the promising strains. Establishment of *Leucaena* was poor at both locations because of low soil fertility and the presence of only few native rhizobia capable of nodulating *Leucaena*. Isolates IRc 1045 and 1050 obtained from *Leucaena* grown at Fashola and IITA were the most effective rhizobia for *Leucaena*. At IITA only inoculated plants nodulated, while at Fashola all the plants produced nodules, and nodulation in uninoculated plots was 69%, partly due to the presence of introduced *Rhizobium* strain IRc 1050, thus indicating that indigenous rhizobia were poor competitors. Inoculation with IRc 1045 and IRc 1050 combined with phosphorus improved plant growth and nitrogen fixation. The amount of N fixed symbiotically by *Leucaena* estimated by the difference method ranged from 225

and 350 kg N ha^{-1} in six months, representing about 58% of the plant N.

0015
AD
Yamoah, C.F., K. Mulongoy, and A.A. Agboola. 1985.
Decomposition and nitrogen contribution by prunings of selected legumes in alley croppings. Pages 482–485 *in* Biological nitrogen fixation in Africa, edited by H. Ssali and S.O. Keya. Proceedings of the First Conference of the African Association for Biological Nitrogen Fixation (AABNF), 23–27 Jul, 1984, MIRCEN, Nairobi, Kenya.

Nitrogen contributions from prunings of *Gliricidia sepium* (Jacq.), *Flemingia congesta*, and *Cassia siamea* Lam. were evaluated in an alley cropping system with maize as the test crop at IITA, Ibadan, Nigeria. During the 120-day maize growth, leaf decomposition of cutbacks from 2 year-old plants was 96% dry-matter loss for *Gliricidia*, 58% for *Flemingia*, and 46% for *Cassia*. Dry-matter losses for the subsequent *Gliricidia* were 100%, 73% for *Flemingia*, and 83% for *Cassia* prunings. During the cropping season, the prunings released 252 kg N ha^{-1} for *Gliricidia*, 70 kg N ha^{-1} for *Flemingia*, and 120 kg N ha^{-1} for *Cassia*. Maize grain yield increased by 15% for *Gliricidia*, 25% for *Flemingia*, and 50% for *Cassia* relative to the control without prunings.

0016
A
Balasubramanian V. and A. Egli. 1986.
The role of agroforestry in the farming systems in Rwanda with special reference to the Bugesera-Gisaka-Migongo (BGM) region. Agroforestry Systems 4: 271–289.

A review: Rwandan farmers, faced with a perpetual land shortage, have evolved certain intensive systems of organic agriculture. These systems, particularly the homestead (compound) farming, involve the combination of food, fodder, and tree crops. The systems can satisfy the multiple needs of the farmers living under several risks and constraints, but they cannot cope with the expanding food demand of the growing population. Some multipurpose, low-input technologies and agroforestry approaches have been designed to improve the productivity of these traditional systems. These include inter/mixed cropping systems and rotations, alley cropping with leguminous trees and shrubs, use of planted "fallow", planting trees on anti-erosive lines, mixed farming, community forestry and woodlots, and tree planting on farm/field boundaries. The essential aspects of these technologies were briefly discussed.

0017
A
International Institute of Tropical Agriculture. 1986.
Performance of woody species in alley cropping with food crops. Pages 29–30 *in* Annual Report and Research Highlights 1985. Ibadan, Nigeria.

Four woody species– *Acioa barteri* (Chrysobalanaceae), *Alchornea cordifolia* (Euphorbiaceae), *Gliricidia sepium* (Papilionoideae), and *Leucaena leucocephala* (Mimosoideae)– were evaluated for their performance in alley cropping on a degraded Alfisol at IITA, Ibadan, Nigeria. In 1985, despite a heavy pruning regime of five times each year since 1982, all four species still showed vigorous coppicing after pruning, and produced substantial amounts of dry matter and nutrient yields. With or without nitrogen application, maize yield in the fifth cropping year grown under no tillage was higher than in the control treatment. In the control plot, maize yield peaked with an application of 90 kg N ha^{-1}, while the yield with *Leucaena* alley cropping was significantly higher with half the application of nitrogen (45 kg N ha^{-1}). This indicates that not only nitrogen, but also other soil improvement factors through alley cropping, may play mportant roles in ensuring higher maize yields on a degraded Alfisol.

0018
D
Mulongoy, K. and B.T. Kang. 1986.
The role and potential of forage legumes in alley cropping, live mulch, and rotation systems in humid and subhumid tropical Africa. Pages 212–231 *in* Potentials of forage legumes in farming systems of sub-Saharan Africa, edited by I. Hague, S. Jutzi, and P.J.H. Neate. Proceedings of a workshop held 16–19 Sep, 1985. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Fragile, low activity soils that are prone to erosion and are characterized by inherently low fertility are common in humid and subhumid tropical Africa. On these soils, forage legumes play an important role in developing sustainable low-input crop production systems. Woody and herbaceous species such as *Leucaena leucocephala, Gliricidia sepium, Flemingia congesta,* and *Sesbania rostrata* have good potential for inclusion in alley cropping systems. *Mucuna pruriens* var. *utilis* is one of the most promising sources of *in situ* mulch in small- and large-scale crop production. Live mulches of *Psophocarpus palustris* and *Centrosema pubescens* smother weeds effectively and could sustain high maize yield with little fertilizer N input. Despite the encouraging results obtained with forage legumes on less acid soils, further research is needed to select species that can be included in low-input crop production systems on strongly acid soils.

0019
C
Wilson, G.F., B.T. Kang, and K. Mulongoy. 1986.
Alley cropping: Trees as sources of green-manure and mulch in the tropics. Biological Agriculture and Horticulture 3: 251–167.

A review: Alley cropping brings to the tropics an effective means of using trees and woody shrubs to hasten biological soil fertility restoration. The leaves and twigs are means of returning nutrients to the soil, when applied to the soil as green manure or mulch. There are indications that nitrogen use efficiency is higher with green manuring than with mulching. Alley cropping is compatible with both green manuring and mulching. Unlike herbaceous legumes that die during the long dry season that precedes the major planting season in most part of the tropics, the trees used in alley cropping remain functional in the dry season, providing fresh material for green manure or mulch. Besides soil fertility restoration, alley cropping can be managed to prevent soil erosion and other forms of environmental decay and to provide firewood, a renewable energy source in the tropics.

0020
C
Yamoah, C.F., A.A. Agboola, and K. Mulongoy. 1986.
Decomposition, nitrogen release and weed control by prunings of selected alley cropping shrubs. Agroforestry Systems 4: 239–246.

Decomposition of prunings and weed monitoring studies were conducted in a field under alley cropping with hedgerows of *Cassia siamea, Flemingia congesta* and *Gliricidia sepium*, at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Decomposition of cutbacks and subsequent prunings ranged from 2.7 to 5.8% dry matter loss per week, and the order was: gliricidia > flemingia > cassia for the cutbacks, and gliricidia > cassia > flemingia for the prunings. In 120 days, gliricidia cutbacks released 71% of the total nitrogen required by maize, cassia 77%, and flemingia, 26%. The 29% nitrogen deficit in the gliricidia plots could be offset from a second pruning at about 66 days after planting maize, while in the case of flemingia and cassia external sources of nitrogen would be needed. During the fallow period, weed control was most effective under cassia, and its mulch still maintained a fairly good weed control during the cropping period.

0021
CD
Yamoah, C.F., A.A. Agboola, and G.F. Wilson. 1986.
Nutrient contribution and maize performance in alley cropping systems. Agroforestry Systems 4: 247–254.

The dry-matter yield and the potential contribution of N, P, and K of some woody perennials, and the performance of maize were assessed in an alley cropping system at the International Institute of Tropical Agriculture, Ibadan, Nigeria. Dry matter yield was highest for *Cassia,* and it varied significantly at the various pruning times more than those of *Gliricidia* and *Flemingia* that were relatively uniform. *Gliricidia* contributed the highest amount of nitrogen from the cutback (first pruning) and the three subsequent prunings, and also had the fastest coppicing rate. Dry wood yield at cutback was 29.7, 14.5, and 6.8 Mg ha^{-1} for *Cassia, Gliricidia*, and *Flemingia*, respectively. Root growth of maize and the uptake of the major nutrients (N, P, and K) were restricted in control plots without hedges. The results indicated that supplemental nitrogen is needed in the alley cropping systems to optimize yield, with the highest amount required in *Flemingia* alleys compared with *Gliricidia* and *Cassia*.

0022
C
Yamoah, C.F., A.A. Agboola, G.F. Wilson, and K. Mulongoy 1986.
Soil properties as affected by the use of leguminous shrubs for alley cropping with maize. Agriculture, Ecosystems and Environment 18: 167–177.

Alley cropping is a crop production system whereby food crops are planted in spaces created by hedgerows of selected shrubs that supply nitrogen and organic materials, and recycle leached nutrients. This study evaluated the effects of prunings of three leguminous shrubs on some soil properties in an alley cropping system. Soils under Cassia had the highest content of N, P, K and organic carbon with values of 0.344%, 45.6 ppm. 0.55 meq/100g, and 2.32%, respectively, after the second maize crop. Bulk density, mean aggregate diameters, water-holding capacity, and gravimetric moisture content were better in the alley cropped sites, relative to the control. *Cassia* maintained a relatively high soil biomass C, probably because of its slow rate of decomposition. Nitrogen fertilizer applied at 90 kg ha^{-1} promoted soil biomass C, essentially through increased shrub and maize dry matter production.

0023
BD
Yamoah, C.F., P. Ay, and A.A. Agboola. 1986.
The effects of some methods of establishing *Gliricidia sepium* on food crop performance, growth, and survival rate of *Gliricidia*. The International Tree Crop Journal 4: 17–31.

Establishment of *Gliricidia sepium* in an alley cropping system with arable crops was studied in the Guinea savanna zone of Nigeria. Maize height, grain yield, and percent ear-leaf nutrients content were not adversely affected by *Gliricidia* during the establishment phase. Maize grain yield and *Gliricidia* growth rate were significantly improved by the application of N fertilizer. But the survival rate of *Gliricidia* declined with time in all the establishment methods used due to the erratic rainfall pattern, especially in the case of 0.5 m cutting. The use of longer (1.2 m) cuttings gave the highest survival rates during the dry season when rainfall was erratic. Results show that when intercropping *Gliricidia* with food crops, it is safe to plant both at the same time.

0024
A
International Institute of Tropical Agriculture. 1987.
Nitrogen contribution of hedgerow trees in alley cropping systems. Pages 27–28 *in* Annual Report and Research Highlights 1986. Ibadan, Nigeria.

In 1986, the nitrogen contributions of three hedgerow species (*Flemingia congesta, Cassia siamea,* and *Gliricidia sepium*) established on a degraded Alfisol at IITA, Ibadan, to an associated maize crop grown in the alleys were determined. Treatments were prunings of the three shrubs: *Flemingia* (3 Mg ha^{-1}), *Cassia* (8 Mg ha^{-1}), and *Gliricidia* (5 Mg ha^{-1}), and different pruning application times ranging from three weeks before to four weeks after planting maize. The nitrogen content of maize was highest with *Gliricidia* prunings, because a greater amount of nitrogen was released from the decomposing *Gliricidia* prunings than from prunings of the other species. Prunings applied as from three weeks before up to planting time had an effect on the maize nitrogen content equivalent to that of applying N fertilizer at 90 kg ha^{-1} for *Gliricidia* or 60 kg ha^{-1} for *Flemingia* and *Cassia*. Maize grain yields with *Flemingia* were not influenced by time of pruning application. Nitrogen released from *Cassia* and *Gliricidia* prunings was more effectively used by maize when the prunings were applied close to the time of planting, and the effect on grain yield was comparable to that of fertilizer applied at 30 to 60 kg N ha^{-1}. Results indicate that the prunings of the three species can contribute significant amounts of nitrogen to the companion crop, which leads to higher yields without the use of chemical fertilizer.

0025
BD
International Institute of Tropical Agriculture. 1987.
***Calliandra calothyrsus*: A promising tree for alley cropping systems. Pages 29–30 *in* Annual Report and Research Highlights 1986. Ibadan, Nigeria.**

Because of the multipurpose nature of the leguminous perennial tree *Calliandra calothyrsus*, for animal feed and high quality fuelwood, and its slow growing habit compared to other species such as *Leucaena leucocephala*, which will save labor for pruning, investigation was made of its suitability for use in alley cropping systems. In 1986, yields of maize (TZPB) and a second season cowpea (IT82E-9) as affected by application of *Calliandra* prunings and by application of nitrogen fertilizer (0, 45, and 90 kg ha^{-1}) were determined on an eroded Oxic Paleustalf at Ibadan, Nigeria. Maize grain yields of plots that received prunings as mulch were 70% higher compared with those of plots from where prunings were removed, without nitrogen fertilizer. Yields of plots that received prunings and fertilizer were only slightly higher compared with those that received only prunings, indicating that *Calliandra* prunings supplied much of the nitrogen required by the crop. But the second season cowpea yield was not affected by the pruning treatment or by the inorganic fertilizer applied in the first season. Results suggest that *Calliandra* showed promise as an alley cropping species because the application of prunings alone gave good maize yields.

0026
D
International Institute of Tropical Agriculture. 1987.
Weeding requirement in alternate-year maize production in alley cropping with *Leucaena leucocephala*. Pages 31–32 *in* Annual Report and Research Highlights 1986. Ibadan, Nigeria.

Alley cropping trials with *Leucaena* hedgerows, established in 1978, had been managed with one-year cropping alternating with one-year fallow under *Leucaena*, to ensure the production of high quality stakes, poles, and firewood. *Leucaena* seeds produced during the fallow year could constitute a weed problem in maize production in the cropping year; therefore, in 1986 a hand-weeding trial was carried out to determine the weeding requirement for small farmer operations. Treatments were no weeding (control), weeding every two weeks, one weeding at 3 to 4 weeks after planting (WAP), and two weedings: at 3 to 4 WAP and at 7 to 8 WAP. Maize grain yields were 34 to 36% higher when weeding was done than without weeding (control), but there were no differences in yields among weeding frequencies. A single weeding at 3 to 4 WAP was, therefore, the only weeding required for maize in alley cropping with *Leucaena*. Results support previous findings that low competition exists between *Leucaena* seedlings and maize, indicating

that no extra weeding was required for alternate-one year maize production in alley cropping with *Leucaena* than was needed in maize sole cropping.

0027
CD
International Institute of Tropical Agriculture. 1987.
Alley cropping and soil erosion control. Page 33 *in* Annual Report and Research Highlights 1986. Ibadan, Nigeria.

Soil erosion is a serious problem in the humid and subhumid tropics, where soils are easily degraded by frequent and intense rainfall. A study was initiated in 1983 to determine whether hedgerows of shrubs (*Leucaena leucocephala* and *Gliricidia sepium*) used in alley cropping can reduce the amount of soil erosion on cultivated land. The two perennial shrubs were grown on contours at spacings of 2 m and 4 m. In 1986, with a rainfall of 41.9 mm, maize was sown in the alleys during the first season and cowpea in the second season. Maize and cowpea were also sown in two other established plots, one with no tillage and the other plowed, but both without hedgerow species. The amount of soil erosion was measured with an H-flume. Soil erosion of the alley-cropped plots was considerably less than that of the plowed plots, and was more effectively controlled at a hedgerow spacing of 2 m than of 4 m. Grain yields of maize planted in the 2-m alleys, however, were 30 to 40% below those planted in the 4-m alleys or those in zero-tillage and plowed plots, partly because of the additional space occupied by the shrubs.

0028
B
International Institute of Tropical Agriculture. 1987.
Performance of leguminous shrubs in alley cropping trials at Kagasa, Rwanda. Pages 34–35 *in* Annual Report and Research Highlights 1986. Ibadan, Nigeria.

The suitability of various leguminous shrubs for providing firewood, fodder, and nitrogen to the crops grown in alleys, was evaluated in a semiarid soil in Kagasa, Rwanda. The treatments were a control and four shrubs: *Cassia spectabilis, Leucaena leucocephala, Calliandra calothyrsus*, and *Sesbania sesban*. *Cassia spectabilis* produced the highest amount of nitrogen in the prunings, but the prunings cannot be used as fodder for domestic animals, while *Leucaena leucocephala* prunings provided good fodder. *Calliandra calothyrsus* produced the most firewood, and *Sesbania sesban* though it grew vigorously, was more highly susceptible to nematode attack, and performed poorly after the first cutting. Yields of the associated maize, bean, and sorghum crops were either better or as good as those grown without hedgerow shrubs (controls). The performance of these alley species was encouraging and their benefits could be substantial.

0029
A
Kang, B.T. and G.F. Wilson. 1987.
The development of alley cropping as a promising agroforestry technology. Pages 227–243 *in* Agroforestry: a decade of development, edited by H.A.A. Steppler and P.K.R. Nair. ICRAF, Nairobi, Kenya.

This book chapter reviewed studies on alley cropping conducted at IITA, Ibadan, Nigeria. It highlighted the constraints and management problems of upland soils in the humid and subhumid tropics, including soil acidity and Al toxicity, low nutrient reserves, nutrient imbalance and multiple nutrient deficiencies common in Ultisols and Oxisols, and major physical limitations frequent in Alfisols and associated soils. The role of planted fallow in sustainable crop production, and the potential and adoption of alley cropping as a sustainable farming system in the tropics are discussed.

0030
A
International Institute of Tropical Agriculture. 1988.
Alley cropping. Pages 87–104 *in* Resource and Crop Management Program Annual Report for 1986. Ibadan, Nigeria.

In 1986, alley cropping trials were carried out on an Alfisol at IITA, Ibadan and on Ultisols at the high rainfall station at Onne, Nigeria. Investigations were done on the long-term effects of alley cropping on soil productivity, crop yield, and soil properties; selection of suitable species for use in alley cropping, establishment of woody species, and on-farm adaptive research to test the suitability of alley cropping management systems under farmers' conditions. From a long-term trial established on a sandy soil in 1976, the effects of alley cropping with *Leucaena leucocephala* on soil productivity and crop yield were studied. The alley cropped plots had four treatments and three N rates (0, 40, 80 kg N ha^{-1}) arranged in a systematic design with four replications, and the control plots, without alley species, had five nitrogen rates (0, 40, 80, 120, 160 kg N ha^{-1}). Without nitrogen and without prunings applied, the yield of maize grown adjacent to the hedgerows was higher than those grown in the middle of the alleys, because of soil enrichment resulting from leaf fall from the hedgerows. But the reverse results were obtained with addition of *Leucaena* prunings and nitrogen. Maize yields from alley cropped plots with additions of prunings and nitrogen were slightly higher than yields in the control plots receiving the same nitrogen rates. With continuous removal of prunings and no nitrogen application, maize yields were quite low, less than 1.0 Mg ha^{-1}.

From an alley cropping trial initiated in 1983 at the high rainfall zone in Onne, Nigeria, using *Acioa barteri, Cassia siamea, Gmelina arborea, Flemingia congesta*, and *Acacia mangium*, evaluations were made to identify potential tree and shrub species for

suitability for alley cropping with cassava on Ultisols. Main treatments were the five alley species and the sub-treatments were prunings only, prunings + fertilizer, and fertilizer only, with prunings removed from the plots. The fertilizer rate was 30 N-30 P_2O_5-30 K_2O in kg ha^{-1}. Alley cropping with *Acioa* or *Cassia* did not affect cassava (var. TMS 30572) yield compared to the control, indicating that the tuber yield per plant of cassava, alley cropped with these species, was higher than in the control plot which had a higher plant density. Alley cropping with *Gmelina arborea* severely reduced tuber yield, mainly due to root competition and shading effects. There was an indication that the prunings of *Acioa* and *Cassia* could partially substitute for fertilizer use without significant effect on cassava yields.

A screenhouse trial was carried out to measure the nutrient contribution of worm casts collected from alley cropping plots established in 1981, and assess the differential effects of woody species. There were ten main plots consisting of combinations of control, woody species, and worm casts and corresponding surface soils, while the subplots consisted of six fertilizer treatments (0, PK, NP, NK NPK, NPKMgZn). Rice variety, ITA 307 was used as a test crop. At four weeks after sowing, yield of plant tops was significantly higher when grown in the worm casts than in surface soil. The highest rice yield was obtained when grown in worm casts collected from a *Leucaena* plot due to the higher soil nutrient status, while the lowest yields were obtained when rice was grown on worm casts from the control and *Alchornea* plots.

In alley cropping, direct seeding can reduce the cost of establishment of woody species hedgerows. But no data are available on the effect of seeding depth for the establishment of potential leguminous woody species. Greenhouse trials were carried out with *Cassia siamea*, *Gliricidia sepium*, and *Leucaena leucocephala* in a randomized complete block design to test seven seeding depths in four replications. Results showed contrasting effects of seeding depth on the emergence of the three species. *Leucaena* showed good emergence at all planting depths ranging from 0.5 to 6.0 cm. Fast and good emergence were obtained with a shallow planting depth of between 0.5 to 2.0 cm for *Cassia* and 0.5 to 1.0 cm for *Gliricidia*.

On-farm adaptive research was carried out in Nigeria, at Ajaawa, Oyo State, and at Zakibiam, Benue State, to validate the alley cropping technology developed at IITA. At Ajaawa village, *Leucaena* hedgerows spaced 4 m apart were established in 1983/1984, and in 1986 two treatments, with fertilizer (75 N-30 P_2O_5-30 K_2O) and without fertilizer were imposed. Maize variety TZSRW was planted in all plots. In both the control and the alley cropped plots, maize responded to fertilizer application. Maize yield was 55% higher with alley cropping than the control. At Zakibiam, however, maize yield was low and was not affected by alley cropping with *Leucaena*. But yam tuber yield responded to fertilizer application in the control and in the alley cropped plots. With fertilizer application, tuber yield was higher in alley cropped plots. Since *Leucaena* stakes were used in the alley cropping plots, there appeared to be more benefit from staking under high fertility conditions.

0031
A
Atta-Krah, A.N. and J.E. Sumberg. 1988.
Studies with *Gliricidia sepium* for crop/livestock production systems in West Africa. Agroforestry Systems 6: 97–118.

The paper reports 4-year research studies on *Gliricidia sepium* carried out by the Humid Zone Program (HZP) of the International Livestock Centre for Africa (ILCA) at Ibadan in Southwest Nigeria from 1982 to 1986. It examined the biological characteristics of the species with respect to growth, flowering, and seed production, and analyzed its potential for improving crop production through soil fertility maintenance, and livestock production through the production of improved fodder. The alley farming system was presented as a means of achieving sustainability in crop production through the integration of trees, such as *Gliricidia*, into cropping systems. The use of *Gliricidia* in Intensive Feed Gardens, for the production of leguminous fodder is also described as an alternative production system. Finally, the paper presented experiences with local farmers in on-farm research and development for the integration of *Gliricidia* and *Leucaena* into the local farming systems, and suggested more research targeted specifically at improving the species and utilization for improved crop and livestock production.

0032
D
Duguma, B., B.T. Kang, and D.U.U. Okali. 1988.
Effect of pruning intensities of three woody leguminous species grown in alley cropping with maize and cowpea on an Alfisol. Agroforestry Systems 6:19–35.

Field trials were carried out on an Oxic Paleustalf in the humid zone of southwestern Nigeria with *Leucaena leucocephala* (Lam) de Wit, *Gliricidia sepium* (Jacq.) Steud., and *Sesbania grandiflora* (L.) Pers. to investigate the influence of pruning regimes of these woody species on the performance of alley-cropped maize and cowpea. Trials were carried out one year after the establishment of the hedgerows spaced at 2 m, using a split-plot design with the three hedgerows as the main plot treatments. For the *Leucaena* trial the subplot treatments were twenty pruning combinations comprising five pruning heights and four pruning frequencies, and for *Gliricidia* and *Sesbania* hedgerows, the subplot treatments were nine pruning combinations consisting of three pruning heights and three pruning intensities. For the three woody species, biomass, dry wood, and nitrogen yields from the hedgerow prunings increased with decreasing pruning frequency and increasing height, with a ranking of *Leucaena* > *Gliricidia* > *Sesbania*. Pruning intensities had no effect on survival of *Leucaena* plants, but pruning frequency had a larger effect than pruning height on the survival of *Gliricidia* and *Sesbania* plants. The various pruning

intensities of the hedgerow species had more pronounced effects on the seed yield of the alley-cropped cowpea than on maize grain yield. Higher yields of maize and cowpea were obtained with increasing pruning frequency and decreasing pruning height.

0033
B
Duguma, B., B.T. Kang, and D.U.U. Okali. 1988.
Factors affecting germination of leucaena (*Leucaena leucocephala* [Lam.] de Wit) seed. Seed Science and Technology 16: 489–500.

The effects of stage of seed development, seed treatment, and storage on the germination percentage of *Leucaena* seeds were studied with the objectives of economizing and improving existing seed treatment methods. The freshly harvested mature green, light brown, and dark brown seeds showed high germination percentages of 72, 98, and 97, respectively, while dry seeds showed a low germination percentage of less than 20. Germination percentage of dry seeds was improved by hot water and sulphuric acid treatment and by mechanical scarification. A one to one seed: acid ratio and 10 min treatment was as effective as a 10 to one seed: acid ratio with 60 min treatment implying that a higher seed to acid ratio would economize the use of acid. Seed storage was best in a refrigerator (2 °C) or in a cold room (6 °C), but dry seed could be stored satisfactorily under room temperature or in a screen house without losing germination potential for at least one year.

0034
B
Gichuru, M.P. and B.T. Kang. 1988.
Potential woody species for alley cropping on acid soils. Page 55 *in* Agronomy Abstracts. American Society of Agronomy, Madison, USA.

Woody species are effective in regenerating the fertility of acid soils under natural fallow systems. In southeastern Nigeria, where fallow periods have been shortened due to land scarcity, farmers recognize the importance of including species such as *Acioa barteri* and *Anthonata macrophylla* in the planted fallow systems. The suitability of these and other potential species for alley cropping was evaluated. The suitability of a species depends on the primary purpose that it serves. To recycle nutrients for short duration crops, species such as *Cassia siamea* is preferred, with high biomass production and a rapid decomposition rate of prunings. Species whose prunings persist, such as *Acioa barteri*, would be effective in protecting the soil from erosion, suppressing weeds, and supplying slow release nutrients.

0035
B
International Institute of Tropical Agriculture. 1988.
Factors affecting field establishment of hedgerows in Alley farming. Pages 61—62 *in* Annual Report and Research Highlights 1987/88. Ibadan, Nigeria.

To identify the causes of poor growth and chlorosis (yellowing) in two species of hedgerow trees used in alley farming on some farms in southern Nigeria, early growth and nodulation of *Leucaena leucocephala* and *Gliricidia sepium* in two Oxic Paleustalf soils were monitored in the greenhouse. Soil samples were collected from an alley farm where the trees had chlorotic leaves ("poor" soil) and from a farm where the trees had green leaves ("fertile" soil). Both soils were treated with nitrogen and phosphorus fertilizers and inoculated with rhizobia. The chemical properties of the soil showed that the poor soil had 0.74% organic C and 0.053% total N and the fertile soil contained 24% more organic C and 89% total N. The relative symbiotic effectiveness (RSE) in N fixation, calculated as the ratio of N content of plants in the zero-N treatment with or without *Rhizobium* inoculant to N content of plants fertilized with urea, was always lower in the poor soil than in the fertile soil. Values less than 50% were obtained for *Leucaena* in the poor soil, indicating the need to inoculate it with more effective rhizobia. For *Gliricidia*, RSE values were usually high, suggesting that it fixed relatively more N in association with the indigenous rhizobia. Inoculation with rhizobia increased the number of nodules only for *Leucaena* in the poor soil. The addition of P increased nodulation, plant growth, and N uptake. Relative increases in nodule numbers and dry weights were more pronounced in the poor soil than in the fertile soil. The highest shoot dry matter increases in both soil types were obtained a with combined application of N and P. Also, the highest N uptake was obtained in these treatments, and in those where rhizobia inoculants were used with fertilizer P. Results indicate that low soil N and P contents were partly responsible for the nutritional disorders observed in the poor soil. Since the relative symbiotic effectiveness of *Gliricidia* was higher than that of *Leucaena*, the former should be encouraged for use in alley farming to avoid the need for inoculation with rhizobia. Furthermore, P application was needed to ensure proper nodulation, nitrogen fixation, and early growth of both species in Alfisols.

0036
C
Juo, A.S. R. and R.E. Meyer. 1988.
Woody legumes and soil quality maintenance with special reference to alley cropping. Paper presented at the International Conference on Dryland Farming, 15–19 Aug 1988, Bushland, Texas, USA.

Multipurpose woody legumes such as *Leucaena leucocephala, Acacia* spp., and *Prosopis* spp. (mesquite) maintain favorable soil and chemical properties through improving organic C and N in the surface soil, recycling subsoil nutrients, and controlling water and wind erosion. In the *Leucaena*/maize alley cropping system, *Leucaena* planted in 4 m-alleys can produce 7 Mg ha^{-1} (dry weight) of green manure in 2 to 3 prunings. Such green manure contains 250 kg of N, 20 kg of P, 185 kg of K, and 100 kg of Ca. Alley cropping fields established on nonacid soils at Ibadan, Nigeria, have maintained high soil productivity and crop yields over 10 years. In drier regions, although the use of *Acacia albida* and mesquite as multipurpose trees in traditional farming is well known, the use of these woody legumes in more intensive mixed food-crop or pasture production systems requires better a understanding of the plant-soil water relationships within a watershed or a land unit.

0037
A
Kang, B.T. 1988.
Agroforestry systems for sustained crop production in the tropics. Page 57 *in* Agronomy Abstracts. American Society of Agronomy, Madison, USA

The need to develop viable farming systems for tropical uplands dominated by low-activity clay soils is imperative; such systems should ensure sustained crop production, while protecting the soil resource base. Alley cropping has a potential to meet this, and has been tested with varying results, in various agroecological zones for over a decade. Results obtained so far show that the system has greater potential on the high-base status soil in the humid and subhumid zones, and that crop production can be sustained in these ecozones with low chemical inputs. Further research is needed to increase the suitability of the system in other ecozones, particularly with inclusion of more adapted or indigenous hedgerow species.

0038
B
Kang, B.T. 1988.
Nitrogen cycling in multiple-cropping systems. Pages 333–348 *in* Advances in nitrogen cycling in agricultural ecosystems, edited by J.R. Wilson. Proceedings of the Symposium on Advances in Nitrogen Cycling in Agricultural Ecosystems, 11–15 May 1987, Brisbane, Australia. CAB International, Wallingford, Oxford, UK.

Nitrogen is the key nutrient for sustaining or increasing food production in the tropics. Multiple cropping systems, particularly intercropping, sequential cropping, and rotations have benefited from the inclusion of legumes in the production system. Multiple-cropping systems are more efficient in using native N, biologically fixed N, and fertilizer N. The N benefit to the nonlegumes in multiple cropping with legumes is mostly derived from N left in crop residues. The amount of N transferred from grain legumes is usually low because most of the N is removed in the harvested grain. There are some indications that in intercropping systems, N excretions from the legumes to the associated crop may take place. The N contribution is higher from solecropped than intercropped grain legumes. Sole-cropped grain legumes can contribute between 40 and 70 kg N ha^{-1} to the succeeding crop. The inclusion of woody legumes in an alley cropping system can help to maintain soil productivity with less N input.

0039
A
Kang, B.T. and L. Reynolds. 1988.
Alley farming: its potential for humid and subhumid tropics. *in* Agroforestry for food wood production, edited by J. O. Adegbehin. Proceedings of a national agroforestry training workshop, 1–4 Aug 1988. Ibadan, Nigeria.

The traditional shifting cultivation system is biologically a stable production system when adequate land is available. Increasing land pressure due to rapid population growth and other land uses, which makes long fallow period unattainable has, however, destabilized the system. The alley farming system has been shown to be an attractive, potential alternative for modernizing the less productive traditional farming systems, particularly for food and browse production. Observations for a number of years on Alfisols and related upland soils in southern Nigeria have shown that continuous alley farming of food crops with *Leucaena* and *Gliricidia* is feasible. The system can sustain crop yield, maintain soil productivity with low input levels, conserve the soil and suppress weeds. The system can also provide browse throughout the year, staking materials, and firewood. Investigations are in progress to identify suitable species for alley farming on Ultisols, Oxisols, and related soils. Technology transfer and adoption of the system in Nigeria need to be promoted. Adoption of the technology can assist in increasing food and livestock

production and reducing the problem of deforestation and land degradation.

0040
D
Mulongoy, K. and M.K. van der Meersch. 1988.
Nitrogen contribution of leucaena (*Leucaena leucocephala*) prunings to maize in an alley cropping system. Biology and Fertility of Soils 6: 282–285.

In western Nigeria on an Alfisol, the nitrogen uptake of maize was assessed in a sole crop and in an alley cropping system with *Leucaena leucocephala*. Main plot treatments were maize alley cropped with Leucaena and maize only, and the subplots contained Leucaena prunings applied at maize planting and 8 weeks after planting and the omission of prunings. The nitrogen contributed to the maize by the prunings was low, ranging between 4.4 and 23.8 kg ha^{-1}, equivalent to 3.2% and 9.4% of the nitrogen released during the decomposition of the prunings. Application of prunings increased the grain yield of the sole crop maize by 38% and the maize yield in the alley-cropped plots by 104%. Results indicate that part of the nitrogen from the prunings was retained in the soil organic-nitrogen pool.

0041
D
Palada, M.C., M. Gichuru, and B.T. Kang. 1988.
Alley cropping maize+cassava and maize-cowpea with *Leucaena* and *Gliricidia* in Southern Nigeria. Page 60 *in* Agronomy Abstracts. American Society of Agronomy, Madison, USA.

A field trial was established in 1986 in southern Nigeria on an Apamu soil (Psammentic Ustorthent) which had been under *Imperata* fallow, to determine the effect of alley cropping on yields of maize and cassava intercropping and yields of maize and cowpea in sequential cropping. During the establishment year, maize and cassava yields were not affected by either of the hedgerows, but cowpea yield was significantly reduced by 40 to 60% due to shading by the hedgerows. When prunings were applied in the second year, there was a positive effect of alley cropping, particularly with *Gliricidia* on maize and cowpea yields. Both hedgerows reduced cassava yields by 15 to 35%, with *Leucaena* having the highest reducing effect.

0042
C
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1988.
Response of Leucaena/Rhizobium symbiosis to mineral nutrients in southwestern Nigeria. Plant and Soil 112: 121–127.

In pot and field experiments carried out at the International Institute of Tropical Agriculture (IITA) and Fashola, southwestern Nigeria, the effect of inoculation, and N, P, and micronutrients on nodulation and growth of *Leucaena leucocephala* (Lam) de Wit was examined. Treatments were varying levels of nitrogen phosphorus, micronutrients, and *Rhizobium* inoculation in a factorial combination. In pot studies, inoculation, nitrogen, and phosphorus improved most parameters measured, but micronutrients increased only nitrogen and allantoin contents. Field experiments showed that the establishment of uninoculated and unfertilized leucaena was poor at both locations because of low soil fertility and the presence of only a few native leucaena rhizobia. Shoot dry weight, total nitrogen and phosphorus contents of inoculated plants were similar to those of nitrogen-fertilized plants. In general, micronutrients had no influence on nodulation, total nitrogen, or leucaena growth, but had a positive effect on nitrogenase activity. A 75% increase in shoot dry weight was obtained when 80 kg P ha^{-1} was applied to leucaena inoculated with *Rhizobium* strain IRc 1045. Inoculated plants contained more allantoins than uninoculated ones, but no correlation was found between these compounds and other parameters of N fixation.

0043
B
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1988.
Nodulation and growth of *Leucaena leucocephala* (Lam.) de Wit as affected by inoculation and N fertilizer. Plant and Soil 112: 129–135.

At IITA, Ibadan, Nigeria, the influence of nitrogen on nodulation, nitrogen fixation, and growth of *Leucaena leucocephala* (Lam.) de Wit was examined in Leonard jar, pot, and field experiments. Shoot growth, and total N and P contents of inoculated plants were similar to those of the highest N treatment, and the values were about 55% greater than those of uninoculated plants. Field data showed that with application of 40 or 80 kg N ha^{-1}, total nitrogen yields of inoculated leucaena were increased by 50%. Nitrogen-fixation was delayed for about 8 weeks in zero-N plots, while small amounts of starter nitrogen (20 ppm) were beneficial in meeting the plant need during the early growth stage. The rhizobial strains IRc 1045 and IRc 1050 were effective and competitive, and survived well in the field one year after their establishment.

0044
CD
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1988.
Nitrogen contribution of Leucaena/Rhizobium symbiosis to soil and a subsequent maize crop. Plant and Soil 112: 137–141.

The nitrogen contribution from the shoot and root system of symbiotically grown leucaena was evaluated in a field experiment on an Alfisol at IITA in Southern Nigeria. Maize grown in plots that received prunings from inoculated leucaena contained more nitrogen, and grain yield was increased by 1.9 Mg ha^{-1}. Leucaena prunings contained large quantities of nitrogen (300 kg N ha^{-1} in six months), but the efficiency of utilization of this nitrogen by the maize crop was lower than that from 80 kg N ha^{-1} inorganic fertilizer. The nitrogen fixed symbiotically when leucaena was inoculated with *Rhizobium* strain IRc 1045 was equivalent to 25 kg ha^{-1} inorganic fertilizer. Results showed that application of prunings from inoculated leucaena gave higher soil organic C, total N, pH, and available nitrate than prunings from uninoculated leucaena.

0045
D
Sumberg, J.E. and A.N. Atta-Krah. 1988.
The potential of alley farming in humid West Africa – a re-evaluation. Agroforestry Systems 6: 163–168.

Previously published hypotheses concerning the potential impact of alley farming on maize yields were re-examined relative to the humid regions of West Africa. With more realistic assumptions regarding the availability of organic nitrogen, it was concluded that alley farming could have a potential in a wider range of maize yield environments in West Africa than was previously proposed. A pragmatic approach to alley farming research was proposed, and the importance of on-farm research in the development of "farmer friendly" alley farming was stressed.

0046
CF
Cobbina, J., B.T. Kang, and A.N. Atta-Krah. (1989).
Effect of soil fertility on early growth of *Leucaena* and *Gliricidia* in alley farms. Agroforestry Systems 8: 157–164.

Young leucaena (*Leucaena leucocephala* [Lam] de Wit) and gliricidia (*Gliricidia sepium* [Jacq] Steud) alley-cropped with food crops on farmers' fields in southwestern Nigeria showed marked variability in growth and foliage coloration. A field study was conducted to determine whether variability in soil fertility was responsible for the differential growth

of the two tree species. Plant height of leucaena and gliricidia at 6 and 9 months after planting (MAP) were significantly correlated with soil organic C and total N. Dry matter yield at 12 MAP also correlated with plant height, soil organic C, and total N for leucaena, but not for gliricidia. Soil and plant N concentrations were higher in farms with normal than those with chlorotic plants.

0047
D
Gichuru, M.P. and B.T. Kang. 1989.
***Calliandra calothyrsus* (Meissn) in an alley cropping system with sequentially cropped maize and cowpea in southern Nigeria. Agroforestry Systems 9: 191–203.**

Only a few potential trees/shrubs have been tested for their suitability for use in alley cropping. The performance of *Calliandra calothyrsus* as an alley cropping species was evaluated on an Oxic Paleustalf. The treatments were prunings removal, prunings application, and three N levels (0, 45, and 90 kg ha^{-1}). The cropping sequence was main season maize followed by minor season cowpea. Four annual prunings of *Calliandra* hedgerows produced a total of 6 Mg ha^{-1} of dry matter prunings containing about 200 kg N ha^{-1}. Maize yields were increased by the application of prunings, but no benefits were obtained by supplementing the prunings with inorganic nitrogen. An average maize grain yield of 3.1 Mg ha^{-1} yr^{-1} was maintained without any chemical fertilizer input. Cowpea yield did not respond to the application of prunings, but plants grown adjacent to the hedgerows had a reduced yield, probably due to shading. Results suggest that six rows (0.57 m inter-row spacing) between *Calliandra* hedgerows spaced at 4 m are optimum for this cowpea variety. The performance of *Calliandra* was comparable to that of *Leucaena* that has been widely shown to be effective in alley cropping systems of the region.

0048
A
International Institute of Tropical Agriculture. 1989.
Resource management research– alley farming studies. Pages 15–50 *in* Resource and Crop Management Program Annual Report for 1987. Ibadan, Nigeria.

This summarized various trials carried out on the long-term effects of alley cropping on crop performance and soil properties, short-term trials on species evaluation and on crop performance and hedgerow management, and on-farm trials to fine-tune the technology for farmers' conditions. In 1985, a long-term experiment was established at the IITA substation, Cotonou, Benin Republic, with three alley species, under three nitrogen rates (0, 40, and 80 kg ha^{-1}). The objective was to determine the effect of alternative land use in alley cropping, yearly versus alternate year cropping, and species performance and crop

yield response in the systems. Half of each plot was left fallow. In 1986, these fallow plots were put into production in split-split plot arrangement with cropping intensity as subplot and nitrogen levels as sub-subplot. Maize (TZSR-W) was sown in the first season and cowpea (ITA 84E-1-108) in the second season. In 1987, the plots were resown to maize at an increased nitrogen levels of 0, 60, and 120 kg ha^{-1}. In 1986, results showed that there was no significant effect of cropping intensity. Maize and cowpea yields associated with alley species were highest with *Gliricidia sepium*, evidently due in part to the limited residual shading of the crops by this species when compared to *Leucaena leucocephala* and *Albizia zyggia* that showed vigorous growth, in spite of pruning. Increasing nitrogen levels increased maize grain yield by over 36%, but had no effect on cowpea seed yield. Results were confirmed in 1987. The higher contribution of albizia and leucaena prunings to improved soil productivity was not enough to compensate for the greater degree to which these shrubs prevented light from reaching the crops.

In 1985, an experiment was initiated in the subhumid zone of Cotonou, Benin Republic, to study the growth and performance of some woody species: *Leucaena leucocephala*, *Gliricidia sepium*, *Flemingia congesta*, *Dalium guineense*, *Albizia zyggia*, and "Spa" (indigenous species). In 1986, because of poor establishment, *Flemingia congesta* and *Dalium guineense* were replaced with a local pigeonpea and *Gliricidia*. The plots were sown to maize (TZSR-W). Results showed that there was no significant difference in the yields of maize grown between the alley species. By 1987 cropping season with comparatively larger size and faster, but still differential regrowth of the alley shrubs, the effect on maize yield had become clearly evident, in contrast to the results of 1986. The dry matter of *Leucaena* seemed to have reached a level at which its contribution to the soil had began to compensate for the shrub's tendency to shade the crop. The results continue to show *Leucaena* as a highly promising species even for the subhumid zone. The most promising species in term of dry matter production was the local pigeonpea, but it is reputed to experience regrowth problems after two to three cuttings.

In an alley cropping trial started in 1981 on a degraded Alfisol, Ibadan, Nigeria, evaluation continued on the long-term effect of woody species spaced 4 m apart and pruned regularly to 0.75 m, nitrogen application, and tillage on the performance of maize grown in 1987. The main plot treatments were combinations of control, four woody species (*Acioa barteri*, *Alchornea cordifolia*, *Gliricidia sepium*, and *Leucaena leucocephala*), and nitrogen rates of 0 and 45 kg ha^{-1} applied to alley-cropped plots, and 0, 45, 90, and 135 kg N ha^{-1} to the control plots. The subplot treatments were with and without tillage. Maize (TZSRW) and cowpea (TVU 3236) were cropped sequentially, but no fertilizer was applied to the cowpea. The first season maize grain yield responded significantly to tillage by 21% over no-tillage. With zero or low rate of N (45 kg ha^{-1}), the highest maize yields (2.9 to 3.4 kg ha^{-1}) were observed when alley cropped with gliricidia and leucaena. In the control plots, maize yield responded only to the application of 90 kg N ha^{-1}, and the yield was about the same as that observed when 45 kg N ha^{-1} was applied

to the alley-cropped plots. The nitrogen contribution from the hedgerows was estimated for the 1986 maize crop on tilled plots receiving no nitrogen application to be about 40 kg N ha^{-1} for gliricidia and leucaena. Seed yield was highest (496 kg ha^{-1}) when alley-cropped with gliricidia and lowest when alley-cropped with leucaena (369 kg ha^{-1}). There were no effects of residual N applied to the maize or tillage on cowpea seed yields.

In 1987 an experiment was carried out to investigate the effect of nitrogen rates on the performance of maize and soybean varieties alley-cropped with various combinations of two woody species, *Acioa barteri* and *Leucaena leucocephala* established in 1983 on a degraded Alfisol (Oxic Paleustalf), and cropped as from 1985. The main plot treatment consisted of combinations of leucaena and acioa grown either in alternate hedgerows or in mixture in the hedgerows, and of two nitrogen levels (0 and 60 kg N ha^{-1}). During the first season, the subplots consisted of three maize varieties: TZESRW A-cross'84 (early maturing), TZSRW-1, and 8321-18 (hybrid); and three soybean varieties, TGX 1025-8E (early maturing), TGX 1061-29D, and TGX 814-54D, were sequentially cropped in the second season. No fertilizer was applied to the soybean crop. The early maturing maize (TZESRW) gave the lowest grain yield, about 55% of the grain yield of the open pollinated variety TZSRW-1 and 59% of the yield of the hybrid 8321-18. Average maize grain yield was at least 21% higher in the alley cropped plots without nitrogen than in the absolute control. Early termination of the rains affected soybean seed yield. Average biomass at mid-flowering was higher when alley-cropped than in the control plot, and was lowest with variety TGX 814-54D. There was no residual effect of nitrogen on the soybean crop.

In well-established alley cropping plots on a degraded Alfisol (Oxic Paleustalf) at IITA, Ibadan, Nigeria, cropped for six years, chemical and nutrient spatial variability was studied in 1987. The main plots consisted of control (no alley) and four woody species (*Acioa barteri*, *Alchornea cordifolia*, *Gliricidia sepium*, and *Leucaena leucocephala*) spaced 4 m apart. Plots were sequentially cropped with maize and cowpea, and maize received only annual basal dressings of phosphorus and potassium, and no nitrogen. The subplot treatments consisted of five surface soil (0–10 cm) samples collected from each of the alleys (a) from the upper hedgerow; (b) at 1 m from the upper hedgerow; (c) in the middle of the alley, 2 m from the hedgerow; (d) at 1 m from the lower hedgerow; and (e) from the lower hedgerow. There was large lateral variability in soil pH, organic C level, P, K, Ca, and Mg status observed within the alleys, mainly due to alley cropping with the woody species. Long-term alley cropping with the four woody species also resulted in differential soil properties. In alley cropping with *Leucaena*, the surface soils showed higher organic C, extractable P, and exchangeable K and Mg status than the other treatments, indicating that after six years of alley cropping with *Leucaena* it maintained the highest soil fertility status. Soil from plots alley-cropped with *Acioa* had the lowest exchangeable K and Ca levels, implying that much of the nutrients were retained in the slowly decomposing prunings of this species. Higher fertility status was maintained under the hedgerows than in the control, which may be linked with litter fall.

In 1983, the hedgerows of *Calliandra calothyrsus* were established at 4 m spacing on an eroded Oxic Paleustalf at IITA, Ibadan, Nigeria, to determine the suitability of this species for alley cropping in maize + cowpea sequential cropping system. Treatments in 1986 and 1987 consisted of prunings removed, prunings retained, and three nitrogen levels, 0, 45, 90 kg ha^{-1}, in a factorial arrangement. Maize was sown in the first rainy season and cowpea in the second season. Yields of cowpea in 1986 and 1987 second season were neither influenced by prunings nor by the residual effect of inorganic nitrogen applied to the previous maize, probably because cowpea is a legume and can meet its nitrogen needs from atmospheric nitrogen fixation. The optimum number of rows within the alleys for increased pod number and grain yield was estimated at four to six. Maize grain yields in 1987 were depressed when prunings were not applied, but without nitrogen application, the retention of prunings (135 kg N ha^{-1}) in the plots resulted in 45% more grain yield than when prunings were removed. Yield increases of 41 and 52% were obtained with the application of 45 and 90 kg N ha^{-1}, respectively. Results show that prunings from *Calliandra calothyrsus* are a suitable source of nitrogen for maize production, but cowpea does not derive any benefit from the prunings. *Calliandra calothyrsus* has a slower growth rate than other hedgerow species such as leucaena, and would, therefore, be preferable where labor for pruning is a constraint.

A common feature of on-farm alley cropping trials with *Leucaena leucocephala* is poor establishment of hedgerows, particularly when the shrubs are direct seeded, because of the absence of effective *Rhizobia* strains, and the problem of phosphorus deficiency in sandy soils. A greenhouse pot experiment was conducted to determine the effect of phosphorus application, and inoculation with *Rhizobia* on leucaena establishment. Main plot treatments were five soil sources from different parts of Nigeria: two from on-farm sites (Psammentic Ustorthent), one from IITA (Oxic Paleustalf), and an acid soil (Typic Paleudult) from Onne. The sub-plot treatments were phosphorus levels (0 and 50 ppm P), and inoculants (control, broth with laboratory-cultured *Rhizobia*, and soil from well nodulated leucaena) in a factorial arrangement. Extra treatments were included to test the effect of lime ($CaCO_3$) on acid soil from Onne. Plants were grown for 14 weeks. *Leucaena* growth responded most to "soil inoculant" treatment. Phosphorus was limiting in all four soils, but inoculation had the greatest effect on the IITA soil, suggesting the presence of effective *Rhizobia*. In acid soil, leucaena growth and nodulation were increased by the application of either lime or phosphorus, but lime had a greater effect.

In spite of the large nitrogen content of a well-nodulated *Leucaena leucocephala* species, supplementary nitrogen fertilizer is needed to maximize maize yields in alley cropping systems with leucaena hedgerows. In 1986 and 1987 first growing seasons, experiments were carried out on an Alfisol at IITA, Ibadan, Nigeria, to assess the efficiency with which the associated maize crop utilizes nitrogen from leucaena prunings. The main plots were alleys and no alleys. The subplots contained leucaena hedgerow prunings applied at planting, and 8 weeks after planting maize (Ekona 83 TZSR-4-1), and a control, without prunings. Average dry weight of prunings applied at planting of maize

was 6.5 Mg ha^{-1}, and 5.0 Mg ha^{-1} 8 wk later. Decomposition of leucaena prunings was determined in the first year by the litter bag technique. In both years, the application of prunings resulted in higher maize stover and grain yields, and nitrogen content than in plots without prunings. Maize dry matter production and nitrogen uptake were lowest in the alley plots with prunings removed. The highest nitrogen contribution of 24 kg ha^{-1}, representing 63% of maize nitrogen content, occurred in the alley plots where prunings were retained, while in the no-alley plots, the contribution averaged 27% of maize nitrogen in both years. But the contribution due to alleys alone was negative, due in part, to competition for nutrients and water between leucaena hedgerows and maize. Nitrogen recovery from prunings by maize was low, possibly because much of the nitrogen in the pruning was retained in the soil organic matter or lost through leaching and volatilization.

Preliminary studies had shown that *Leucaena leucocephala* had no direct effect on weed control when the alley species was interplanted with maize. In 1987, an experiment was set up at IITA, Ibadan, Nigeria, to study the long-term effect of leucaena on the biology and ecology of tropical weeds. The main plot treatments were: no leucaena, leucaena pruned and cropped yearly, and leucaena cropped every other year with pruning in the cropped year. Leucaena seeds were planted a year before observations were made on weed biology. Maize was used as the test crop. Results showed that there were differences in the germination patterns and in the amount of annual grasses and broadleaf weeds, with the former accounting for more than 90% of the weeds observed in all the treatments. Whereas the broadleaf weeds maintained two peak flushes in weed germination, at maize planting and at 8 weeks after planting, the annual grasses showed a single peak flush at planting only. The highest weed density occurred at 4 weeks after maize planting, but decreased to the lowest level at maize harvest, partly because some weeds had a short life span, and partly because some died early.

Staking is a major labor-demanding operation in yam production that can be eliminated by the use of alley cropping system. In 1986 and 1987, yam staking trials were carried out in 4 m-wide *Leucaena leucocephala* alleys established six years earlier at IITA, Ibadan, Nigeria, to evaluate the effect of staking on yam production in leucaena alleys. The treatment factors were two yam species, *Dioscorea alata* and *D. rotundata*; and three staking treatments: leucaena cut back at 0.3 m from the ground, leucaena ringed at 0.3 m from the ground to kill the shoot, and leucaena cut and used as dead stakes. The use of dead stakes resulted in the highest tuber yield of 2.2 Mg ha . *Dioscorea alata* was higher yielding and tolerated non-staking better, but had lower mean nitrogen content than *D. rotundata*. Staking increased the nitrogen level of both species, and also resulted in higher P and K contents of *D. alata*. Results showed that on the basis of tuber yields, staking yams remains the better option.

On-farm adaptive research was carried out Ajaawa village (Psamments) Oyo State, and Zakibiam (Plinthustalfs) Benue State, Nigeria, to validate alley cropping technology. At Ajaawa village, in 4-m spaced leucaena hedgerows established in 1984, two treatments, with fertilizer ($75N\text{-}30P_2O_5\text{-}30K_2O$) and without fertilizer were imposed in

1986 and 1987. At Zakibiam the fertilizer rate was 90N-45P_2O_5-45K_2O, but some trials were in 2-m spaced alleys established in 1981, while others were with 4-m spaced alleys established in 1985. Maize was used as the test crop in both locations. Results showed that at both locations, maize responded to nitrogen application and alley cropping. The mean grain yield of alley cropped maize was 21% higher than in plots with no alleys. At Zakibiam, yields were low, with a high degree of variability of treatment effects between sites.

In 1985, a researcher-managed trial was established at Alabata (Psamments) Oyo State Nigeria, to investigate the possibility of rehabilitating an *Imperata*-infested piece of land. The treatments were three main plots: control, alley cropping with *Leucaena*, and alley cropping with *Gliricidia*; and four subplot treatments: no fertilizer and no residue, no fertilizer plus residue, fertilizer (30N-30 P_2O_5-30 K_2O) only, and fertilizer plus residue. In 1987, results showed that maize (TZSRW) grain yield was higher in the control than in any of the treatments with alley cropping, possibly because the plot was located at the bottom of the block. Application of prunings and fertilizers increased maize yield. Alley cropping with *Gliricidia*, especially when fertilizer was applied, gave a higher yield than with *Leucaena* alley cropping.

0049
C
Juo, A.S.R. and B.T. Kang. 1989.
Nutrients' effects of modification of shifting cultivation in West Africa. Pages 289–300 *in* Mineral nutrients in tropical forest and savanna ecosystems. Blackwell Scientific Publications, Oxford, UK.

Recycling of plant residues, fertilizer use, and the inclusion of trees and perennials in crop fields are key components in systems for improved food crop production on infertile soils in the forest regions of West Africa. On Alfisols of pH 5.5 or above in the forest and forest-transitional zones, systems including food crop-cover crop rotation, minimum tillage, and the judicious use of fertilizer can sustain yield on small farms for 10 years or more without reverting land to bush fallow. Interplanting leguminous trees such as *Leucaena leucocephala* with annual crops is shown to improve food crop yields. The leguminous trees fix atmospheric nitrogen, recycle mineral nutrient from the subsoil, and prevent soil erosion and runoff water on sloping land. On strongly leached acid soils (Ultisols and Oxisols) in high-rainfall regions, nutrient cycling and green manuring are less effective because of subsoil infertility. Intensive food crop production on such soils requires costly inputs of fertilizer and lime. Experiments have shown, however, that the periodic application of small dosages of lime can sustain a moderate crop yield. Gradual saturation of subsoil horizons with calcium is a prerequisite for effective recycling of nutrients in agricultural systems in the high-rainfall regions.

0050
C
Kang, B.T. and O. Onafeko. 1989.
Spatial chemical soil variability in alley cropped plots. Pages 55 *in* Agronomy Abstracts. American Society of Agronomy, Madison, USA.

Research was undertaken to determine the spatial chemical soil variability in well-established alley cropped plots that had been continuously cropped for six years. The experimental area was located on a degraded Alfisol (Oxic Paleustalf). The effects of four hedgerow species (*Acioa barteri, Alchornea cordifolia, Gliricidia sepium*, and *Leucaena leucocephala*) grown at 4 m interhedgerow spacing were compared to control (no hedgerow) plot. Large lateral variability in surface soil pH, organic C level, and P, K, Ca, and Mg status was observed within the alleys. Alley cropping with *Leucaena leucocephala* gave the highest soil organic C, extractable P, and exchangeable K and Mg status.

0051
D
Kang, B.T., A.C.B.M. van der Kruijs, and D.C. Couper. 1989.
Alley cropping for food crop production in the humid and subhumid tropics. Pages 16–26 *in* Alley farming in the humid and subhumid tropics. Proceedings of an International Workshop, 10–14 March 1986, IITA. Ibadan, Nigeria, edited by B.T. Kang and L. Reynolds. Ottawa, Ont., IDRC.

Upland arable farming on fragile, tropical soils requires viable, sustainable, and environmentally sound production systems that can meet the requirements of farmers who use traditional cultivation practices. Trials where various crops were grown between *Gliricidia sepium* and *Leucaena leucocephala* tree rows in the lowland humid and subhumid tropics on non-acid soils have shown good results. Prunings from selected leguminous woody species, such as *Leucaena* and *Gliricidia,* give high nitrogen yield and assist nutrient cycling. Such prunings also improve and maintain the organic matter, nutrient status, and biological activity of the soil. Results from long-term plots showed that maize yields were higher in the alley cropping plots than in the control plots. *Cassia siamea* and *Acioa barteri* are promising crops for alley farming on acid soils. The inclusion of hedgerows reduced runoff and erosion. Mechanized alley cropping is feasible if properly managed.

0052
D
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. I. Soil moisture and crop yields. Agroforestry Systems 8: 7–29.

Field experiments were conducted on a tropical Alfisol at Ibadan, Nigeria, to evaluate the effects on soil moisture and crop yields of three agroforestry systems. Treatments were hedgerows of two perennial shrubs (*Leucaena leucocephala* and *Gliricidia sepium*), each established at 2-m and 4-m row spacing, and a control without perennial hedgerows and consisting of plow-till and no-till systems of seed bed preparation. Alterations in soil properties and effects on maize (*Zea mays*) and cowpea (*Vigna unguiculata*) grown in a rotation were evaluated from 1982 to 1987. Seed germination and seedling establishment of *Leucaena* hedgerows were satisfactory, while the establishment of *Gliricidia* from stem cuttings was unsatisfactory. Maize grain yield in agroforestry systems averaged about 10% lower than that in the control. Agroforestry systems drastically suppressed cowpea seed yield, with average yield ranging from 30 to 50% of the control. Regardless of the management system, grain yields declined over time at a rate of 340 kg ha^{-1} yr^{-1} for maize and 96 kg ha^{-1} yr^{-1} for cowpea. Hedgerows of the two species acted as windbreaks, consequently soil moisture content in the top 0–5 cm layer in the agroforestry systems was generally higher than that in the control during both the wet and dry season.

0053
C
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. II. Water runoff, soil erosion, and nutrient loss. Agroforestry Systems 8: 97–111.

Field runoff plots were set up on a tropical Alfisol in southwestern Nigeria to monitor water runoff, soil erosion, and nutrient loss in water runoff. The treatments were two agroforestry systems based on contour hedgerows of *Leucaena leucocephala* and *Glirircidia sepium* established at 4-m and 2-m spacings, and a non-agroforestry control treatment established at two levels: plow-till and no-till systems of seedbed preparation. Hydrological measurements were made for uniform maize-cowpea rotation for 12 consecutive growing seasons from 1982 through 1987. Once established, hedgerows of *Leucaena* at 2-m spacing were effective in reducing water runoff and controlling erosion. Runoff, erosion and nutrient losses were generally more from maize grown in the first season than from cowpea grown in the second. The mean seasonal erosion in the treatments (Mg ha^{-1}) from maize was 4.3 (plow-till), 0.10 (no-till), 0.57 (*Leucaena*-4m), 0.10 (*Leucaena*-2m), 0.64 (*Gliricidia*-4m) and 0.6 (*Gliricidia*-2m). While the mean runoff in the first season from these treatments listed in the order above was 17.0, 1.3, 4.9, 3.3,

4.3, and 2.4% of the rainfall events received. There were high losses of bases in water runoff from agroforestry treatments, probably due to nutrient recycling by the deep-rooted perennials.

0054
C
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. III. Changes in soil chemical properties. Agroforestry Systems 8: 113–132.

Effects of three agroforestry systems were evaluated on changes in soil chemical properties over a period of 12 consecutive crops of maize-cowpea rotation grown on a tropical Alfisol in southwestern Nigeria. The treatments were plow-till, no-till, *Leucaena* hedgerows established on the contour at 4-m and 2-m spacing, and *Gliricidia* hedgerows established at 4-m and 2-m spacings. Soil chemical properties for 0–5 cm depths were measured over a period of 5 years from 1982 to 1986. Soil organic matter, total N, pH, and exchangeable bases declined in all treatments, whereas total acidity and exchangeable Al^{+3} increased. Depletion of soil fertility was the most severe in plow-till and the least severe in Leucaena-based systems. There was an increase in soil pH and exchangeable bases in the soil during the third and fourth years of hedgerow establishment.

0055
C
Lal, R. 1989.
Agroforestry systems and soil surface management of a tropical Alfisol. V. Water infiltrability, transmissivity, and soil water sorptivity. Agroforestry Systems 8: 217–238.

In a long-term agroforestry experiment established on an Alfisol in western Nigeria the soil infiltrability was evaluated once a year for 5 consecutive years. The treatments were plow-till, no-till, and contour hedges of *Leucaena leucocephala* and *Gliricidia sepium* at 4- and 2-m intervals. Continuous cultivation based on two crops per year caused drastic reductions in infiltrability in all treatments, with the rate of decline most severe in the no-till treatment. After 5 years of continuous cultivation, the equilibrium infiltration rates were 8, 19, 21, and 24 cm h^{-1} for no-till, *Gliricidia*-based, plow-till, and *Leucaena*-based, respectively. The cumulative infiltration at 2 h was 24, 59, 70, and 76 cm for no-till, *Gliricidia*-based, *Leucaena*-based, and plow-till treatments. The soil/water sorptivity (S) also differed among treatments. Philip and Kostiakov's infiltration models were used to express the infiltration data.

0056
F
Palada, M.C. 1989.
On-farm research methods for alley cropping. Pages 84–91 *in* Alley farming in the humid and subhumid tropics. Proceedings of an International Workshop, 10–14 March 1986, IITA. Ibadan, Nigeria, edited by B.T. Kang and L. Reynolds. Ottawa, Ont., IDRC.

On-farm research methods, which follow a sequence of events until the technology is ready for adoption by farmers, can be applied to alley cropping research and development. A well-focused on-farm research consists of well defined objectives, criteria for site selection, identification of target groups, accurate descriptions of the farming system, constraints and opportunities, appropriate design of on-farm trials and a well-established on-farm testing program. On-farm trials can be researcher-managed, whereby trials are conducted in the early stages of alley farming research and provide information of biological nature. It could also be farmer-managed trials that give indications of both the biological and socioeconomic aspects of alley cropping technology.

0057
D
Shannon, D.A., M. Kubaluapa, and M.L. Mpoy. 1989.
A promising technology for the savanna of Zaire. Page 59 *in* Agronomy Abstracts. American Society of Agronomy, Madison, USA.

A trial was carried out in Gandajika, Zaire (Republic of Congo), to study the effects of alley cropping on maize yields. Hedgerows of *Leucaena leucocephala* spaced 4 m apart were seeded together with maize in January 1986, on a coarse-textured Alfisol. Treatments were presence or absence of hedgerows, and presence or absence of a low rate of fertilizer. Pruning frequency and timing were adjusted to minimize competition to the maize crop. Alley cropping decreased maize yields slightly in the first season and increased yields from the fourth season onward. Without alley cropping, yields generally declined after the third season. Alley cropping without fertilizer resulted in a stable yield over time, but with fertilizer, resulted in increased yields over time.

0058
F
Vogel W.O. 1989.
Economic returns of alley farming. Pages 196–206 *in* Alley farming in the humid and subhumid tropics. Proceedings of an International Workshop, 10–14 March 1986, IITA. Ibadan, Nigeria, edited by B.T. Kang and L. Reynolds. Ottawa, Ont., IDRC.

Economic evaluations of alley cropping had focused in the past on how profitable it is to the individual farmer. The decision to invest in alley farming is an individual one, but as farmers are aggregated to groups and groups to regions, the costs and benefits to these aggregates increase. This paper suggests mathematical programming as a method for the *ex ante* evaluation of alley farming at different levels of aggregation. The models measure the benefits to the society, and information can be incorporated as it becomes available. Alley farming was compared with other technologies that maintain fertility and control erosion in the long term.

0059
B
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1989.
Effectivity of indigenous rhizobia for nodulation and early nitrogen fixation with *Leucaena leucocephala* grown in Nigerian soils. Soil Biology and Biochemistry 21: 231–235.

Rhizobium strains isolated from *Leucaena leucocephala*, *Sesbania rostrata*, *S. grandiflora*, *S. punctata*, *Tephrosia vogelii*, *Acacia albida* and *Vigna unguiculata* growing in Nigerian soils were characterized and tested for their ability to nodulate and fix atmospheric nitrogen with *L. leucocephala*. Isolates from *L. leucocephala*, *S. rostrata*, *S. grandiflora* and *S. punctata* were fast growing and acid producers, whereas those from *A. albida*, *T. vogelii*, and *V. unguiculata* were slow growing and alkali producers. The effectivity of the rhizobia isolates on *L. leucocephala* tested in Leonard jars showed that the isolates from all the plant species except those from *S. grandiflora* and *V. unguiculata* nodulated *L. leucocephala*, but with a wide range of effectiveness. Pot trials using soils collected from IITA, Ibadan and Fashola, showed that the establishment of *L. leucocephala* was poor in soils without a previous history of *L. leucocephala* cultivation due to the presence of only a few native leucaena rhizobia (< 1000 g^{-1} soil). *Rhizobium* isolates IRc 1045 and IRc 1050 obtained from *L. leucocephala* grown at Fashola and at IITA were most effective and competitive on this host, and they survived well in the field 1 year after their establishment.

0060
B
Sanginga, N., K. Mulongoy, and A. Ayanaba. 1989.
Nitrogen fixation of field-inoculated *Leucaena leucocephala* (Lam.) de Wit estimated by ^{15}N and the difference methods. Plant and Soil 117: 269–274.

The amount of nitrogen fixed by *Leucaena leucocephala* (Lam.) de Wit was assessed on an Alfisol at IITA, Ibadan, Nigeria. Estimation by the difference method gave nitrogen fixation of leucaena inoculated with *Rhizobium* strain IRc 1045 of 133 kg ha^{-1} in six months and a lower nitrogen fixation of 76 kg ha^{-1} when inoculated with *Rhizobium* strain IRc 1050. Fertilization with 40 and 80 kg N ha^{-1} inhibited nitrogen fixation by 43 to 76% and 49 to 71%, respectively. Estimates with the ^{15}N dilution method gave nitrogen fixation of 134 kg ha^{-1} in six months when leucaena was inoculated with *Rhizobium* strain IRc 1045, and 98 kg ha^{-1} when inoculated with *Rhizobium* strain IRc 1050. Inoculated leucaena derived a range of 5 to 6% of its nitrogen from applied fertilizer, 34 to 39% from nitrogen fixation and 54 and 56% from soil.

0061
D
Wilson, G.F. and R. Swennen. 1989.
Alley cropping: potential for plantain and banana production. Pages 37–41 *in* Alley farming in the humid and subhumid tropics. Proceedings of an International Workshop, 10–14 March 1986, IITA. Ibadan, Nigeria, edited by B.T. Kang and L. Reynolds. Ottawa, Ont., IDRC.

Plantain and cooking bananas are important carbohydrate food sources in the humid tropics. They are traditionally grown in bush-fallow rotational systems, multistorey cropping systems, or backyard gardens. Mulching is beneficial for plantains and bananas. Alley cropping with trees and shrubs is proposed as a source of mulch. Three concepts for managing plantains with woody legumes are being tested.

0062
CD
Atta-Krah, A.N. 1990.
Alley farming with Leucaena: Effect of short grazed fallows on soil fertility and crop yields. Experimental Agriculture 26: 1–10.

A long-term trial with *Leucaena leucocephala* was initiated in 1982 to test the sustainability of *Leucaena*-based alley farming compared to a conventional cropping system without trees and with continuous cultivation of maize. The study assessed the integration of short grazed fallows in rotation within *Leucaena* alleys and their effects on

soil fertility and crop yields. The organic C and total N contents of the soils under conventional cropping were lower by the end of the fourth year than those under alley cropping and alley grazing treatments, whereas soil P levels were lower in the alley cropping and grazing plots. Alley cropping in rotation with 2-year grazed fallows gave higher crop yields during cropping years than those under continuous cultivation. There is a need to establish a cropping/fallow rotation management system that will enhance sustainability and optimize the benefits to crop and livestock production in alley farming systems.

0063
CG
Ehui, S.K., B.T. Kang, and D.S.C. Spencer. 1990.
Economic analysis of soil erosion effects in alley cropping, no-till, and bush fallow systems in southwestern Nigeria. Agricultural Systems 34: 349–368.

Most upland soils in the humid and subhumid tropical Africa are characterized by low inherent soil fertility and are also susceptible to soil erosion and compaction with cultivation. Based on a simulation model, a capital budgeting approach was used to determine the profitability of alternative land use systems, considering the short- and long-term impact of soil erosion on agricultural productivity in southwestern Nigeria. The fallow systems were: (1) two continuous cultivation alley cropping systems with leucaena hedgerows planted at 2 m and 4 m interhedgerow spacings; (2) the continuous cultivation no-till farming system; and (3) two traditional bush fallow systems with a 3-yr cropping period in 6- and 12-year cycles. Under a 10% discount rate, when no yield penalties were imposed (reflecting the case of low population density), the 12-year-cycle shifting cultivation system was most profitable, followed by the 4 m alley cropping. But when penalties were imposed on yields due to land being taken out of production because of fallow vegetation (reflecting the case of rising land values), the 4 m alley cropping was most profitable. Thus, where access to new forest land is "costless", slight yield damage from erosion will not detract significantly from the immediate profit advantage of traditional bush fallow systems, with longer fallow periods.

0064
B
Gichuru, M.P. and B.T. Kang. 1990.
Potential woody species for alley cropping on acid soils. Pages 85–86 *in* Agroforestry land use systems, edited by E. Moore. NFTA, Hawaii, USA.

An alley cropping system can be used for sustained low input production on nonacid soils. Because woody species such as *Leucaena* and *Gliricidia* do not perform well on acid soils, trials were undertaken at the IITA high rainfall station at Onne, Nigeria, to

evaluate the potential of some native and exotic woody species suitable for alley cropping on acid soils that have a low nutrient supply. Two indigenous species, *Acioa barteri* and *Anthonatha macrophylla*, and two exotic species, *Cassia siamea* and *Inga edulis*, appeared to be promising for alley cropping on acid soils. All four species coppiced well and showed similar levels of K, Ca, and Mg. *Acioa barteri* had lower levels of N and P than other species, and appeared to be well adapted to grow under low N and P conditions. *Acioa barteri* and *Anthonatha macrophylla* are widely used in the traditional farming system as fallow crops planted on acid soils and under high rainfall conditions in southeastern Nigeria. During the 9-month alley trial, *Acioa* prunings produced over 6 tonnes of dry material, while *Cassia* produced only 3 tonnes. *Gmelina arborea* produced more woody than leafy biomass. A long-term alley cropping trial with *Acioa barteri* showed the suitability of this species for alley cropping in acid soils. Cassava top and tuber yields per plant were higher when alley cropped with *A. barteri* than under the control treatment. A similar trend was observed when cassava was alley cropped with *C. siamea*; but cassava yield were depressed when alley cropped with *Gmelina arborea* because of subterranean and area competition.

0065
B
Gichuru, M.P. and K. Mulongoy. 1990.
Effect of inoculation with rhizobium, P application, and liming on early growth of Leucaena (*Leucaena leucocephala* Lam. de Wit) Pages 72–80 *in* Maximizer la FBA pour la Production Agricole et la Forestière en Afrique, edited by M.Gueye, K. Mulongoy, and Y. Dommergues. III^me^ Conference de l'AABNF, 7–12 Nov 1988.

The effects of P application (0 and 50 mg P/kg soil), inoculation with soil from a field with well nodulated *Leucaena leucocephala*, and a water suspension of rhizobium strain IRc 1045 specific for *Leucaena* were studied in four soils, two Psammentic Ustorthents, one Oxic Paleustalf, and one Typic Paleudult. Application of P improved *Leucaena* growth and nodulation in all the four soils, but the highest response was obtained in the Psammentic Ustorthent from a farm where *Leucaena* established poorly. Soil inoculation with *Rhizobia* improved *Leucaena* growth, and increased nodulation and dry-matter yield, except on the Oxic Paleustalf from the International Institute of Tropical Agriculture (IITA) on which *Leucaena* normally performs well. The soil inoculant performed better than the water suspension of strain IRc 1045. Dicalcium phosphate affected the early growth of *Leucaena* on the Typic Paleudult because of its liming properties.

0066
C
Hulugalle N.R. and B.T. Kang. 1990.
Effect of hedgerow species in alley cropping systems on surface soil physical properties of an Oxic Paleustalf in southwestern Nigeria. Journal of Agricultural Science (Cambridge) 114: 301–307.

The effects of hedgerow species on surface soil physical properties were studied in a trial established since 1981 on an Oxic Paleustalf in southwestern Nigeria. The treatments were *Leucaena leucocephala*, *Gliricidia sepium*, *Alchornea cordifolia*, and *Acioa barteri* hedgerows planted at 4 m interhedgerow spacing and a control (no hedgerows). Plots were sequentially cropped with maize (*Zea mays*) and cowpea (*Vigna unguiculata*). Soil physical properties of alley-cropped plots were superior to those of the control. Soil compaction was highest in the control and lowest with *L. leucaena*. Between the hedgerow species, within-season increases in soil compaction were largest with *A. cordifolia*. Results of soil temperatures monitored from February to June 1989 showed that the lowest temperatures were observed with *L. leucocephala* and *A. barteri*. The frequency, quantity, and quality of prunings produced by the hedgerow species seemed to have a major beneficial effect on soil physical properties.

0067
A
Kang, B. T., L. Reynolds, and A. N. Atta-Krah. 1990.
Alley farming. Advances in Agronomy 43: 315–359.

The rising demand for food and feed has resulted in increased in deforestation and land degradation in many parts of the tropics. In sub-Saharan Africa, food production relies mainly on area expansion and the use of traditional farming methods that depend on inherent soil fertility. In the 1980s, research attention has been focused on the development of low input technologies for sustainable food production for smallholder farmers. Alley cropping is one of such technologies. It involves the cultivation of food crops between hedgerows of multipurpose trees. The use of woody legumes provides nitrogen-rich mulch and green manure to maintain soil fertility and enhance crop production, and protein-rich fodder for livestock. Hedgerows planted along the contour, on sloping lands, greatly reduce soil erosion. Within the forest zone, and particularly in the forest-savanna transition areas of Africa with nonacid soils, on-station and on-farm trials have shown that alley farming with *Leucaena* and *Gliricidia* allows a higher level of production than the traditional system. Similar results have also been obtained in comparable agroecological zones in Asia and the Pacific regions.

0068
A
Kang, B.T. and R.J. van Denbeldt. 1990.
Agroforestry systems for sustained crop production in the tropics with special reference to West Africa. Pages 13–35 *in* Agroforestry land-use systems, edited by E. Moore. Nitrogen Fixing Tree Association (NFTA), Hawaii, USA.

Trees and shrubs feature prominently in traditional farming systems in the tropics because of their many uses and their environmental and socioeconomic benefits. Woody species form a major component of the bush fallow system and are also widely grown on cropped land. Intercropping woody species with annual crops in temporal and spatial agroforestry systems could enhance sustainability of production systems. The inclusion of woody species, particularly certain legumes, can enhance nutrient cycling, soil fertility maintenance and erosion control; provide biologically fixed N and a basis for developing intensive, more productive, and sustainable upland food crop production with low purchase inputs. Potential agroforestry systems suitable for sustainable crop production in the humid and semiarid tropics of sub-Saharan West Africa are described and recent research advances and future research needs are discussed.

0069
D
Anoka, U.A., I.O. Akobundu, and S.N.C. Okonkwo. 1991.
Effects of *Gliricidia sepium* (Jacq.) Steud and *Leucaena leucocephala* (Lam.) de Wit on growth and development of *Imperata cylindrica* (L.) Raeuschel. Agroforestry Systems 16: 1–12.

Field studies were carried out in a forest transition site on a tropical Alfisol in southwestern Nigeria to assess the influence of leguminous hedgerow trees, gliricidia (*Gliricidia sepium* [Jacq.] Steud) and leucaena (*Leucaena leucocephala* [Lam.] de Wit) on the growth and development of speargrass (*Imperata cylindrica* [L.] Raeuschel). Shading by gliricidia hedgerow reduced speargrass density by 67% and shoot biomass by 81%, while leucaena hedgerow decreased the density by 51% and shoot biomass by 78%. The reduction in speargrass rhizome biomass was 96% in gliricidia plots and about 90% in leucaena plots. Gliricidia was better than leucaena hedgerow species in suppressing speargrass.

0070
CD
Balasubramanian, V. and L. Sekayange. 1991.
Effects of tree legumes in hedgerows on soil fertility changes and crop performance in the semiarid highlands of Rwanda. Biological Agriculture and Horticulture 8: 17–32.

The soil fertility improvement potential of five tree legumes as alley hedges was studied on a Ultic Haplustox soil at a semiarid highland site in Rwanda from 1983 to 1989. The tree species tested included *C. calothyrsus* Meissn., *C. spectabilis* DC, *L. diversifolia* (Lam.) de Wit., *L. leucocephala* (Lam.) de Wit., and *S. sesban* (L.) Merr., all grew to a height of 1.01 to 2.15 m and 2.85 to 3.37 m after 1 and 1.5 yr, respectively. Most of the species could withstand intensive prunings, but with *S. sesban*, 83 % of the trees died after six prunings. The aboveground dry matter production increased steadily with the age of the trees, with mean dry weight of leaf biomass of 5.6 to 7.3 Mg ha^{-1} and a range of 3.7 to 5.0 Mg ha^{-1} of wood. The mean annual nutrient addition to the soil through leaf biomass was: 72 to 119 kg ha^{-1} of N, 2 to 3 of P, 47 to 94 of Ca, 8 to 19 of Mg, and 29 to 60 of K. This was equivalent to an application of 10 Mg ha^{-1} yr^{-1} of cattle manure. A combined application of leaf biomass and manure increased the soil pH (water) by 0.4 to 0.5 units, K by 0 to 0.7 mmol, Ca by 10.8 to 17.6 mmol, Mg by 0.5 to 2.3 mmol, and exchange capacity by 10.5 to 34.0 mmol above the level of soils cleared from the savanna vegetation. Grain yield increase of beans (*Phaseolus vulgaris* L.) and sorghum (*sorghum bicola* L.) to tree foliage application was largest in *C. spectabilis* alleys. Maize (*Zea mays*) response was poor, while tuber yield of sweet potato (*Ipomoea batatas* [L.] Lam.) decreased when planted in alleys, due to the lower tuber yield per unit crop area in alleys than in the control and a 14 to 32% yield fall off at the tree/crop interface.

0071
F
Dvorák, K.A. 1991.
Methods of on-farm, diagnostic research on adoption potential of alley cropping. Agroforestry Systems 15: 167–181.

An approach to on-farm diagnostic research on alley cropping is described. The objective of the economic assessment was to evaluate the adoption potential of the technology. The three research activities involved included firstly, cost-route surveys and field measurements carried out for a small sample of farmers with recently established alleys, aimed at developing a framework for analyzing alley cropping on-farm. The second activity involved administration of a focused, formal single visit survey to a large sample of farmers who have participated in alley farming trials at several locations. Intensive data collection with a small sample continued in order to quantify factors identified as key in

the first activity. Even though still developmental, it is hoped that the combination of methods will contribute to the development of more rapid and readily accessible methods of evaluating agroforestry technology on-farm.

0072
CD
Kang, B.T. and B.S. Ghuman. 1991.
Alley cropping as a sustainable system. Pages 172–182 *in* Development of conservation farming on hillslopes, edited by W.C. Moldenhauer, N.W. Hudson, T.C. Shang, and S.W.J. Lee. Soil and Water Conservation Society, Ankeny, Iowa, USA.

A long-term trial was established in 1982 near Ibadan, Nigeria, to evaluate the effect of alley cropping and tillage on soil properties, runoff, soil loss, and crop performance. Treatments were hedgerows of *Leucaena leucocephala* or *Gliricidia sepium* established across a slope of about 7%, at interhedgerow spacings of 2 or 4 m, with the alley tilled by hand hoeing before maize was planted. The control (without hedgerows) treatments were either tilled or not tilled. The hedgerows were allowed to grow freely in the 1987-88 dry season and were pruned in March 1988. The resulting twigs and leaves were spread as mulch between the tilled alleys, and the stems were placed against the upslope of the hedgerows. During cropping season, hedgerows were pruned twice in May and July to 0.75 m to prevent shading. Maize was planted in the first season and cowpea in the second season. In 1988 cropping season, soil properties showed that soil pH was slightly lower (5.1–5.2) in alley cropped plots than in the control (5.3–5.4). The tilled control had the lowest organic C and exchangeable K, Ca, and Mg. Biomass and wood yield from prunings were highest in the 2-m spaced alleys for both species. Maize grain and stover yields were significantly higher in the alley-cropped plots than in both controls. Cowpea biomass and seed yield and nodulation were lowest in the tilled-control plots, while the alley-cropped plots showed higher plant biomass and seed yield than the no-tillage control. The values were depressed in the 2-m *L. leucocephala* plot, mainly due to shading. Runoff, soil loss, and nutrient loss were lowest in the tilled-control plot, but the values were lowest in the no-tillage control and in the 2-m alley-cropped plots.

0073
A
Kang, B.T., M.N. Versteeg, O.A. Osiname, and M.P. Gichuru. 1991.
Agroforestry in African's humid tropics: three success stories. Agroforestry Today 3: 4–6.

Describes traditional agroforestry systems in tropical Africa. Brief accounts are given of three low input and sustainable systems including, the Adja oil palm fallow system, the

traditional *Acioa barteri* alley cropping system, and the *Cajanus cajan* fallow system.

0074
BD
Siaw, D.E.K.A., B.T. Kang, and D.U.U. Okali. 1991.
Alley cropping with *Leucaena leucocephala* (Lam. De Wit) and *Acioa barteri* (Hook. f) Engl. Agroforestry Systems 14: 219–231.

On an Alfisol in the humid forest of southern Nigeria, the effect of alley cropping with seven combinations of *Acioa* and *Leucaena* hedgerows and a control (no hedgerow) on sequentially cropped maize and cowpea was studied in 1985 and 1986. The hedgerows were established in 1983, using 4 m inter-hedgerow spacing and pruned to 25 cm height during cropping. The highest dry matter, wood, and nutrient yields of prunings of *Acioa* and *Leucaena* hedgerows were obtained with sole cropping. Growing both species in the same hedgerows suppressed dry matter production and nutrient yield of *Acioa* more than that of *Leucaena* because of the faster growth of *Leucaena*. *Leucaena* prunings had higher nutrient yield than *Acioa*. Under 22-month old uncut hedgerows, weed biomass declined in the presence of *Leucaena*, either alone or in combination with *Acioa*. Alley cropping with various combinations of *Acioa* and *Leucaena* hedgerows increased maize and cowpea yields compared to the control. Mean yield increase due to N application was lowest in hedgerows with *Leucaena* and highest in the control. There seemed to be no advantage for the tested *Leucaena* and *Acioa* combinations on maize and cowpea crops when compared to the sole hedgerows.

0075
B
Cobbina, J., K. Mulongoy, and A.N. Atta-Krah. 1992.
Effect of fertilization and *Rhizobium* inoculation on the growth of *Leucaena* and *Gliricidia* on an Alfisol in southwestern Nigeria. Pages 161–169 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, U.K.

A pot experiment was carried out using soils differing in fertility obtained from alley farms, to determine the response of *Leucaena leucocephala* and *Gliricidia sepium* to nitrogen and phosphorus fertilizers and to inoculation with rhizobia. The application of the fertilizers, separately or combined, in the low-fertility soil increased plant height and shoot dry matter and nitrogen yield at 84 days after planting. Inoculation with the *Rhizobium* strains IRc 1045 (local) and Lx 382 (Nitragin, USA) improved shoot dry matter and nitrogen yield in some cases, but was not as effective as the use of nitrogen fertilizer. There is, thus, a need to identify more effective strains of *Rhizobium* for these

environments. Nitrogen fertilizer decreased nodule number on *L. leucocephala* in the relatively poor soil with or without phosphorus application, but had no effect on the plant's nodule numbers in the relatively fertile soil with P treatment. In this zone, phosphorus fertilizer may be necessary to ensure adequate nodulation, nitrogen fixation, and plant growth.

0076
B
Ezenwa, I.V. and A.N. Atta-Krah. 1992.
Early growth and nodulation in *Leucaena* and *Gliricidia* and the effects of pruning on biomass productivity. Pages 171–178 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, U.K.

Two pot experiments were carried out to assess the patterns of early root and shoot growth and nodulation, and the effects of increasing frequency of pruning on leaf dry-matter yield, root weight and nodulation of *Leucaena leucocephala* and *Gliricidia sepium*. In *G. sepium* the emphasis during the early growth was on the production of lateral roots and nodulation, whereas in *L. leucocephala* it was on the elongation of the taproot. This may have caused the delay in nodulation in *L. leucocephala* as the lateral roots (the major point of nodule attachment) were observed only at 12 weeks after planting. Increasing the frequency of pruning from 12-week to 4-week intervals significantly reduced leaf and root dry-matter yields and nodulation in both species. The highest leaf dry-matter yields were produced with 8-weekly and 12-weekly pruning regimes, while the uncut plants produced the highest root weight. Based on nodulation parameters measured, uncut plants performed better than plants cut every 4 weeks, but were inferior to those cut every 8 or 12 weeks, indicating that a lenient pruning regime may enhance nodulation and/or nodule longevity.

0077
A
Kang, B.T. and K. Mulongoy. 1992.
Nitrogen contribution of woody legumes in alley cropping systems. Pages 367–375 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, U.K.

Despite the potential for obtaining high and sustainable crop yields under rainfed upland conditions in the tropics with high fertilizer input, this technology is not widely used in Africa. Alley cropping is an alternative, sustainable, and low-input production system.

The inclusion of nitrogen-fixing woody legumes in alley cropping contributes significant amounts of nitrogen to associated crops, while the system itself contributes organic matter to the soil. This paper reviews recent progress in quantifying some of the components of the nitrogen-cycling mechanism in alley cropping and highlights those issues that still require research attention, particularly areas characterized by acid soils, in order to enhance nitrogen utilization by the associated crops.

0078
B
Osunde, A.O., F. Zapata, and N. Sanginga. 1992.
Agronomic evaluation of a rock phosphate as a phosphorus source for *Leucaena leucocephala* grown on an Ultisol. Pages 133–138 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, U.K.

A greenhouse experiment using an Ultisol from southeastern Nigeria was conducted to assess phosphorus availability to two *Leucaena leucocephala* lines (K 28 and K 636) using ^{32}P radioisotope techniques. All plants were inoculated at planting and received either 250 mg P pot^{-1} as Gafza rock phosphate or 50 mg P pot^{-1} as triple superphosphate. Dry-matter yields at 7 and 14 weeks after planting (WAP) showed a significant superiority of the rock phosphate over the triple superphosphate in this soil. None of the plants nodulated at 14 WAP and no significant differences were noted between the two *L. leucocephala* lines in their utilization of P from rock phosphate source. The ^{32}P isotopic data indicated that the plants derived significantly more of their P at 7 and 14 WAP from rock phosphate than from single superphosphate.

B
0079
Ruhigwa, B.A., M.P. Gichuru, B. Mambani, and N.M. Tariah. 1992.
Root distribution of *Acioa barteri*, *Alchornea cordifolia*, *Cassia siamea*, and *Gmelina arborea* in an acid Ultisol. Agroforestry Systems 19: 67–78.

A major constraint to alley cropping is the competition of tree or shrubs roots with those of companion food crops for available water and nutrients in the topsoil. Root distribution patterns of *Acioa barteri*, *Alchornea cordifolia*, *Cassia siamea*, and *Gmelina arborea* grown on an acid Ultisol at Onne in the humid forest zone of southeastern Nigeria were examined to a depth of 1.2 m and laterally to 2 m from the tree trunk. The objective was to study the suitability of the species for alley cropping. The four woody species had roots throughout the soil profile examined but differed in the concentration of roots both laterally and vertically. *Alchornea cordifolia*, *Cassia siamea*, and *Gmelina arborea*, in

spite of higher underground biomass production, had most of their fine roots (< 2 mm diameter) in the top 20 cm of the soil, implying that their root systems would compete with food crops for nutrients and moisture in the surface soil. *Alchornea cordifolia* and *Gmelina arborea* had many large woody roots in the surface soil which will make any tillage or seedbed preparation difficult. In contrast, *Acioa barteri* had the desirable rooting systems with fewer fine roots in the surface soil. Its roots were concentrated close to tree trunk and decreased markedly away from the tree base. In addition, its roots penetrated deeper soil horizons and can result in more efficient nutrient cycling from these layers, and in reduced competition with shallow-rooted food crops, indicating that the species is a promising alley cropping shrub in the acid soils of the humid forest ecology. Rooting characteristics of potential tree/shrub species should be considered in the development of agroforestry systems such as alley cropping.

0080
B
Sanginga, N. 1992.
Early growth and N_2-fixation of leucaena and gliricidia at different levels of phosphorus application. Fertilizer Research 31: 165–173.

The phosphorus (P) uptake and use efficiency in relation to N_2 fixation and growth of three provenances of gliricidia (*Gliricidia sepium*), two cultivars of leucaena (*Leucaena leucocephala*) and one of *L. diversifolia*, all inoculated with *Rhizobium*, were determined at five levels of P application. Increasing the P application rates resulted in a 33% increase in dry matter and total N of *L. diversifolia* and an 18% increase in dry matter of gliricidia provenance 13/84 over the control without P. Leucaena K8, that did not respond to P application, yielded as well with low P as *L. diversifolia* at the high P, indicating the lower P requirement of cultivar K8. Correlation analyses showed that differences between species and cultivars/provenances for P uptake per plant were largely related to differences in shoot growth rate and distribution of P between roots and tops. Phosphorus use efficiency (shoot dry weight per mg P in shoots) was not related to dry matter production. Genetic control of and dry matter distribution of P are probably more important than P availability in the growth media for gliricidia and leucaena provenances or cultivars. Increasing the application rate significantly increased the number and mass of nodules in leucaena cultivars and gliricidia provenances. Significant increases in the proportion of N derived from atmospheric N_2 (% Ndfa) due to low P application (20 mg P kg^{-1} soil) were observed within leucaena, but not for gliricidia provenances. No increases in % Ndfa occurred with higher P, suggesting that symbiotic N_2 fixation *per se* is stimulated only with low rates of P.

0081
B
Sanginga, N., F. Zapata, S.K.A. Danso and G.D. Bowen. 1992.
Estimating nitrogen fixation in *Leucaena* and *Gliricidia* using different ^{15}N labelling methods. Pages 265–275 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, U.K.

A pot experiment was conducted to compare the proportion of nitrogen derived from the atmosphere in *Leucaena leucocephala* and *Gliricidia sepium*, using two nitrogen applications and four different methods of introducing ^{15}N into the soil. A single application of 5 mg N kg^{-1} soil (20 atom % ^{15}N excess) rotated in different pots at seedling stage, 3, 6, and 9 months after planting resulted in high estimates (about 80%) of nitrogen derived from the atmosphere. Labelling the soil with 20 mg N kg^{-1} (5 atom % ^{15}N excess) gave significantly lower estimates. When based on leaves, the proportion of nitrogen derived from the atmosphere was significantly higher than when estimations were based on the means of the different plant parts or the weighted-average. The results obtained suggest that ignoring roots can lead to errors in estimating nitrogen fixation.

0082
BD
Hauser, S. 1993.
Effect of *Acioa barteri*, *Cassia siamea*, *Flemingia macrophylla* and *Gmelina arborea* leaves on germination and early development of maize and cassava. Agriculture, Ecosystems and Environment 45: 263–273.

The potential allelopathic effects of *Acioa barteri*, *Cassia siamea*, *Flemingia macrophylla*, and *Gmelina arborea* leaf material on the germination of maize and early growth of cassava cuttings were investigated. Incubation of maize seeds with freshly added *G. arborea and C. siamea* leaf material reduced germination by 35%. Under non-sterile conditions, *F. macrophylla* and *A. barteri* leaf material significantly reduced the number of roots of maize seedlings; and the root and shoot weight per seedling were reduced by 50%. Under sterile conditions, *G. arborea* and *C.siamea* leaf material reduced germination and number of roots per seedling at 7 days after inoculation. Early development of cassava was retarded by amendments with *A. barteri* leaves. *G. arborea* leaf material retarded fungal growth, but this potential benefit was outweighed by the reduction of maize and cassava yields.

0083
BD
Hauser, S. 1993.
Root distribution of *Dactyladenia* (*Acioa*) *barteri* and *Senna* (*Cassia*) *siamea* in alley cropping on an Ultisol. I. Implication for field experimentation. Agroforestry Systems 24: 111–121.

Root observations were carried out on a Typic Paleudult in the humid forest zone of southeastern Nigeria in an alley cropping trial using *Dactyladenia* (*Acioa*) *barteri* and *Senna* (*Cassia*) *siamea* as hedgerow trees and the interrow space planted to maize/cassava intercrop. Rooting depth of both hedgerow species exceeded 1.6 m, while lateral root propagation of *S. siamea* was 15 m, and that of *D. barteri* was 5 m from the hedgerows. In the no-tree control plot, rooting density and depth of *S. siamea* was generally higher than that of cassava, and the root densities of both species were inversely correlated. Assuming radial symmetry of root propagation, water and nutrients were available from an area of 6.1 and 2.3 times larger than the allocated plot size of *S. siamea* and *D. barteri*, respectively. Data obtained in alley cropping trials, not considering lateral root propagation, can be invalidated through exploitation of the no-tree control treatment and nutrient acquisition by hedgerow species from a larger area than allocated, thus underestimating or overestimating the performances of the respective treatments.

0084
CD
Hauser, S. and B.T. Kang. 1993.
Nutrient dynamics, maize yield, and soil organic matter in alley cropping with *Leucaena leucocephala*. Pages 215–222 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. J. Wiley, Chichester, UK.

This study presents the results of a *Leucaena leucocephala* alley cropping trial conducted on an Alfisol at Ibadan in southwestern Nigeria. Maize grain yield was generally higher in the alley cropped plots than in the plots without hedgerows (control) partly due to nutrients being readily available from the first pruning. The average yield advantage in five years of alley cropping was 25.8% compared to the control. The amounts of N and K applied with the first pruning were significantly correlated with maize grain and dry-matter yield, grain–N and –K contents, and the K content in the dry matter. Over 90% of the K applied with the first pruning was released by the second pruning, but N release was slower. After six years of continuous cropping a surface (0–15 cm) soil organic carbon level of 0.94% was maintained in the alley cropped plots compared to the control plots with 0.59%, while higher levels (1.23%) were maintained under the hedgerows. More earthworm casting was observed under the hedgerows than in the alley or the control,

resulting in greater nutrient and C recycling and retention under the hedgerows.

0085
CD
Hulugalle, N.R. and J.N. Ndi. 1993.
Effects of no-tillage and alley cropping on soil properties and crop yields in a Typic Kandiudult of southern Cameroon. Agroforestry Systems 22: 207–220.

The effects of no-tillage and alley cropping with *Cassia spectabilis* hedgerows on soil properties and crop yields in a Typic Kandiudult of the humid forest zone of Central Africa were studied over the period 1990–1992 in southern Cameroon. The treatments were no-tillage and hand tillage, that were either alley cropped with *C. spectabilis* hedgerows at interhedgerow spacing of 6 m or not alley cropped (control). A maize + cassava intercrop was planted in all plots at the commencement of each growing season. No-tillage had no significant effects on soil physical properties except to decrease soil temperature, but it increased soil organic C and total N in both years and soil pH in 1991 when compared to hand tillage. No-tillage also resulted in a greater proportion of *C. spectabilis* roots occurring in the topsoil. Alley cropping caused significant reductions in dry season soil temperature, surface seal formation and cassava root growth, and increases in exchangeable Ca, effective CEC and water infiltration compared with non-alley cropped controls. Infiltration rates at 2 hours after commencing measurements were greater by 75% with alley cropping than without alley cropping. Lowest maize cob and cassava tuber yields were observed when no-tillage was combined with alley cropping whereas highest yields occurred with no-tillage alone.

0086
C
Kachaka, S., B. Vanlauwe, and R. Merckx. 1993.
Decomposition and nitrogen mineralization of prunings of different quality. Pages 199–208 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. John Wiley & Sons/Sayce Publishing/IITA/K.U. Leuven (copublication), Chichester, UK.

Plant residues of four alley cropping hedgerow species (*Leucaena leucocephala, Senna siamea, Dactyladenia barteri*, and *Flemingia macrophylla*) were compared in laboratory incubation experiments to relate the observed decomposition/nitrogen mineralization pattern and microbial biomass dynamics to the quality factors, such as C/N ratio, lignin/N ratio and polyphenol content. Fractionation of the residues into readily soluble components, cellulose, hemicellulose, and lignin showed quality differences between species. In the case of *S. siamea* and *D. barteri*, all quality parameters were shown to be age dependent. Amongst the parameters used, only the lignin/N and lignin +

polyphenol/N ratios accounted for the observed patterns in decomposition and N mineralization. Soil microbial biomass could be predicted in soils amended with *L. leucocephala* and *S. siamea*, whereas in soils amended with more resistant materials, such as *F. macrophylla* and *D. barteri*, it was largely overestimated.

0087
C
Mulongoy, K. and M.O. Gasser. 1993.
Nitrogen-supplying capacity of leaves of *Dactyladenia barteri* (Hook ex olw) and *Leucaena leucocephala* (Lam.) de Wit in two soils of different acidity from southern Nigeria. Biology and Fertility of Soils 16: 57–62.

A laboratory experiment was carried out to study the evolution of mineral and hydrosoluble organic N released from two soils differing in pH. The treatments were leaves of *Leucaena leucocephala* at the rate of 0, 8.3, 16.7, and 33.3 g kg^{-1} soil and *Dactyladenia barteri* at 0 and 16g kg^{-1} soil. Nitrogen mineralization in untreated soils and in soils supplemented with 8.3 g leucaena leaves was 41–53% higher in the soil from Onne (pH 4.7) than in the soil from Ibadan (pH 6.2), but the organic N content was similar with these treatments in both locations. The application of 16.7 or 33.3 g of either or both type of leaves reduced the rate of mineral N production during the first 4 weeks, particularly in soils treated with dactyladenia leaves (C:N = 36), after which it proceeded at a faster rate in the soil from Ibadan treated with 16.7 or 33.3 g of leucaena leaves (C:N = 12), even in the presence of dactyladenia leaves. The addition of dactyladenia and leucaena leaves did not increase the mineral N content in the acid soil from Onne, but leaching of soluble organic N with addition of 16.7 or 33.3 g of leaves contributed to an N-mineralizable pool of 5.9% of the N applied.

0088
C
Mulongoy, K., E.B. Ibewiro, O. Oseni, N. Kilumba, A.O. Opara-Nadi, and O. Osonubi. 1993.
Effect of management practices on alley-cropped maize utilization of nitrogen derived from prunings on a degraded Alfisol in southwestern Nigeria. Pages 223–230 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. John Wiley & Sons/Sayce Publishing/IITA/K.U. Leuven (copublication), Chichester, UK.

Previous studies on a degraded Alfisols in southwestern Nigeria showed that maize recovery of nitrogen released from prunings of hedgerow trees was low. This study compared prunings of different biochemical composition, prunings applied at different times or in different quantities, and two methods of pruning placement in order to identify

the management practices that would increase maize nitrogen uptake in alley-cropping systems. Prunings of *Senna (Cassia) siamea*, *Gliricidia sepium*, and *Leucaena leucocephala* contributed the largest amount of N when applied close to maize planting time, with an effect equivalent to fertilization with 70 kg urea N ha^{-1}. The effect of surface application of these prunings and the prunings of *Flemingia macrophylla* on maize N uptake was similar to that of their incorporation into the soil. The rate constant of decomposition of prunings of *L. leucocephala* (C/N=11; lignin/N=4) was reduced by 60% when prunings were mixed with the relatively high C/N (15) or lignin/N (11) leaves of *S. siamea*, implying that the N contribution to food crops will be prolonged. Results showed that an application of prunings close to maize planting time and a mixture of high N and low N prunings could enhance N recovery from prunings in alley-cropped maize.

0089
C
Mulongoy, K., K.N. Kunda, and C.N.K. Chiang. 1993.
Effect of alley cropping and fallowing on some soil fertility parameters in southern Nigeria. Pages 47–55 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. John Wiley & Sons/Sayce Publishing/IITA/K.U. Leuven (copublication), Chichester, UK.

Under tropical conditions, the rapid decline of soil fertility when land is cleared and cultivated has emphasized the key role played by soil organic matter in sustaining soil productivity. This study assessed the efficiency of planted or selected fallows and alley cropping in maintaining soil organic matter at five sites in southern Nigeria. In general, soil organic C content was at least 46% less in fields under maize or cassava alone than in planted fallow plots and adjacent natural bush fields. Established trees maintained soil organic C at levels found in natural bush fallow plots. The performance of leguminous hedgerow trees in maintaining soil organic matter was similar to that of the non-legumes, except at Onne, where organic C and humic acid content were highest under *Dactyladenia barteri*. Organic C significantly correlated with soil N and ECEC, but not with humic acid.

0090
C
Ruhigwa, B. A., M.P. Gichuru, N.M. Tariah, N.O. Isirimah, and D.C. Douglas. 1993. Spatial variability in soil chemical properties under *Dactyladenia barteri*, *Alchornea cordifolia*, *Senna siamea*, and *Gmelina arborea* hedgerows on an acid Ultisol. Experimental Agriculture 29: 365–372.

Spatial nutrient distribution was studied under a 3.5-year-old fallow of *Dactyladenia barteri*, *Alchornea cordifolia*, *Senna siamea*, and *Gmelina arborea* hedgerows grown on

an acid Ultisol in southeastern Nigeria. The objectives were to evaluate the nutrient cycling capacity and suitability of the hedgerow species for alley cropping. There were no consistent patterns in the lateral distribution of soil pH, total nitrogen, organic carbon, available phosphorus, exchangeable cations, total acidity, and effective cation exchange capacity in the 4 m-wide alleys formed by the hedgerow species. *Senna siamea* and *Gmelina arborea* tended to increase soil organic carbon, calcium, magnesium, and effective cation exchange capacity, particularly in the top 50 cm soil, compared with *Alchornea cordifolia* and *Dactyladenia barteri*, and can therefore, be recommended for soil fertility regeneration on acid Ultisols during fallow period. They, however, appear to be less suitable for alley cropping than *Dacyladenia barteri* because they are shallow rooting.

0091
C
Van der Meersch, M.K., R. Merckx, and K. Mulongoy. 1993.
Evolution of plant biomass and nutrient content in relation to soil fertility changes in two alley cropping systems. Pages 143–154 *in* Soil organic matter dynamics and sustainability of tropical agriculture, edited by K. Mulongoy and R. Merckx. John Wiley & Sons/Sayce Publishing/IITA/K.U. Leuven (copublication), Chichester, UK.

The amount of prunings produced and the nitrogen contributed to the soil and to maize by *Leucaena leucocephala* and *Senna (Cassia) siamea* was studied over a 5-year period at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. Biomass production of *L. leucocephala* was highest (19 Mg DW ha^{-1} yr^{-1}). The decomposition rate of *L. leucocephala* which had a high N content of 3.7% was faster (half-life of 27 days) than that of *S. siamea* (1.8% N, half-life of 75 days). Synchronization between N release and N uptake seemed to be highest during the period between 50 and 90 days after planting, indicating that improvements was possible if dates of the second pruning operation are changed. There was a contribution of 20% of the N released from the *L. leucocephala* prunings, and 30% from *S. siamea* prunings. Plant nutrients declined in the cultivated systems, but less so in the alley cropping systems than in the continuous monocropping systems. Changes in soil microbial biomass, used as an early indicator of changes in soil fertility, indicated that soil fertility was improving in the alley cropping systems. Maize yields were maintained in the alley cropping systems, with the highest yields of 3.7 Mg ha^{-1} obtained in the fertilized *S. siamea* system, compared to 3.0 Mg ha^{-1} obtained in adjacent bush regrowth cropped after 4 years of fallow.

0092
F
Versteeg, M.N. and V. Koudokpon. 1993.
Participative farmer testing four low external input technologies, to address soil fertility decline in Mono Province (Benin). Agricultural Systems 42: 265–276.

Farmer participation in experimenting with technologies in Mono province (Benin) increased when attention was focused on their major problems. One such problem is soil degradation caused by over-exploitation of land. Four different low external input technologies, all with leguminous components and half of them based on agroforestry, have been tested since 1990 by sub-groups of farmers, who belong to a discussion group focusing on this problem. The technologies are: (i) a short season fallow of *Mucuna pruriens* var. *utilis*; (ii) an improved perennial tree fallow of *Acacia auriculiformis*; (iii) a short season fallow of pigeonpea; and (iv) an alley-cropping system on the basis of alternating hedgerows of *Gliricidia sepium* and *Leucaena leucocephala*. The first two technologies were aimed at the regeration of very degraded plots, while the latter two technologies concentrate on stabilizing land still moderately fertile.

0093
C
Hauser, S. and M.P. Gichuru. 1994.
Root distribution of *Dactyladenia (Acioa) barteri* and *Senna (Cassia) siamea* in alley cropping on Ultisol. II. Impact on water regime and consequences for experimental design. Agroforestry Systems 26: 9–21.

Tensiometer measurements were carried out on a Typic Paleudult in the humid forest zone of southeastern Nigeria in an alley cropping trial using fertilized and unfertilized *Dactyladenia* (*Acioa*) *barteri* and *Senna* (*Cassia*) *siamea* as hedgerow trees with a no-tree control. The interrow spaces of alley cropped and no-tree control plots were planted to maize/cassava intercrop. Water withdrawal during short dry spells and the dry season was fastest in the no-tree control plot and resembled the pattern in the adjacent *S. siamea* alley cropping. Installation of a root barrier 70 cm deep led to a retarded water withdrawal to a depth of 150 cm in unfertilized no-tree control plots. In fertilized no-tree control, this retardation occurred to a depth of 110 cm, and at 130 and 150 cm water withdrawal with root barriers was faster than without barriers. *S. siamea* depleted water resources in the no-tree control plot and shortened the growing season of cassava. Restricting roots to the assigned plot size can reduce competition for water in adjacent plots even in layers below the depth of the barrier, but can also induce compensative water withdrawal from layers that were not necessarily affected by the barrier. Methods to determine minimum plot size in order to reduce the risk of invalidation through root interference and misinterpretation of results are suggested.

0094
CD
Hulugalle, N.R. and J.N. Ndi. 1994.
Changes in soil properties of a newly cleared Ultisol due to establishment of hedgerow species in alley cropping systems. Journal of Agricultural Science (Camb.) 122: 435–443.

This study evaluated the short-term (< 3 yr) ability of some selected hedgerow species adapted to acid-soil when planted in alley-cropping systems to improve soil properties in a newly cleared Ultisol (Typic Kandiudult) of southern Cameroon, 1990–92. Three selected hedgerow species including, Senna (*Senna spectabilis*), Flemingia (*Flemingia congesta*) and Acioa (*Acioa barteri*) and a non-alley-cropped control were used in the trial. The greatest quantities of prunings and hence, mulch, were produced by Senna and Flemingia. Exchangeable Ca, effective CEC, and water infiltration were greatly increased in the alleys of plots where either Flemingia or Senna had been planted within 2.5 years of establishment. Root growth of Senna in the subsoil was significantly greater than that of either Acioa or Flemingia, but that of cassava was reduced by alley cropping with all the three hedgerow species. When compared with the control or alley cropping with Acioa, maize and cassava yields were greater when alley cropped with either Flemingia or Senna hedgerows.

0095
B
Kadiata, B.D. and Mulongoy, K. 1994.
Effect of pruning frequency on nitrogen accumulation and fixation in two woody legumes. Pages 203–213 *in* Recent development in biological nitrogen fixation in Africa, edited by M. Sadiki and A. Hiali. Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco.

Nitrogen accumulation and fixation were studied in 12-month-old *Leucaena leucocephala* (Lam.) de Wit cv. K 28 and *Albizia lebbeck* (L.) Benth, subjected to no pruning, pruning once at 4 months after planting (MAP) and twice at 4 and 8 MAP under screenhouse conditions. Increasing pruning frequency reduced biomass production, N accumulation, and the amount of N_2-fixed per plant at 12 MAP, but the number of nodules and % Ndfa were unaffected. Nitrogenase activity increased by 16% and 118% over the control in trees subjected to 1 and 2 successive prunings. Nitrogen fixed per plant in *Albizia* dropped from 5.8 to 3.4 and 3.5 g and in *Leucaena* from 3.1 to 1.8 and 1.7 g with 1 and 2 successive prunings, respectively. Regardless of the pruning regime, *Albizia* had the highest ARA (25.5 μmol $plant^{-1}$ hr^{-1}), nodule biomass, nodulation index, and fixed twice as much nitrogen as *Leucaena*. *Albizia lebbeck* has a potential for use in alley cropping

systems as a woody species with high biomass and N_2 fixation.

0096
C
Kang, B.T., F.K. Akinnifesi, and J.L. Pleysier. 1994.
Effect of agroforestry woody species on earthworm activity and physiochemical properties of worm casts. Biology and Fertility of Soils 18:193–199.

The effects of five agroforestry woody species on the surface casting activity of *Hyperiodrilus africanus* were studied in an Alfisol (Oxic Paleustalf) in southwestern Nigeria. The casting activity under the woody species decreased in the following order: *Dactyladenia barteri* (26.4 Mg ha^{-1} yr^{-1}) > *Gliricidia sepium* (24.4 Mg ha^{-1} yr^{-1}) > *Treculia africana* (22.9 Mg ha^{-1} yr^{-1}) > *Leucaena leucocephala* (18.6 Mg ha^{-1} yr^{-1}) > *Senna siamea* (18.3 Mg ha^{-1} yr^{-1}), and could be partly explained by microclimate effects. Irrespective of the woody species, the worm casts were higher in clay and silt contents, bulk density, water-stable aggregates, pH, organic C, extractable cations, effective cation exchange capacity, and extractable P levels than the corresponding surface soils. The content of water-stable aggregates of worm casts was highest in *Dactyladenia* sp. and lowest in *Gliricidia* sp. The highest extractable P level (11.5 mg kg^{-1}) and P sorption were observed on worm casts under *Senna* sp. and *Dactyladenia* sp., respectively, while the lowest values of these P fractions were found on casts under *Treculia* sp. With NPK applications, the dry weight and N uptake of maize grown in worm casts associated with *Treculia* sp. was significantly lower than that of maize grown in the other worm casts, mainly due to the low extractable P level (4.9 mg kg^{-1}). Despite a high organic C and exchangeable K status, maize grown in the worm casts still responded significantly to N and K applications.

0097
B
Okogun, J.A., K. Mulongoy, C.T.I. Odu, and A.A. Agboola. 1994.
Screening of multipurpose trees for alley cropping on Alfisol and Ultisol. Pages 551–562 *in* Recent development in biological nitrogen fixation in Africa, edited by M. Sadiki and A. Hiali. Hassan II Institute of Agronomy and Veterinary Medicine, Rabat, Morocco.

Fifteen local and exotic woody species were screened, on fertilized and non-fertilized Alfisol and Ultisol soils in a pot trial, at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. The trees were harvested at 6 months after planting, to assess some growth parameters and biological nitrogen fixation (BNF). Application of NPK fertilizer improved nodulation in *Abizia lebbeck* by 80% in nonacid soil and by 56% in acid soil, while it enhanced nitrogenase activity by over 80% in *Gliricidia sepium* ILG55

(nonacid soil) and *A. lebbeck* (acid soil). Nitrogen fixation in *Leucaena* varieties was lower with fertilizer than without. With or without fertilizer application, *Abizia lebbeck* produced the highest biomass in nonacid soil, and *Afzelia bella, Cassia spectabilis*, and *Dialium guineense* performed poorly in both soils. *Gliricidia sepium* ILG55, *L. leucocephala* var K28 and *L. diversifolia* produced high biomass on both Ibadan and Onne soils, and therefore, are good potential trees for alley cropping establishment on acid soil.

0098
B
Sanginga, N., S.K.A. Danso, K. Mulongoy, and A.A. Ojeifo. 1994.
Persistence and recovery of introduced *Rhizobium* ten years after inoculations on *Leucaena leucocephala* grown on an Alfisol in southwestern Nigeria. Plant and Soil 159: 199–204.

To improve the establishment of *Leucaena leucocephala* in the low fertility soils of Ibadan and Fashola in southwestern Nigeria, inoculation was done in these two locations in 1982 using *Rhizobium* strains IRc 1045 and IRc 1050 isolated from *L. leucocephala* grown in Nigeria. Because of the perennial nature of *L. leucocephala* and its use in long-term alley farming experiments, the persistence of inoculated rhizobial strains after inoculation and their ability to sustain N_2-fixation and biomass production at Ibadan was examined. In 1992, ten years after *Rhizobium* introduction, uninoculated, *L. leucocephala* fixed about 150 kg N ha^{-1} yr^{-1} or about 41% of total plant N compared to 180 kg N ha^{-1} yr^{-1} or 43% measured in 1982. Serological typing of nodules using the Enzyme-Linked-Immunosorbent Assay (ELISA) and intrinsic resistance to the streptomycin test showed that most of the nodules (96%) formed on *L. leucocephala* in 1992 were the *Rhizobium* strains IRc 1045 and IRc 1050, that were inoculated in 1982. Nodules were absent on uninoculated *L. leucocephala* grown on an adjacent field with no history of *L. leucocephala* cultivation. Results indicate that the N_2 fixed by *Rhizobium* strains IRc 1045 and IRc 1050 persisted for many years in the absence of *L. leucocephala,* and sustained effectively fixed N_2 with growth and yield of *L. leucocephala* after several years, thus, encouraging a possible low-input alley farming system by smallholder farmers in Nigeria.

0099
B
Sanginga, N., S.K.A. Danso, F. Zapata, and G.D. Bowen. 1994.
Influence of pruning management on P and N distribution and use efficiency by N_2 fixing and non-N_2 fixing trees used in alley cropping systems. Plant and Soil 167: 219–226.

Pruning of hedgerow trees is an important management practice in the alley cropping system that affects biomass production, but there is little evidence of its effect on the distribution of nutrients among the different plant organs after tree regrowth. A field study was conducted on an Alfisol (low in P) at Fashola in southwestern Nigeria, to examine the effect of pruning on the distribution and use efficiency of N and P in a N_2-fixing leguminous tree species, *Gliricidia sepium*, and two non-N_2 fixing leguminous trees: *Senna siamea* and *S. spectabilis*. Treatments were four P rates: 0, 20, 40, and 80 kg P ha^{-1} as single superphosphate and two management treatments, pruned versus unpruned plants. The ^{15}N-isotope dilution technique was used to measure N_2 fixation in *G. sepium*. The partitioning of total P among the different plant organs was influenced by plant species and pruning management, but was not affected by P application rates. Pruned plants distributed about 118% more total-P to branches and had a higher physiological P use efficiency (PPUE) than unpruned plants. Leaves were the biggest sink for total N, and N allocation in the other plant organs was influenced by plant species and pruning management. *G. sepium* had relatively more of its total N and P partitioned into roots (about double that of the non-fixing trees), but had a lower PPUE. Unpruned and pruned *G. sepium* derived 35 and 54%, respectively of their total N from atmospheric N_2, with about 54% of the fixed N_2 being allocated to leaves and roots. Results showed that N and P pools turned over in the branches during regrowth after pruning but the causative factors associated with the phenomenon were not clear.

0100
D
Shannon, D.A., W.O. Vogel. 1994.
The effects of alley cropping and fertilizer application on continuously cropped maize. Tropical Agriculture (Trinidad) 71: 163–169.

Alley cropping is a technology for sustained crop production, but long-term trials are lacking in literature. A trial was conducted to study long-term effects of alley cropping on maize under continuous cropping with and without fertilizer. Maize was planted twice a year for 4 years. Maize yields were higher with than without alley cropping from the fourth crop onward. Average yields over the eight crops were highest for the combination of alley cropping and fertilizer application. Without alley cropping, maize yields declined, while with alley cropping, maize yields increased over time. Alley cropping with

moderate fertilizer use may be the best means to stabilize yield and to increase productivity where long fallow periods are no longer possible.

0101
A
Tonye, J., B. Duguma, and T. Tiki-Manga. 1994.
Stepwise approach to alley cropping technology development and transfer in the forest zone of Cameroon. Agroforestry Systems 28: 267–278.

Two projects on alley cropping research and development have been implemented in the forest zone of Cameroon (FZC) since 1988 to identify the main agricultural constraints in the FZC and to introduce alley cropping in the farming systems to improve soil fertility and crop yields. The first step in the implementation process was the participatory surveys which revealed that the main agricultural constraint in the FZC is low fertility; alley cropping is an agroforestry technology that may solve the problem; and alley cropping should be targeted to farmers who own inherited or purchased lands. The second step was the on-station tree screening activity from which *Leucaena leucocephala*, *Gliricidia sepium*, *Calliandra calothyrsus*, and *Paraserianthes falcataria* were identified as promising tree species. The third activity was to test alley cropping with three promising tree species (*Leucaena*, *Gliricidia*, and *Calliandra*) on farmers' fields. Results of the first year testing on farmers' fields showed that the direct seeding method used was ineffective, because the seedling emergence rate was only 45% for *Leucaena* and 52% for *Gliricidia*. Also, cassava suppressed the growth of *Leucaena* by 57% and of *Gliricidia* by 45%; and the three-month-old *Calliandra* seedlings planted 1 m away from cassava plants had 96% survival rate. Based on this last finding, all new farms were established with *Calliandra* seedlings using maize as the test-crop in the year of establishment and in the subsequent year. After 2 years of cropping, maize grain yield in alley plots was 52% higher than maize grown on no-tree plots. In 1993, 52 farmers who had witnessed the alley farm maize growth in 1992 requested to join the project. This sudden interest of farmers in starting their own alley farms was considered a positive sign for adoption and therefore, a success in alley cropping introduction in the zone.

0102
B
Kadiata, B.D. and K. Mulongoy. 1995.
Early nitrogen fixation and utilization in *Albizia lebbeck*, *Leucaena leucocephala*, and *Gliricidia sepium* using nitrogen (^{15}N) labelling. Communications in Plant and Soil Analysis 26: 1397–1409.

High nitrogen (N_2)-fixing potential is a desirable characteristic for any candidate hedgerow tree, thus this study evaluated *Albizia lebbeck* as a N_2-fixing tree in comparison

to *Leucaena leucocephala* and *Gliricidia sepium*, currently used in alley cropping. Nitrogen fixation and utilization were assessed in a screenhouse at 4 months after planting by the ^{15}N-dilution technique using *Senna siamea* as a non N_2-fixing reference. *A. lebbeck* accumulated significantly more N than *L. leucocephala* and *G. sepium*, mainly due to its abundant nodule dry weight that accounted for up to 10.8% of its total N. Also, *A. lebbeck* had bigger but significantly lower number of nodules per plant than only *G. sepium*. Furthermore, it ranked among the best N_2 fixers with 44% Ndfa equivalent to 533 mg N per plant. The relatively higher N_2 fixation, however, was not translated into higher N or dry matter yields. *A. lebbeck* seems to be a potential hedgerow species for alley cropping purposes.

0103
B
Kadiata, B.D., K. Mulongoy, and N.O. Isirimah. 1995.
Dynamics of nodulation, nitrogen fixation, nitrogen use and biomass yield over time in pot-gown *Leucaena leucocephala* (Lam.) de Wit. Biology and Fertility of Soils 20: 163–168.

The dynamics of nodulation, N_2-fixation and N use in leuceana (*Leucaena leucocephala*) cv. K28 over time was investigated in a screenhouse at 4, 8, 12, and 16 months after planting (MAP) using ^{15}N-labelling method. Leucaena had a consistently increasing pattern of nodulation, dry biomass, and nitrogen yield. A sharp rise in nodulation was observed between 12 and 16 MAP, whereas for biomass, N accumulation, and N_2-fixation an upward surge occurred between 4 and 12 months. Throughout the 16-month growth period, N derived from the atmosphere (mg N_2 fixed $plant^{-1}$) was equivalent to 191 at 4 MAP, 1623 at 8 MAP, 2395 at 12 MAP, and 3385 at 16 MAP. Nitrogen assimilation from the soil and fertilizer decreased inversely to the increase in symbiotic nitrogen fixation with time.

0104
B
Kang, B. T., D.O. Ladipo, and O. Ofeimu. 1995.
Phosphorus and liming effects on alley growth of selected plant species grown on an Ultisol. Communications in Plant and Soil Analysis 26: 1659–1673.

A series of pot experiments were conducted to test the effect of phosphorus (P) application and liming on early growth performance of *Zea mays*, *Mucuna pruriens*, and nine woody species (*Albizia ferruginea*, *Cajanus cajan*, *Dactyladenia barteri*, *Dalbergia sissoo*, *Enterolobium cyclocarpum*, *Flemingia macrophylla Gliricidia sepium*, *Leucaena leucocephala*, and *Pentacletra macrophylla*) on an Ultisol. A low response to liming and a high response to P application were observed. Early top growth of the eleven species

was correlated with seed nitrogen (N), P, and calcium (Ca) contents, with the highest correlation observed with seed P content (r = 0.896**). Species with large seeds (*D. barteri*, *E. cyclocarpum*, *M. pruriens*, and *P. macrophylla*) showed the least response to P application, while the remaining species with small seeds showed significant responses to P application. The species with large seeds also showed relatively small increases in N, P, and Ca uptake with P application and liming. Results emphasize the need for consideration of seed size in selecting multipurpose tree and shrub for establishment in low P and on degraded soils; and pot tests can be used in prescreening woody species for use on low P and acid soils.

0105
D
Osonubi, O., M.O. Atayese, and K. Mulongoy. 1995.
The effect of vesicular-arbuscular mycorrhizal inoculation on nutrient uptake and yield of alley-cropped cassava in a degraded Alfisol of southwestern Nigeria. Biology and Fertility of Soils 20: 70–76.

Leaf and root (tuber) nutrient uptake patterns of cassava (*Manihot esculenta* Crantz) alley-cropped with gliricidia (*Gliricidia sepium*), leucaena (*Leucaena leucocephala*), and senna (*Senna siamea*) as influenced by vesicular-arbuscular mycorrhizal (VAM) inoculation in a degraded Alfisol were investigated for 3 years. The cassava plants were mulched with fresh prunings of each hedgerow tree species at 2-monthly intervals in the second and third years of alley cropping. VAM inoculation significantly influenced the root uptake of nutrients, but except for uptake of P, leaf uptake of nutrients was not affected. In most cases, there was no difference between inoculated and uninoculated plants, either in the leaf or in the root, indicating that the productivity of cassava was regulated by the amount of nutrients the roots could absorb. Uptake of N, P, and K and concentrations of K were greater in the roots of cassava in plots alley-cropped with inoculated gliricidia and leucaena than with senna. This indicates that there was a greater mineralization and availability of nutrients to cassava roots from the prunings of nodulating gliricidia and leucaena than from the non-nodulating senna. VAM inoculation significantly enhanced cassava root dry weights, indicating than an effective VAM fungus can be an agent of greater nutrient uptake in a competitive environment.

0106
B

Sanginga, N., S.K.A. Danso, F. Zapata, and G.D. Bowen. 1995.
Phosphorus requirements and nitrogen accumulation by N_2-fixing and non-N_2-fixing leguminous trees growing in low P soils. Biology and Fertility of Soils 20: 205–211.

The variation in P uptake and use efficiency and N accumulation by *Gliricidia sepium* (N_2-fixing tree), *Senna siamea* and *S. spectabilis* (leguminous non-N_2-fixing trees) were examined in the field at Fashola (savanna zone), southwestern Nigeria, using four P rates, 0, 20, 40, and 80 kg P ha^{-1}. Growth of *G. sepium* and *S. spectabilis* responded to P application at 24 weeks after planting (WAP) and average yield increases of 58% and 145% were observed with the application of 40 kg P ha^{-1} to the two species, respectively. On average, *G. sepium* accumulated more P, had greater root length, and a higher percentage of mycorrhizal infection than *S. siamea* and *S. spectabilis* at 24 WAP, but *S. siamea* had 2.5 times more P than *G. sepium* at 48 WAP. Differences in the physiological P-use efficiency between *G. sepium* and the non-N_2 fixing trees were significant only at the zero-P level, and was higher for *S. siamea* (0.61 g shoot mg^{-1} P) than for *G. sepium* (0.27 g shoot mg^{-1} P). *S. spectabilis* was selected as the best reference plant for measuring N_2 fixation in *G. sepium* because it had the lowest variability (CV < 20%). *G. sepium* fixed on average, 35% of its N at 24 WAP and 54 % at 48 WAP. The percentage and amount of N fixed were not generally enhanced by P application, except at the lowest P rate.

0107
B

Sanginga, N., B. Vanlauwe, and S.K.A. Danso. 1995.
Management of biological N_2 fixation in alley cropping systems: Estimation and contribution to N balance. Plant and Soil 174: 119–141.

Alley cropping is being widely tested in the tropics for its potential to sustain adequate food production with low agricultural inputs, while conserving the resource base. Measurements of biological N fixation (BNF) in alley cropping systems show that some tree species such as *Leucaena leucocephala, Gliricidia sepium*, and *Acacia mangium* can derive between 100 and 300 kg ha^{-1} yr^{-1} from atmospheric N_2, while species such as *Faidherbia albida* and *Acacia senegal* could fix less than 20 kg ha^{-1} yr^{-1}. Other species such as *Senna siamea* and *S. spectabilis* are also used in alley cropping, although they do not nodulate, and therefore, do not fix N_2. The long-term evaluation of the potential or actual amounts of N_2 fixed in trees, however, poses problems that are associated with perennial nature and massive size, the great difficulty in obtaining representative samples and applying reliable methodologies for measuring N_2 fixed. Strategies for obtaining

representative samples, the application of ^{15}N procedures and selection criteria for appropriate reference plants were discussed. Data using ^{15}N labelling techniques have indicated that up to 50% or more of the tree's N may be below ground after pruning. Thus, quantification of N_2 fixed which disregards roots, nodules, and crowns would result in serious errors and the amount of N_2 fixed may be largely underestimated. Large quantities of N are harvested with hedgerow prunings (> 300 kg N ha^{-1} yr^{-1}), but N contribution to crops is commonly in the range of 40 to 70 kg N ha^{-1} $season^{-1}$, representing about 30% of N applied as prunings. The low N recovery in maize (*Zea mays*) is partly caused by lack of synchronization between the hedgerow trees N release and N demand from the associated maize crop. The N not taken up by the associated crop remains in the system through immobilization in soil organic matter or assimilation by the hedgerow trees, and some is lost from the system through denitrifcation, or volatilization, or leached below the rooting zone. Below ground contribution (from root turnover and nodule decay) to an associated food crop in alley cropping is estimated at about 25 to 102 kg N ha^{-1} $season^{-1}$. Timing and severity of pruning may allow for management of underground transfer of fixed N_2 to associated crops. But many aspects of root dynamics in alley cropping systems are poorly understood. Current research projects, based on ^{15}N labelling techniques or natural abundance measurements outlined, would lead to estimates of N_2 fixation and N saving resulting from the management of N_2 fixation in alley cropping systems.

0108
DF
Tonye, J. and P. Titi-Nwel. 1995.
Agronomic economic evaluation of methods establishing alley cropping under a maize/groundnut intercrop system. Agriculture, Ecosystems and Environment 56: 29–36.

Agronomic and economic benefits of maize intercropped with groundnut in alleys formed by *Leucaena leucocephala* were assessed at Matomb, Cameroon, from 1990 to 1992, without fertilizer and with application of 200 or 400 kg ha^{-1} of $N–P_2O_5–K_2O$ (20–10–10). In the treeless (control) plots, maize grain yields decreased from 1.2 Mg ha^{-1} in 1990 to 0.8 Mg ha^{-1} in 1992, while groundnut yields declined from 1.1 to 0.5 Mg ha^{-1}during the same period. With the application of *Leucaena* prunings alone, groundnut yield was maintained around 1 Mg ha^{-1} for 3 years, while maize yield yields stabilized at 2.5 Mg ha^{-1} in the second and third year; the yields of both crops were greater over the 3 years than the control. *Leucaena* prunings applied in combination with 200 kg ha^{-1} of $N_2–P_2O_5–K_2O$ increased maize yield by 1.7 Mg ha^{-1} while 400 kg ha^{-1} increased maize yield by 2.0 Mg ha^{-1}, but groundnut yield decreased by 13 and 24% over the 3 years. The dominance analysis showed that alley cropping without fertilizer was the only non-dominated alternative, with a marginal rate of return of 447%. It was the best system at this early

stage (third year) of implementing the technology.

0109
F
Dvorák, K.A. 1996.
Adoption potential of alley cropping: Final project report. Resource and Crop Management Research Monograph No. 23. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

The monograph reports a project on the adoption of alley cropping initiated in 1987 in the Resource and Crop Management Program of IITA, Ibadan, Nigeria. The project determined the adoption potential of alley cropping for the lowland, humid, and subhumid tropics in West and Central Africa, and identified the constraints on adoption that could be addressed by research. Models for alley cropping for on-farm research were discussed.

0110
B
Kadiata, B.D., K. Mulongoy, and N.O. Isirimah. 1996.
Time course of biological nitrogen fixation, nitrogen absorption and biomass accumulation in three woody legumes. Biological Agriculture and Horticulture 13: 253–266.

To determine how dependent a woody legume can be upon potential N sources, the time course of N_2 fixation and N absorption was studied on *Gliricidia sepium* cv. ILG50, *Leucaena leucocephala* cv. K28, and *Albizia lebbeck* in a screenhouse for 16 months using *Senna siamea* as a reference tree. Dry matter and N yield, and number and dry weight of nodules in the four species increased steadily with tree age. N-difference and ^{15}N dilution methods correlated well ($r = 0.87–0.93$) in defining an increasing pattern of N_2 fixation with time in all species, with the highest increment rate between sowing and 8 months. For the period between 4 and 16 months, the percentage N fixed ranged from 17.9 to 74% in *Leucaena*, equivalent to 191 to 3385 mg N; from 27.7 to 71.9% in *Gliricidia*, equivalent to 321 to 2863 mg N; and from 43.6 to 83.6% in *Albizia*, equivalent to 533 to 6419 mg N. The proportion and amount of N_2 fixed over time were greatest in *A. lebbeck*. The proportion of plant N derived from absorption (soil + fertilizer) over time decreased inversely to increase in symbiotic N_2 fixation, with soil being the predominant source. Results show the benefit of relying on N_2-fixing woody legumes as sustainable N-supplying sources to soil-crop systems.

0111
B
Kadiata, B.D., K. Mulongoy, N.O. Isirimah, and M.A. Amakiri. 1996.
Screening woody and shrub legumes for growth, nodulation and nitrogen-fixation potential in two contrasting soils. Agroforestry Systems 33: 137–152.

A screening study was carried out on ten woody and shrub legumes (*Acacia auriculiformis*, *Albizia lebbeck*, *Gliricidia sepium*, *Leucaena diversifolia*, *L. leucocephala* cv. K28 and cv. K636, *Lonchocarpus sericeus*, *Cajanus cajan*, *Crotalaria junce*, and *Tephrosia candida*) for 6 months using an acid Ultisol and a non-acid Alfisol. The objective was to identify new candidate species with high biomass and nitrogen-fixing potential for alley cropping. A wide interspecific variability of legumes appeared within soil types and there were significant species-by-soil interactions for many of the parameters studied. In the acid Ultisol, plant height and girth, nodule numbers, nitrogen yield and N_2-fixing potential were significantly lower than those in the Alfisol. *Albizia lebbeck* was outstanding in both acid and non-acid soil conditions for most performance criteria, whereas *L. leucocephala* cv. K28 was most sensitive to soil acidity. In addition to *L. leucocephala* cv. K28 and *G. sepium*, the most common hedgerow species, *A. lebbeck*, *L. leucocephala* cv. K636, and *L. diversifolia* on the Alfisol, and *A. lebbeck*, *L. leucocephala* cv. K636, *L. diversifolia*, *Tephrosia candida* and *Cajanus cajan* on the acid Ultisol, are promising and, thus, worthy of further site adaptability trials.

0112
CD
Kang, B.T. and A. Ojo. 1996.
Nutrient availability of earthworm casts collected from under selected woody agroforestry species. Plant and Soil 178: 113–119.

Pot experiments were carried out to assess the nutrient availability of earthworm casts (wormcasts) of *Hyperiodrilus africanus* that were collected from plots of *Dactyladenia barteri*, *Leucaena leucocephala*, and *Treculia africana* grown on an Alfisol (Oxic Paleustalf) as affected by drying and grinding, different periods of preincubation of ground wormcasts, and fertilizer application. Experiments were carried out using a double pot technique and rice (*Oryza sativa*) was used as the test crop. Wormcasts had a higher nutrient status than corresponding surface soils. Rice grown on wormcasts produced higher shoot dry weight and showed higher nutrient uptake, and lower fertilizer response than rice grown on surface soils. Poor rice growth and nutrient uptake when grown on unground wormcasts are attributed to the high bulk density of the wormcasts. Preincubation of the wormcasts did not benefit the crop. Drying and grinding and fumigation of wet wormcasts improved rice plant growth and nutrient uptake.

0113
C

Vanlauwe, B., O.C. Nwoke, N. Sanginga, and R. Merckx. 1996.
Impact of residue quality on the C and N mineralization of leaf and root residues of three agroforestry species. Plant and Soil 183: 221–231.

A laboratory incubation experiment with ^{15}N labelled root and residues of three agroforestry species (*Leucaena leucocephala, Dactyladenia barteri* and *Flemingia macrophylla*) was conducted under controlled conditions (25 °C) for 56 days to quantify residue C and N mineralization and its relationship with residue quality. The leucaena and dactyladenia roots contained more lignin and less N than the lignin and N contents of their leaves, whereas the differences between the lignin and N contents of flemingia leaves and roots were not significant. The leucaena leaves contained more polyphenols than the roots, while the polyphenol content of the other residues was similar. Three patterns of N mineralization were distinguished, the first depicted by residues producing the highest amounts of CO_2, showed an initial immobilization of soil derived N, followed by a net release of both soil and residue derived N after 7 days of incubation. The second pattern was depicted by flemingia leaf residues that are of intermediate quality, and produced intermediate amounts of CO_2. It showed no significant immobilization of soil derived N, but a significant mineralization of residue N. The third pattern was shown by the low quality dactyladenia residues. It had a low release of residue derived N and a continued immobilization of soil derived N. Residue C mineralization was significantly correlated with the residue lignin content, C-to-N ratio, and polyphenol-to-N ratio. The proportion of residue N mineralized (immobilized) after 56 days of incubation showed quadratic relationships with the residue N content ($P < 0.01$) and the C-to-N ratio ($P < 0.05$). The ratio of the proportion of residue N mineralized over the proportion of residue C mineralized after 56 days was linearly related with the lignin content ($P < 0.01$), C-to-N ($P < 0.001$), lignin-to-N ($P < 0.01$), polyphenol-to-N ($P < 0.01$), and (lignin+polyphenol)-to-N ratios. This indicates that due to the low availability of the residue C, relatively less N is immobilized for the low quality residues (lignin+polyphenol)-to-N ratio:29.7) than for the residues with a relatively higher quality ([lignin+polyphenol]-to-N ratios of between 3.3 and 12.5).

0114
C
Vanlauwe, B., M.J. Swift, and R. Merckx. 1996.
Soil litter dynamics and N use in a leucaena (*Leucaena leucocephala* Lam. (de Wit) alley cropping system in southwestern Nigeria. Soil Biology and Biochemistry 28: 739–749.

The recovery of a single application of leucaena (*Leucaena leucocephala*) leaf N (78 kg N ha^{-1}) in maize crop, the hedgerow and the top 10 cm soil of a leucaena alley cropping system was measured for 236 days by the use of ^{15}N labeled residues. The leucaena-derived-N (LDN) was followed in the surface litter and the soil-litter– separated by a flotation method on water– during the same period. At 45 and 129 days after the residue application (DAA), only 4.2 and 10.0% of the added leucaena-N was recovered in the maize crop while the aboveground hedgerow incorporated 9.6% in its first canopy regrowth and 9.4% in its second. At 45 and 129 DAA, 19.7 and 13.2% remained in the surface litter and soil, but the total recoveries were 33.5 and 42.2% on the respective dates. The C and N content of the coarse and fine soil-litter fraction of the top 5 cm layer strongly increased after residue application. A significant positive relationship ($P < 0.01$) was found between the microbial biomass C and the total soil-litter C. The LDN release rate from the combined surface litter-coarse soil-litter was 0.0477 d^{-1}, while the fine soil-litter had a LDN release rate of 0.0083 d^{-1}. These turnover rates led to a poor synchronization of the LDN released from all litter pools with the maize LDN uptake during the first 45 days of maize growth, while between day 45 and 129, all released LDN was recovered either in the soil, maize, or hedgerow.

0115
D
Akinnifesi, F.K., B.T. Kang, N. Sanginga, and H. Tijani-Eniola. 1997.
Nitrogen use efficiency and N-competition between *Leucaena* hedgerows and maize in alley cropping system. Nutrient Cycling in Agroecosystems 47: 71–80.

A two-year field experiment was undertaken on an Alfisol in the forest-savanna transition zone of southwestern Nigeria, to study the effect of alley cropping, root barrier, application of N fertilizer and *Leucaena leucocephala* (Lam.) de Wit. prunings on N utilization by maize and *Leucaena* hedgerows. The main plot treatments were alley cropping with *Leucaena* planted at 4 m interhedgerow spacing and control (no hedgerow), while the subplot treatments were with and without the addition of hedgerow prunings, and with and without the presence of root barriers. There were no significant effects of the presence of *Leucaena* hedgerows and root barriers on maize grain yield. *Leucaena* hedgerows recovered about 7% of the 30 kg N ha^{-1} applied as $(^{15}NH_4)_2 SO_4$ to maize during one year. Application of hedgerow prunings increased maize yield by 82% and N-

uptake in the grain by 50% over treatment without prunings. Recoveries of ^{15}N-labelled prunings by maize plants were about 10% and of fertilizer N were 16%. Prunings addition increased ^{15}N-fertilizer recovery in main season maize and the residual value during the minor season by about 36% over the treatment without prunings. Absence of the root barrier increased N-use from prunings. Results of the trial showed that without a root barrier there was no measurable belowground N competition between *Leucaena* hedgerows and maize.

0116
B
Kadiata, B.D., K. Mulongoy, and N.O. Isirimah. 1997.
Influence of pruning frequency of *Albizia lebbeck*, *Gliricidia sepium* and *Leucaena leucocephala* on nodulation and potential nitrogen fixation. Biology and Fertility of Soils 24: 255–260.

The influence of four pruning frequencies on biomass production and N_2 fixation was investigated on *Albizia lebbeck*, *Gliricidia sepium*, and *Leucaena leucocephala* in the screenhouse using acetylene reduction and ^{15}N dilution methods. Frequent prunings at 4-monthly intervals had no deleterious effect on symbiotic N_2 fixation that particularly increased in *Gliricidia* and *Leucaena*. Cumulative assessment of pruning effects showed higher biomass, N yield, and N_2-fixing capacity of the woody species than at the last harvest, and appeared to have more practical relevance. Across species, cumulative total dry matter, N yields, and percentage and absolute amount of N_2 fixed increased with pruning frequency, except when trees were pruned three times. Of the three species, *G. sepium* had the lowest biomass production, N_2 fixation, and N accumulation.

0117
C
Risasi, E.L., G. Tian, E.E. Opuwaribo, and B.T. Kang. 1997.
Effect of root size on root nutrient concentrations of four woody trees and maize. Forest, Farm, and Community Tree Research Report 2: 13–17.

The study reports data on the nutrient concentrations of fine and coarse roots of four woody species, *Gliricidia sepium*, *Leucaena leucocephala*, *Dactyladenia barteri*, and *Senna siamea* used in agroforestry systems in the tropics. The information is relevant in estimating root nutrient-supplying capacity of the species.

0118
BC
Vanlauwe, B., N. Sanginga, and R. Merckx. 1997.
Decomposition of four *Leucaena* and *Senna* prunings in alley cropping systems under subhumid tropical conditions: The process and it modifiers. Soil Biology and Biochemistry 29: 131–137.

A litterbag experiment with *Leucaena leucocephala* and *Senna siamea* residues collected at four different pruning activities was carried out in no-tree control and alley cropping plots. The objectives were to measure the biochemical quality, and the decomposition and N release process of the residues, and to estimate the relative importance of the modifying factors of the process in soil. Decomposition was followed for 112 days after the respective pruning dates. The leaf litter of the same species, collected at the different prunings had different qualities. Older *Leucaena* residues contained more soluble polyphenols than residues younger than 8 weeks, while 8-week-old *Senna* residues contained more soluble polyphenols than residues of 28 weeks. The lignin content of the *Leucaena* residues was greatest for the oldest prunings, but no clear trend was observed for the *Senna* residues. The decomposition and N release patterns of the four *Leucaena* and *Senna* pruning residues were different, with the first and second prunings following a first order kinetics. For the third pruning, a negative exponential regression procedure against the number of days where rainfall exceeded pan evaporation ("rainy day") yielded a better fit than against time, while less than 10% of the dry matter of the fourth pruning decomposed after 112 days. Significant correlations were found between the decomposition rate calculated against the number of "rainy days" and the N content, the C-to-N and the (lignin + polyphenol)-to-N ratio. The N release rate, calculated against the number of "rainy days" correlated significantly with the polyphenol-to-N and (lignin + polyphenol)-to-N ratio. The presence of a fully established crop increased the decomposition and N release of the residue of the second pruning in the no-tree control plots.

0119
F
Adesina, A.A. and O.N. Coulibaly. 1998.
Policy and competitiveness of agroforestry-based technologies for maize production in Cameroon: An application of policy analysis matrix. Agricultural Economics 19: 1–3.

Questions have been raised about the ecological consequences and economic sustainability of exclusive reliance on chemical fertilizers for the rapidly expanding maize production across sub-Saharan Africa. Alternative agroforestry-based natural resource management technologies have been developed for farmers. This paper applies the policy

analysis matrix (PAM) to analyze the social profitability of agroforestry-based technologies for maize production in the highland savanna zone of Cameroon, and the impacts of policy shifts on the financial competitiveness of maize production under these technologies. The paper shows that maize production under agroforestry-based systems has high comparative advantage.

0120
C
Hauser, S. and D.O. Asawalam. 1998.
Effects of fallow system and cropping frequency upon quantity and composition of earthworm casts. Zeitschrift Für Pflanzenernährung Bodenkunde 161: 23–30.

The quantities of earthworm surface casts were monitored in traditional bush fallow regrowth, *Pueraria phaseoloides* live mulch, *Leucaena leucocephala* alley cropping, and undisturbed forest to establish the relationship between soil and cast organic carbon and nutrient concentrations. The fallow systems were planted to maize/cassava intercrop either permanently or for one year after 3 years of fallow, i.e, at 100 and 25% cropping frequencies. Earthworm casting activity was lower in fields cropped after clearing 3-year-old fallow than in the respective permanently cropped fallow management system. The reduction in casting was related to the degree of biomass removed through burning and to re-establishment of cover crops. The higher exchangeable cation concentration in the soil did not cause increased casting activity. Concentrations of organic C, total N, and exchangeable Ca and Mg were significantly higher in casts than in the 0–15 cm topsoil. Topsoil (0–15 cm) exchangeable Ca and Mg did not correlate with cast exchangeable Ca and Mg, but the concentrations of organic C and total N in casts were significantly correlated with organic C and total N in the topsoil. Coefficient of variability of organic C, total N and exchangeable Ca and Mg were about twice as high in the soil than in the casts. The significant negative correlations between the cast to soil ratio (cast enrichment factor) of organic C, total N and exchangeable Ca and Mg and the respective concentrations in the soil indicate that earthworms are increasingly selective in organic C and nutrient uptake as these parameters of soil fertility are declining.

0121
C
Hauser, S., D.O. Asawalam, and B. Vanlauwe. 1998.
Spatial and temporal gradients of earthworm casting activity in alley cropping systems. Agroforestry Systems 41: 127–137.

The amount of earthworm surface casts were monitored for 200 days after commencement of casting in three alley cropping experiments of different ages and hedgerow species. Casts were collected twice a week in transects from under the

hedgerow to the middle of the interrow space. Average annual cumulative amounts of casts were higher in alley cropping systems with one to five years of cropping than in the no-tree control, but the amounts of casts were similar in all treatments after five years of cropping. Within the alley cropping systems, casting activity was highest under the hedgerows and decreased towards the middle of the interrow space. In systems using *Leucaena leucocephala* as hedgerow species, the hedgerow to interrow space gradient of casting activity became more pronounced with increasing length of cropping, but *Senna siamea*, that produced a more recalcitrant mulch, did not show a strong decline in casting in the interrow space. With perpendicular distance from the hedgerows, the largest gradients in casting activity occurred close to the hedgerows in *L. leucocephala*. The shading effect of trees and a relatively low level of soil disturbance is apparently more beneficial for the earthworms in a cropped system than a supply of readily available food from fast decomposing *L. leucocephala* prunings.

0122
C
Vanlauwe, B., N. Sanginga, and R. Merckx. 1998.
Recovery of leucaena and dactyladenia residue nitrogen-15 in alley cropping systems. Soil Science Society of America Journal 62: 454–460.

Quantification of the fate of residue N is essential in low-input tropical cropping systems for the development of management practices that optimize N-use efficiency. The recovery of N derived from ^{15}N-labeled leucaena [*Leucaena leucocephala* (Lam.) de Wit] and dactyladenia [*Dactyladenia barteri* (Hook f ex Oliv.) Engl.] leaf residues were followed in the soil, crop, and hedgerow of the respective alley cropping systems during three maize (*Zea mays* L) and two cowpea (*Vigna unguiculata* L. Walp. subsp. *unguiculata*) seasons. More residue-N was recovered in the top 5 cm of soil in the leucaena than in the dactyladenia microplots during the first 471 days after residue application (DAA). The first maize crop recovered 8.6% of N from leucaena and 5.2% from dactyladenia, while the two subsequent crops recovered < 1%. Cowpea plants in the leucaena and dactyladenia microplots contained 0.5 and 1.1% of the residue N in the first harvest. The total N recovery in the leucaena microplots was ≈90% at 120 and 471 DAA, compared with 56 and 35% in the dactyladenia microplots. At 858 DAA, 62% of the added leucaena N was accounted for, compared with 25% of the dactyladenia N. Residue quality had a major impact on the dynamics of applied residue-N in alley cropping systems, and should be considered when deciding on which residue-supplying plant species to integrate into similar cropping systems.

0123
C
Vanlauwe, B., N. Sanginga, and R. Merckx. 1998.
Soil organic matter dynamics after addition of nitrogen-15-labeled leucaena and dactyladenia residues. Soil Science Society of America Journal 62: 461–466.

Quantification of the movement of residue N through various biologically meaningful soil organic matter (SOM) fractions is essential in low-input tropical cropping systems for the development of management practices aimed at optimizing N-use efficiency. The flow of N derived from ^{15}N-labeled leucaena [*Leucaena leucocephala* (Lam.) de Wit] and dactyladenia [*Dactyladenia barteri* (Hook f ex Oliv.) Engl.] leaf residues was followed through the SOM of different particle-size fractions during 858 days. A bioassay study with maize (*Zea mays* L.) was carried out to assess the availability of residue-derived N (RDN) incorporated in the particle-size fraction. At 53 days after planting (DAP), most of the RDN was found in the fraction between 0.25 and 2 mm in the leucaena treatment and the fraction > 2 mm and the surface litter in the dactyladenia treatment. The RDN content of all fractions <0.25 mm was significantly higher in the leucaena than in the dactyladenia treatment up 471 DAP. Highly significant relationships between RDN present in the particulate organic matter (POM) and uptake of RDN by maize indicated the relatively high availability of RDN in the POM. Fractionating the SOM pool into different particle-size classes yielded useful information on the relative contributions of the different SOM fractions to N turnover and availability, needed in identifying SOM polls with direct relevance to plant nutrition in low-input cropping systems.

0124
C
Vanlauwe, B., J. Diels, L. Duchateau, N. Sanginga, and R. Merckx. 1998.
Mineral N dynamics in bare and cropped *Leucaena leucocephala* and *Dactyladenia barteri* alley cropping systems after the addition of ^{15}N-labelled leaf residues. European Journal of Soil Science 49: 417–425.

In tropical cropping systems with little external input, efficient management of mineral N derived from added organic residues is essential for the proper functioning of the system. The dynamics of mineral nitrogen (N) was studied in the top 100 cm of soil with a system of tensiometers and suction cups after applying ^{15}N-labelled *Leucaena leucocephala* and *Dactyladenia barteri* residues to bare and cropped microplots. The fate of N was followed for two maize-cowpea rotations in 1992 and 1993. Fifty days after applying the residues (DAA), 20% of the added residue N was found in the soil profile of the bare *Leucaena* treatment, and 5% under *Dactyladenia*, compared with 5% and 1%, respectively, where cropped. All values decreased to 1% after 505 days. In the cropped soil, during the first 6 weeks, no mineral-N derived from the residues was lost by leaching. As the maize grew,

the soil profile was gradually depleted of nitrate to near zero in the *Dactyladenia* treatment, whereas during the cowpea season the amount of nitrate N increased to 36 kg N ha^{-1} for the *Leucaena*, and 26 kg N ha^{-1} for the *Dactyladenia* treatment. On average, during the first year, the soil of the bare microplots contained substantially more nitrate N (98 kg N ha^{-1} under *Leucaena* and 47 kg N ha^{-1} under *Dactyladenia*) than that of the cropped microplots, except during the cowpea season in 1993. Nitrate residing in the 80 to 100 cm subsoil in the bare treatments was not readily leached to deeper soil. The risk of losses of native mineral N was greatest during the first 50 DAA and to a lesser extent during the cowpea seasons. Improved management of the hedgerows could increase the potential of the hedgerow trees to recycle mineral N.

0125
C
Alhou, K., N. Sanginga, B.Vanlauwe, O. Lyasse, J. Diels, and R. Merckx. 1999. Alley cropping in the moist savanna of West-Africa: I. Restoration and maintenance of soil fertility on *terre de barre* soils in Benin Republic. Agroforestry Systems 42: 213–227.

The potential of alley cropping systems supplied with a limited amount of fertilizer to restore crop productivity on a degraded site and to maintain crop productivity on a recently cleared, non-degraded site on *terre de barre* soils in southern Benin was investigated from 1994 to 1996. The hedgerow species used were *Leucaena leucocephala, Senna siamea*, and *Gliricidia sepium*. Maize yields of the no-tree control plots dropped from the initial (1990) 401 and 2181 kg ha^{-1} on degraded and non-degraded sites, respectively, to 109 and 1346 kg ha^{-1} in 1996, even with application of a minimal amount of mineral fertilizer. On average, when compared with the initial 1990 values, the alley cropping systems produced 107% more grain on the degraded site, but 11% less grain on the non-degraded site. *Senna* treatment yielded consistently more grain than the control. The *Senna* trees contained a larger amount of N and produced more wood during the first pruning on the degraded site (155 kg N ha^{-1} and 14 t fresh wood ha^{-1}) than on the non-degraded site (49 kg N ha^{-1} and 6.6 t fresh wood ha^{-1}), possibly because of the differences in subsoil fertility, as indicated by the higher clay, exchangeable bases, and N content between 60 and 125 cm. Nitrogen accumulation and wood production by the *Leucaena* and *Gliricidia* trees was similar in both sites. When a limited amount of fertilizer is available, *Senna* appears to be the best choice hedgerow species on sites with relatively fertile subsoil, but for other soils an N_2-fixing species may be a better choice.

0126
DF
Kormawa, P.M., A.Y. Kamara, S.C. Jutzi, and N. Sanginga. 1999.
Ecomomic evaluation of using mulch from multi-purpose trees in maize-based production systems in southwestern Nigeria. Experimental Agriculture 35: 101–109.

Cutting and carrying of mulch from established tree plots is an alternative to *in situ* mulch in agroforestry systems. Through the cut-and-carry method, the undesirable effects of tree-crop competition characterizing *in situ* mulching can be avoided. An economic evaluation of the cut-and-carry method of providing nutrients for maize production was investigated in southwestern Nigeria. The results showed that the use of mulch from multipurpose trees (MPTs) through cut-and-carry method contributed to higher maize grain yields than those obtained with fertilizer or in untreated controls. Providing nutrients for crop production by this method, however, is unprofitable in the short- and in the long-term, because of high labor requirements and scarcity of land in the study area. This may serve as a constraint for the adoption of this technology by farmers. Alternative options that require less labor and land requirements should be investigated in the quest to replace shifting cultivation.

0127
CD
Tossah, B.K., D.K. Zamba, B. Vanlauwe, N. Sanginga, O. Lyasse, J. Diels, and R. Merckx. 1999.
Alley cropping in the moist savanna of West Africa: II. Impact on soil productivity in a north-to-south transect in Togo. Agroforestry Systems 42: 229–244.

The impact of the biophysical environment on hedgerow N uptake, wood production and maize grain yield was assessed for three years in three alley cropping trials with a selected number of hedgerow species in Glidji, Amoutchou, and Sarakawa in Togo. *Senna siamea* hedgerows accumulated the least amount of N (17–26 kg N ha^{-1}) in Amoutchou in the first pruning because of the infertile subsoil in Amoutchou that was sandy up to 1 m and had a shallow groundwater table. The amount of N accumulated in the *Gliricidia sepium* biomass varied between 38 kg N ha^{-1} in Glidji and 142 kg N ha^{-1} in Amoutchou. Averaged across all species and sites, 9 to 29% of the annual N accumulation in the hedgerow biomass was incorporated in the second and 9 to 39% in the third pruning. *Gliricidia* trees produced a range of 12 to 26 Mg ha^{-1} of fresh wood, whereas *Senna* trees produced between 4 and 38 Mg ha^{-1}. In Sarakawa, maize grain yield was the same (3.8 Mg ha^{-1}) in *Gliricidia* and *Senna* plots, while in Amoutchou the greatest yield of 2.8 Mg ha^{-1} was produced with *Gliricidia* treatment. No treatment effect on yield in Glidji. Top- and sub-soil characteristics were an important modifier of the functioning of alley cropping

systems and should be considered when deciding on the use of alley cropping and in selecting the hedgerow species.

0128
C
Vanlauwe, B., S. Aman, K. Alhou, B.K. Tossah, V. Adebiyi, N. Sanginga, O. Lyasse, J. Diels, and R. Merckx. 1999.
Alley cropping in the moist savanna of West Africa: III. Soil organic matter fractionation and soil productivity. Agroforestry Systems 42: 245–264.

In cropping systems with limited amounts of external inputs, the soil organic matter pool (SOM) may contribute significantly to plant nutrition. The impact of organic inputs on total SOM and particulate organic matter (POM) N contents as affected by soil type, and the relationships between sources of N and maize N uptake were assessed in alley cropping trials in the West African moist savanna. The trials were established in Niaouli (Benin Republic), Glidji, Amoutchou, Sarakawa (Togo), Bouaké, and Ferkessédougou (Côte d' Ivoire). Averaged across treatments and years, total soil N varied between 324 and 1140 mg N kg^{-1} soil and POM-N content ranged from 50 to 160 mg N kg^{-1} soil. The average proportion of soil N belonging to the POM pool ranged from 9 to 29% and was significantly related to the annual N inputs from maize stover and prunings. The Ferkessédougou soil contained a higher proportion of total soil N in the POM pool because of its relatively high silt and clay content, compared to the other sites. The relative change in POM-N between initial sampling and 1996, was twice the relative change in total soil N content, suggesting that N incorporated in the POM was relatively labile compared to N incorporated in the other SOM fractions. Maize N uptake was related to the amount of added pruning-N, rainfall during the growing season, POM-N content, and to a lesser degree, to the POM-N concentration, fertilizer N rate, and the silt and clay content of the soil. The POM-N content was influenced by organic matter additions and soil characteristics and it contributed significantly to maize N supply. This pool may be an important indicator of the fertility status of savanna soils.

0129
F
Versteeg, M.N., F. Amadji, A.Etèka, A. Gogan, and V. Koudokpon. 1998.
Farmers' adoptability of Mucuna fallowing and agroforestry technologies in the coastal savanna of Benin. Agricultural Systems 56: 269–287.

As technologies to counter soil fertility decline, alley farming with *Leucaena leucocephala* and *Gliricidia sepium*, annual short-season *Mucuna pruriens* var. *utilis* fallowing, and perennial *Acacia auriculiformis* fallowing have been tested. With alley farming, timely pruning is a critical element in farmers' capacity to match on-station yield

levels. Results showed that 55% of the farmers who delayed pruning suffered about 60% yield losses. Farmers are now comparing a new alley band concept, grouping trees in bands, 20 m apart with five times less tree/crop competition. An improved, planted fallow of *A. auriculiformis* to regenerate exhausted soils, however, grew a great deal in popularity because of quick regeneration of yields and a profitable bonus of good quality firewood. *Mucuna* that was grown by 15 farmers in 1987 for *Imperata* control is now known by almost 100 000 farmers. The regular use for soil fertility improvement is, however, hampered by the lack of known uses of *Mucuna* products. A farmer-applicable detoxifying method for *Mucuna* seeds was recently developed. The essential impact of farmer interaction on the course of experimentation, results, and adoption were highlighted.

1.1.2 Multistrata agroforestry

This agroforestry system comprises two or more crops, one of which is a woody perennial, that are storeyed, horizontally mixed, and usually harvested at different times. The system mimics natural forest structure whereby vegetation forms several strata. Examples include growing a wide range of food crops, spices, and herbs with fruit trees, cocoa, palms, or timber trees. The system is proposed as a replacement for slash and burn agriculture in the humid tropics with the aim of providing ecological benefits as well as diversifying the farming system and increasing farmers' income. This technology is being developed by IITA's Humid Forest Station in Cameroon and is in its infancy. Plantain, an important food/cash crop in southern Cameroon, is well adapted to the system. In prototype multistrata systems established in 6- and 18-year-old *Terminalia ivorensis* plantations, to assess the effects of timber tree densities and low-input soil management regimes on plantain, initial results indicated that plantain bunches were heavier under tree stands with a 65% canopy cover than under sole timber tree stands with about 15% cover. Greater bunch yield was associated with significantly lower damage from black sigatoka disease. Greater shade, however, prolonged the beginning of flowering, resulting in lower yields per hectare per year. Shade in high tree density plots also reduced the vigor of the noxious arable weed *Chromolaena odorata*, allowing for the less aggressive forest species to establish, thus reducing weeding labor. Activities of beneficial soil fauna, including earthworms and soil-feeding termites, were maintained at the same level as in undisturbed forest, enhancing soil properties.

More research is needed on identifying suitable combinations of food crops adapted to multistrata environments, and on yield responses of food crops, especially important staples such as plantain and banana, to shade and competition from upper canopy trees. Such information is needed to design and improve multistrata systems in the humid tropics.

Abstracts

0130
Norgrove, L. 1998.
Musa in multistrata systems: Focus on shade. INFO*MUSA* 7: 17–22.

This paper reviewed studies on the responses of *Musa* species to shade in multistrata systems. The effect of shade on phenology, incidence of foliar diseases and weed pressure, and marketable yields of *Musa* species were discussed. The interaction of shade with nutrient and water status, where these factors are limiting, was presented. It concluded that there were positive yield and productivity responses of *Musa* species to shade, but more research is required in comparing the responses of different cultivars of plantains (AAB) and cooking bananas (ABB) to shade.

0131
Norgrove, L. and S. Hauser. 1998.
Effects of tree density and crop management upon growth of plantain in a low-input agrisilviculture system. Acta Horticulturae 490: 187–193.

The feasibility of growing plantain as an understorey crop was assessed. The effects of timber stand density, and burning the biomass versus mulching and intercropping with cocoyam upon percentages of flowering plants and their height, circumference, number of standing leaves, number and size of suckers at flowering were observed in a 6- and 18-year-old timber plantation. In the 6-year old plantation, significantly more plants had flowered in the low density than in the high timber plant density by 500 days after planting (DAP). At flowering, in the high timber stand density, plants were more etiolated, being taller with smaller circumference. In the older plantation, fewer plants had flowered by 500 DAP, 10.6% in the low compared to 0.8% in the high timber stand density. Results show that a higher timber plant density significantly prolonged the planting to flowering period and resulted in etiolated plants at flowering.

1. 2 Short fallow systems

Studies conducted at IITA on improved fallow management in previous years were concentrated mostly on alley farming systems. Initial experiences of alley farming were marked by low adoption and uncertainty of its benefits, and this gradually led to more emphasis being given to short-term improved fallows. With the renewed efforts to sustain the productivity of African soils, in 1994 the Short Fallow Stabilization project was initiated. This had the aim of increasing farm productivity and arresting resource degradation due to land-use intensification through sustainable short-fallow systems. Crop rotation and legume cover crop technologies were addressed under this project.

1. 2. 1 Crop rotation systems

Crop rotation may be defined as the temporal alternation of two or more different crop species on the same land in a regular sequence. The improvements in yield associated with crop rotations have been attributed to factors including the improvement of soil fertility, particularly where legumes are involved, complementary use of nutrients, and improvement of soil physical properties such as aggregation, water-holding capacity, and infiltration. Other advantages of crop rotation include soil conservation, organic matter restoration, and pest and disease control. Farmers practice crop rotation, but the sequence is often not systematized. The success of a rotational cropping system depends largely on the choice of crops, the cropping sequence, and the management practices used.

Recent studies on the benefits of crop rotation with legumes in the West African savannas showed that nitrogen contribution from legumes, soybean, cowpea, and *Stylosanthes* to a subsequent crop ranges from -8 to 80 kg N ha^{-1}. The contribution depended on the effectiveness of the legume-*Rhizobium* symbiosis, legume growth duration, and legume residue management. A positive effect of previous legumes on the subsequent maize grain yield has been observed. On farmers' fields, maize grain yield was increased by 20 to 25% from previous legumes with legume residues except fallen litter, removed from the fields.

Legume rotations break the cycles of cereal pests and diseases, and the allelopathic and phytotoxic effects of different crop residues. The greater the differences between crops in a rotation sequence, the better cultural control of pests can be expected. Crop rotation is an effective tool for control of certain pests. Studies have shown that some legume cultivars including soybean and *Aeschynomene histrix* (fodder legume) could reduce the incidence and severity of *Striga hermonthica* (Del.) Benth., a parasitic weed of cereals and the severity of cereal nematodes in the northern Guinea savanna of Nigeria.

Further studies, however, are needed on legume residue management strategies to maximize the benefits of legumes to the subsequent crops. Also, long-term crop rotation experiments involving legumes and assessing water and nutrient management are needed for the savannas, results of which could be used for simulation modeling and systems

analysis. Furthermore, more studies are needed on the use of legumes for cultural control of pests for developing integrated pest control programs.

Abstracts

0132
Wilson, G.F. and E.F. Caveness. 1980.
The effects of rotation crops on the survival of root knot, root-lesion and spiral nematodes. Nematropica 10: 56–61.

Potential rotation crops for replacement of natural soil regeneration in tropical agriculture were grown in nematode infested soil following *Celosia argentea* to check their effectiveness in the suppression of plant-parasitic nematodes. The aggregate nematode population mean after 6 months was one-third of the preplant mean. *Meloidogyne incognita* juvenile soil populations were reduced under 15 crops and maintained under 3. *Helicotylenchus pseudorobustus* populations were reduced under 8 crops and maintained under 10. *Pratylenchus sefaensis* populations were maintained under 17 crops and significantly increased under *Crotalaria juncea*.

0133
Carsky, R.J., R. Abaidoo, K. Dashiell, and N. Sanginga. 1997.
Effect of soybean on subsequent maize grain yield in the Guinea savanna zone of West Africa. African Crop Science Journal 5: 31–38.

Two varieties of soybean (*Glycine max* [L.] Merr.) and maize (*Zea mays* L.) as a control were grown in replicated trials at 10 sites in the northern Guinea savanna of Nigeria in 1993 followed by a test crop of maize fertilized with 20 or 60 kg N ha^{-1} in 1994. The objective was to test the effect of soybean on the subsequent maize grain yield. The main effect of the previous soybean crop on the subsequent maize grain yield was positive, even though the soybean was not inoculated with rhizobia and the aboveground soybean residues, except litter fallen before harvest, were exported from the field, following the current farmer practice. The yield increase following the medium-maturing soybean (TGx1660–19F) was similar to that from 40 kg N ha^{-1} applied 4 weeks after planting to maize preceded by maize. The increase following the early-maturing soybean (TGx1456–2E) was smaller ($P<0.05$) than that following the medium duration soybean variety. Mean (across sites) total nitrogen in the 0 to 10 cm depth of the previous TGx1660–19F plots (0.063%) was greater than in the previous maize plots (0.058%), suggesting that the effect of the previous soybean crop on maize grain yield was due to residual nitrogen availability. Additional research is justified to estimate how soybean crop management increases the yield of subsequent maize in the savanna zone.

0134

Carsky, R.J. and D.K. Berner. 1997.
Benefits of crop rotation with soybean and cowpea in savanna cereal-based systems. Pages 391–402 *in* Technology options for sustainable agriculture in sub-Saharan Africa, edited by T. Bezuneh, A.M. Emechebe, J. Sedgo, and M. Ouedraogo. Publication of the Semi-Arid Food Grain Research and Development Agency (SAFGRAD) of the Scientific, Technical and Research Commission of OAU, Ouagadougou, Burkina Faso.

Results of research in the West African savannas to quantify benefits of rotation of soybean and cowpea to cereal-based systems are reviewed. Nitrogen contribution from soybean and cowpea to a subsequent crop varies from 0 to 80 kg N ha^{-1}. The contribution depends on the effectiveness of the legume-*Rhizobium* symbiosis, legume growth duration, and legume residue management. The residual nitrogen effect increases with increasing amounts of nitrogen from atmospheric N_2 fixation and the amounts of biomass nitrogen left after harvest. Field experiments with cultivars of cowpea and soybean selected for the efficacy in germinating *Striga hermonthica* seeds have shown substantial benefit in reducing levels of *S. hermonthica* infection on both sorghum and maize. Cultivars of these legumes varied in their effects because *S. hermonthica* has site-specific strains. Field screening for efficacious cultivars is inefficient and is inferior to laboratory screening that uses a simple, inexpensive technique.

0135

Sanginga, N., K. Dashiell, J.A. Okogun, and G. Thottappilly. 1997.
Nitrogen fixation and N contribution by promiscuous nodulating soybeans in the southern Guinea savanna of Nigeria. Plant and Soil 195: 257–266.

Attention is being paid to improving the N_2 fixation of promiscuous nodulating soybean in an attempt to develop sustainable cropping systems in the moist savanna. There is, however, a dearth of reliable estimates of N_2 fixation by these promiscuous soybean and hardly any quantitative information is available on their residual nitrogen benefits to subsequent cereal crops grown in the southern Guinea savanna zone. The ^{15}N isotope dilution method was used to assess symbiotic N_2 fixation and response to inoculation and nitrogen contribution of three IITA promiscuous and two Brazilian soybean lines grown in the field at Mokwa (southern Guinea savanna) for 2 years. Rhizobial inoculation increased total nitrogen and grain yield of early-maturing cultivars IAC 100 and TGX 1456–2E, but did not affect the late-maturing cultivar TGX 1660–19F. Fixed nitrogen (Ndfa) and nitrogen derived from the soil were the major sources of nitrogen, accounting for 84 kg N ha^{-1} (46% of the plant total nitrogen) or 75 kg N ha^{-1} (43%). A line effect was apparent, with the late-maturing line TGX 1660–19F deriving on the average 126 kg N ha^{-1} or 52% of plant total nitrogen from N_2 fixation compared to the early-maturing line

IAC 100 with 37 kg N ha^{-1} or 38%. At physiological maturity (R_8), N_2 fixed accounted for an average of 70% of the total nitrogen accumulated in the seeds. Roots accumulated about 13%, leaves 53%, and stems 32% of the entire plant nitrogen at R_5/R_4 stage. It was estimated after grain removal that soybean growth gave a net contribution of an average of 18 kg N ha^{-1} to soil nitrogen. The nitrogen contribution, however, ranged from –8 to 43 kg N ha^{-1} depending on the soybean cultivars and inoculation treatment.

0136

Oikeh, S.O., V.O. Chude, R.J. Carsky, G.K. Weber, W.J. Horst. 1998.
Legume rotation in the moist tropical savanna: managing soil nitrogen dynamics and cereal yields in farmers' fields. Experimental Agriculture 34: 73 – 83.

The contribution of root and leaf litter to soil nitrogen dynamics, nitrogen uptake and balance was evaluated under cereal–legume rotations in a tropical moist savanna soil. Two legumes, soybean (*Glycine max*) and stylo (*Stylosanthes hamata*), and maize (*Zea mays*) as a control were grown in four farmers' fields of different native fertility in 1993. At the end of the season, soybean grain and stover were harvested and stylo biomass was removed for fodder. At the beginning of the 1994 season, levels of total mineral nitrogen at a depth of 0–30 cm were 75 kg ha^{-1} after soybean, 52 kg ha^{-1}after stylo, and 44 kg ha^{-1} maize. Total nitrogen uptake by maize was over 25% higher following legumes than following maize. Maize yield was 24% greater when grown after soybean and 20% greater after stylo than after maize in spite of the removal of the standing legume biomass from the plots. Sorghum grain yield and nitrogen uptake were not significantly affected by the previous crops. Nitrogen balance estimates indicated that loss of nitrogen, probably due to leaching, was lowest in the plots previously planted with stylo. Results indicated opportunities to integrate appropriate legume-based technologies into the farming systems based on an identification of inherent nitrogen-release patterns.

1. 2. 2 Legume cover crop systems

In addition to alley cropping systems, other technologies involving the use of herbaceous legumes have been developed to improve the efficiency of the natural bush-fallow cultivation with the aim of protecting the soil from erosion, restoration of nutrients, and weed control. These technologies permit more intensive crop production with minimum use of purchased inputs, without degrading the natural resource base, thereby promoting easy adoption by small-scale farmers. The technologies include live-mulch systems and *in situ* cover crop systems. The first step in developing these technologies involved screening a wide range of legume species to identify promising species capable of maintaining a level of biodiversity in the farming systems. In selecting promising species, the following are considered: species with rapid development of complete ground cover, positive effects on soil physical and chemical properties, improvement in soil organic matter, and weed control. Other factors are the ability to fix nitrogen and to maintain a low soil temperature, deep rooting habit, shade/drought tolerance, good insect and disease tolerance, and ease of establishment, preferably from seeds.

1. 2. 2. 1 Live-mulch system

This is a crop production system in which a food crop is planted directly in the living cover of an established cover crop without tillage or the destruction of the fallow vegetation. It is aimed at reducing the cost of crop production through efficient use of environmental resources. Promising herbaceous legumes that have been tested can yield a range of 30 to 300 kg N ha^{-1} and they begin to contribute N to the associated crop in the second year of cultivation. A live-mulch system has been shown to give a mean maize yield of 2 Mg ha^{-1} over five seasons of continuous cropping without nitrogen fertilizer, at least twice the yield of other systems involving no-tillage and conventional tillage with the application of nitrogen fertilizer. Even when food crops are not planted in the live-mulch system, most of the benefits of herbaceous legumes could be derived by using the system as a cover-crop to improve fallow management. Examples of promising legumes tested for the live-mulch system include some spreading/climbing species, *Centrosema pubescens*, *Psophocarpus palustris*, *Pueraria phaseoloides*, *Mucuna pruriens*, and non-creeping/erect species, including *Pseudovigna argentea*, *Crotalaria verrucosa*, and *Cajanus cajan*. *Pueraria phaseoloides* and *P. argentea* have been reported to be the most promising candidate species.

Most studies on this technology have been done on station, with limited on-farm adaptive research. The adoption of the technology, therefore, seemed low. The drawbacks to its adoption are incompatibility with some crops, including rice or sweet potato in areas where these crops are important components of the farming system. Other factors are the absence of firewood or staking materials that are obtainable in a natural bush-fallow system, and difficulty in the management of the thick mulch layer. Also, the benefit of the

system to food crop production is not immediate which may discourage adoption by farmers. Furthermore, competition between the establishing cover crops and the food crop could be high, to the detriment of the food crop.

Further research needs include multilocational screening to identify more species suitable for use as live-mulch under different soil conditions and meeting the diverse needs of the farmers, and more on-farm adaptive research in areas where rural appraisal show that legume cover crops have potential for meeting farmers' needs. Furthermore, process-level knowledge is required to understand the pathways of nitrogen transfer from live-mulch to the food crop, to enable fine-tuning of the technology.

Abstracts

0137
Akobundu, I.O. 1980.
Live mulch: A new approach to weed control and crop production in the tropics. Pages 377–382 *in* Proceedings 1980 British Crop Protection Conference– Weeds, 17–20 November 1980, Brighton, England, edited by C. Wheeler and J. Holroyd. ARC Weed Research Organization, Oxford, UK.

Live mulch is a crop production technique in which a food crop is planted directly in the living cover of an established cover crop without tillage or destruction of fallow vegetation. The effect of several established legume covers on weed competition, fertilizer requirement, and yield of maize was studied in the field at the International Institute of tropical Agriculture. Weed infestation was heaviest in unweeded conventionally tilled and no-tillage plots, but very low in unweeded *Centrosema pubescens* and *Psophocarpus palustris* plots. Consequently, maize yield was reduced in all ground covers where weed infestation was heavy but not in the covers that effectively suppressed weeds. Maize yield was significantly higher in the live mulch plots that received no fertilizer than in similarly treated conventionally tilled and no-tillage plots. When 60 kg ha^{-1} each of N, P_2O_5 and K_2O was applied to all covers, maize yield was either equal or better than in the conventionally tilled and no-tillage plots.

0138
Akobundu, I.O. 1982.
Live mulch crop production in the tropics. World Crops 34: 125–126.

This paper reviewed research results on live mulch crop production with respect to crop (mostly maize) performance, weed control and soil fertility improvement. It itemized the characteristics of a good legume or plant for live-mulch crop production. The management of the live-mulch legume cover crop and crop production in live-mulch systems are discussed. Furthermore, the potentials for live-mulch crop production to the smallholder farmers who constitute 95% of the farming population of West Africa were highlighted. It concluded that live-mulch cropping, an alternative land management system which efficiently combines restoration of soil fertility with continuous cropping, will increase land productivity in West Africa.

0139

Akobundu, I.O. and B.N. Okigbo. 1984.
Preliminary evaluation of ground covers for use as live mulch in maize production. Field Crops Research 8: 177–186.

Several ground covers were assessed over a 2-year period to determine their effects on weed competition on maize yield. Maize was planted directly into established covers of *Axonopus compressus* (SW) Beauv., *Desmodium triflorum* (L) DC, and *Indigofera spicata* Forsk. Planting rows in the *Arachis repens* Handro plots were marked by manually pulling off stem segments of the legume cover. *Paspalum notatum* Fluegge cover was first killed with glyphosate (3.6 kg ha^{-1}) before planting maize, and different legume management methods, including slashing and spraying with either paraquat or a hormone were evaluated for use in *Centrosema pubescens* Benth and *Psophocarpus palustris* Desv. Weed infestation was highest in *Axonopus compressus*, *Desmodium triflorum* and no-tillage; moderate in *Arachis repens* and maize stover; and very low in *Centrosema pubescens* and *Psophocarpus palustris*. Maize yield was highest in the maize stover and poorest in the *Indigofera spicata* plots. Good maize yield was obtained in the live mulch in which weed competition was minimized by the legume cover. Because over 40% of farmers' time in the humid tropics is devoted to weeding, this technique promises to eliminate or significantly reduce weeding.

0140

Mulongoy, K. and I.O. Akobundu. 1985.
Nitrogen uptake in live mulch systems. Pages 285–290 *in* Proceedings of an International Symposium in Nitrogen Management in Farming Systems in the Tropics, 23–26 Oct. 1984, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, edited by B.T. Kang and J. van der Heide. Institute for Soil Fertility, Haren, The Netherlands/ IITA, Ibadan, Nigeria.

The nitrogen contribution of *Psophocarpus palustris*, *Centrosema pubescens*, and *Arachis repens* grown as live mulch was evaluated at IITA, Ibadan, Nigeria. The live mulches contained between 89 and 161 kg N ha^{-1}, and were not affected by N fertilization and weeding. In newly established fields, the N content of maize was about the same with 0 and 120 kg N ha^{-1} and was lowest in the centrosema plots. A negative N contribution of the cover crop was observed, indicating that N competition between the live mulch and the maize crop. In the field cropped for six seasons, N uptake by maize was lowest in the unfertilized and unweeded plots with no cover crop. In the absence of N application, with continuous cropping, higher maize yields could be sustained in live mulch systems with *P. palustris* and *C. pubescens*. *P. palustris* gave the highest N contribution, averaging 31 kg N ha^{-1}, less than 30% of the mulch N content. *A. repens* in the unweeded plots contributed the least N.

0141

Mulongoy, K. 1986.

Microbial biomass and maize nitrogen uptake under a *Psophocarpus palustris* live-mulch grown on a tropical Alfisol. Soil Biology and Biochemistry 18: 395–398.

Nitrogen uptake by maize was monitored for five cropping seasons in a live-mulch of *Psophocarpus palustris* (psopho) established in an Alfisol at IITA, Ibadan, Nigeria. During the first 4 cropping seasons, psopho and maize competed for soil nitrogen in the live-mulch, and maize grown in a psopho live-mulch contained less nitrogen than sole-cropped maize. In the fift season, psopho contributed 15 kg N ha^{-1} to maize in the psopho-maize plots that were cropped continuously for 5 seasons. Maize grown in a psopho live-mulch that was established for four cropping seasons contained 36 kg ha^{-1} more nitrogen than sole maize. This positive nitrogen contribution was partly due to increases in microbial biomass and organic matter derived from from the cover crop in the form of litter and earthworm casts. The casts under the cover crop represented a supplementary nitrogen reserve of 13–21 kg ha^{-1}, and had a larger biomass carbon content, higher percentage stress-labile N (PSN), organic carbon and total nitrogen than the corresponding soils. Biomass carbon and PSN values were the lowest in soils from bare maize plots, indicating that live-mulch improved soil nutrient availablility and biological properties.

0142

Hulugalle, N.R. 1989.

Effect of tied ridges and undersown *Stylosanthes hamata* (L.) on soil properties and growth of maize in the Sudan savannah of Burkina Faso. Agriculture, Ecosystems and Environment 25: 39-51.

The effect of tied ridges and undersown *Stylosanthes hamata* (L.) on soil properties and growth of maize (*Zea mays* [L.]) was studied on an Alfisol in the Sudan savanna of Burkina Faso. The treatments were tied and open ridges, both were planted to either a moncropped maize or maize undersown with *S. hamata*. Soil profile water was greater with tied ridging than with open ridging. Among the tied ridge plots, undersowing with *S. hamata* resulted in drier profiles in 1986 and 1987, whereas no significant effects were observed with open ridging. Clay content, organic matter, total cation exchange capacity and exchangeable Ca, Mg, and K were greater, and sand content was lower, in the furrows of tied ridged plots than in the open ridged furrows. Undersowing with *S. hamata* resulted in higher levels of exchangeable bases and CEC in furrows of open ridged plots. Tied ridging and undersowing maize with *S. hamata* resulted in a deeper and a more dense root system. Tied ridges significantly increased grain dry matter (DM) production in maize but not DM production of *S. hamata*. Grain and DM yields of maize in tied ridged plots were reduced by undersowing with S. *hamata* only when drought occurred

during the reproductive and late vegetative growth. Cropping system had no significant effect on maize yield of open ridged plots. Undersowing maize with *S. hamata* resulted in significant increases in total DM (maize + *S. hamata*) production.

0143

Mulongoy, K. and I.O. Akobundu. 1990.

Agronomic and economic benefits of nitrogen contributed by legumes in live-mulch and alley cropping systems. Pages 625–632 *in* Nitrogen fixation: Achievements and objectives, edited by P.M. Gresshoff, L.E. Roth, G. Stacey, and W.E. Newton, Chapman and Hall, London, U.K.

This paper reviewed study conducted at the International Institute of tropical Agriculture (IITA), Ibadan, Nigeria, on the nitrogen contribution of legume components in alley cropping and live-mulch systems. Because nitrogen-rich leaves of N_2-fixing legumes decompose rapidly in tropical environments, and their N is prone to losses through volatilization, denitrification, and leaching, the different management practises that would increase N-use efficiency in these systems were discussed. Some economic considerations on the profitability of alley cropping and live-mulch systems, relative to the use of inorganic N and to the traditional bush fallow systems were presented, as adoption of these technologies would depend on their realized economic benefits.

1. 2. 2. 2 *In-situ* cover-crop system

This system involves planting food crops into the dead residue of a legume cover crop for weed control, soil conservation, organic matter and nitrogen addition into the soil. The effectiveness of the technology depends on the thickness of the mulch and on the rate of decomposition from both dead top growth and below ground residues. Some of the promising legumes for *in-situ* mulching include *Mucuna pruriens*, *Centrosema pubescens*, *Psophocarpus palustris*, and *Pueraria phaseoloides*. More attention, however, has been given to *Mucuna pruriens*, as it has been a success story in adoption particularly in the Republic of Benin where it is used as a weed-suppressing and soil-improving legume cover crop. The driving force in the adoption of *Mucuna* as a cover crop in Benin has been its significant benefit in suppressing noxious speargrass (*Imperata cylindrica*). The slight drawback to adoption is that *Mucuna* volunteers tend to smother crops grown after fallow, as a result of seeds set during the fallow period, and there is limited use of *Mucuna* seeds for human consumption.

It is perceived that the adoption of this technology will occur in areas where soil fertility is declining, inorganic fertilizers are expensive, *Imperata* infestation severely affects farmers' production, there are markets for *Mucuna* seeds, and in areas with long growing seasons of 7 or more months. Other factors are the need for additional livestock feed and the desire to reduce the buildup of nematodes and parasitic weeds such as *Striga* nfestation in intensifying cereal-based cropping systems.

Abstracts

0144

Lal, R., G.F. Wilson, and B.N. Okigbo. 1978.
No-till farming after various grasses and leguminous cover crops in tropical Alfisol. I. Crop performance. Field Crops Research 1: 71–84.

The effects of 4 grasses and 4 leguminous cover crops on soil properties, and on the applicability of zero-tillage for arable crop production with killed sod mulch, were investigated on an Alfisol in western Nigeria. The grass cover crops include, *Panicum maximum*, *Setaria sphacelata*, *Brachiaria ruziziensis*, and *Melinis minutiflora*, and the legumes were *Centrosema pubescens*, *Pueraria phaseoloides*, *Glycine wightii*, and *Stylosanthes guianensis*. Two years after the establishment of the cover crops, arable crops including maize (*Zea mays*), cowpea (*Vigna unguiculata*), pigeonpeas (*Cajanus cajan*), soybeans (*Glycine max*), and cassava (*Manihot esculenta*) were sown through chemically killed sod. Organic-carbon, total nitrogen, and CEC were higher under *Melinis minutiflora*, *Glycine wightii*, *Centosema*, and *Pueraria* than with control or other cover crops. Infiltration rate and soil bulk density were generally low under cover crops than under the control plots. Maximum soil temperature was 10 °C lower and soil moisture storage was generally higher under killed sod mulch compared to the control. Significantly higher crop yields were obtained under *Centrosema*, *Pueraria*, *Stylosanthes*, and *Bruchiaria* than with the control or other cover crops. Bruchiaria sod was, however, difficult to eradicate and to plant with zero-tillage technique. Maize grain, cowpea seed, and cassava tuber yields were positively related to infiltration rate and negatively to soil bulk density.

0145

Lal, R., G.F. Wilson, and B.N. Okigbo. 1979.
Changes in properties of an Alfisol produced by various crop covers. Soil Science 127: 377–382.

The effect of 3 grasses and 5 legumimous covers, grown on an eroded tropical Alfisol for 2 years, on soil properties were invested. Improvements in soil characteristics under *Brachiaria*, *Paspalum*, *Cynodon* spp., *Pueraria*, *Sylosanthes*, *Stizolobium*, *Psophocarpus*, and *Centrosema* were compared with that of weed-fallow control. There were significant improvements in soil organic-matter, total nitrogen, cation exchange capacity (CEC), infiltration rate, moisture retention at low suctions, and bulk density under various grass and leguminous fallow compared with the control.

0146

Hulugalle, N.R., R. Lal, and C.H.H. Ter Kuile. 1986.
Amelioration of soil physical properties by mucuna after mechanized land of a tropical rain forest. Biological Agriculture and Horticulture 141: 219–224.

In western Nigeria, the effect of mucuna (*Mucuna utilis*) cover on physical properties of an Oxic Paleustalf, previously cleared by four different methods, including manual clearing, clearing with a shearblade, a treepusher, and a treepusher/root rake were studied. In contrast to cropping, mucuna cover improved soil porosity, penetrometer resistance, and hydraulic properties in all treatments. Total soil pososity of the 0- to 100-mm soil depth increased with mucuna cover by 7% in the manual, by 6% in the shearblade, and by 4% in the treepusher clearing treatment; while the pososity of the soil cleared with treepusher/root rake method was unaffected by mucuna cover. Penetrometer resistance of the 50- to 70-mm depth decreased with mucuna by 4%, in the manual, by 2% in the shearblade, by 10% in the treepusher, and by 2% in the treepusher/root rake method. Cumulative infiltration amounts over 3 hr of the plots sown to mucuna were greater than the corresponding cropped plot by 134% for the manual, by 55% for the shearblade, by 15% for the treepusher, and by 187% for the treepusher/root rake method. The beneficial effects of mucuna cover were greater in manually cleared and treepusher-cleared plots. Results indicate that where land clearing causes high compaction, mucuna cover for one year would be a useful practice to restore soil physical properties to favorable levels for arable farming.

0147

Manyong, V.M., A.V. Houndékon, A. Gogan, M.N. Versteeg, and F. van der Pol. 1996.
Determinants of adoption for a resource management technology: The case of *Mucuna* in Benin Republic. Pages I–86 to I–93 *in* Advances in Agricultural and Biological Environment Engineering, edited by Z. Senwen and W. Yunlong. Proceedings of a conference (ICABE), Beijing, 15–19 August 1996. China Agricultural University press, Beijing, China.

An adoption study was conducted in 1994 in Mono Province where an improved resource management system that incorporates Mucuna (*Mucuna pruriens* var. *utilis*) was introduced to the farmers 6 years earlier. The sample consisted of 277 farmers selected in four villages of the study area. Results indicate a high rate of successful adoption above the thresholds defined by Rogers in all but one village, though between-village differences were noticed. Econometric analysis using probit and logit models indicate that the physical characteristics of the resource base were major determinants for adoption of the new technology compared to farm and farmer's characteristics or technology-specific attributes. Logit and probit models yield slightly different results but lead to the same

recommendations.

0148

Sanginga, N., E.B. Ibiwero, P. Houngnandan, B. Vanlauwe, J.A. Okogun, I.O. Akobundu, and M.N. Versteeg. 1996.

Evaluation of symbiotic properties and nitrogen contribution of mucuna to maize grown in the derived savanna of West Africa. Plant and Soil 179: 119–129.

The adoption of mucuna (*Mucuna pruriens*) technology by smallholder farmers in the derived savanna of West Africa was enhanced by the severity and increase of *Imperata cylindrica* weed infestation, decline of the traditional bush fallow systems as a means of soil fertility management, and the lack of inorganic fertilizer. It is not known, however, the extent to which the establishment and N contribution of mucuna depend on symbiotic properties such as effective nodulation and mycorrhizal infection. Results of short-term surveys of 34 farmers' arable fields located in four sites in the derived savanna, southern Benin, West Africa, and results of greenhouse and field studies showed that mycorrhizal infection rate of mucuna ranged from 2 to 31% and correlated positively with nodulation and shoot dry weight. Nodulation occurred in 79% of the fields with numbers of nodules ranging from 0 to 135 plant^{-1}. Mucuna responded to inoculation and N fertilizer in degraded soils, but the growth response depended on the rhizobia strains and mucuna varieties. In 12 weeks, mucuna accumulated about 313 kg N ha^{-1} as a sole crop and 166 kg N ha^{-1} when mixed/intercropped with maize. Across all cropping systems, it derived an average of 70% of its N from atmospheric N_2 (by the ^{15}N isotope dilution method), representing 167 kg N ha^{-1} per 12 weeks in the field. Mucuna interplanted with maize obtained a greater proportion of its nitrogen (74%) from fixation than did mucuna grown alone (66%), suggesting that competition for soil N influences the proportion of nitrogen fixed by mucuna. The total amount of N_2 fixed per hectare was, however, reduced significantly by intercropping mucuna with maize. A preceding mucuna crop provided a maize yield equivalent to application of 120 kg N ha^{-1} of inorganic N fertilizer.

0149

Kolawole, G.O., and B.T. Kang. 1997.

Effect of seed size and phosphorus fertilization on growth of selected legumes. Communications in Soil Science and Plant Analysis 28: 1223–1235.

A screenhouse experiment was conducted to assess the effects of seed size and phosphorus (P) fertilization on growth of 12 herbaceous and shrub legumes grown on a P-deficient Plinthustalf. Species with large seed size showed higher biomass accumulation, nodulation and higher plant nutrient element content. The response to P fertilization was higher in species with small size seeds. Plant top dry weight was highly correlated with seed weight and seed nutrient element contents. Even though P application increased

nitrogen, phosphorus, potassium, calcium, and magnesium contents of plant tops, high rate of P fertilization was not beneficial to the early growth of the species tested on this P-deficient soil. The use of large-size seed with high content of nurient elements was recommended for the fast establishment of fallow legume species for P-deficient soils.

0150

Carsky, R.J. and R. Ndikawa. 1998.
Identification of cover crops for the semi-arid savanna zone of West Africa. Pages 179–187 *in* Cover crops in West Africa contributing to sustainable agriculture, edited by D. Buckles, A. Etèka, O.A. Osiname, M. Galiba, and G. Galiano. IDRC, Ottawa, Canada/ IITA, Ibadan, Nigeria.

Leguminous cover crops may be an appropriate component of sustainable food crop production systems in the semiarid savannas of West Africa. A set of erect and spreading legumes was observed for adaptation to a semi-arid climate (700–900 mm annual rainfall), without fertilizer application, on three soil types in northern Cameroon. *Mucuna pruriens* generally reached 100% ground cover 60–90 days after planting, whereas *Canavalia ensiformis* rarely reached 100% ground cover. Two *C. ensiformis* accessions, one erect and one spreading, differed in their ability to cover the soil surface. Foliage dry matter (DM) of *M. pruriens*, *C. ensiformis*, *Crotalaria ochroleuca*, and *Cajanus cajan* generally exceeded 4 t ha^{-1} at all but the most degraded site. At the degraded site, erect *C. ensiformis* accession produced 5–7 Mg DM ha^{-1}. *Canavalia ensiformis* grew longer into the dry season and maintained higher moisture content, suggesting some level of drought resistance. Strong winds during the dry season, trampling during seed collection, and uncontrolled cattle grazing were threats to persistence of mulch through the dry season.

0151

Carsky, R.J., S.A. Tarawali, M. Becker, D. Chikoye, G. Tian, and N. Sanginga. 1998. Mucuna – herbaceous cover legume with potential for multiple uses. Resource and Crop Management Research Monograph no. 25. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 52 pp.

This monograph, targeted to scientists developing and testing crop and/or livestock systems using mucuna (*Mucuna pruriens*), summarizes information from many agroecological zones in the tropics with particular reference to Africa. It reviewed the determinants of mucuna adaptation, utilization and benefits of mucuna, and current season management of mucuna crop and subsequent season management of the residues. Future research needs for mucuna utilization and management in Africa are highlighted. Frequent references were made to two databases, *LEXSYS* (Legume Expert System) and *COVERCROPS* that provide decision support for integrating herbaceous legumes into the farming systems.

0152

Houndékon, V., V.M. Manyong, C.A. Gogan, et M.N. Versteeg. 1998. Déterminants de l'adoption du *Mucuna* dans le départment du Mono au Bénin. Pages 45–53 *in* Cover crops in West Africa contributing to sustainable agriculture, edited by D. Buckles, A. Etèka, O. A. Osiname, M. Galiba, and G. Galiano. IDRC, Ottawa, Canada/ IITA, Ibadan, Nigeria.

Using an econometric model, an analysis of the determinants of *Mucuna* revealed that the probability of adoption was significantly affected by land ownership; number of weeding before harvest; source of information; unavailability of the land for second-season crops; soil types; appreciation of soil fertility trend; and revenue derivable from the sale of *Mucuna* seeds. About 42% of farmers surveyed cited loss of the opportunity to use land during the second rainy season as a reason for not adopting *Mucuna*. Among adopters, the degree of *Imperata* infestation (indicated by the number of weeding before harvest) was the strongest motive for adoption. In general, when the number of weeding was four or more, the farmer had access to information on *Mucuna*, had land security, and was able to realize up to 10 000 CFA francs on seed sales, the probability of *Mucuna* adoption was 84.7%. On the other hand, when all farmers had land security and access to information, the number of weeding before harvest was four, and the soil fertility was poor, the level of adoption was 71.6%.

0153

Tian, G. and B.T. Kang. 1998.

Effects of soil fertility and fertilizer application on biomass and chemical compositions of leguminous cover crops. Nutrient Cycling in Agroecosystems 51: 231–238.

The biomass and chemical compositions of 12 selected leguminous cover crops were studied in a pot experiment using soils of 2 fertility levels. Biomass yield responded to soil fertility levels and fertilizer application. The highest response to soil fertility when fertilizer was not applied was observed with *Centrosema brasilianum*. While the highest response to fertilizer application was observed with *Psophocarpus palustris*, in high fertility soil and *Centrosema pascuorum* in low fertility soil. Legumes grown without fertilizer application allocated more biomass to the roots than those grown with fertilizer. *Chamaecrista rotundifolia*, *Lablab purpureus*, *Pseudovigna argentea*, *Mucuna pruriens*, and *Cajanus cajan* showed higher N content in the roots than in the shoots. Soil fertility levels did not affect nitrogen content of shoot, but fertilizer application increased it by 30%. Except for *Cajanus cajan*, the only shrub species, all the herbaceous legumes had lower lignin content (6–10%) in the shoots. The mean liginin content in the roots was above 20% with no fertilizer, and decreased with fertilizer application compared to the

zero-fertilizer treatment. Polyphenol concentration in the shoots was higher than in the roots.

0154

Versteeg, M.N., F. Amadji, A. Etèka, V. Houndékon, and V.M. Manyong. 1998. Collaboration to increase the use of *Mucuna* in production systems in Benin. Pages 33–43 *in* Cover crops in West Africa contributing to sustainable agriculture, edited by D. Buckles, A. Etèka, O. A. Osiname, M. Galiba, and G. Galiano. IDRC, Ottawa, Canada/ IITA, Ibadan, Nigeria.

In 1987, the leguminous cover crop *Mucuna pruriens* var. *utilis* was introduced on researcher-managed demonstration fields for novel technologies with the objective of addressing the serious soil-fertility decline on the Adja Plateau in southern Benin. Farmers were more impressed by the ability of *Mucuna* to control the rampant weed *Imperata cylindrica* and requested seeds to use for their own experimentation. However, soil fertility bonus became highly visible, and this was further explored by farmers with seriously depleted ("comatose") fields. Extension services and nongovernmental organizations, such as Sasakawa Global 200, accelerated the spread of this dual-purpose technology. Adoption studies and econometric analyses indicated that the most important factor driving adoption was control of the *Imperata* weed. Eight other factors contributed significantly, three of these were related to field characteristics, including soil fertility, clay, and the presence of young palms. Four factors relate to the farmers: age, land security situation, possession of fallow reserves, and contact with extension services. The last was linked to the technology, that is, farmers' reluctance to use technology for regular soil fertility management because it would result in unproductive fields during the short rainy season. Farmers' reluctance was addressed through trials to rotate maize-*Mucuna* relay crops with more conventional crop combinations in alternate years, and ways were sought to make *Mucuna* grain economically useful as food for human consumption. Cracking the seeds, soaking overnight, boiling for 20 min, and resoaking overnight lowered the level of L-Dopa, the main toxic factor from about 6% to about 0.4% (an acceptable level). More toxicological tests are needed before the flour is launched for large-scale consumption. Other niches for *Mucuna* adoption observed in northern Benin were the use of *Mucuna*-maize relay crops for hay production and for *Striga* control.

0155

Vissoh, P., V.M. Manyong, R.J. Carsky, P. Osei-Bonsu, and M. Galiba. 1998. Experiences with *Mucuna* in West Africa. Pages 1–32 *in* Cover crops in West Africa contributing to sustainable agriculture, edited by D. Buckles, A. Etèka, O.A. Osiname, M. Galiba, and G. Galiano. IDRC, Ottawa, Canada/ IITA, Ibadan, Nigeria.

Soils of West Africa are relatively infertile and easily degraded under intensive agriculture, and fertilizer use is low. Shifting cultivation, the basis of the traditional agricultural systems, cannot be sustained because of the rapidly growing population. One of the most promising alternative soil-management strategies that has evolved is the use of *Mucuna* (*Mucuna pruriens*) as a weed-smothering and soil-improving cover crop. *Mucuna* adoption first occurred in southwestern Benin, where researchers and extensionists tested the technology with farmers from 1988 to 1992. The possibility that the technology could solve farmers' problems in other areas of West Africa prompted studies to examine factors responsible for adoption in Benin. Adoption first occurred in an area of very high rural population density, where land pressure no longer permitted the use of long fallow to restore soil fertility and reduce weed infestation. Suppression of speargrass (*Imperata cylindrica*) was seen as a major benefit of *Mucuna* fallowing, and therefore was the major factor promoting adoption of the technology. Results indicate that expansion of *Mucuna* fallowing is likely to occur in areas where soil fertility is declining, inorganic fertilizers are expensive, noxious weeds such as *Imperata* severely affect farmers' production, and development organizations have contact with farmers. Other determinants include new markets for *Mucuna* seeds, areas with long growing seasons of 7 or more months, the need for additional livestock feed and to reduce the buildup of soil pests such as *Striga hermonthica* and nematode infestation in intensified cereal systems.

0156

Salako, F.K., O. Babalola, S. Hauser, and B.T. Kang. 1999.
Soil macroaggregate stability under different fallow management systems and cropping intensities in southwestern Nigeria. Geoderma 91: 103 –123.

Evaluation of soil aggregate stability under managed fallow systems is very relevant in the assessment of their agricultural sustainability. This study was carried out in southwestern Nigeria to quantify the effects of three fallow management systems (bush fallow, *Pueraria phaseoloides*, and *Leucaena leucocephala*) and three fallow periods (1–3 years after 1-year cropping) on the macroaggregate stability of surface soil. A long-term fallow management trial established in 1989 on an Alfisol toposequence was used for the study. Cropping consisted of maize + cassava intercrop. Soil aggregate samples were wet-sieved to evaluate their mean-weight diameter (MWD) and fractal dimension (*D*). Results of data collected between 1994 and 1995 showed that the mean of MWD for

fallow systems and cropping intensities ranged from 2.4 to 6.4 mm. The mean of *D* values ranged from 2.29 to 2.72 while the mean intercepts (log k) of the regression ranged from 2.01 to 2.28. Low *D* values (cohesive and stable aggregates) were associated with fallowing, implying that fallowing enhanced soil aggregate stability, whereas high D values (fragmented aggregates) were associated with cultivation. The *Pueraria* system also enhanced soil aggregate stability more than bush fallow and *Leucaena* systems under continuous cropping. Fallowing 2 or 3 years after 1-year of cropping gave a similar aggregate stability as the secondary forest soil. Fractal analysis showed further that soil aggregates in the dry season and on the upper slope of the toposequence were more cohesive than in the wet season and on the lower slope.

Chapter Two

2. Technologies on cropping systems based on crops and agroecological zones

In the late 1980s, the Resource and Crop Management Division of IITA created interdisciplinary research groups, each of which focused on the development of technologies to address the problems of the predominant crop production system in one of three major agroecosystems. The crop production systems and the agroecologies were the cassava-based cropping systems for the humid forest, the maize-based cropping systems for the moist savanna, and the rice-based cropping system for the inland valleys. The development of technologies in each agroecosystem was done in five phases: (1) characterization and diagnosis of the cropping system/agroecosystem to provide a description of the natural resource base and constraints to improved productivity; (2) analysis of the interactions among components that contribute to or detract from the stability of the resource base; (3) design, involving the modification of the current practices or development of new systems for managing resources and crops to improve output without degrading the resource base; (4) validation and adaptation through on-farm experimentation of technologies generated from experiment station research, and (5) feedback, involving reporting of information from all on-farm work conducted in the different phases to scientists developing new technologies for resource and crop management or generating improved germplasm. A multidisciplinary approach was employed in carrying out research in each phase. The following section summarizes the work done in each cropping system/agroecosystem.

2. 1 Cassava-based systems for the humid forest

The humid forest region has an annual rainfall of at least 1500 mm and with a temperature difference between the warmest and coldest months of only a few degrees. Soils in this agroecological zone are generally highly weathered, acidic, and infertile. Soils of basement complex rocks from the forest agroecosystem (Araromi, Egbeda, and Apomu series) have a higher potential for cassava production than those from sandy sedimentary rocks (Alagba, Onne, and Npologu series). Studies on cassava-based systems for the humid forest were carried out at IITA, Ibadan and in a pilot research site located in Ohosu area of Edo State, Nigeria, and in other sites in southern Nigeria, Cameroon, and the Republic of Congo (Zaire) in collaboration with national program scientists.

Cassava is the dominant crop in the multiple cropping system practiced in this ecology, possibly because of its adaptability to relatively marginal soils and erratic rainfall conditions, its high productivity per unit of land and labor, and the possibility of maintaining continuity of supply throughout the year. Cassava/maize is the most common

intercropping system. Other crops that are combined with cassava in the system include cowpea, groundnut, yam, cocoyam, melon, okra, pineapple, plantain, citrus, cocoa, guava, kolanut, oil palm, and rubber. Some complex crop mixtures such as cassava/maize/melon, cassava/maize/okra/melon, and cassava/maize/okra/cowpea are found in the system.

Intercropping has some advantages over sole cropping. These include the provision of favorable microclimate, the reduction in labor requirements for a more even distribution of labor, supply of greater diversity of subsistence products over a long period, stability of yield production, and higher productivity per unit area of land.

Research aimed at improving the production of intercropping systems is often difficult because of the many constraints that have to be tackled. The research agenda at IITA, therefore, placed more emphasis on the improvement of cassava-based cropping systems through genotype evaluation to identify suitable varieties for the system. Considerable research attention was focused on achieving higher productivity per unit area of land and stability of yield production in intercropping systems involving cassava.

Results indicate that greater yields per unit land from cassava-based intercropping systems can be attributed to differences in the growth cycles and growth habits (tall, short, or spreading) of the component crops which ensure that peak demands for growth resources occur at different times. From studies on the pattern of canopy development in a cassava/maize/melon mixture, cassava was reported to develop its leaf area rather slowly during the first 3–4 months after planting, with leaf area index (LAI) of 0.5–1.0. A greater proportion of insolation that might otherwise be wasted between the cassava rows was utilized by the short, spreading melon, consequently reducing the soil temperature. There is also a considerable variation in leaf area development between varieties so that some varieties attain comparatively higher LAI than others during the early growth stage. For example, TMS 30572 develops a higher leaf area than TMS 91934 in the early growth stages, but at a later stage, TMS 91934 assumes a much faster leaf development with a higher peak LAI. This implies that even though cassava develops leaf area slowly during the early stages of growth, there are some vigorous leafy varieties that establish their canopy early and may not be suitable for intercropping systems.

Cassava has a wide range of growth habits in terms of branching and leafiness that influence its competitive abilities in intercropping systems. A series of experiments were carried out to examine the compatibility of a wide range of maize genotypes (early vs late, tall vs short, and spreading vs erect leaves) and plant population with one improved cassava variety, TMS 30572 developed at IITA, to identify genotypes that compete least with the cassava and minimally reduce cassava root yield. Results showed that maize genotypes selected for high yields as monocrops behave similarly when intercropped with cassava, suggesting that yield responses of solecropped maize can be used to predict accurately the performance when it is intercropped with cassava. A maize population of 40–80 x 10^3 plants ha^{-1} gave no significant reduction in yield of intercropped cassava. Population response varied with maize growth habits. The short, early-maturing types produced the best yield at a higher maize population of 80 x 10^3 plants ha^{-1}, while the late-

maturing, taller maize types performed best at 40 x 10^3 plants ha^{-1}. This indicates that height and plant population of the component crops are important factors influencing compatibility.

The performance of a wide range of improved cassava varieties under three cropping systems (monoculture, intercrop with maize, or with a local groundnut cultivar) was also assessed. In all cropping systems, cassava was planted at a standard spacing of 1 x 1 m or 10 000 plants ha^{-1}, while in the intercrop, maize and groundnut were planted each at 200 000 plants ha^{-1}. Intercropping cassava with maize or groundnut decreased cassava root yield, but the extent of the reduction varied much with the genotype and the component species, suggesting that the relative competitive abilities of cassava were greatly influenced by its genotype. The varieties that yielded high in a monocrop situation also yielded consistently high when intercropped with both maize and groundnut. The implication of this is that, as with maize, cassava clones or genotypes selected on the basis of their pure stand performance would perform equally well when under intercropping.

There has been limited research work on improving soil fertility and plant nutrition in cassava-based cropping systems, possibly because cassava is tolerant to a wide range of soil types. Cassava tends to show a limited response to nitrogen application in intercropping systems. Studies on the effects of nitrogen rates on intercropped maize and cassava carried out on Alagba soil (Oxic Paleustalf) at Ikenne, showed that in the first year, there was no response to nitrogen on sole or intercropped maize, but with early harvest, root yield of TMS 30395 was significantly depressed with N application and intercropping. During the second year, however, both the sole and the intercropped maize, but not the cassava, responded significantly to nitrogen application. The most economic rate of nitrogen fertilizer application to cassava intercropped with maize was 80 kg ha^{-1}.

Cassava appears to have a low phosphorus requirement, possibly because of its association with vesicular-arbuscular mycorrhizal fungi. Cassava in sole crop has been shown to respond to potassium and magnesium on an Ultisol (Typic Paleustalf) when the 1*N* ammonium acetate extractable soil K and Mg test levels were $\leq$ 0.15 me K 100 g^{-1} and $\leq$ 0.20 me Mg 100 g^{-1}. The critical tissue concentrations of cassava index leaves sampled at 6 months after planting were $\leq$ 0.1% K and $\leq$ 0.33% Mg. Application rates of 30 to 60 kg K ha^{-1} and 20 kg Mg ha^{-1} were optimum.

In 1989 the Collaborative Study of Cassava in Africa (COSCA) was initiated with the aim of collecting authoritative information over a wide area on cassava production systems, processing methods, market prospects, and consumption patterns. The information was needed to improve the relevance of research on cassava, in order to realize the potentials of this crop for increasing food supply and improving the welfare of the peoples of Africa.

The COSCA surveys were conducted in three phases. Phase I involved a broad characterization of the physical, social, and economic environments, and production, processing, marketing, and consumption patterns. Phase II dealt with cassava production

details such as yield, land area under production, utilization (sale vs home use, processing vs fresh use), input/output, and production practices. The third phase involved detailed studies on postharvest issues including processing (characterization of techniques and product quality assessment), marketing, and consumption/demand.

The study revealed clearly that cassava production was expanding in Africa. The expansion was in response to demographic and market pressures as well as to periodic famine caused by drought, plant pests and disease, or civil disturbances. The adoption of improved varieties and improved processing techniques was also a driving force in the expansion of cassava production.

Nutrient balance studies need to be addressed in cassava-based systems to sustain cassava production in Africa. It is important also to assess varietal differences in nutrient use efficiency in cassava to maximize the use of soil amendments applied to maize in the intercropping systems.

Abstracts

0157
Devos, P. and G.F. Wilson. 1979.
Intercropping of plantains with food crops: maize, cassava and cocoyams.
Fruits 34: 169–174.

In the local systems of production, plantain is cultivated in association with other food crops. No experimental study on mixed cropping involving plantain has, however, been reported. A preliminary experiment was set up to study the effects of cocoyam (*Xanthosoma sagittifolium* Schott.) and combinations of maize (*Zea mays* L.) and cassava (*Manihot utilissima* Pohl.) as intercrops on plantain yield in the first cycle. Plantain yields were not suppressed by any of the crop combinations tested. The poor performance of cassava suggested that this crop was not well adapted to the association with plantain. The reduction of plantain density to accommodate maize and cassava resulted in lower income to the farmer. Plantain with cocoyam appears the ideal combination, because the labor input and cost of production were relatively low and returns were high.

0158
Kang, B.T., R. Islam, F.E. Sanders, and A. Ayanaba. 1980.
Effects of phosphate fertilization on inoculation with VA-mycorrhizal fungi on performance of cassava (*Manihot esculenta* Crantz) grown on an Alfisol. Field Crop Research 3: 83–94.

Field and greenhouse experiments were carried out in southern Nigeria to study the effects of phosphate fertilization and inoculation with vesicular-arbuscular mycorrhiza on the performance of the local cassava (*Manihot esculenta* Crantz) cultivar Ishinukakijan grown on Egbeda soil series (Oxic Paleustalf). Field-grown cassava appears to have a low P requirement. At 3.4 ppm Bray-1 P or about 0.01 ppm P solution, tuber yield was reasonably high at 35 Mg ha^{-1}. However, 8 ppm Bray-1 P or 0.04 ppm P in solution was needed for maximum tuber yield of about 49 Mg ha^{-1}. Sampled at 3 months after planting, a P concentration of above 0.5% in the leaf blades and 0.38% in the leaf petioles was considered adequate. Inoculation with mixed native VA-mycorrhizal fungi or with *Glomus mosseae* significantly improved growth, lowered P response and increased P uptake in plant tops of pot-grown cassava in sterilized soil. Inoculated cassava appears to utilize phosphorus better from the more available Morocco rock phosphate than from the type from Togo. Inoculation with *Glomus mosseae* reduced plant growth and P uptake in unsterilized soil. Results of the pot trials lend support to the observation that the low P requirement of field-grown cassava may be related to its association with VA-mycorrhizal fungi.

0159

Akobundu, I.O. 1981.

Weed control in maize–cassava intercrop. Pages 124–128 *in* Tropical root crops: Research strategies for the 1980s, edited by E.R. Terry, K.A. Oduro, and E.F. Caveness, International Development Research Centre (IFDC), Ottawa, Canada.

Two improved cassava cultivars consisting of a profusely branching type (TMS 30395) and an upright, moderately branching type (TMS 30001) were grown at two population densities as components of mixtures involving two maize (TZB) populations. Maize yield was depressed by TMS 30395 at the higher cassava population density of 10 000 plants ha^{-1} but not at 5000 plants ha^{-1}. Two hand weedings or the use of a pre-emergence herbicide (Primextra) at 2.5 kg a.i ha^{-1} limited yield reduction caused by weeds in the maize–cassava intercrop. Root yield was generally higher for TMS 30001 than for TMS 30395. The highest root yield for each cassava cultivar was obtained when 10 000 plants ha^{-1} were intercropped with maize at 20 000 plants ha^{-1}. The highest total food energy and the lowest weed weight were observed at this population. The cost of weeding was lowest where the herbicide, Primextra, was used. This treatment gave the highest return on investment at the optimum crop combination.

0160

Kang, B.T. and G.F. Wilson. 1981.

Effect of maize plant population and nitrogen application on maize–cassava intercrop. Pages 129–133 *in* Tropical root crops: Research strategies for the 1980s, edited by E.R. Terry, K.A. Oduro, and E.F. Caveness, International Development Research Centre (IFDC), Ottawa, Canada.

The effects of maize population on the performance of a maize and cassava intercrop were studied on an Egbeda soil (Oxic Paleustalf) at Ibadan. Maize and cassava were spaced at 100 x 100 cm, with cassava planted between maize along the same row. The number of maize plants per hill varied from 1 to 7, giving a population of 10–70 x 10^3 plants ha^{-1}. Increasing maize populations from 10 to 30 x 10^3 plants ha^{-1} significantly increased maize grain yield and had no effect on cassava root yield. Higher populations, however, had no effect on grain yield but significantly depressed root yield. Three maize plants per hill seemed optimum in intercrop with cassava. The effects of nitrogen rates on intercropped maize and cassava were studied on an Alagba soil (Oxic Paleustalf) at Ikenne. In the first year, no response to N was observed on sole or intercropped maize, but with early harvest, root yield of TMS 30395 was significantly depressed with N application and intercropping. During the second year, both the sole and the intercropped maize, but not the cassava crop, responded significantly to N. Maize–cassava intercropping appeared to be more efficient than the corresponding sole crops as indicated by the higher land equivalent-ratios.

0161

Lal, R. 1981.

Effects of soil moisture and bulk density on growth and development of two cassava cultivars. Pages 104–110 *in* Tropical root crops: Research strategies for the 1980s, edited by E.R. Terry, K.A. Oduro, and E.F. Caveness, International Development Research Centre (IFDC), Ottawa, Canada.

A study of the effects of soil moisture and soil density on cassava yields was undertaken on a well-drained soil derived from fine-grained biotite gneiss and schist parent materials. Two soil densities and two soil moisture treatments were used. Two cassava varieties were tested– Isunikakiyan and improved 30211. Water use, plant growth, and dry-matter production were evaluated. Results showed that soil-moisture stress adversely affected shoot and root growth, water consumption, and water-use efficiency, although there were varietal differences to drought stress. The adverse effects of drought stress were accentuated when the plant root development was inhibited by high soil bulk density or low total porosity.

0162

Okeke, J.E. and B.T. Kang. 1981.

Evaluation of some major soils from southern Nigeria for cassava production. Pages 99–103 *in* Tropical root crops: Research strategies for the 1980s, edited by E.R. Terry, K.A. Oduro, and E.F. Caveness, International Development Research Centre (IFDC), Ottawa, Canada.

A pot trial was carried out with cassava and seven benchmark soils commonly used for cassava production in the forest and derived savanna of southern Nigeria. Soils of basement complex rocks from the forest zone (Araromi, Egbeda, and Apomu series) have a higher potential for cassava production than those from sandy sedimentary rocks (Alagba, Onne, and Npologu series) or sandy soil from the derived savanna (Shante series). Differential N, P, K, Mg, S responses and Zn deficiency were also observed among the seven soils. The data obtained can be used as a guide for fertilizer experiments.

0163

Ghuman, B.S. and R. Lal. 1983.

Mulch and irrigation effects on plant-water relations and the performance of cassava and sweet potato. Field Crops Research 7: 13–29.

Mulch and irrigation effects on plant-water relations and performance of cassava cv. TMS 30001 and sweet potato cvs. TIS 2148 and TIS 2295 were investigated at Ibadan, Nigeria. Straw mulch at 6 Mg ha^{-1} was spread immediately after planting of crops in September

1980. Irrigation equal to pan evaporation (4.5 mm day^{-1}) was applied during the dry season of 1980/81. Averaged over all treatments and cultivars, cassava had 15.00 h leaf water potential of -3.6 bars as compared to -9.6 bars of sweet potato. The daytime leaf diffusion resistance of cassava was similar (2–5 s cm^{-1}) in unirrigated mulched and irrigated mulched and unmulched plots. But in unirrigated unmulched plots, the resistance increased to 19 s cm^{-1} at 15.00 h. At harvest, the yields of cassava and sweet potato were not significantly affected by mulching. Cassava yield was, however, greater in irrigated (24.7 Mg ha^{-1}) than in nonirrigated plots (18.2 Mg ha^{-1}) Similarly, irrigated sweet potato outyielded the nonirrigated one by 70 to 211%.

0164
Kang, B.T. 1984.
Potassium and magnesium responses of cassava grown in an Ultisol in southern Nigeria. Fertilizer Research 5: 403–410.

Potassium and magnesium responses of three consecutive croppings of two improved cassava cultivars TMS 30395 and 30211 were studied on an acid, sandy loam Ultisol (Typic Paleudult) in southern Nigeria. On land newly cleared from *Eupatorium* fallow, a significant potassium response in the first cropping year was observed only with the more vigorous cultivar TMS 30395. Both cultivars responded to potassium applications at rates of 30 kg K ha^{-1} in the second cropping and 60 kg K ha^{-1} in the third croppings. A significant response to the application of 20 kg Mg ha^{-1} was observed in the third cropping with cultivar TMS 30211. Potassium and magnesium responses on this Ultisol can be expected when the 1*N* Ammonium Acetate extractable soil K and Mg test levels are $\leq$ 0.15 me K $100g^{-1}$ and $\leq$ 0.20 me Mg $100g^{-1}$. Critical tissue concentrations of cassava index leaves sampled at 6 months after planting were $\leq$ 0.1% K for both cultivars and $\leq$ 0.33% Mg for cultivar TMS 30211.

0165
Ezumah, H.C. 1987.
The effects on harvesting leaves on cassava yield in Zaire. Agriculture International 39: 152–155.

Cassava leaves are an important source of revenue in Zaire, providing about twice the revenue from roots, depending upon frequency of leaf harvest and provided all the harvested leaves are marketed. Frequent harvesting of cassava leaves resulted in a high incidence of cassava mosaic disease (CMD), depressed development of the leaf area, roots, and ultimately of yields. But commercial cassava fields destined for root production, especially those established in November at the onset of rains, could be a source of leaf vegetable with no significant loss in root yield and revenue.

0166

Hulugalle, N.R., R. Lal, and A.V. Opara-Nadi. 1987.
Management of plant residues for cassava (*Manihot esculenta*) production on an acid Ultisol in southeastern Nigeria. Field Crops Research 16: 1–18.

A study consisting of two experiments was conducted in southeastern Nigeria during 1983 and 1984 to determine whether the production of cassava (*Manihot esculenta* Crantz) on sandy, acid Ultisols could be improved by residue management techniques. One experiment studied the effect of location of *Eupatorium odoratum* mulch on soil properties and crop growth, and the second was on the effect of tillage system and *Eupatorium odoratum* mulch on soil properties and crop growth. In both experiments mulch was applied at an annual rate of 12 Mg ha^{-1} (25% moisture content) in a split application at planting and 150 days after planting. No fertilizer was applied during the experiment. The concentration of mulch in the plant row reduced within-row bulk density in surface 0.10 m by 15% in 1983 and by 13% in 1984. Tillage in combination with mulch reduced bulk density in the surface 0.10 m by an average of 10% in 1983 and 9% in 1984. Cassava tuber yield was not affected by the location of *Eupatorium odoratum* mulch. Both plowing and no-tillage, when combined with mulch, improved tuber yield over unmulched plots by 11–32% during 1983–1984 and 58–64% during 1984–1985.

0167

Ezumah, H.C. 1990.
Maize (*Zea mays*) genotypes for intercropping with cassava (*Manihot esculenta*) in southern Nigeria. 1. Yield responses. Discovery and Innovation 2: 63–72.

In order to ascertain the recommended changes as breeders release new improved maize varieties for use in cassava-based systems in a tropical Alfisol in southern Nigeria, the effects of maize variety and population on cassava root and maize grain yield, under the intercropping system, were evaluated. Five maize varieties, of contrasting growth habits, each at five populations (10, 20, 40, 80 and 160 x 10^3 plants ha^{-1}) were intercropped with cassava. The results of a 2-year study showed that a maize population of 40–80 x 10^3 plants ha^{-1} gave no significant reduction in yield of intercropped cassava. Population response varied with maize growth habits, the short, early-maturing types requiring higher maize populations. Maize grain yield tended to decline or remained constant at the highest population of 160 000 plants ha^{-1}. Results indicate that maize varieties selected by breeders for high yields as monocrops behave similarly when intercropped with cassava, suggesting that the yield responses of solecropped maize can be used to make accurate predictions of responses when it is intercropped with cassava.

0168

Ezumah, H.C. 1990.

Maize (*Zea mays*) genotypes for intercropping with cassava (*Manihot esculenta*) in southern Nigeria. 2. Growth morphological changes and yield advantages. Discovery and Innovation 2: 73–79.

Five maize varieties were evaluated at five populations (10, 20, 40, 80, 160 x 10^3 plants ha^{-1}) under intercropping with cassava in a tropical Alfisol in southern Nigeria. The increase in maize population enhanced maize and cassava height, increased stem and root lodging, and barrenness in maize cobs. Increased maize population, however, reduced cassava leaf number, maize stalk diameter, and maize leaf angle. The decline in cassava root yield under intercropping with maize at high populations was related to these morphological changes which persisted 7 months after cassava was planted and 4 months after maize was harvested. The early-maturing, short maize type produced the best overall yield at 80 000 plants ha^{-1} population based on land equivalence ratio (LER). The late-maturing, taller maize types performed best at 40 000 plants ha^{-1}. Land equivalent-ratio of 1.9 or more can be realized from cassava and maize intercropping systems, if the right maize variety is planted at the right density with cassava spaced at 1 m x 1 m or at 1 m x 0.67 m.

0169

Ikeorgu, J.E.G. and H.C. Ezumah. 1991.

Some analytical aspects of cassava/maize/okro/egusi-melon complex mixture: I. Soil temperature in relation to leaf-area variation. Field Crops Research 27: 51–60.

A study was initiated in 1981 to investigate the various ways egusi-melon (*Citrullus lanatus* Thunb.) and okra (*Abelmoschus esculentus* Moench) affect the microenvironment of intercropped cassava/maize (*Zea mays* L.). This paper examines the effects of okra and egusi-melon in reducing soil temperature that may otherwise be supra-optimal for cassava (*Manihot esculenta* Crantz) and maize. Afternoon soil temperature of about 39 °C observed at 5 cm depth under sole cassava early in the growing season was reduced by intercropping as follows: with maize, by 1.0 °C; with maize/okra, by 1.3 °C; with maize/egusi-melon, by 3.0, and with maize/okra/egusi-melon, by 4.4 °C. There was a negative but significant relationship between soil temperature and combined leaf area index (L) of crops grown in mixture with sparse-canopy cassava ($r = -0.91^{**}$) and with dense-canopy cassava ($r = -0.93^{**}$). For effective soil temperature reduction under cassava, results showed that associated intercrops must attain L of at least 1.5 within the first 8 weeks of growth. Since the L of cassava is below 0.5 during the first 8 weeks of growth, intercrops such as egusi-melon and maize would help reduce supra-optimal temperatures under cassava.

0170

Polson, R.A. and D.S.C. Spencer. 1991.

The technology adoption process in subsistence agriculture: The case of cassava in southwestern Nigeria. Agricultural Systems 36: 65–78.

The adoption decisions of subsistence multicrop producers regarding improved cassava variety (TMS 30572) in the humid tropical rainforest ecology of southwestern Nigeria were analyzed within a qualitative choice framework. The empirical results revealed that younger farmers producing marketable surpluses on holdings in excess of the mean farm size of 0.6 ha exhibited higher propensities of adopting TMS 30572 compared with farmers producing primarily for household consumption. The activities of extension agents among subsistence producers were significant in the technology adoption process. Migrant farmers were identified as early adopters by the empirical model. These results have significant implications for extension personnel, research scientists, and policy makers, and provide further justification for strengthening the extension capacities of the national research programs within the cassava belt of the humid forest ecologies of West and Central Africa.

0171

Hulugalle, N.R. and H.C. Ezumah. 1991.

Effects of cassava-based cropping systems on physicochemical properties of soil and earthworm casts in a tropical Alfisol. Agriculture, Ecosystems and Environment 35: 55–63.

The effects of cassava-based intercropping systems and rotations on the physical and chemical properties of earthworm casts and the adjacent soil were studied on an Oxic Paleustalf in southwestern Nigeria. Earthworm activity was greater with intercropping, even though it was not significantly affected by the number of component crops in the mixture. The particle size distribution, bulk density, exchangeable cations, Bray-1- P, pH, and effective cation exchange capacity (ECEC) of soil and earthworm casts did not differ among the cassava-based cropping systems investigated. Greatest values of mean weight diameter, organic carbon, and total nitrogen were observed in earthworm casts from three component crop mixtures, although adjacent soil was not similarly affected. Water infiltration into the soil was increased by intercropping and may be related to earthworm activity. Cropping systems may, therefore, influence soil fertility indirectly by changing water infiltration characteristics and hence, nutrient losses in runoff and erosion. In relation to soil, earthworm casts had higher silt and clay contents, bulk density, mean weight diameter, pH, Bray-1-P, organic carbon, total nitrogen, C: N ratio, exchangeable cations and effective CEC, and lower sand content.

0172
Nweke, F.I., R. Polson, and J. Strauss. 1994.
Cassava production trend in Africa. Pages 311–321 *in* Tropical root crops in a developing economy, edited by F. Ofori and S.K. Hahn. International Society for Tropical Root Crops (ISTRC), Wageningen, The Netherlands.

This paper which is based on primary information collected over a wide area in sub-Saharan Africa shows that cassava production is expanding in the region. The expansion is in response to demographic and market pressures as well as to periodic famine caused by drought, plant pests and disease, or by civil disturbances. In addition, the adoption of improved processing techniques is aiding the expansion in cassava production.

0173
Nweke, F.I., E.C. Okorji, J.E. Njoku, and D.J. King. 1994.
Expenditure elasticities of demand for major food items in southeast Nigeria. Tropical Agriculture (Trinidad) 71: 229–234.

Expenditure elasticities were estimated for yam, cassava, and seven other food items widely consumed by the people of southeastern Nigeria. For all households, the combined elasticity estimate for yam was above unity and almost as high as that of meat. For high expenditure households, however, it was significantly below unity but still positive. The estimate for any cassava product was below unity but positive for all households combined. For high expenditure households, especially urban households, the estimate for all cassava products combined was negative, but that for gari, a high quality processed cassava product, although still below unity, was positive and higher than the estimate for yam. The estimates also suggest that although in certain forms of preparation cassava may be an inferior food item, in other forms, it is far from being inferior; it may even be superior to yam. There is need, therefore, for improvement in cassava-processing technology to improve quality and expand its market.

0174
Nweke, F.I. and D.S.C. Spencer. 1995.
Future prospects for cassava root yield in sub-Saharan Africa. Outlook on Agriculture 24: 35–42.

Primary data collected over a wide area in Africa show that average cassava root yield is not declining as population increases because the land is being cultivated more intensively in response to demographic pressures. Even though fallow periods are becoming shorter, organic manuring, improved market infrastructures, and the use of purchased inputs such as labor compensate for this. The yields of improved cassava varieties in Nigeria show that technology can be relied upon to raise production in the

future, provided that the conditions necessary for the widespread adoption of improved varieties prevail in most African countries.

0175

Osiname, O.A. and T. Muamba. 1995.

Responses of groundnut (*Arachis hypogaea* L.) in sole crop and in intercrop with cassava (*Manihot esculenta* Crantz) to lime in an Ultisol in Bas-Zaire. African Journal of Root and Tuber Crops 1: 11–14.

Field trials were carried out in M'Vuazi, Bas-Zaire, to test the response of groundnut (cv P43), planted sole or intercropped with cassava (cv Kinuani), to lime application. Groundnut responded significantly to low rates of lime of 250 to 500 kg ha^{-1}. Maximum cost : benefit ratio of 1:7 was obtained when 500 kg lime ha^{-1} was applied. Whether groundnut was planted sole or intercropped with cassava, its critical soil calcium level was estimated at 0.6 cmol kg^{-1}. There was no cassava root yield response to lime application at a soil calcium level of 0.11cmol kg^{-1}. Lime application below 2 000 kg ha^{-1} did not significantly change the surface soil pH and did not affect the subsoil chemical properties. The main effects of lime on groundnuts were, therefore, to supply adequate calcium to produce the maximum number of mature pods and reduce the incidence of unfilled pods.

2. 2 Rice–based systems for the inland valleys

Inland valleys are relatively narrow and shallow valleys that occur in the upper reaches of watersheds. They are a particular category of wetlands that provide a high potential production environment for a wide diversity of food crops including rice, sugarcane, cassava, yam, sweet potato, maize, legumes, vegetables, plantain and banana, among others. They are ideally suited for rice production.

Almost three-quarters of the 85 million hectares of inland valleys in the sub-Saharan Africa are found in the West and Central Africa. An inland valley can extend up to 25 km in length, and its width can vary from about 10 m in its upper levels to about 800 m in its lower stretches. Three hydrological processes converge in the inland valleys: seepage, runoff, and vertical fluctuations in the water table. The topsoil lost through erosion from uplands is often deposited in the valleys, making their soils more fertile than on the uplands. The potential yields of crops grown in the inland valleys are much higher than in the upland fields. For example, rice yields in the inland valleys are as high as 4.0 Mg ha^{-1} as against 1.5 Mg ha^{-1} in upland fields. Despite the high potential, only an estimated 10 to 25% of the inland valleys are used for cropping.

Research at IITA to develop appropriate technologies to improve the rice–based cropping systems was conducted in two selected environments representative of inland valley swamps (IVS) and hydromorphic soils in West and Central Africa. Research work started in the two pilot research areas located in Bida, Nigeria (medium rainfall, Guinea savanna zone) in 1985 and Makeni in Sierra Leone (High rainfall, humid zone) in 1986. Initial studies from farm surveys revealed the constraints hindering the productivity of the rice–based systems. These include lack of water control and poor soil fertility (soil nutrient toxicities and deficiencies), problems of weeds, insect pests, and diseases, lack of credit facilities to purchase fertilizers, low labor supply in the peak season, and lack of efficient farm power equipment and small tools. Human diseases are prevalent in the inland valleys, perhaps the reason for their being thinly settled. Clearing the natural vegetation and developing land for farming is quite difficult. In general, water conditions or balances and soil fertility are two major physical factors that determine the productivity of the rice–based cropping systems.

In order to develop prototype technologies to address some of these constraints, two strategies were adopted. The first was aimed at developing technologies to alleviate labor shortages during the peak rainy season, intensifying cropping activities during the slack labor demand period of the dry season, and identifying high-yielding, short-season rice and other varieties to increase short-run crop productivity. The second was aimed at the conduct of more basic research to develop technologies of soil and water management appropriate to the natural conditions and economic capabilities of the small-scale farmers.

A tillage system that consists of an annual cycle of mounding and flat tillage is practiced on about 80% of inland valley fields, with the rice planted on flat seedbeds and dry season crops on mounds. This tillage system recycles the organic matter and soil

nutrients by incorporating the crop residues and weeds during the making and spreading of the mounds. The practice of growing dry season crops has an economic implication of reducing land preparation labor input for rice that occurs during the peak period by 30 to 50%.

Studies have also shown that farmers' practice of growing rice on ridges in some swampy iron-toxic areas can increase grain yields threefold or even more, through the use of IITA resistant varieties. The tillage practice permits air to reach the rice roots, and oxidize the ambient iron into a form harmless to the plant.

Basic research on water-balance necessary to improve soil and water management of paddies showed that most of the bottom land can be used for rice, whereas fields along the valley fringe have a high drought probability and are too risky for rice. In paddies with continuous flooding for 100–130 days, early-maturing improved varieties are suitable, but in paddies with continuous flooding for longer than 130 days, traditional, long-duration rice varieties can be grown. In those with less than 100 days continuous flooding, rice production becomes too risky. Farmer-managed trials on the effect of field water duration on rice yield showed that a yield difference of almost 100% can be obtained when fields are kept saturated or flooded for at least 50% or more of the growing period.

The use of improved high-yielding crop varieties suitable for inland valleys is the simplest technology that can be introduced to small-scale farmers. Improved varieties outyielded farmers' varieties, and increasing nitrogen application from 30 to 80 kg ha^{-1} significantly increased grain yield. Farmers' assessment showed that earliness and high yield are important factors that they consider before adopting improved rice varieties. The performance of the second (dry) season crops such as cowpea and cassava was influenced by the interval between the date of harvesting the first season rice crop and the date of planting the second crop. When planting is delayed at the start of the next crop season, the second season crops (cowpea and cassava) suffer from moisture stress that results in reduced yields.

In 1990, research work on rice was completely handed over to the West Africa Rice Development Association (WARDA). WARDA was given the mandate to focus specifically on the clear opportunity for increased crop production in the inland valleys throughout tropical Africa. Research work, however, continued on the inventory and classification of inland valleys using geographical information systems (GIS) and satellite imagery (remote sensing), on the quantification of constraints, and the design, evaluation and testing improved technologies for inland valleys.

Presently, under the farming systems diversification project, studies are being carried out to improve dry season crop production in inland valleys. Some of these studies include the adaptability and adoptability of early-maturing maize and cowpea in the inland valleys of the northern Guinea savanna of Nigeria, and the testing of early maize varieties in the inland valleys of the humid forest margin.

Abstracts

0176

Osiname, O.A. and B.T. Kang. 1975.

Response of rice to sulphur application under upland conditions. Communications in Soil Science and Plant Analysis 6: 585–598.

A greenhouse experiment was carried out to determine the sulphur response and plant sulphur content of rice (*Oryza sativa* L.) cultivars OS-6 and IR-20 grown in sandy Apomu soil series under upland conditions. Sulphur application increased growth and dry-mattter yield. Cultivar OS-6 gave the greatest grain yield at low sulphur rates and produced more straw at high rates than cultivar IR-20. At flower emergence, the blade of the Y-leaf appeared to be a suitable index measuring the sulphur status of the plant. The critical sulphur contents were estimated at 0.15% for the leaf, and at harvest, 0.12% for grain and 0.10% for straw. The N/S ratios for the grain and straw at harvest appeared not to be a useful index for determining the critical S status of the plant.

0177

Kang, B.T. and E.G. Okoro. 1976.

Response of flooded rice grown on a Vertisol from northern Nigeria to zinc sources and methods of application. Plant and Soil 44: 15–25.

Greenhouse and laboratory studies were conducted to study the effect of zinc sources and methods of application on correcting zinc deficiency in flooded rice (var. IR-20) on a Vertisol from Ngala, northern Nigeria. Plant dry-matter yield was similar for $ZnSO_4$, ZnEDTA, metallic Zn and fritted Zn with mixed soil application. Zinc uptake was affected in the following order: ZnSO4 > ZnEDTA > metallic Zn > fritted Zn. Comparable dry-matter yield and Zn uptake were obtained with mixing, surface broadcasting, and banding of ZnEDTA. Mixing the fritted Zn gave greater dry-matter yield and zinc uptake than broadcasting or banding. Seed soaking with a suspension of fritted Zn resulted in a greater dry-matter yield and a higher zinc uptake than with ZnEDTA solution. Seed soaking for 24 hours with fritted Zn suspension at a concentration of about 0.5% zinc appeared to be suitable method for allying zinc with direct seeded rice.

0178

Kang, B.T. and A. Sajjapongse. 1980.
Effect of heating on the properties of some soils from southern Nigeria and the growth of rice. Plant and Soil 55: 85–95.

The effect of heating on the properties of 3 types of surface soils was studied under laboratory conditions. The soils were Apomu (Psammentic Ustorthent), Egbeda (Oxic Paleustalf), and Gambari (Typic Plinthustalf. Heating at a low temperature of ≤ 100 °C had no detrimental effects on soil properties, but on the contrary increased the soil extractable P, Mg, Fe, Mn, and Zn levels. Pronounced reductions in total N, organic matter, organic P, and extractable Ca and Mg levels and marked increases in extractable P, Zn, Mn and Fe were observed after heating to 200 °C. Heating to ≥ 500 °C had an adverse effect on soil chemical and physical properties. Plant height and dry-matter yield of rice plants were higher when grown on Egbeda soil previously heated to 100 °C. With the addition of N, P, and K there was no beneficial effect from the heating treatment. Rice plants grown on Egdeda soil previously heated to 200 °C showed high uptake of Mn. Plants grew badly in soil previously heated to 500 °C.

0179

Mambani, B. and R. Lal. 1983.
Response of upland rice varieties to drought stress. I. Relationship between root system development and leaf water potential. Plant and Soil 73: 59–72.

Field investigations on the relationship between root growth in three upland rice varieties (IB 6, IR 1529–680–3 and IET 1444) and leaf water potential were conducted under two soil moisture regimes (i.e., with and without supplementary irrigation). The root system of IB 6 penetrated below 20 cm, while that of the other two varieties was confined to between 15 and 20 cm. The leaf water potential of IB 6 was higher (less negative), and its leaves regained turgidity sooner than the other varieties. Root density at a depth of 15–25 cm was positively correlated with leaf water potential and with the development of accumulative internal plant water stress. The mean grain yields (Mg ha^{-1}) for the 3 varieties in 2 soil moisture regimes were as follow: IB 6, 4.7 (high), 4.1 (low); IR 1529–680–3, 4.9 (high), 2.6 (low); and IET 1444 2.6 (high), 1.5 (low). The results indicate that changes in leaf water potential with time $\{\psi_L(t)\}$ can be used for screening rice cultivars for drought avoidance.

0180

Mambani, B. and R. Lal. 1983.

Response of upland rice varieties to drought stress. II. Screening rice varieties by means of variable moisture regimes along a toposequence. Plant and Soil 73: 73–94.

The effects of variable soil moisture regimes on root development, plant water status, and grain yield were investigated for ten rice varieties along a toposequence. The depth water of the table below the soil surface in three regions along a toposequence was 100 cm (M_1), 30 cm (M_2), and 15 cm (M_3). Soil moisture regimes had no significant effect on total root dry weight. Roots of the tall varieties (63-83, IB 6, and IRAT 13) penetrated more deeply into the soil profile than roots of the short varieties. The pattern of soil moisture depletion was similar to that of the root density profile. Relative water stress, expressed as a ratio of leaf water deficit under the M_1 moisture regime to that under M_3, increased exponentially with the decrease in root density at a depth of 25 cm. The mean grain yields for the different moisture regimes were 2.4 for M_3, 1.9 for M_2, and 1.4 Mg ha^{-1} for M_1. Variety IB 6 and other tall varieties maintained stable yields under the adverse moisture regime. Grain yield was linearly related to root density at a depth of 25 cm.

0181

Mambani, B. and R. Lal. 1983.

Response of upland rice varieties to drought stress. III. Estimating root system configuration from soil moisture data. Plant and Soil 73: 95–104.

Root density profile of three varieties grown along a toposequence under three soil moisture regimes was estimated from soil moisture depletion patterns in the soil profile. Each of the three varieties (IB 6, IR 1529-680-3, and IET 1444) had a different rooting pattern. The three soil moisture regimes corresponded to water table depths of 100 cm (M_1), 30 cm (M_2), and 15 cm (M_3) below the soil surface. Soil moisture potential was negatively correlated with root density, and the differences in the rate of moisture depletion at various depths were due largely to differences in root activity. Varietal differences in root activity, however, were observable only within a narrow range of soil moisture potential, generally above –0.60 bar.

0182

Akobundu, I.O. and A. Ahissou. 1985.

Effect of interrow spacing and weeding frequency on the performance of selected rice cultivars on hydromorphic soils of West Africa. Crop Protection 4: 71–76.

Field experiments were conducted on hydromorphic soils at Ibadan, Nigeria, to determine the effects of crop-management practices on rice yield. The performances of three rice cultivars at different crop densities and weeding regimes were investigated. Weed weight

decreased significantly as the interrow spacing was decreased from 45 cm to 15 cm. Tillering and the number of rice panicles also decreased with the reduction in interrow spacing. When rice was kept weed free, there was no difference in yield between rice planted at 15, 30, and 45 cm interrow spacing. Yield reduction caused by weed competition at the wide interrow spacing was more pronounced in the semi-dwarf cultivar than in the taller cultivars. All cultivars competed better with weeds when grown at 15 and 30 cm interrow spacing than at the wider spacing used by most rice farmers in West Africa.

0183

Carsky, R. J. and E.O. Ajayi. 1992.

Fitting soil-improving legumes into inland valley rice-based cropping systems in West Africa. Pages 395–404 *in* Biological nitrogen fixation and sustainability of tropical agriculture, edited by K. Mulongoy, M. Gueye, and D.S.C. Spencer. John Wiley & Sons/Sayce Publishing/IITA/AABNF (copublication), Chichester, UK.

The small inland valleys of West Africa offer the possibility of sustainable increases in food crop production because of their favorable hydrology. A key component in any sustainable cropping system is the maintenance or restoration of soil fertility. This paper explores avenues for introducing biological nitrogen fixation management into existing cropping systems. Various activities are being conducted to generate technology to introduce legumes into rice-based cropping systems in the inland valleys. These include *Sesbania rostrata* management trials, screening of exotic leguminous green manure germplasm under inland valley conditions, survey of legumes indigenous to inland valleys, and screening of soybean and cowpea varieties under inland valley conditions.

2. 3 Maize-based systems for the moist savanna

The moist savanna agroecosystem is characterized by a length of growing period between 150 and 270 days with a precipitation of 900 to 1500 mm. The predominant soils are kaolinitic Alfisols of moderately low inherent soil fertility. The zone has a great potential to produce crops and shows signs of becoming the breadbasket for sub-Saharan Africa where it occupies 29% of the total cropland. The major crops include maize, sorghum, millet, cowpea, cotton, soybean, cassava, and yam. In the past two decades, in areas with good access to markets and fertilizer inputs, maize has become the predominant crop.

Research on maize-based systems for the moist savanna started at IITA with studies on the intensification process of maize production and its problems. The maize-based cropping systems in the savanna of Nigeria and Côte d'Ivoire were characterized and classified, the impact on *Striga* infestation of intensifying maize-based cropping in the northern Guinea savanna (NGS) of Nigeria was diagnosed, and cultural methods were developed for the control of *Striga* and improvement of soil fertility.

Results showed that agricultural production in the moist savanna had intensified. The fallow period had either declined or been completely eliminated. In response to the increased profitability of farming, farmers had expanded the size of farms and diversified their crops. Maize and rice became cash crops, while the production of other cash crops such as pepper, cowpea, and sugarcane had grown.

The process of intensification of maize production in the moist savanna of Nigeria has resulted in substantial increases in productivity and improved farmer welfare. The essential preconditions for this phenomenon were identified as first, improved access to markets as a result of a good road network that made it practicable for farmers to market a cash crop such as maize and intensify the production system. Secondly, the availability of improved maize varieties that are compatible with the biophysical and socioeconomic environment of the farmers also contributed to drive the process of intensification.

Studies on agricultural system dynamics based on an analysis of the evolutionary change presented an approach for addressing the development and transfer of technology in the NGS. The study identified, on the basis of some exogenous and endogenous determinants, 4 agricultural systems with the proportion of the agricultural land of the NGS under each system: population-driven systems in the land expansion phase (16.7%), population-driven systems in the early (25.9%) and advanced (16.7%) stage of land intensification phase, market-driven systems in the early (15.5%) and advanced (24.1%) stage of land intensification phase, and market-driven systems in the land expansion phase (11.1%). The interaction of the characteristics of agricultural systems and those of the biophysical resource base led to the formation of five different resource domains: (1) moderately fertile uplands with low or no application of fertilizers and/or organic residues; (2) fertile uplands of high fertility possibly due to intensive fertilizer use; (3) degraded uplands of low-fertility, due to over-exploitation and lack of amendments to restore fertility; (4) inland valleys with hydromorphic soils of varying fertility, and (5)

lands that are reserved for non-agricultural purposes. The term 'farming domains' was used to classify the evolution of cropping and livestock systems. These domains constitute an adequate level for conducting research on crop and resource management and for extension. At least 10 farming domains were identified. On the basis of analysis of changes in equity and externalities, 'farmer domains' were identified at the village/land-use unit level. These classifications provide the basic framework for technology development and transfer in the NGS.

Studies on population dynamics of *Striga hermonthica* analyzed on farmers' fields in the NGS showed that soil seed density of *Striga* varied due mainly to differences in cropping history, and was higher for sorghum than for maize. Sorghum was the major host of *Striga* reproduction. In areas with intensified maize cropping, maize functions as a *Striga*-suppressive crop while in areas with extensive crop management, maize contributes significantly to *Striga* reproduction. Using a simple regression model, yield loss assessment from *Striga hermonthica* in 66 farmers' fields in the NGS was estimated at between 0 and 46%, with an average of 10%. This further suggests that the risk of *Striga hermonthica* infestation is low in the maize–based system under intensive management.

Abstracts

0184

Weber, G., K. Elemo, and S.T.O. Lagoke. 1995.
Weed communities in intensified cereal-based cropping systems of the northern Guinea savanna. Weed Research 35: 167–178.

The dynamics of weed population was analyzed in intensified cereal-based cropping systems of the northern Guinea savanna in Nigeria. Four common weed associations were identified through cluster analysis. Five factors describing soil fertility conditions and field history best differentiated the weed communities according to a descriminant model. The analysis showed that maize-based cropping systems with a high frequency of cereal cropping and a low frequency of noncereal cropping tended to be dominated by weeds such as *Commelina* spp. and *Kyllinga squamulata*. As soil fertility declined, *Vernonia* spp. and *Eclipta prostrata* became more important. Increased frequency of noncereal crops in mixed cropping with cereals was associated with reduced incidence of weeds such as *Leucas martinicensis*, *Oldenlandia corymbosa*, *Spermacoce verticillata*, *Ludwigia hyssopifolia*, *Celosia laxa*, and *Ipomoea* spp. Further diversification of cereal-based systems to obtain a reduced frequency of cereals is likely to increase the incidence of *Dactyloctenium aegyptium* in crop fields. The information provides guidance for technology development and transfer on weed control for intensifying systems in the northern Guinea savanna of Africa.

0185

Weber, G., P.S. Chindo, K.A. Elemo, and S. Oikeh. 1995.
Nematodes as production constraints in intensifying cereal-based cropping systems of the northern Guinea savanna. Resource and Crop Management research monograph No. 17. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 36 pp.

This monograph summarizes the information on a collaborative research project that pioneers the characterization and assessment of nematode problems in farmers' fields in the northern Guinea savanna of Nigeria. The research approach includes participatory methodologies and detailed field monitoring. The study identified and classified plant-parasitic nematodes associated with cereal-based systems. It also identified the determinants of the buildup of nematode populations and the various farming systems with a high risk of cereal damage caused by nematodes. Opportunities for nematode suppression were diagnosed. Assessment of farmers' perceptions of nematode problems and the implications of those perceptions for on-farm research were discussed. Various future research needs were highlighted.

0186

Weber, G., K. Elemo, A. Awad, S.T.O. Lagoke, and S. Oikeh. 1995. *Striga hermonthica* in the cropping systems of the northern Guinea savanna. Resource and Crop Management research monograph No. 19. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. 69 pp.

This monograph summarizes the information collected over 3 years on a collaborative research project on *Striga* as a constraint in the cropping systems of the northern Guinea savanna. The determinants of incidence and severity of *Striga*, and the cropping systems most at risk from *Striga* attack were identified. It also reports the performance of some on-farm control technologies and how best to target the available control technologies to the farming systems. Future research needs were enumerated.

0187

Weber, G., K. Elemo, S.T.O. Lagoke, A. Awad, and S. Oikeh. 1995. Population dynamics and determinants of *Striga hermonthica* on maize and sorghum in savanna farming systems. Crop Protection 14: 283–290.

The population dynamics of the parasitic plant *Striga hermonthica* were analyzed on farmers' fields in the northern Guinea savanna of Nigeria. Soil seed density of *Striga* varied among farmers' fields between 0 and more than 80 000 seed m^{-2}. The differences among fields were mainly due to cropping history, and were larger for maize than for sorghum, mainly due to differences in crop management practices being used by farmers. The number of emerged, surviving, and reproducing *Striga* plants were analyzed on maize and sorghum and showed a large variability among fields. The number of newly produced *Striga* seed at the end of the season varied between 0 and 109 000 seed m^{-2} and proved to be largely independent of the initial soil seed bank. Sorghum was the major host of *Striga* reproduction. In an area with intensified maize-cropping, maize functions as a *Striga*-suppressive crop while in an area with extensive crop management, maize contributes significantly to *Striga* reproduction. The analysis of the population dynamics of the parasite shows the importance of a farming systems approach to pest management and to the development of sustainable cropping systems for the savannas.

0188

Oikeh, S.O., G. Weber, S.T.O. Lagoke, and A.E. Awad. 1996. Assessment of yield losses from *Striga hermonthica* in farmers' fields in the northern Guinea savanna. Nigerian Journal of Weed Science 9: 1–6.

Yield losses occurring from *Striga hermonthica* were assessed in farmers' fields in the northern Guinea savanna of Nigeria. Individual maize plants were analyzed for the number of emerged *Striga*, damage symptoms from *Striga* parasitism and grain yield. Grain yield of individual plants was closely correlated with damage symptom but not with

the number of emerged *Striga*. A linear regression model described the relationship between symptom expression and grain yield, and was used to develop a simple model for estimating yield losses in farmers' fields. In a separate study, yield losses of between 0 and 46% were estimated in 66 farmers' fields using the model. Average yield loss was 9.8%.

0189
Weber, G. 1996.
Legume-based technologies for African savannas: Challenges for research and development. Biological Agriculture and Horticulture 13: 309–333.

Legume-based technologies have the potential to contribute to crop and livestock productivity, to improved human nutrition, and to resource conservation in low input agriculture. Adoption of such technologies lags far behind claimed potentials. There is a need to review present technical and methodological approaches to the design and transfer of these technologies by research and development organizations. Research needs to shift from detailed experimentation with a few promising technologies towards developing a basket of a large number of prototype technologies that match the diversity of the target conditions in farmers' fields. Preparing the resulting information in a user-friendly database or expert system can guide the choice of appropriate technologies for target sites. Development needs to improve its technical capacity to characterize target sites and the underlying causes of constraints and its ability to identify appropriate prototype technologies for the farmers. The evolving research-development scenario with a large number of non-governmental organizations operating at the local scale provides an opportunity to experiment with more appropriate legume-based technologies for a large number of diverse farming systems, if those involved in research and development respond to the new challenge.

0190
Weber, G., J. Smith, and M.V. Manyong. 1996.
Systems dynamics and the definition of research domains for the northern Guinea savanna of West Africa. Agriculture, Ecosystems and Environment 57: 133–148.

The northern Guinea savanna in Africa (NGS) with a season length of 151–180 days and an altitude below 800 m has long been recognized as highly suitable for crop production and animal husbandry. At present, land use intensity and farming as well as livestock systems vary widely across the zone. Subsistence farming, traditional pastoralism, intensive, market-oriented production of cash crops, and highly integrated crop-livestock systems are present. This article presents an approach for addressing the challenge of technology development and transfer in the NGS. It is based on the evolutionary change of the agricultural systems. Exogenous and endogenous determinants have been identified

for the formation of, at present, four agricultural systems, five major resource domains, and at least ten major farming domains in the NGS. The domains cluster areas of similar resource endowments and development potential that are at a similar point along generalized evolutionary pathways. The additional differentiation of farmer domains integrates changes in equity and externalities into the concept. Resource degradation, biotic constraints, and issues of equality are briefly analyzed according to the framework.

0191

Carsky, R.J., S. Nokoe, S.T.O. Lagoke, and S.K. Kim. 1998.
Maize yield determinants in farmer-managed trials in the Nigerian northern Guinea savanna. Experimental Agriculture 34: 407–422.

Farmer-managed tests of *Striga hermonthica*-resistant maize varieties were conducted in 1994 in a moderately intensified zone in the northern Guinea savanna of Nigeria. Field history, soil properties, current season fertility management, and crop management observations were recorded for 37 farmer-managed trials. Mean site grain yield varied from 0.3 to 4.0 Mg ha^{-1}. The grain yield was significantly greater for the *Striga*-resistant hybrid 8321-18 compared with the improved open-pollinated variety (STR Syn-W) and the farmers' current variety. Correlation and stepwise regression analyses of grain yield on measured variables suggested that maize yield was a function of plant density for all three varieties. The rate of nitrogen fertilizer application was an important variable only for the hybrid, while the date of first weeding was most important for the improved varieties. The yield of the local varieties and STR Syn-W was related to the number of emerged *Striga* at harvest in the stepwise regression, and the yield of the local varieties was highly correlated with the *Striga*-damage score on maize. The *Striga*-damage score was significantly lower on 8321-18 than on the other varieties, suggesting some degree of resistance in the hybrid. Farmers were almost unanimous in ranking the hybrid as the variety with least damage from *Striga* and the highest yield. *Striga*-damge score was lower if crop residue was observed on the field at the time of site confirmation. The greatest yield of about 4.0 Mg ha^{-1} was recorded on fields near the homestead (compound fields) where soil organic carbon values were 2.0–2.5%. Realization of maize yield potential in the absence of manure or fertilizer will only be possible on long-term compound fields. *Striga*-resistant maize can maintain high yields under moderate infestation of *S. hermonthica*.

0192

Olkeh, S.O., J.G. Kling, W.J. Horst, V.O. Chude, and R.J. Carsky. 1999. Growth and distribution of maize roots under nitrogen fertilization in plinthite soil. Field Crops Research 62: 1–13.

To improve efficiency of soil N and water use in the savanna, maize (*Zea mays* L.) cultivars with improved root systems are required. Two rainfed field experiments were conducted in Samaru, Nigeria in the 1993 and 1994 growing seasons with five maize cultivars under various rates of nitrogen fertilizer. The capacity of maize for rapid early root growth and to later develop a deep, dense root system was assessed. In addition, the effect of N fertilization on root growth of maize was studied in 1994. The widely cultivated cultivar TZB-SR had a poor root system in the surface soil layer and was more susceptible to early-season drought, as indicated by low plant vigor and aboveground dry-matter yield at this stage. It had a lower grain yield and a relatively small harvest index, but ranked among the highest in total aboveground dry-matter production compared to other cultivars. The size of root system alone did not always relate well with grain yield among cultivars. Partitioning of dry matter within the plant was important in determining differences in grain yield and N stress tolerance between cultivars. A semiprolific cultivar (SPL) had high seedling vigor and a high, dense root system in the surface soil layer that conferred a higher tolerance to early-season drought stress and improved uptake of "the early-season N flush", as indicated by a higher dry-matter yield at 35 days after sowing (DAS) compared to other cultivars in both years. It also had a fine, deep, dense root system at flowering that could have improved water- and N-use efficiency in the subsoil (> 45 cm), thereby avoiding midseason drought stress in 1994. SPL had a large harvest index and the greatest yield among cultivars in 1994. Averaged across cultivars, greater root growth and distribution was observed at a moderate N rate of 0.56 g plant^{-1} than at zero-N or high N (2.26 g plant^{-1}). Differences in root morphology could be valuable as selection criteria for N-efficient and drought-tolerant maize.

Chapter Three

3. Technologies on land and soil management

3.1 Zero/minimum tillage

Tillage is a soil management technique that plays an important role in maintaining the productivity of soils through soil and water conservation. Zero-tillage or minimum tillage implies maximum retention of crop residues on the soil surface. Reduced or zero-tillage is also called conservation tillage. A no-tillage system is based on the zonal tillage concept, whereby land is divided into a seedling zone and a soil management zone. The seedling environment zone provides optimum physical conditions for good emergence, proper stand, and satisfactory yield. The soil management zone is managed to conserve soil and water and to create an optimum soil temperature regime. Zero-tillage permits intensive cropping, particularly when it involves the return of crop residues to the soil on otherwise highly erodible and shallow tropical soils.

No-tillage techniques have been extensively used in temperate countries. The practice involves planting in the stubble of a previous crop, combined with the use of a herbicide to control preplanting vegetation. In the early 1970s, IITA scientists initiated studies to explore the possibilities of adapting this technology to tropical conditions in the humid forest and forest-savanna transition agroecologies. Research efforts concentrated on the effects of zero-tillage on soil properties, erosion control, and crop responses across different agroecologies and soil types.

Results showed that no-tillage has a lot of benefits over conventional tillage. It lowers soil surface temperature and enhances a favorable moisture regime by increasing water infiltration rates and saturated hydraulic conductivity, thereby stimulating biological activities, for example, of earthworms. It provides organic matter in the soil surface and enhances soil fertility. In particular, higher concentrations of nitrate-nitrogen, available phosphorus, exchangeable calcium, magnesium, and potassium have been reported on no-tilled plots than on plowed plots. Zero-tillage maintains soil structure and minimizes runoff and erosion losses. It also suppresses annual grass weeds. Furthermore, it has been found to increase nutrient-use efficiency with some crops.

Variable crop responses to no-tillage technology have been reported. Maize grain yield from three seasons was found to increase by 20% in no-till plots over conventionally plowed plots. Also, maize grain yield of 3 Mg ha^{-1} was reported for no-till plots from the twelfth consecutive crop as against 1 Mg ha^{-1} for the plowed plots. Years after the adoption of the technology, the beneficial effect on yield was more noticeable than in the first year of adoption.

Crop response varies with the fertility of the soil. Under high fertility or with adequate fertilizer application, maize yields from no-till plots were equal to those from the conventional plots. On low fertile soil, however, no-tillage maize production is not

recommended without adequate nitrogen fertilizer application.

Roots and tubers, that are sensitive to soil compaction, inadequate aeration, or poor drainage, respond more favorably to intensive tillage followed by ridging or mounding in combination with mulch than to zero-tillage. On light-textured soil, however, cassava can be grown without tillage or with minimum tillage as long as weeds are controlled.

Because of the variable response of crops to tillage practices in different soils, a tillage guide was proposed in the mid-1980s to make possible the systematic adoption of tillage technology in the tropics. In developing the rating scale the following properties were considered: erosivity, erodibility, soil loss tolerance, compaction, available water holding capacity, cation exchange capacity, soil organic-matter content, soil temperature regime, and the quantity of crop residue on the soil surface. The minimum and maximum cumulative ratings for all the factors ranged from 14 to 70. No-tillage was recommended for soils with cumulative rating values of less than 30 and conventional tillage system of plowing and harrowing for soils with cumulative rating values above 45. Reduced or minimum tillage was suggested for soils with an intermediate rating. Separate rating systems were suggested for rice and tropical root crops.

In spite of the numerous benefits of no-tillage technology, widespread adoption among small-scale farmers has been low, because of its dependence on herbicides for weed control. Apart from the high cost of the herbicides, it is difficult to find a single product that controls a wide range of perennial weeds. Therefore, herbicide mixtures or sequential herbicide applications are needed for effective weed control. There is also the problem of health hazards associated with the use of herbicides as a result of contamination of underground water. Furthermore, a shortage of trained personnel for effective transfer of the technology has limited its adoption.

With renewed interest in the integration of herbaceous legumes into the cropping system, as cover crops useful for fallow management especially for the suppression of noxious weeds, planting directly into a deadmulch of a legume cover crop, without tillage, may be attractive to farmers. Further on-farm investigation is, however, required. Further studies are also needed on the management of macronutrients, secondary elements, and micronutrients in no-tillage crop production, when planting is done directly into a deadmulch of a legume cover crop.

Abstracts

0193
Lal, R. 1973.
Effects of seedbed preparation and time of planting on maize (*Zea mays* L.) in western Nigeria. Experimental Agriculture 9: 303–313.

The maize variety, Nigerian Synthetic-5 was evaluated under five methods of seedbed preparation and eight planting dates, five in the first season (from 15 April to 15 June) and three in the second, on 20 August, 4 and 23 September, at approximately 15-day intervals. The methods of seedbed preparation and time of planting affected yields. The effects could be related to soil temperature and soil moisture reserve during crop development. Maize planted in August produced the greatest yield; heaps and ridges gave the lowest yield at all planting dates, while planting on flat or in furrows produced the highest yield among the seedbed methods.

0194
Lal, R. 1974.
No-tillage effects on soil properties and maize (*Zea mays* L.) production in western Nigeria. Plant and Soil 40: 321–331.

The no-tillage technique has been extensively used in the temperate countries, but its potential for soil and water management has hardly been explored in the tropics. This experiment was set up to study the effect of no-tillage techniques on soil properties and maize production in western Nigeria. The grain yields of no-tillage plots were equivalent to those of conventionally plowed treatments. No-tillage treatments had higher organic-matter content and, as erosion was controlled, the silt and clay content compared with that of the plowed plots. A decrease in the maximum soil temperature and a favorable moisture regime in the no-tillage plots stimulated biological activity, for example, of earthworms. While the fertilizer had no response on the plowed plots, irrigation had a negative effect due probably to severe leaching losses. No-tillage techniques have the potential to achieve continuous cultivation on otherwise highly erodible and shallow tropical soils.

0195
Rockwood, W.G. and R. Lal. 1974.
Mulch tillage: a technique for soil and water conservation in the tropics.
SPAN 17: 77–79.

Large scale clearing of land in the tropics aimed at increasing food production introduces problems of accelerated soil erosion, decreases in soil organic matter and water-holding capacity, crop-damaging fluctuations in soil temperature and, in the long run, a potential

decline rather than an increase in crop production. Research at the International Institute of Tropical Agriculture, Ibadan, Nigeria, indicates that mulch, or no-tillage farming techniques based on sound principles of soil management offer an improved system of land use for highly erodible and difficult-to-manage tropical soils.

0196
Lal, R. 1976.
No-tillage effects on soil physical properties under different crops in western Nigeria. Soil Science Society of America Journal 40: 762–768.

Five years of no-tillage vs. the conventional method of tractor plowing significantly affected the physical and chemical properties of an Alfisol in western Nigeria. Continuous cropping of maize for 3 consecutive years was followed by 4 seasons of cultivation with cropping sequences of maize-maize (*Zea mays* L.), maize-cowpea (*Vigna unguiculata* L. Walp.), pigeon pea (*Cajanus cajan* Millsp.) -maize, soybean-soybean (*Glycine max* Merr.), maize-soybean, and cowpea-cowpea. The no-tillage plots had higher organic-matter contents in the surface soil horizons and higher concentrations of nitrate-nitrogen, available P, and exchangeable Ca^{2+}, Mg^{2+}, and K^{+} than the plowed plots. The infiltration rates of no-tillage plots were higher than those of the plowed plots, thus minimizing runoff and erosion losses. The no-tillage plots had the highest soil moisture contents throughout the growing seasons, but maximum soil temperatures were higher in the plowed plots. Greater earthworm activity in the no-tillage plots reduced compaction and crust formation. Yields equal to those from the plowed plots were harvested from the no-tillage plots under suitable crop rotations.

0197
Lal, R. 1976.
Soil erosion on Alfisols in western Nigeria. I. Effects of slope, crop rotation, and residue management. Geoderma 16: 363–375.

The effect of slope, crop rotation, and residue management on runoff and soil loss was investigated using field runoff plots on natural slopes of 1, 5, 10, and 15% on an Alfisol in Ibadan, Nigeria. The soil and crop management treatments consisted of conventionally plowed bare fallow, maize-maize (conventionally plowed and mulched), maize-maize (conventionally plowed), maize-cowpea (zero-tillage), and cowpea-maize (conventionally plowed). The effect of two contour lengths of 12.5 and 37.5 m was also investigated for the maize-cowpea rotation. Soil erosion under slopes of 5, 10, and 15% was severe for these soils and if not controlled could limit crop growth. Mulching and no-till treatments had negligible runoff and soil loss. During 1973, the annual runoff losses from the 15% slope were 36% of the total annual rainfall for the bare-fallow treatment, 2% for mulch, and 2% for no-till. Annual soil losses during 1973 from 15% slope were 230 Mg ha^{-1} from

bare-fallow, 0 Mg ha^{-1} from maize-maize (mulched), 41 Mg ha^{-1} from maize-maize (conventional plowing), 0.1 Mg ha^{-1} from maize-cowpea (no-till), and 43 Mg ha^{-1} from cowpeas–maize (plowed). There was no definite relationship between contour length and runoff or soil loss.

0198

Kang, B.T. and M. Yunusa. 1977.
Effect of tillage methods and phosphorus fertilization on maize in the humid tropics. Agronomy Journal 69: 291–294.

The recent interest in adopting minimum tillage for crop production in the humid tropics for better soil and water conservation has raised questions concerning crop yield and nutrient absorption. There is no information on the most suitable method of P application with minimum tillage as compared to conventional tillage with tropical soils. This study was conducted on Egbeda soil series (Oxic Paleustalf) in southern Nigeria in 1974 and 1975, to investigate the interaction between soil tillage and P application methods on (a) P movement in the soil profile, (b) maize root distribution, (c) P content, and (d) maize yield. Main plot treatments were conventional tillage and minimum tillage, and subplots were P rates and placement. Root density of maize was increased with P application. There was a tendency for higher root concentration in the upper 10 cm of the soil surface with minimum tillage. Movement of broadcast P in the soil profile was slow with minimum tillage. Broadcast, band, and hill methods were, however, observed to be equally effective in supplying adequate P to the maize crop at P rates of $\geq$ 20 kg P ha^{-1} on the Egbeda soil. Therefore, no effect of P placement method on maize yield was observed with either minimum or conventional tillage methods. The lower maize yield with minimum tillage in 1974 was attributed to early N stress, while in 1975 with 160 kg N ha^{-1}, maize yields were equal with conventional and minimum tillage methods.

0199

Ajunwon, S.O., B.A. Olunuga, and R. Lal. 1978.
Applicability of no-tillage techniques in the forest and savanna regions of western Nigeria. Nigerian Journal of Science 12: 247–266.

The effects of five tillage practices on soil characteristics and crop production were evaluated for forest (Ikenne) and savanna (Ilaro) regions of western Nigeria during 1974 and 1975. The tillage treatments include plowing, plowing after burning, no plowing with manual weed control, no plowing with chemical weed control, and no plowing after burning with chemical weed control. A two-course rotation, maize-maize or maize-cowpea, was superimposed on the tillage treatments, and two maize varieties Western Yellow and IITA–composite, were used. At Ikenne with a well-drained, structurally stable soil, traditional plowing and harrowing had no beneficial effect on maize grain

yield. Maize yield at Ilaro was 10% higher for plowed than for unplowed treatments. The use of herbicides was superior to plowing with respect to weed control, moisture conservation, and activities of soil fauna. The activities of soil fauna were adversely affected by plowing and burning. There were no appreciable differences in the performance of the two maize varieties.

0200

Lal, R., P.R. Maurya, and S. Osei-Yeboah. 1978.
Effects of no-tillage and plowing on efficiency of water use in maize and cowpea. Experimental Agriculture 14: 113–120.

Water-use efficiency of maize (*Zea mays*) and cowpea (*Vigna unguiculata*) was investigated, with or without tillage, under four irrigation frequencies in which 12 mm of water was applied at 2, 4, 8, and 12 day intervals, using sprinkler system. Both maize and cowpea under no-tillage yielded more than with conventional plowing. The percentage water-use efficiency of maize without tillage was greater than with tillage at irrigation frequencies: 2 days (18.3), 4 days (17.5), 8 days (57.8), and 12 days (100). Whereas, the leaf water potential of cowpea was not affected by tillage, that of maize was generally higher for no-tillage compared with conventional plowing.

0201

Juo, A.S.R. and R. Lal. 1979.
Nutrient profile in a tropical Alfisol under conventional and no-till systems. Soil Science 127: 168–173.

The chemical properties and nutrient status of an Alfisol under no-tillage and conventional plowing were investigated after 6 years of continuous maize. No tillage with crop residue mulching resulted in higher concentrations of organic C, total N, available P, and exchangeable Ca and K than the plowed plots in the 0 to 10 cm layer. No-tillage led to stratification of soil pH in the 0 to 50-cm profile. Nutrient depletion in the conventionally tilled plots was mainly due to accelerated soil erosion. Grain yield was consistently higher from the no-till than from the plowed treatment at the same rate of N application.

0202

Lal, R. 1979.
Influence of 6 years of no-tillage and conventional plowing on fertilizer response of maize (*Zea mays* L.) on an Alfisol in the tropics. Soil Science Society of America Journal 43: 399–403.

The effects of four rates of N (0, 40, 80, and 120 kg ha^{-1}) and three rates of P (0, 13, and 26 kg ha^{-1}) were investigated for no-tillage and conventionally plowed plots on an Alfisol

in southwestern Nigeria. The experiments were conducted for three consecutive seasons. Mean grain yields (2.9 Mg ha^{-1}) from no-till treatments were greater than yields (2.4 Mg ha^{-1}) from conventionally plowed plots in all three seasons. There was no effect of P on grain yield. Nitrogen application had a significant effect on grain yield in all three seasons. Relative grain yield in the plowed plots without N application was 85% of that in no-tillage plots. These results, obtained 6 years after adopting these tillage systems, are contradictory to those obtained in the first year of adoption.

0203
Kang, B.T., K. Moody, and J.O. Adesina. 1980.
Effects of fertilizer and weeding in no-tillage and tilled maize. Fertilizer Research 1: 87–93.

Field trials were carried out on Apomu soil (Psammentic Ustorthent) and Egbeda soil (Oxic Paleustalf) in southern Nigeria to investigate the effects of fertilizer and weeding on the growth and yield of maize (*Zea mays* L.) under no-tillage and tilled land preparations. On the newly cleared Apomu soil, broadleaf weeds dominated the weed flora, with the shrubs being more important under no-tillage. More grasses and sedges were present when the soil was tilled. Regardless of tillage method, there was a ≥ 38% yield reduction due to weeds in the unfertilized plots, with yield in tilled plots being almost double that in the no-tillage plots. Grain yield of no-tillage maize was less than that of tilled maize with no or low rates of N application, but with adequate N fertilization yield from no-tillage maize equaled that of tilled maize. Lower yield of no-tillage maize may partly be attributed to severe N stress during early growth. Consequently, on low fertility soil, no-tillage maize production is not recommended without adequate N fertilization.

0204
Maurya, P.R. and R. Lal. 1980.
Effects of no-tillage and plowing on roots of maize and leguminous crops. Experimental Agriculture 16: 185–193.

Root development of maize (*Zea mays*), soybean (*Glycine max*), cowpea (*Vigna unguiculata*), and pigeonpea (*Cajanus cajan*) was investigated with or without tillage. Observations were made at different growth stages by digging trenches perpendicular to the rows, by core sampling, and by observing the growth of roots against glass windows. There were more maize roots in the surface layer (0–10 cm) with no-tillage than with conventionally plowed plots, but maize roots were more abundant at 10–40 cm and soybean and pigeonpea roots less so in the no-tillage plots.

0205

Maurya, P.R. and R. Lal. 1981.

Effect of water table depths and tillage methods on plant-water status and yield of rice. Plant and Soil 59: 17–22.

The effects of water table depths on plant-water status, and on growth and yields of two rice varieties (TOS 78 and TOS 848) were studied in a lysimetric investigation. A field study was also conducted on a hydromorphic soil to investigate the effects of a fluctuating water table on rice. The leaf-water potential of TOS 78 monitored at 1300 hours at 50% flowering-stage was –17.5 bar at 0 cm water table depth and –23.0 bar at 60 cm. When grown under soil moisture stress, TOS 848 maintained higher leaf-water potential (–17.5 bar *vs* –22.5 bar) and yielded more than TOS 78. Under hydromorphic soil conditions, no-tillage treatments had the same yields as conventionally tilled plots.

0206

Akobundu, I.O. 1983.

No-tillage weed control in the tropics. Pages 32–44 *in* Proceedings of a Symposium on No-tillage Crop Production in the Tropics, 6–7 August 1981, Monrovia, Liberia, edited by I.O. Akobundu and A.E. Deutsch. Corvallis, Oregon: Oregon State University.

To derive the benefits associated with no-tillage crop production, proper weed management practices that incorporate weed control and reduction in weed seed population in the soil must be developed and made available to the farmers. Two approaches to no-tillage crop production in the tropics were suggested, including a no-tillage system that depends on herbicides for its implementation, and an alternative system that depends the use of mulch (living and dead) from herbaceous legumes. Effective transfer of these technologies to farmers in the developing countries requires trained personnel and the availability of herbicides in consumer-useable packages. Ultimately, the success of food production in the tropics requires the recognition of these constraints and a demonstrable willingness of researchers and policymakers to solve the research, staff, and infrastructural problems that directly and indirectly limit food production.

0207

Akobundu, I.O. 1983.

Weed control in No-tillage cassava in the subhumid and humid tropics. Pages 119–126 *in* Proceedings of a Symposium on No-tillage Crop Production in the Tropics, 6–7 August 1981, Monrovia, Liberia, edited by I.O. Akobundu and A.E. Deutsch. Corvallis, Oregon: Oregon State University.

Studies on land preparation show that high root yield in cassava is obtained when land is cultivated. The need to reduce erosion hazards has stimulated interest in no-tillage production of cassava. This study assessed cassava crop performance and the efficacy of preemergence herbicides in selected tillage systems. Results showed that cassava root yield was lower in no-tillage plots than with conventional tillage (flat or ridge). No-till plots treated with preemergence herbicides had high weed biomass, greater than 15 Mg ha^{-1} at 16 weeks after planting, while similarly treated conventional tillage plots had low weed biomass, less than 6 Mg ha^{-1}, indicating that weed control was better in the conventional than in the no-till plots. The need to reduce erosion hazards makes it necessary to plant cassava on tied ridges rather than on the flat in conventionally cultivated fields.

0208

Kang, B.T. and A.D. Messan. 1983.

Fertilizer management for no-tillage crop production. Pages 111–118 *in* Proceedings of a Symposium on No-tillage Crop Production in the Tropics, 6–7 August 1981, Monrovia, Liberia, edited by I.O. Akobundu and A.E. Deutsch. Corvallis, Oregon: Oregon State University.

For soils with low fertility, yield of no-tilled maize may be less than that of conventionally tilled maize. Yields may, however, be equal or higher on fertile soil or after high rates of nitrogen are applied. Surface application of non-volatile nitrogen sources is satisfactory for no-tillage, but care should be taken when using volatile nitrogen sources. On the predominantly low phosphorus-fixing soils in the humid and subhumid region of tropical Africa, surface application of soluble phosphorus sources, readily available for the crops, is satisfactory. Further studies are needed on the management of potassium, secondary elements, and micronutrients in no-tillage crop production in the tropics.

0209

Akobundu, I.O. 1984.

Tillage in relation to cultural weed control in grain legumes. Pages 93–113 *in* Proceedings of the International Workshop in International Pest Control for Grain Legumes, 3–9 April 1983, Goiânia, Goiás, Brazil, edited by P.C. Matteson. EMBRAPA, Brasilia, Brazil.

Tillage practices suitable for weed control in grain legumes vary with soil type, climate, farm size, technological advancement of the farming community, and soil conservation needs of the area in which the crops will be produced. Appropriate tillage practices from tropical farmers should be those that will enable them to combine good land, crop and pest management using land intensively and economically to obtain moderate-to-high crop yields on a sustained basis. Reduced tillage practice that can suppress weeds involves planting the grain legume without tillage directly into a deadmulch of a legume cover crop killed before the cover crop sets seed. In the semiarid tropics, an appropriate tillage system is one that involves planting on tied ridges and earthing-up when necessary as a supplemental weeding practice.

0210

Khatibu, A.I., R. Lal, and R.K. Jana. 1984.

Effects of tillage methods and mulching on erosion and physical properties of a sandy loam in an equatorial warm humid region. Field Crops Research 8: 239–254.

Field experiments were conducted at Kizimbani Experiment Station in Zanzibar to study the effects of different mulch materials and tillage methods on soil temperature and moisture regimes, soil physical properties, runoff, and soil erosion. Treatments consisted of black and white polyethene mulch, no-tillage, ridged seedbed, and plowed and harrowed soil surface. For maize and cowpea, all mulch and no-till treatments had a greater moisture reserve than other treatments. The maximum soil temperature at a depth of 5 cm was also as much as 6 °C lower in the no-tillage than in the other treatments and correlated significantly with leaf area index, solar radiation, and soil moisture at depths of 15 and 30 cm. The infiltration rate declined as a result of two seasons of cultivation and was least for the ridged and the highest for no-till treatments. Runoff was 10.2% from the bare plots and 0.01% in mulched treatments. Total soil loss from the mulched treatment was 3.6% and nutrient loss was 6.6% of the losses from the bare plot. In the Vuli season, a cool rainy season from September to December, white polyethene mulch produced significantly more grain yield of maize, cowpea and soybean than other treatments.

0211

Lal, R. 1984.

Mechanized tillage systems effects on soil erosion from an Alfisol in watersheds cropped to maize. Soil and Tillage Research 4: 349–360.

The degrading effects of mechanized farming operations on soils in the tropics are not widely documented. This study was carried out on twin watersheds of about 5 ha each, to quantify the effects of mechanized no-till and conventional tillage systems on runoff, erosion, and changes in soil properties. The conventionally plowed watershed was terraced to control erosion. Measurements using a rate-measuring H-Flume indicated that runoff and erosion from the terraced and conventionally tilled watershed were several times greater than those from the unterraced no-till watershed. Cumulative runoff in 1979 was 10 times and erosion 42.2 times higher from the plowed watershed than from the no-till watershed. Infiltration capacity 5 years after land development was 3.8 cm h^{-1} for the plowed and 10.4 cm h^{-1} for the no-till watershed, and the surface soil from the no-till watershed retained more water at all soil water potentials than surface soil from the plowed treatment. The maize grain yield from the twelfth consecutive crop was 3 Mg ha^{-1} for the no-till and 1 Mg ha^{-1} for the plowed watershed.

0212

Maduakor, H.O., R. Lal, and O.A. Opara-Nadi. 1984.

Effects of methods of seedbed preparation and mulching on the growth and yield of white yam (*Dioscorea rotundata*) on an Ultisol in southeastern Nigeria. Field Crops Research 9: 119–130.

Effects of ridge and flat planting of yam, with and without surface mulch, on soil moisture and temperature regimes, root and shoot development, tuber yield, and yield components were investigated for an Ultisol near Port Harcourt in southeastern Nigeria. Mulching slightly improved the soil moisture regime and decreased the maximum temperature at 5 cm depth by 2–3 °C early in the season. Leaf area index (LAI) was significantly lower in unmulched ridges than in other treatments. Mulching significantly increased yield by about 20% in both ridged and unridged plots. There were no differences in tuber yield among flat and ridge plantings. Tuber diameter and length were greater in mulched than unmulched treatments.

0213

Hulugalle, N.R., R. Lal, and O.A. Opara-Nadi. 1985.

Effect of tillage system and mulch on soil properties and growth of yam (*Dioscorea rotundata*) and cocoyam (*Xanthosoma sagittifolium*) on Ultisol. Journal of Root Crops 11: 9–22.

The effects of tillage systems and mulch on soil properties and growth of yam and cocoyam were studied on a sandy Ultisol in eastern Nigeria. Treatments were no tillage, with and without mulch, and conventional tillage, with and without mulch. Mulch was applied at a rate of 12 Mg ha^{-1} (25% moisture content) as a split application at planting, and at 150 DAP. At the end of the experiment, bulk density (Mg m^{-3}) in the surface 0.10 m, for the 4 treatments was 1.33 (untilled/mulched), 1.33 (untilled/unmulched), 1.24 (conventionally tilled/mulched) and 1.27 (conventional tilled/unmulched). Equilibrium infiltration rate was 0.07, 0.05, 0.11, and 0.07 mm s^{-1} in untilled/mulch and unmulched, and conventionally tilled/mulched and unmulched plots, respectively. Daily maximum soil temperature in the 50-mm depth was lowest in the untilled/mulched plots. Mulching and no-tillage increased levels of exchangeable cations and decreased acidity saturation. Conventional tillage increased P availability in the 0.1–0.2 m depth. Depth of rooting and yam yield, and cocoyam top growth, root growth and yield were improved by conventional tillage in combination with mulch.

0214

Lal, R. 1985.

A soil suitability guide for different tillage systems in the tropics. Soil and Tillage Research 5: 179–196.

A tillage guide is needed to give systematic adoption of tillage technology in the tropics. A rating system is proposed for assessing the applicability of tillage and no-tillage practices for different soils. Soil and climatic properties considered in developing the rating system include erosivity, erodibility, soil loss tolerance, compaction, soil temperature regime, available water-holding capacity, cation exchange capacity, and soil organic-matter content. The quantity of crop residue on the soil surface was also included in the rating. The minimum and maximum cumulative rating values for all factors range from 14 to 70. No-till is applicable for soils with cumulative ratings less than 30 and the conventional tillage system of plowing and harrowing is suitable for soils whose cumulative rating values exceed 45. For soils with intermediate ratin, some form of minimum or reduced tillage is suggested. Separate rating systems are suggested for rice and tropical root crops.

0215

Rodriguez, M. S. and R. Lal. 1985.
Growth and yield of paddy rice as affected by tillage and nitrogen levels.
Soil and Tillage Research 6: 163–187.

There is limited knowledge of the optimum soil and crop management practices required for rice (*Oryza sativa* L.) production in tropical wetlands. This study evaluated the effects of different tillage systems on the growth and yield of paddy rice, grain yield response to nitrogen application, and weed control in five experiments conducted for three consecutive seasons on hydromorphic soils in Ibadan, Nigeria. Treatments were zero tillage (without dry tillage and puddling) and conventional tillage (dry tillage and puddling) at 2 or more N levels, ranging from 0 to 150 kg ha^{-1}. In two of the experiments, the effects of either 2 moisture regimes or chemical versus manual weed control were also evaluated. Results of four of the experiments showed no differences in grain yield between zero-tillage plots sprayed with paraquat and conventional-tillage plots. Only in Experiment 2 did zero-tillage (with paraquat) plots give a significantly lower yield (5.2 Mg ha^{-1}) than the conventional-tillage plots (5.6 Mg ha^{-1}) because of greater rat damage in the no-till plots. The continuous flooding treatment (Experiment 1) gave better weed control and a greater grain yield than the saturation moisture regime. In zero-tillage plots where weeds were slashed before transplanting (Experiment 2), grain yield was lower and the weed growth greater than in zero-tillage and low N level. Satisfactory weed control was obtained with paraquat and continuous flooding.

0216

Lal, R. 1986.
Effects of 6 years of continuous no-till or puddling systems on soil properties and rice (*Oryza sativa*) yield of a loamy soil. Soil and Tillage Research 8: 181–200.

Rice responses to no-till and puddling methods of seedbed preparation were evaluated under four N levels (0, 50, 100, and 150 kg ha^{-1}) on an Aeric Tropaquent in southwestern Nigeria. The mean grain yield after 11 consecutive crops of rice were (a) from 0 kg N ha^{-1}, 3.5 Mg ha^{-1} from no-till treatments and 3.9 Mg ha^{-1} from puddling systems; (b) from 150 kg N ha^{-1}, 5.5 Mg ha^{-1} from no-till treatments and 5.6 Mg ha^{-1} from puddling systems. In general, puddling treatment yielded more at a low level of N than the no-till plots, and grain yields were lower in the second season than in the first growing seasons. The mean organic carbon content measured after 6 years in the 0–5 cm layer was 2.2% (w/w) for the no-till and 1.7% for the puddled seedbed, while in the 5–10 cm layer, the no-tilled soil contained less organic carbon than the puddled soil. The mean bulk densities in the surface 0–2 cm layer and clay content in 0–1 cm layer were higher in the puddled than in the no-till treatment. The surface 0–1 and 1–2 cm layers of the no-till system retained significantly more water at water potentials from 3 kPa to 1.5 MPa than the puddled soil.

The differences in soil moisture retention in favor of no-till were more pronounced at high than at low soil moisture potentials.

0217

Ogunremi, L.T. and R. Lal, and O. Babalola. 1986.
Effects of tillage methods and water regimes on soil properties and yield of lowland rice from a sandy loam soil in southwest Nigeria. Soil and Tillage Research 6: 223–234.

Field experiments were conducted on a sandy loam soil (Aeric Tropaquent) during 1981 and 1982 to assess the effects of compaction, puddling, and no-till systems on soil physical properties and on rice growth and yield with or without supplementary irrigation. Soil compaction decreased macro-and micro-pores more than puddling or no-till treatments. The equilibrium infiltration rates, and saturated hydraulic conductivity, void ratio and moisture content at –0.01 and –1.5 MPa water potential were highest in no-till and lowest in compacted treatments. The mean grain yields (6.4 Mg ha^{-1}) for four consecutive crops were significantly greater with compacted than with puddled and no-till systems. Compared with puddling and no-till treatments, soil compaction resulted in significant yield increases of about 20% under the rain-fed regime and from 34 to 40% in the flooded moisture regime. There was about 26% increase in rice grain yield by continuous flooding over the rain-fed treatment due to a higher uptake of P, K, Ca, Mg, Na, Mn, Fe, and Zn.

0218

Ogunremi, L.T, R. Lal, and O. Babalola. 1986.
Effects of tillage and seeding methods on soil physical properties and yield of upland rice for an Ultisol in southeast Nigeria. Soil and Tillage Research 6: 305–324.

The yield of direct-seeded and transplanted upland rice was investigated with seven tillage methods in an Ultisol in a high rainfall region of southeastern Nigeria. The tillage methods included two compaction passes of a 6-t roller with and without residue mulch; six compaction passes with mulch; plowing with and without mulch, and no-till with and without mulch. Soil compaction decreased seedling emergence, and shoot and root growth. Residue mulching decreased seedling emergence by 35.6% in direct-seeded rice. Root densities at 10–30 cm soil depth were higher by 47 to 157% with plowed treatments than with other tillage methods. The highest grain yields of 6.1–6.3 Mg ha^{-1} obtained in plowed plots, were associated with greater uptake of P, Na, Fe and Zn at flowering, and of N, Mg, K, Mn and Cu at maximum tillering and flowering growth stages. Mulching decreased grain yield by 43% on compacted plots, 27% on no-tilled plots, and 12% on plowed plots, due to transient flooding and mechanical impedance to seedling emergence by the mulch cover. Within the unmulched treatments, plowing increased rice yield by

71% over two compaction passes and by 35% over the no-till treatment. The lowest bulk density and penetrometer resistance was also observed in plowed plots.

0219

Hulugalle, N.R., R. Lal, and M. Gichuru. 1990.
Effect of 5 years of no-tillage and mulch on soil properties and tuber yield of cassava on an acid Ultisol in southeastern Nigeria. Experimental Agriculture 26: 235–240.

The effect of no-tillage and mulch on soil properties and tuber yield of cassava was studied over a 5-year period on an infertile, acid Ultisol in southeastern Nigeria. Mulch was applied at a rate of 12 Mg ha^{-1} as a split application, once at planting and once 6 months after planting, but no chemical fertilizer was applied. Bulk density and proportion of micropores (pore radius, r, <1.4μm) were greater, and proportion of macropores (r >14.4 μm) lower, with no-tillage. Water infiltration was increased by mulching, being greatest in tilled, mulched plots. Soil chemical properties were not significantly affected by tillage system. Soil physical and chemical properties were best with tillage and mulching, and poorest when neither tillage nor mulch was used. Cassava tuber yield was unaffected by tillage system but increased by mulching.

0220

Hulugalle, N.R. and M.C. Palada. 1990.
Effect of seedbed preparation method and mulch on soil physical properties and yield of cowpea in rice fallow of an inland valley swamp. Soil and Tillage Research 17: 101–113.

Soil physical properties and yield of cowpea (*Vigna unguiculata* [L.] Walp.) were studied in rice fallow of an inland valley swamp in central Nigeria during the dry seasons in 1988 and 1989. Treatments were three seedbed preparation methods: mounds, minimum (handhoe) tillage, and zero tillage; and two residue management methods including application of 4 Mg ha^{-1} of rice straw mulch and no mulch. In general, soil compaction was such that zero tillage > minimum tillage ≅ tillage mounds. The proportion of macropores in the 0–0.05 m soil depth was 18% with zero tillage, 35% with minimum tillage, and 42% with mounds. Mulching had no effect on soil compaction but decreased diurnal soil temperature and increased soil wetness. The combination of zero tillage and mulch resulted in a wet, cool, and compacted seedbed, whereas the warmest, driest, and most porous seedbed was the bare mound. Grain yield of cowpea was not significantly affected by seedbed preparation. Mulching was effective in increasing yield only when rainfall occurred prior to the onset of flowering as observed in 1988 but not in 1989. The least risky and hence, the most appropriate soil management system for dry-season cowpea production in rice fallows in inland valley swamps is, therefore, a combination of minimum tillage and mulch.

0221

Ohiri, A.C. and H.C. Ezumah. 1990.
Tillage effects on cassava (*Manihot esculenta*) production and some soil properties. Soil and Tillage Research 17: 221–229.

Cassava is traditionally grown on tilled soils. Interest in reduced-tillage systems is increasing in the humid tropics due to erosion problems. A field study was conducted on a sandy clay loam Ultisol to compare cassava performance in three tillage systems and the effects of the tillage on soil water and organic-matter contents. Tillage treatments were: (1) plowing, harrowing, and ridging (conventional); (2) digger-made holes (minimum); (3) pushing the sharpened end of cassava cuttings directly into the soil (no-till). There was no effect of tillage in the first year. In the second year, no-tillage gave 40% and conventional tillage 23% significantly greater yield of tops over the conventional tillage, but no had effect on yield of fresh roots. Soil moisture contents in no-till and minimum tillage were higher (P = 0.05) than in the conventional-tillage system. Conventional tillage gave the highest reduction in organic carbon over time. Cassava may be grown successfully in reduced tillage systems in Ultisols of the humid tropics.

0222

Hulugalle, N.R. and P.R. Maurya. 1991.
Tillage systems for the West African semi-arid tropics. Soil and Tillage Research 20: 187–199.

The West African SemiArid Tropics (WASAT) are characterized by a monomodal rainfall pattern, and based on the amount of annual rainfall, can be divided into three ecologies, sahel, sudan, and northern Guinea savannas. The major soil groups of the WASAT are Alfisols, Inceptisols, Entisols, and Vertisols, with the first three predominating. The major constraints to soil production include soil compaction, low soil fertility, high temperature, and low soil-water retention, available water-holding capacity and infiltration rate. Tillage in traditional farming systems is manual. Mechanization of tillage operations, however, has received emphasis in the recent past. The accelerated soil degradation that is a feature of mechanized-tillage systems under rainfed agriculture can be minimized with no-tillage. Low yields, however, have been reported to occur with no-tillage because of the absence or low amounts of residue mulch, high soil compaction, presence of harmful soil insects in crop residues, and the creation of stable pores by tillage in soils high in organic matter, silt, and fine sand contents. Unavailability of crop residues is a major constraint to the adoption of no-tillage. The use of heavy and intensive mechanical tillage in irrigated agriculture leads to the formation of plow soles. No-tillage appears to hold a promise for use in the irrigated agriculture of the WASAT, but more research is needed.

0223

Howeler, R.H., H.C. Ezumah, and D.J. Midmore. 1993.
Tillage systems of root and tuber crops in the tropics. Soil and Tillage Research 27: 211–240.

Even though limited information is available on tillage practices for root crops, published results show that tillage methods vary widely depending upon the specific root crop, the soil type, the previous vegetation, and the socioeconomic conditions of farmers. These aspects have been discussed in this review. In general terms, root and tubers are sensitive to soil compaction, inadequate aeration, or poor drainage, and therefore, respond favorably to intensive tillage, followed by ridging or mounding. Large differences exist between crops, with potato, sweet potato, and yam requiring more intensive cultivation than cassava and taro. On light-textured soils, cassava can be grown without or with minimum tillage as long as weeds are controlled, but in heavy or compacted soil it responds favorably to tillage and yields tend to increase when it is grown on ridges. To reduce erosion and production costs, cassava should be grown with as little tillage as possible, as long as high yields are maintained. Contour ridging and mulching are other practices that can increase yields and reduce erosion losses. Research efforts should be directed towards the characterization of the physicochemical and biological factors that determine the tillage requirements of a given soil for a given root crop.

0224

Frazen, H., R. Lal, and W. Ehlers. 1994.
Tillage and mulching effects on physical properties of a tropical Alfisol. Soil and Tillage Research 28: 329–346.

The mechanization of field operations such as seeding, spraying, and harvesting in continuous zero-tillage may lead to a severe compaction of the surface layer of coarse-textured tropical soils, especially when mulch is sparse or missing. A two-year (1982 – 1984) field experiment was initiated on an Alfisol in Nigeria to study the effect of tillage, mechanization, and mulch on soil structure and physical properties. Three zero-tillage treatments and a plow treatment were compared. The disk-plow and one of the no-till treatments were highly mechanized: all the fieldwork was performed with tractors and machines, and consisted of secondary bush clearing, crop cultivation, and harvest. For the other two no-till treatments, the impact of machine load was reduced, either by hand harvesting or by performing all the operations manually. These four tillage-traffic systems were either treated with mulch or left unmulched. Maize (*Zea mays* L.) was used as the test crop and grown for four seasons. After 2 years of zero-tillage, the bulk density (BD) and penetration resistance (PR) were significantly greater on plots with high mechanization than with hand-treated plots. Because of the hard-setting nature of the soil,

the plowed plots with or without mulch exhibited a dramatic change in BD and PR during the season. On no-till the infiltration transmissivity (A) was greater and the BD and PR were less in the mulched than in the unmulched treatments. The gravel content of the topsoil was negatively correlated with BD, and positively correlated with A. Results indicate that mechanization of a no-till system on sandy Alfisol will be successful in the long run if appropriate measures such as mulching, crop rotation, and fallow systems are applied to regenerate soil structure and to enhance macroporosity.

0225

Hulugalle, N.R. 1994.

Long-term effects of land clearing methods, tillage systems and cropping systems on surface soil properties of a tropical Alfisol in S.W. Nigeria. Soil Use and Management 10: 25—30.

The long-term effects of land clearing methods (manual, shear blade, tree-pusher/root-rake combination, traditional), tillage systems (disc plowed, mechanized no-tillage, traditional) and cropping systems (annual cropping, alley cropping, grazed pasture) on the physical and chemical properties of surface soil were evaluated on an Alfisol in southwestern Nigeria 10 years after clearing. Long-term soil physical degradation was greatest after mechanized land clearing or tillage systems. The erosion resulting from soil compaction with mechanized land management systems led to the exposure of the subsoil. Cropping systems had no effects on soil physical properties, however, alley cropping decreased exchangeable calcium and pH, and increased total acidity mainly through the greater demand for calcium by the hedgerow species. Grazed pasture depleted exchangeable potassium because it was taken up by the grass and exported from the site through consumption of the grass by cattle.

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