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PROGRESS REPORT FOR THE PERIOD JANUARY 1988 TO JANUARY 1990

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1. INTRODUCTION

This is the first technical report of the **KEFRI-KARI-ICRAF Collaborative Agroforestry Research Project** covering the period from January 1988 to January 1990 and including the results of the first four cropping seasons. Subsequent reports will be published on an annual basis, covering two cropping seasons. The project is located in Maseno in Nyanza Province in West Kenya. The project is part of the AFRENA (Agroforestry Research Networks for Africa) programme of ICRAF which covers, among other regions, the bimodal highlands of East and Central Africa.

The mandate of AFRENA is to develop appropriate agroforestry technologies for selected landuse systems and to develop the regional and national capability to plan, formulate and implement agroforestry research in the participating countries and regions.

In Kenya, the project is implemented in collaboration with two national research institutes, viz. the Kenya Forestry Research Institute (KEFRI) and Kenya Agricultural Research Institute (KARI) and is funded by the United States Agency for International Development (USAID).

The repört summarizes the activities undertaken and the preliminary research results obtained during the reporting period. It is to be noted that during the first year of project implementation (November 1987-October 1988), the emphasis was on the development of research facilities, the formation of the research team and the establishment of a number of on-station agroforestry experiments. Results from the research undertaken have started to emerge from the second year (1989) onwards and they are included in this report. However, the technical results and conclusions presented should be read with the ususal caution since data collection and analysis continues and preliminary conclusions may change or have to be amended in the light of future findings.

The Maseno agroforestry research centre also houses the multi-purpose tree germplasm evaluation and development project implemented by ICRAF and funded by GTZ/BMZ from The Federal Republic of Germany. The "Germplasm" project is mainly involved in testing, evaluation and improvement of multi-purpose tree and shrub germplasm and it is designed to support and strengthen the ongoing AFRENA activities. Plans for the implementation of an on-farm agroforestry research project, funded by the Rockefeller Foundation, are under way. This project will take some of the agroforestry technologies developed at the Maseno station and test them under farmers' conditions in various parts of West Kenya. Besides pure technology testing, the on-farm project is involved in studying the socio-economic framework in which the agroforestry interventions (have to) function.

The physical implementation of the on-station activities started in November 1987 with the establishment of the AFRENA (Maseno) nursery by ICRAF scientist Mr. D. Wambuguh, assisted by Mr. A.M. Heineman and Forest Department Maseno Tree Nursery staff. Since November 1987, Mr. Heineman has worked full-time on the development of the project in Maseno. In early 1988, KEFRI seconded Mr. J.H.O. Otieno to the project. From September 1988 until October 1989, Mr. Otieno was in the U.K. (Wales) for further studies. In July 1988, Dr. A.D. Olang (agronomist) joined the project as the KARI-seconded scientist. Dr. Olang was project team leader from August 1988 until October 1989. In September 1988, KEFRI seconded Mr. E.K. Mengich as its resident scientist to the project. In November 1989, Mr. Otieno returned to the project and was appointed Director of the 'Maseno Agroforestry Research Centre' and team leader of the on-station project. Since the second quarter of 1988, KEFRI has steadily provided a number of additional support staff members to the project. A complete list of project staff as of January 1990 is given in Annex 1.

2. BACKGROUND TO THE STUDY ZONE, THE AFRENA PROJECT AND THE MASENO AREA

2.1 Landuse analysis in the AFRENA study zone

Based on a zonal comparison of landuse systems in the East and Central African Highlands and their current problems as well as an inventory of already ongoing agroforestry research in each of the participating countries, a regional research programme was developed to generate agroforestry technologies aimed at solving the diagnosed landuse problems and developing its potentials.

To determine what role agroforestry can play on small farms in the bimodal highland areas of Kenya, a multi-disciplinary team studied these landuse systems and evaluated their limitations and potentials. Possible agroforestry solutions to specifically identified problems were formulated (Minae and Akyeampong (ed.), 1988).

The importance of the Kenya Highlands is exemplified by the fact that it covers only 15% of the country's land area but it supports 50% of the total population. Six major landuse systems were identified during the landuse analysis (Diagnosis & Design) exercise, each with its unique set of activities and agroforestry potentials. Each landuse system is named after the major food or cash crop grown within that system. The six major landuse systems are based on coffee, tea, maize, potatoes, sugar and (subsistence) food crops.

In the food crops based system, primarily found in the Highlands west of the Rift Valley, a variety of crops such as maize, beans, cassava, bananas, sweet potatoes, sorghum and millet are cultivated. Cowpeas, upland rice and groundnuts are also found and various cash crops such as cotton, coffee and sugar are sometimes grown on a small scale.

2.2 Identified landuse constraints in the study zone

Practically all highland farming systems in Kenya are characterized by high population densities resulting in relatively small farms where continuous cultivation is the practice rather than the exception. Because the use of organic and inorganic fertilizers is usually insufficient, farmers experience a gradual decline in soil fertility, especially in their food crop plots. Apart from losses in soil fertility, physical soil loss and gully formation is often experienced on steep slopes.

Another problem commonly seen in the highland farming systems is the shortage of good quality fodder for livestock, especially during the dry season. In the Central Highlands where small scale commercial dairy production is advanced, the supply of protein rich fodder is presently inadequate to meet the demand. Similar problems are experienced in other parts of the highlands where farmers maintain livestock, mostly for home consumption of the products.

Both the commercial and domestic demand for wood products, such as timber, poles and fuelwood as well as the production of fruits were also identified as having a potential for improving the cash income of the farmers and alleviating wood scarcity around the farm.

2.3 Potential agroforestry solutions for the study zone

Central to the philosophy of agroforestry is the environmentally sound and economically viable integration of multi-purpose trees and shrubs (MPTS) in existing agricultural land use systems.

While agroforestry cannot possibly solve all farming problems, it is fair to say that it does offer, in some instances, low cost alternatives to non-agroforestry solutions.

In this context, the use of alley cropping to reduce soil erosion and to supply green manure/mulch to the soil, as an alternative to physical erosion control structures and inorganic fertilizers, is a promising solution. The use of fodder trees and hedges, planted on bunds in combination with grasses is perhaps a viable alternative for the current fodder production practices. Establishment of boundary plantings with MPTS and fast growing woodlots are other promising agroforestry technologies that warrant further attention.

2.4 Agroforestry research at the AFRENA Project in Maseno

At the East and Central Africa AFRENA research site in Maseno in West Kenya, a multi-disciplinary research team is working on the development of a number of priority agroforestry technologies. These include the development of alley cropping systems for the production of green manure, mulch and fodder and the production of feed resources for livestock, especially from MPTS and grasses, grown on field bunds. MPTS are also evaluated in screening trials for a variety of on-farm uses. The experiments found in Maseno can be classified as follows:

- General MPTS species screening trials;
- Soil fertility maintenance and improvement trials;
- Livestock fodder production trials

Before providing a full description and the preliminary results of each group of experiments in the next chapters, some environmental background information on the AFRENA study zone and the Maseno research station area in particular is provided in the section below.

2.5 Climatic features of the study zone with relevance to Maseno

The East and Central African AFRENA Highlands are situated on the Equator between 4 degrees north and 4 degrees south. The study zone is therefore largely influenced by the Intertropical Convergency Zone (ITCZ), which follows the relative movements of the sun and passes the Equator twice a year (Hoekstra, 1988). The ITCZ moves from the Southern Hemisphere to the Northern Hemisphere in March/April and in the opposite direction in September/October. These two movements are followed by periods of precipitation or so called 'rainy seasons' and this explains the in principle bimodal character of the rainfall regime in the region.

The ITCZ can, and often does, undergo serious modifications from passing over the vast landmass of the highlands and since barometric pressure differences are often small, the effects attributed to localised topography and the presence of the large lakes in the region can influence the local climatic patterns considerably.

In the Maseno area, the predominant wind direction is in principle from east to southeast during the first (long) rainy season from June to September and from north to northeast from October to May during the second (short) rainy season and the following dry period. Since Maseno is situated only 30 km north of Lake Victoria, this large body of fresh inland water has a profound influence on localized precipitation, wind direction and wind speed.

2.6 Maseno: location and altitude

The township of Maseno is located on the Equator, 30 km north-west from Kisumu in Nyanza Province at 34 35' East and 0' North, at an altitude of between 1,500 and 1,600 m above sea level.

2.7 Landuse classification

Various classifications have been developed to describe the East African Highlands in terms of climate and landuse systems. Widely accepted are the classifications by Köppen and Jaetzold & Kutch (1982). In the Köppen classification, Maseno region (Western Kenya Highlands) falls in class "A" for climate, i.e. 'Tropical Rain Climates', because the mean temperature for the coldest month is above 18°C (below this value, the climate class is "C", i.e. 'Temperate Rain Climates'). Köppen further allows a sub-classification with "w" for 'winter dry' and "f" for "no distinct dry season". In the AFRENA study zone, the term 'winter' refers to the cooler period of the year from June to September. Finally, the numbers 1 or 2 indicate the existence or absence of bimodality of the experienced rainfall pattern. Considering the above, the Maseno region is classified as " Aw2" - area.

Jaetzold and Kutch developed an agro-ecological zonation methodology for the tropics based on temperature, water supply for plant development and length of the growing periods, which was especially adapted for Kenya (Jaetzold and Schmidt, 1982). Eight main zones are based on water availability, ranging from perhumid to perarid, and these main zones are subdivided into six altitudinal or temperature belts from the lowlands to the tropical alpine zone. Using this zonation methodology, most of the landuse systems in the AFRENA study zone can be classified in the humid and sub-humid main zones and based on altitude they fit into the range from 'lower midlands' to 'upper highlands'. Considering the above, Maseno falls in the lower midland zones (LM1 and LM2).

2.8 Growing seasons

An analysis of the length of the growing seasons in the study zone, which includes humid (rainfall:potential evaporation >0.75) and sub-humid (R/E - Ratio = 0.4 to 0.75) areas, indicates that many areas have, despite bimodal rainfall distribution, only one growing period with a length between 190 and 365 days. In the larger part of the zone, there are two sub-humid periods between the fully humid rainy season periods but moisture availability is always sufficient for plant growth. The situation in Maseno and the south western highlands of Kenya in general is, that there is a distinct and agriculturally relevant bimodality of growing seasons with a first (long) rainy season from March/April until June/July and a second (short) rainy season from September until November. Consequently, food crops are sown twice a year in April and September and although success of harvest varies from season to season, most farmers expect to harvest twice a year, with the major share of the annual food crop produced during the first rains.

2.9 Rainfall

The mean annual rainfall is about 1,750 mm but fairly large deviations from the long term annual mean can occur. For instance around 2,360 mm was recorded at the nearest two weather stations in 1988 and approximately 1,900 mm was recorded in 1989. The actual total amount of rainfall received at the Maseno Veterinary Farm in 1988 and 1989 was 2,377 mm and 1,934 mm respectively. The M.E.N.R. - Forest Department Nursery in Maseno received 2,350 mm and 1,861 mm in the last two years. In Table 1, the monthly total rainfall received in 1988 and 1989 at the two recording sites is summarized. At Siriba Teachers College, 1,929 mm was recorded in 1988, emphasizing that even minor topographical and locational differences of the rainfall recording point within Maseno may have a significant effect on the total amount of precipitation received in any given year. It is further noted that during the rainy seasons, sudden increases in wind speed mark the arrival of torrential rains, whereby up to 50 mm precipitation can fall in less than one hour. The combined erosive force of such high winds and heavy rain is considerable.

2.10 Temperature and potential evaporation

The mean annual day temperature is 20°C with the average maximum daily temperatures not exceeding 31°C and the average minimum night temperatures not dropping below 15°C. The recorded average monthly maximum and minimum temperatures for 1987 - 1989 are shown in Table 2. The largest difference between average daily maximum and minimum temperature was 15°C, measured in October 1989.

In Maseno, the average potential evaporation is estimated at 1,738 mm per year.

Table 1. Monthly rainfall at Maseno Veterinary Farm and M.E.N.R. Forest Department Nursery in 1988, 1989 and the long term average for Maseno (mm)

YEAR:		1988		1989		LONG TERM MEAN
LOCATION:		VET. FARM	M.E.N.R. NURSERY	VET. FARM	M.E.N.R. NURSERY	MASENO TOWN
MONTH						
January	-	90	180	45	68	66
February	-	126	131	195	157	92
March	-	207	125	239	206	151
April	-	413	516	194	188	273
May	-	247	342	240	222	217
June	-	120	90	69	88	114
July -	-	95	81	90	51	88
August	-	62	198	178	170	138
September	-	318	192	265	290	151
October	-	210	155	123	143	165
November	-	374	281	112	113	156
December	-	115	62	185	162	125
TOTAL:	-	2377	2350	1934	1861	1736

Sources: SR-CRSP project, Maseno (1988 - 1989)
AFRENA project, Maseno (1989)
M.E.N.R. Forest Dept. Maseno (1988)

Table 2. Average monthly maximum and minimum air temperature at Maseno in 1987 - 1989 (°C)

	YEAR					
	1987		1988		1989	
TEMPERATURE:	MAX	MIN	MAX	MIN	MAX	MIN
MONTH						
January	-	-	30	18	-	-
February	-	-	31	20	-	-
March	31	21	30	19	29	16
April	30	20	31	18	27	15
May	29	20	30	19	26	15
June	27	18	29	17	28	17
July	30	18	29	19	28	15
August	30	18	30	18	28	15
September	30	19	30	18	29	15
October	31	19	31	18	30	15
November	30	19	30	18	30	16
December	31	19	31	19	30	17

Sources: Siriba Teachers College, Maseno (1987-1988)
AFRENA project Maseno, nursery site (1989)

2.11 Natural vegetation

In many places of Maseno area, the natural vegetation has been replaced by cultivation and settlement and what exists today are isolated indigenous trees on farmlands. The original vegetation of this area consisted of *Albizia* spp., *Bridelia* spp., *Vernonia* spp., *Croton* spp., *Acanthus* spp. and *Chlorophora excelsa.*

Currently, the landscape is dominated by small scale farming activities with a dispersed cover of small, medium and tall sized indigenous and exotic tree species. Predominant species found along roads and in and around farms are *Markhamia* spp., *Sesbania* spp., *Cassia* spp., *Acrocarpus* spp., *Cupressus* spp., *Eucalyptus* spp., *Pinus* spp. and, to a lesser extent, *Casuarina* spp. The fields where AFRENA experiments are located were cleared from either pasture vegetation or a mixture of low shrubs and bushes, including *Psidium guajava* (guava) and *Digitaria sacalarum* (couch grass).

2.12 Soil classification

The predominant soil types in the food crop based landuse system around Maseno and West Kenya in general depend on the location of the agricultural fields in the landscape.

Recognised are uplands and ridges, well drained lands in the centre of the catena's and valley bottoms. The soil types of major importance in the uplands are cambisols with secondary importance attributed to lixisols (tropical luvisols), ferralsols and acrisols. In the valley bottoms which are often imperfectly drained, vertisols, gleysols and fluvisols are found. The Maseno area consists of xanthic and orthic ferralsols, plinthic acrisols and isolated areas consisting of lithosols and regosols (stony phase). The soils around the research centre are all based on Nyanzan basalt, granite and phonolitic lavas as the main parent material. The major soil types found at the project location in Maseno are ferralsols, acrisols and lixisols.

A more detailed description of the soils at individual experimental sites in Maseno is provided in the next chapters. It is sufficient to say here that the texture of most soils in the experiments is light to medium and that their depth is mostly 1.2 m or more. The slopes of the hills around Maseno can be fairly steep, but they are generally less than 20%. All on-station experiments are situated at almost flat land (slopes of less than 3%). The soils in the Maseno area are fairly to strongly acidic (pH in water: 4.5 to 6.5) and highly deficient in P and N.

2.13 Population structure and farm size

The population density in Kisumu district ranges from below 150 to as high as 550 persons per square kilometre, depending on the fertility of the soils and consequently the crop production potential. However, in the areas around Maseno, especially in the very southern tip of Kakamega District in South and East Bunyore Locations, population densities of over 700 people per square kilometre in certain pockets are found. Consequently, farm sizes are ranging from over 10 hectares to less than half a hectare of arable land, often supporting families of 6 to 10 members. In general, the population pressure is so high that cultivation is found everywhere, both in upland areas on the ridges of slopes, the slopes themselves and in the lower lying valley bottoms.

3. GENERAL MULTI-PURPOSE TREE AND SHRUB SPECIES SCREENING TRIALS

3.1 Justification

Research at the AFRENA Maseno site started in 1988 with alley cropping experiments using well known MPTS, i.e. *Leucaena leucocephala*, *Calliandra calothyrsus* and *Sesbania sesban*. In order to be able to select from a wider selection of species and provenances for a variety of uses in agroforestry, general screening of more MPTS species and provenances was considered a priority. Different species and provenances of both indigenous and exotic MPTS were planted in experiments 6, 7, 8, 9 and 10 and they were studied for their site adaptability and potential uses under the conditions of the Maseno area. Species and provenances with good initial performance will be selected for testing under different agroforestry technologies in order to determine their suitability for a range of applications.

3.2. Objectives

The objectives of the general species screening trials are twofold:

- to observe the early growth patterns of MPTS, and

- to screen MPTS on the basis of early growth for their suitability with respect to a range of agroforestry technologies.

3.3. Experimental design and methodology

Experimental design

All general MPTS screening trials were designed as randomised complete blocks. In all experiments, each treatment was replicated three times. In experiments 6, 7, 8 and 10, fifteen trees were established in rows of 11.25 m long, with an initial in-row spacing of 0.75 m. In experiment 9, eleven trees were established in rows of 8.25 m long, with the same initial spacing between trees. Plot width was 3 m with the row of trees placed in the middle of the plot. All tree rows are established in east to west direction, thereby minimizing the effect of shade between plots. Plots were separated from each other by either grass strips (experiment 6) or small earth bunds (experiments 7-10). No crops were grown in the plots. All trees were established from seedlings which were 5 to 6 months old. The only exception were four Leucaena provenances, planted in October 1988, which were 11 months old at the time of transplanting. A starter dose of 25 g DAP was used, equivalent to 4.5 g of N and 11.5 g of P_2O_5 per tree. This is equal to 20 kg/ha of N and 51 kg/ha of P_2O_5.

Management of the trees

Of the fifteen originally established trees in each plot, all odd numbered trees were thinned out once the crowns of neighbouring trees started to touch each other. The initial spacing between trees was thereby increased from 0.75 m to 1.5 m (usually after 6 to 8 months). Of the remaining trees, all even numbered trees were again removed once the crowns of neighbouring trees started to touch each other (usually after another 6 to 8 months).- Thus, after two thinnings, practically within the first fifteen months, four trees per plot, spaced at 3 m , were left for monitoring of essential growth characteristics. The first height and root collar diameter measurements were done 6 to 10 days after the day of planting and then continued on a monthly basis during the first year after planting. Since October 1989, the frequency of height and root collar diameter measurements has been reduced and now coincides with the start and finish of each rainy season.

To obtain additional information from these general screening trials, the thinned out trees were not actually uprooted but cut at the following heights: ground level (0 cm), 25 cm, 50 cm and 75 cm. This was done in order to quantify the potential of each species to coppice, related to these initial cutting heights.

The most recently planted general species screening trial (experiment no.10) was established in October 1989. The trial contains nine provenances of *Leucaena* spp. and one known *Calliandra calothyrsus* provenance as a control species. The experimental design is similar to that of the other general species screening trials with fifteen trees per plot and replicated three times. Since this report covers the period up to January 1990, only few data have been collected which does not justify a full presentation and discussion of experiment 10 at this stage. However, the species list for this experiment is included as Annex 2.

3.4 Site descriptions

Experiment 6

Experiment 6 is located on a sloping site in the forestry department land. The site generally gives the appearance of cleared bushland with some tall trees (mostly *Eucalyptus* spp) scattered around. Prior to the experiment, the land had not been used and had a vegetation of bushes (*Psidium guajava*) and couch grass (*Digitaria sacalarum*). Soils are changing colour from reddish brown on the upper parts where experiment 6 is located to more greyish brown in the lower lying parts. When the site was surveyed in 1988, the soil was classified as a luvisol. The predominant soil texture at different depths at the site was clay to clay loam, well drained with a crummy structure and with a high gravel content in the third (lower) replicate. The experiment is sited on the most inclining section of the station and has a slope of approximately 5%. The site is strongly acidic with a pH (in water) around 5.0. The soil depth varies with location in the experiment; in the upper parts (replicates 1 and 2), it exceeds 1.2 m. In the lower parts (replicate 3), it becomes gravelly from 0.75 m onwards.

Experiment 7, 8 and 9

Experiments 7, 8 and 9 are located next to each other at the veterinary farm in maseno. The experiments were established on land which had been used for a number of years as pasture for livestock. The site is flat with a slope of less than 2%. There is little danger of serious soil erosion. However, after heavy rainstorms, some sheet erosion can be seen. Couch grass (*Digitaria sacalarum*) is the predominant weed species. The soil type was classified as luvisol in 1988. In soil samples taken in experiment 7, no distinct boundaries between horizons were seen. A gradual change in colour from dark reddish brown to reddish brown in the deeper parts of the profile was observed. The soil depth exceeded 1.2 m. Soil texture is clayey to clay loam. Soils were fairly acidic at the onset of the experiments with pH (in water) ranging from 5.0 to 6.0. These soils are lacking in N and P.

Experiment 10 is located at the veterinary farm adjacent to experiments 3 and 5 along the same slope. In the absence of any details on soil analysis for this site, it is reasonable to assume that the initial soil physical and chemical characteristics are similar to those described for experiment 3.

3.5 Results and discussion

Tree survival

The majority of species established well. Poor survival rates were recorded for *Sesbania grandiflora* (100% mortality), *Croton macrostachyus*, *Erythrina abyssinica*, *Erythrina caffra* and *Alnus nepalensis*. Dead seedlings were being replaced up to two months after planting the trials.

Pests and diseases

Pest attacks were observed on *Erythrina abyssinica*, *Erythrina caffra*, *Casuarina junghuniana* (unidentified), *Sesbania sesban* (attacked by the beetle: *Mesoplatys ochroptera*), *Calliandra calothyrsus* (termites), *Gliricidia sepium* (aphids), and *Tipuana tipu* (aphids). Where necessary, insecticides were used in the first half year after establishment as a check to prevent further damage. "Ambush" (Lambdacyhalothrin: 97.5 g/l)) was sprayed at the rate of 0.15 *l* per 100 *l* of water during the first half year to control Mesoplatys and aphids. "Aldrex 48" (Aldrin: 480 g/l)) 1.11 l/100 *l* of water was used against termites. Fungal diseases were noted on *Acacia* spp, *Sapium sebiferum* and *Cassia siamea*. Hail damage to young trees was particularly severe with *Gliricidia sepium*, *Cassia spectabilis* and *Erythrina caffra*.

Height and root collar diameter development

Tables 3, 4, 5 and 6 summarize the height and root collar diameter growth increments over the reporting period for each experiment. Incremental growth is here defined as the difference between the first value measured and the measurement done 9 or 14 months later.

Table 3. Experiment No. 6. (Mixed overstorey screening trial) Height and root collar diameter increments over a period of 14 months: Oct '88-Dec '89 at planting time

Treatment	Species	Seed Origin/ Provenance	Increment Height (m)	RCD (cm)
T1	Acrocarpus fraxinifolius	Muringato, Kenya	3.69	6.56
T2	Markhamia lutea	Kakamega, Kenya	2.23	4.56
T3	Markhamia lutea	Osorongai, Kenya	1.99	4.31
T4	Markhamia lutea	Rusenyi, Rwanda	1.45	3.7
T5	Croton macrostachys	Kieni Forest, Kenya	0.70	2.76
T6	Croton megalocarpus	Kikuyu, Kenya	1.79	4.53
T7	Grevillea robusta	Namanjalala, Kenya	2.88	6.99
T8	Erythrina abyssinica	Nandi, Kenya	Diseased, replanted unreliable data	
T9	Tipuana tipu	Nairobi, Kenya	3.91	4.06
T10	Tamarindus indica	Embu, Kenya	0.36	0.68
T11	Cordia abyssinica	Kedowa, Kenya	1.39	5.17
T12	Casuarina junghuniana	KARI Arboretum, Kenya	3.46	5.68

Experiment 6 consists of different trees of both exotic and indigenous origin and the species planted expectedly showed great variations in initial growth performance. Total amount of rainfall received between October 1988 and December 1989 was 2,359 mm. The results in Table 3 show that the development of the root collar diameter closely followed height growth development in most species. The exceptions were *Grevillea robusta, Tipuana tipu* and *Cordia abyssinica.* Grevillea scored highest (7 cm) on root collar diameter growth increment but was not one of the fastest growing trees in terms of height increment (2.88 m). *Tipuana tipu* was the fastest growing tree in terms of height increment (3.91 m), but not so for root collar diameter increment (4.1 cm). *Cordia abyssinica* was slow in height growth (1.39 m) and appeared increasingly unhealthy but it was fast in root collar diameter growth (5.2 cm). Fast growing species with a total height increment after 14 months of more than 2.5 m were *Tipuana tipu, Acrocarpus fraxinifolius, Casuarina junghuniana* and *Grevillea robusta.* Medium growth between 1.4 and 2.5 m increment was shown by the *Markhamia* spp and *Croton megalocarpus.* Slow growing species with a height increment of less than 1.4 m or less than 10 cm/month were *Croton macrostachyus, Tamarindus indica* and *Cordia abyssinica. Erythrina abyssinica* was diseased and its potential could not be assessed from the specimens planted.

Table 4. Experiment 7. (Leucaena and Gliricidia spp.) Height and root collar diameter increment over a period of 14 months (Oct '88 - Dec '89)

Treatment	Species	Seed Origin/ Provenance	Increment Height (m)	Increment RCD (cm)
T1	Leucaena leucocephala	Kibwezi, Kenya	2.84	6.75
T2	Leucaena leucocephala	Hawaii	3.13	7.75
T3	Leucaena leucocephala	Melinda, Belize	2.92	6.47
T4	Leucaena leucocephala	Hengchun, China	3.19	7.11
T5	Leucaena leucocephala	Yimbo, Siaya Kenya	3.01	6.1
T6	Leucaena diversifolia	Kibwezi, Kenya	1.48	3.51
T7	Gliricidia sepium	Guatemala	2.49	6.53
T8	Gliricidia sepium	Playa Tamarindo, Santa Cruz, Costa Rica	2.08	6.05
T9	Gliricidia sepium	Pontezuela Cartagena, Columbia	2.57	7.59
T10	Gliricidia sepium	Monterrica Taxisco, Guatemala	2.28	8.18
T11	Gliricidia sepium	Vado Hondo, Chiquimala, Guatemala	2.59	6.89
T12	Gliricidia sepium	Playa de Samala, Guyatenogo, Guatemala	2.95	7.59

An indication of general performance of all species in experiment 7 is given in Table 4. The detailed results of statistical analysis of each group of species are summarized in Annexes 3 and 4.

The four *Leucaena leucocephala* provenances (T1 - T4) in experiment 7 showed a remarkable uniformity in height growth increment, ranging from 2.84 m to 3.19 m during the first 14 months after planting. *Leucaena leucocephala* from Hengchun, China performed slightly better than the other provenances. The local *Leucaena leucocephala* seed source from Yimbo in Siaya District attained a satisfactory height increment of 3.01 m. Root collar diameter increment ranged from 6.0 cm (Yimbo, Siaya) to almost 7.5 cm (Hawaii, U.S.A.) over the same period. Height growth differences were significant ($p<0.05$) between the two best performing provenances and the slowest growing entry from Yimbo, Siaya. Root collar diameter increment differences were also significant ($p<0.01$). The more bushy *Leucaena diversifolia* from Kibwezi, Kenya did not display impressive height growth compared to the five *Leucaena leucocephala* species. This species showed a multi-stemmed, rather crooked growth form from the base, early flowering and generally low leafy biomass productivity. It does not seem promising for the Maseno area.

The six *Gliricidia sepium* provenances also showed a reasonable degree of uniformity in height growth performance on this site. The *Gliricidia sepium* provenance from Santa Cruz, Costa Rica was clearly growing slower than the other five provenances. Height increment during the measurement period ranged from 2.08 m to 2.95 m. Significant differences in height growth were observed ($p < 0.05$). Root collar increment ranged from 6.6 to 8.4 cm with a mean of 7.7 cm over the growing period. Significant differences between provenances were found ($p < 0.01$).

Table 5. Experiment 8. (Calliandra, Sesbania and Cassia spp.) Height and root collar diameter increment over a period of 14 months (Oct '88 - Dec '89).

Treatment	Species	Seed origin/ Provenance	Increment Height (m)	RCD (cm)
T1	Calliandra calothyrsus	Guatemala	4.19	8.7
T2	Calliandra calothyrsus	Kibuye, Rwanda	3.94	7.8
T3	Calliandra calothyrsus	Arboretum de Ruhande, Rwanda	4.13	8.5
T4	Sesbania sesban	Kakamega, Kenya	4.50	8.1
T5	Sesbania sesban	Mukururiati, Kenya	4.48	8.9
T6	Sesbania sesban	Kiambu, Kenya	3.08	4.9
T7	Sesbania grandiflora	Kitui, Kenya	Dead at 14 months -	
T8	Cassia spectabilis	Bugarama, Rwanda	4.10	8.8
T9	Cassia siamea	Bugarama, Rwanda	2.71	6.2
T10	Cassia siamea	Kwale, Kenya	2.45	5.6

An indication of general performance of all species in experiment 8 is given in Table 5. The detailed results of statistical analysis of each group of species are summarized in Annexes 5, 6 and 7.

The three *Calliandra calothyrsus* provenances showed a high degree of uniformity in height increment, ranging from 3.94 m to 4.19 m. *Calliandra calothyrsus* from Guatemala was slightly better than the two provenances from Rwanda. However, differences in height growth were not significant ($p > 0.05$). Root collar diameter increment ranged from 7.8 to 8.7 cm and the differences were not statistically significant either.

The three *Sesbania sesban* provenances showed significant differences in height growth performance ($p < 0.01$). *Sesbania sesban* from Kakamega, Kenya and *Sesbania sesban* from Mukururiati, Kenya both reached a top height of around 5.0 m after 14 months, equivalent to a height increment of 4.5 m. *Sesbania sesban* from Kiambu, Kenya grew much slower and reached a top height of 3.4 m during the same period. Its height increment was only 3.08 m. The best performing two provenances showed root collar diameter increments of 8.1 and 8.9 cm, respectively, but *Sesbania sesban* from Kiambu was a much more slender species with a root collar diameter of 4.9 cm, after 14 months. The differences in root collar increment between the faster and the slower growing provenances was significant ($p < 0.05$).

The two *Cassia siamea* provenances showed a high degree of uniformity in height growth increment (2.71 m and 2.45 m, respectively). *Cassia spectabilis* from Bugarama, Rwanda showed very promising height growth increment of 4.10 m over the same period.

Differences in root collar diameter increment followed a similar trend as for height increment and were equally significant between *Cassia spectabilis* and the two *Cassia siamea* provenances ($p < 0.01$).

Table 6. Experiment 9. (Mixed species screening trial) Height and root collar diameter increment over a period of 9 months (April - Dec '89).

Treatment	Species	Seed Origin/ Provenance	Increment Height (m)	Increment RCD (cm)
T1	Albizia lebbeck	India	0.59	1.0
T2	Albizia falcataria	Malaysia	1.53	2.7
T3	Acacia auriculiformis	India	1.34	2.4
T4	Alnus acuminata	Guatemala	1.62	3.1
T5	Alnus acuminata	Mexico	1.64	2.7
T6	Alnus nepalensis	Nepal	1.05	1.4
T7	Erythrina caffra	India	1.32	1.7
T8	Grevillea robusta	India	1.98	3.3
T9	Jacaranda mimosifolia	India	2.41	5.0
T10	Sapium sebiferum	India	0.91	1.9

Experiment 9 is half a year younger than experiments 6, 7 and 8 and the results presented here cover the first 9 months after planting. *Jacaranda mimosifolia* and *Grevillea robusta* were the best performing in both height and root collar diameter development. *Albizia lebbeck* was poor in root collar diameter increment and was generally slower growing than *Albizia falcataria*. The height growth figures for *Erythrina caffra* were the lowest and also somewhat unreliable since there was dieback of apical growth tips, following hailstorm damage. The two *Alnus acuminata* provenances showed better growth performance than *Alnus nepalensis*. *Acacia auriculiformis* has the growth form of a shrub with a dense arrangement of waxy leaves. *Sapium sebiferum* has not shown convincing growth and looks rather unhealthy.

Biomass production from first thinning and coppice regrowth

Tables 7 to 10 summarise the average fresh biomass yield per tree from the first thinning, subsequent coppice regrowth cuttings and second (final) thinning in each experiment. The first thinning was based on cutting back a total of eight trees in pairs of two at different cutting heights (0, 25, 50, 75 cm). The second thinning was based on uniformly cutting back three remaining (non-experimental) trees to ground level.

Table 7. Experiment 6. Total fresh biomass yield (kg/tree) at first (6.5-12 months) and second (14 months) thinni

Treatment	Species	Seed Origin/ Provenance	First Thinning Biomass (kg) Initial	Regrowth	Total	Second thinni Biomass (k
T1	*Acrocarpus fraxinifolius*	Muringato, Kenya	1.8	3.1	4.9	12.2
T2	*Markhamia lutea*	Kakamega, Kenya	1.2	0.7	1.9	3.[illegible]
T3	*Markhamia lutea*	Osorongai, Kenya	1.3	0.7	2.0	2.[illegible]
T4	*Markhamia lutea*	Rusenyi, Rwanda	1.0	1.2	2.2	2.[illegible]
T5	*Croton macrostachys*	Kieni Forest, Kenya	1.4	0.3	1.7	Not yet cu
T6	*Croton megalocarpus*	Kikuyu, Kenya	2.4	0.5	2.9	7.[illegible]
T7	*Grevillea robusta*	Namanjalala, Kenya	1.7	0.4	2.1	6.[illegible]
T8	*Erythrina abyssinica*	Nandi District, Kenya	Dead	-	-	-
T9	*Tipuana tipu*	Nairobi, Kenya	2.2	Not yet harvested		3.[illegible]
T10	*Tamarindus indica*	Embu, Kenya		Slow grower, not yet harvested		
T11	*Cordia abyssinica*	Kedowa, Kenya	2.2	0.5	2.7	3.[illegible]
T12	*Casuarina junghuniana*	KARI Arboretum, Kenya	4.0	1.2	5.2	10.5
		MEAN	1.6	1.0	2.8	5.[illegible]

In experiment 6 with its mixture of overstorey trees, all trees subjected to cutting have shown the ability to coppice although growth differed considerably between the species. The first thinning was done after a period ranging from 6.5 months to 12 months depending on species growth rates and the rate at which their canopies closed. The first thinning has not been done for *Tamarindus indica*, the slowest growing species and *Erythrina abyssinica* which was attacked by yet unidentified pest and had earlier been replaced. It is interesting to note that the predominantly single stemmed species *Acrocarpus fraxinifolius* gave the highest average coppice regrowth after the first thinning (3.1 kg/tree fresh weight). Another significant observation was that the total biomass production harvested from the trees thinned after one year in most cases by far exceeded the sum of initial biomass plus coppice regrowth of trees thinned after 6 and 8 months. Though *Markhamia lutea* (Kusenyi, Rwanda) gave the least biomass in the first thinning, it was together with *Casuarina junghuniana* only second to *Acrocarpus fraxinifolius* in coppice regrowth production (1.2 kg/tree fresh weight). Acrocarpus also gave the highest biomass yields in the second thinning (12.2 kg/tree), but is was closely followed by *Casuarina junghuniana* (10.5 kg/tree).

The differences in potential use of coppice material from different species will need to be supported by foliar analysis and studies on decomposition rates. The potential of some species to form barrier hedges for soil conservation and possibly selection for alley cropping looks promising and is currently further investigated.

Table 8. Experiment 7 (Leucaena and Gliricidia spp.) Total fresh biomass yield (kg/tree) at first (7 months) and second (12 months) thinning

Treatment	Species	Seed Origin/ Provenance	First Thinning Biomass (kg) Initial	Regrowth	Total	Second thinning Biomass (kg)
T1	Leucaena leucocephala	Kibwezi, Kenya	3.9	2.4	6.3	16.0
T2	Leucaena leucocephala	Hawaii	3.8	1.5	5.3	14.1
T3	Leucaena leucocephala	Melinda, Belize	3.1	2.1	5.2	15.7
T4	Leucaena leucocephala	Hengchun, China	3.0	1.8	4.8	19.7
T5	Leucaena leucocephala	Yimbo, Siaya, Kenya	1.8	1.4	3.2	12.4
T6	Leucaena diversifolia	Kibwezi, Kenya	0.9	1.3	2.2	3.7
T7	Gliricidia sepium	Guatemala	1.1	1.1	2.2	6.2
T8	Gliricidia sepium	Playa Tamarindo, Santa Cruz, Costa Rica	1.1	0.9	2.0	5.8
T9	Gliricidia sepium	Pantezuela, Cartagena, Columbia	1.4	1.4	2.8	8.2
T10	Gliricidia sepium	Monterrico, Taxisco, Guatemala	1.4	1.1	2.5	8.4
T11	Gliricidia sepium	Vado Hondo, Chiquimala Guatemala	1.8	1.4	3.2	10.5
T12	Gliricidia sepium	Playa de Samala, Guyatenago, Guatemala	2.1	1.3	3.4	14.1
		MEAN	2.1	1.5	3.6	11.2

Despite its superior height growth performance, *Leucaena leucocephala* from Hengchun, China was not the highest biomass producer in the first thinning (3.0 kg/tree) and the subsequent regrowth cutting (1.8 kg/tree). However, it improved considerably in the second thinning (19.7 kg/tree), further supporting its potential for use in the Maseno region. In the first thinning, *Leucaena leucocephala* from Kibwezi, Kenya produced the largest quantity of biomass; 3.9 kg/tree and it came second after *Leucaena leucocephala* from Hengchun, China in the second cutting (16 kg/tree). Local provenance *Leucaena leucocephala* from Yimbo, Siaya was least productive in both cuttings with 1.8 and 12.4 kg/tree respectively. *Leucaena diversifolia* (Kibwezi, Kenya) with its creeping habit and slower growth produced relatively little biomass; 0.9 and 3.7 kg/tree in the first and second cutting respectively.

Gliricidia sepium from Playa de Samala, Guyatenago, Guatemala was the best biomass producer among the Gliricidia species in both first (2.1 kg/tree) and second thinnings (14.1 kg/tree respectively. *Gliricidia sepium* from Playa Tamarindo, Santa Cruz, Costa Rica produced in both cuttings the least biomass; 1.1 and 5.8 kg/tree respectively.

All the species in this trial coppiced well, with *Leucaena leucocephala* from Kibwezi, Kenya giving the largest quantity of coppice regrowth (2.4 kg/tree) and *Gliricidia sepium* Santa Cruz, Costa Rica giving the least (0.9 kg/tree). It was generally evident that Leucaena species had a higher biomass production potential and coppicing ability than Gliricidia species.

Table 9. Experiment 8. (Calliandra, Sesbania and Cassia spp.) Total fresh biomass yield (kg/tree) at first (7 months) and second (12 months) thinning

Treatment	Species	Seed Origin/ Provenance	First Thinning Biomass (kg) Initial	Regrowth	Total	Secondthinni Biomass (k
T1	Calliandra calothyrsus	Guatemala	4.2	2.1	6.3	15.6
T2	Calliandra calothyrsus	Kibuye, Rwanda	4.9	2.1	7.0	15.8
T3	Calliandra calothyrsus	Arboretum de Ruhande, Rwanda	3.7	1.6	5.3	13.8
T4	Sesbania sesban	Kakamega, Kenya	9.5	0.3	9.8	19.7
T5	Sesbania sesban	Mukururioti, Kenya	7.6	0.4	8.0	15.8
T6	Sesbania sesban	Kiambu, Kenya	3.0	0.2	3.2	4.4
T7	Sesbania grandiflora	Kitui, Kenya	1.1	0.7	1.8	0.4
T8	Cassia spectabilis	Bugarama, Rwanda	2.6	1.5	4.1	14.1
T9	Cassia siamea	Bugarama, Rwanda	2.0	0.6	2.6	8.4
T10	Cassia siamea	Kwale, Kenya	1.9	0.5	2.4	4.4
		MEAN	4.1	1.0	5.1	11.2

During the first and second thinning operations, two of the three *Sesbania sesban* provenances from Kenya (Kakamega and Mukururiati) displayed exceptionally good biomass production. The third provenance (Kiambu, Kenya) showed a relatively lesser performance. Yields from these *Sesbania* spp. were 9.5, 7.6 and 3.0 kg/tree, respectively. In all three cases, the coppice regrowth was very low (<0.5 kg/tree), indicating the poor ability to coppice of *Sesbania sesban*, when cut below 1.0 m after it has passed its juvenile, non-woody stage. The biomass yield at the second cutting for the three Sesbania provenances was 19.7, 15.8 and 4.4 kg/tree, respectively. *Sesbania grandiflora* died in the course of the first year, its biomass yield was very low and the wood did not seem to be attractive for any use. The species is unsuitable for the Maseno area. The three Calliandra provenances were at first cutting less productive than the *Sesbania* spp. and produced 4.2 (Guatemala), 4.9 (Kibuye, Rwanda) and 3.7 kg/tree (Ruhande, Rwanda), respectively. However, at the second thinning after one year, *Calliandra calothyrsus* from Guatemala and *Calliandra calothyrsus* from Kibuye, Rwanda produced good single tree yields of 15.6 and 15.8 kg respectively. A slightly lower yield was achieved by *Calliandra calothyrsus* from Arboretum de Ruhande, Rwanda: 13.8 kg/tree. The initial productivity of the *Cassia* spp. after six months was modest. *Cassia spectabilis* yielded 2.6 kg/tree and the two *Cassia siamea* provenances yielded 2.0 (Bugarama, Rwanda) and 1.9 kg/tree (Kwale, Kenya) . However, reasonable to good productivity was achieved after one year, when *Cassia spectabilis* yielded 14.1 kg/tree and *Cassia siamea* from Bugarama, Rwanda yielded 8.4 kg/tree. *Cassia siamea* from Kwale, Kenya remained low in yield with 4.4 kg/tree.

All *Calliandra calothyrsus* and *Cassia spectabilis* provenances have displayed a strong ability to coppice. *Sesbania sesban, Sesbania grandiflora* and *Cassia siamea* provenances coppiced poorly.

Table 10. Experiment 9. (Mixed species screening trial) Total fresh biomass yield (kg/tree) at first thinning after 9 months

Treatment	Species	Seed Origin/ Provenance	First Thinning Biomass (kg) Initial
T1	Albizia lebbeck	India	0.5
T2	Albizia falcataria	Malaysia	2.3
T3	Acacia auriculiformis	India	2.2
T4	Alnus acuminata	Guatemala	2.0
T5	Alnus acuminata	Mexico	1.4
T6	Alnus nepalensis	Nepal	0.6
T7	Erythrina caffra	India	Diseased
T8	Grevillea robusta	India	2.2
T9	Jacaranda mimosifolia	India	4.2
T10	Sapium sebiferum	India	Not yet thinned
		MEAN	1.9

Except *Erythrina caffra* and *Sapium sebiferum*, which were either diseased or too small to justify any thinning at the time of management, all other species and provenances in experiment 9 have only been thinned once and coppice regrowth has not yet been harvested. Comparison of biomass yields between species and within species across provenances is possible although the biomass yield from first thinning was generally very low clear yield differences were difficult to detect visually at this stage.

Jacaranda mimosifolia gave the highest biomass yields (4.2 kg/tree) while *Grevillea robusta, Albizia falcataria* and *Acacia auriculiformis* produced fairly good yields, in the range of 2.0-2.3 kg/tree. *Alnus nepalensis* was lower in biomass production than the *Alnus acuminata* provenances. The lowest biomass yield was produced by *Albizia lebbeck* (0.5 kg/tree).

Some observations on coppice production, based on all four general screening trials are that: i) on average, the abundance of leafy and woody coppice regrowth after first thinning was positively influenced by placing the initial cutting height higher than ground level, i.e at 0.5 m or even 0.75 m. This could have important implications for the adoption of management regimes when the species are used for certain agroforestry technologies, i.e alley cropping or pollarding for fuelwood and stake production, and ii) experience at Maseno has revealed that early thinning management may produce a limited amount of early biomass but the abundance of the subsequent coppice harvest is lower than when the first thinning operation is delayed until the tree has gained more height and girth and until it has developed a more abundant and leafy canopy.

4. SOIL FERTILITY MAINTENANCE AND IMPROVEMENT TRIALS

4.1 Justification

Decline of soil fertility and increased soil erosion have been diagnosed as major problems in the food crop based landuse systems in the densely populated parts of Western Kenya as well as other parts of the East and Central African Highlands. Alley cropping, a technology whereby hedges of nitrogen fixing, coppiceable trees are grown on contours and managed to produce green manure and mulch for the crops grown in the alleys, is seen as an agroforestry technology that could possibly contribute to solving some of these problems (Kang, Wilson and Sipkens, 1981; Minae and Akyeampong (ed.), 1988).

The principal variables that affect the biological productivity of hedgerows of woody perennials in alley cropping systems are: i) hedgerow species; ii) within-row spacing of hedge plants; iii) number of individual hedge lines within a hedge; iv) cutting height of the hedgerows; and v) proximity of the first and subsequent lines of annual food crop(s) from the hedge. These variables may also interact with the variables on the alley crop such as food crop species, genotype, tillage regime, fertilizer application and food crop population density. There is a need to define the interactions and possible contributions of each variable to the productivity of the entire alley cropping system. Considering that all these variables cannot be studied in one experiment, three separate on-station experiments were started in Maseno to evaluate some of the components of alley cropping. They comprise the selection of suitable MPTS species for alley cropping, the study of the relative contribution of *Leucaena leucocephala* mulch and fertilizer to food crop yields in maize and maize plus bean systems, and the testing of various hedge designs and planting arrangements in an alley cropping system with *Leucaena diversifolia* and maize.

4.2 MPTS species screening trial for alley cropping

4.2.1 Objectives

- to select promising MPTS for alley cropping;
- to quantify biomass production potentials of MPTS under alley cropping management;
- to asses the effect of MPTS on companion crops.

4.2.2 Experimental design and methodology

The experimental treatments are shown below:

Treatment	Species	Origin/Provenance
T1	Leucaena leucocephala	Hengchun, China
T2	Leucaena leucocephala	Melinda, Belize
T3	Calliandra calothyrsus	Guatemala
T4	Gliricidia sepium	Guatemala
T5	No hedge	-
T6	Sesbania sesban	Kakamega, Kenya
T7	Cassia siamea	Siaya, Kenya
T8	Erythrina caffra	Siaya, Kenya

The experiment was laid out in a randomised complete block design and each treatment was replicated four times. Plots measured 5.6 x 5.0 m and in each plot (except control), two hedges were planted at 2.8 m apart. The in-row spacing of trees was 0.25 m. Maize was grown in each plot at a spacing of 0.7 x 0.3 m, resulting in three rows of experimental maize in each plot between the two hedges and two border rows each of maize on the outer sides of the plot (47,620 plants/ha). Therefore, the experimental plot consists of one hedge and three rows of maize. The control plot consists of four rows of experimental maize and two rows of border maize on either side of the experimental plot. The experimental plot size was 5 x 2.8 = 14 m^2.

All trees were established in April 1988 from seedlings except *Erythrina caffra* for which vegetative propagation by cuttings was used. A starter dose of 25 g DAP fertilizer was used per tree, which is equivalent to 64 kg/ha of N and 164 kg/ha of P_20_5 at the hedge population of 14,286 trees/ha.

Hedges were cut back to 50 cm from ground level during the course of 1988 and early 1989 depending on the initial growth performance. Subsequent pruning took place at the start of each season and during the cropping season depending on regrowth rates.

The experiment has gone through 4 cropping seasons since April 1988, starting with beans at the time of tree hedge establishment (first rainy season 1988), followed by another crop of beans during the second rainy season of 1988. During 1989, beans and maize (hybrid 512) were grown together (first season) followed by a locally developed maize composite (cv. Hamisi Double Cobber) in the second season. Beans in 1988 and 1989 (first season) were planted with 100 kg/ha of DAP. Maize in the first season of 1989 was planted with 130 kg/ha of DAP and top dressed with 142 kg/ha of CAN, equivalent to 60/60 kg/ha of N and P_20_5. Maize in the second season of 1989 (cv. HDC) did not receive any fertilizer.

4.2.3 Site description

The experiment is located on land which was planted in the early 1980's with widely spaced *Cupressus lusitanica*. The site had also a thick cover of couch grass (*Digitaria sacalarum*). Soils vary considerably in texture from sandy loam to sandy clay on the surface to sandy clay loam to clay loam at 1 m below ground level. The soils are inherently infertile and highly deficient in phosphorus and nitrogen. Organic matter content is also low. Soil depth varies from about 120 cm to 150 cm. However, hydromorphic properties become apparent at depths of about 100 cm. The pH (in water) is 5.1 and the slope is slightly undulating. The area is occasionally wet during the period of heavy rains and sheet erosion is observed, especially when crops are young and therefore incapable of providing adequate ground cover. Surrounding the experimental area is a bushy vegetation consisting of couch grass, *Psidium guajava*, *Eucalyptus* spp., *Cupressus lusitanica*, and isolated *Acrocarpus fraxinifolius* and *Ficus* spp.

At the start of the experiment in April 1988, soil samples were taken and analyzed for the following chemical components:

Average soil pH (in CaCl2; 1:2.5 ratio)....:	4.6
Organic Carbon (%).......................................:	0.7
Total available Nitrogen (N) (%)...............:	0.11
Phosphorus (P) (Bray no.2a) (ppm)...........:	(not yet available)
Sodium (Na) (me/100 g)..............................:	2.16
Potassium (K) (me/100 g)............................:	2.11

4.2.4 Results and discussion

4.2.4.1 Trees

Survival

Erythrina caffra cuttings established poorly with a survival percentage of 53% at the end of 1989. Mortality of *Sesbania sesban* gradually increased with continued pruning from 13% in February 1989 to 88% by September 1989 and 100% by December 1989. *Cassia siamea* achieved 75% survival one month after establishment with some seedlings showing stunted growth. *Leucaena leucocephala*, *Calliandra calothyrsus* and *Gliricidia sepium* established well. Survival rates for all these species were nearly 100%<x

Pests and diseases

Sesbania sesban was attacked by a beetle (*Mesoplatys ochroptera*) which was controlled by spraying with a pesticide. *Gliricidia sepium* had a mild aphid attack.

Initial height and root collar diameter increment

Table 11 gives initial height and root collar diameter increments at the time of initial cut-back which ranges from five to ten months for various species. The figures in Table 11 clearly illustrate that the fastest growth was displayed by *Sesbania sesban* in five months and the lowest growth rates were recorded for *Gliricidia sepium* in ten months.

Table 11. Tree height and root collar diameter increment (cm) between time of planting (April 1988) and time of first cutback to hedge height, as indicated (in months).

Treatment	Species	Growth period	Growth increment Height	Root collar
T1	Leucaena leucocephala	8	266	2.3
T2	Leucaena leucocephala	8	232	2.3
T3	Calliandra calothyrsus	6	268	2.3
T4	Gliricidia sepium	10	136	2.7
T6	Sesbania sesban	5	343	3.4
T7	Cassia siamea	10	235	3.1
T8	Erythrina caffra	10	191	3.1

Biomass production

The tree biomass harvested from the hedges is summarised in Table 12. Two distinct periods in the development of the hedges are recognized. During the first period from September 1988 to February 1989, all tree species were cut back from their initial height to the standard hedge height of 0.5 m. *Sesbania sesban* received its first cutting after five and a half months; some other slower growing species were first cut after ten and a half months. All the biomass produced by each species between September 1988 and February 1989 is regarded as initial yield, associated with trimming the hedges to experimental size. Because of the different initial cutting dates and the different tree products obtained at the uniform cutting in February 1989, the biomass yields up to February 1989 have not been analyzed statistically. However, there are clear differences in initial leaf yield between species. *Sesbania sesban* gave an initial leaf yield of 20.3 t/ha. *Calliandra calothyrsus* yielded 17.3 t/ha; the two *Leucaena leucocephala* provenances yielded 11.4 t/ha (China) and 10.9 t/ha (Belize) respectively. Lower initial leaf yields were achieved by *Cassia siamea, Erythrina caffra* and *Gliricidia sepium*; 8.3 t/ha, 7.5 t/ha and 4.2 t/ha respectively.

Starting with the yield of April 1989, the leafy biomass production is fully comparable between species because all hedges were cut back to the same cutting height in February 1989. Leafy biomass productivity between species was compared for the April, June, September and December 1989 harvest. Significant differences in leaf yield were found in all four cuttings. In April 1989, significant differences were detected ($p < 0.05$). In all subsequent cuttings the differences were highly significant at $p < 0.001$. Between April and December 1989, the best performing species was *Calliandra calothyrsus* with 36.7 t/ha. The two *Leucaena leucocephala* provenances were practically equal in yield with 24.3 t/ha. *Gliricidia sepium* and *Erythrina caffra* yielded 18.3 t/ha and 17.1 t/ha respectively. Lower leaf yields were achieved by *Sesbania sesban* and *Cassia siamea* with 10.8 t/ha and 8.9 t/ha respectively.

Woody biomass harvested from different species between September 1988 and February 1989 during initial cutback varied considerably. *Sesbania sesban* gave 12.6 t/ha of wood and 18.2 t/ha of twigs. *Calliandra calothyrsus* gave 9.1 t/ha of wood and 13 t/ha of twigs. The two *Leucaena leucocephala* provenances gave 4.5 t/ha (China) and 3.8 t/ha (Belize) of wood and 3.8 t/ha (China) and 3.1 t/ha (Belize) of twig respectively. *Gliricidia sepium* and *Cassia siamea* did not yield any wood at first cutback but they yielded 4 t/ha and 8.6 t/ha of twigs respectively. *Erythrina caffra* yielded 9.1 t/ha of twigs and 4.4 t/ha of wood.

The actual precipitation received at this site was 2,396 mm from April 1988-March 1989 and 1,455 mm from April-December 1989.

Table 12. Fresh leafy biomass yield (t/ha) during the initial formation stage of the hedgerows (September 1988 - February 1989) and during productivity at the standard height of 0.5 m. (April - December 1989)

Treat-ment	Species/Provenance	Cut No. 1	2	3	4	5	6	7	8	Total Yield	Total Yield
		DATES								Sept '88 to Feb '89	April '89 to Dec. '89
		Sept '88	Oct '88	Dec'88	Feb'89	Apr'89	Jun'89	Sept'89	Dec'89		
T1	Leucaena leucocephala (China)	-	-	8.4	3.0	6.3	5.5	4.5	7.9	11.4	24.2
T2	Leucaena leucocephala (Belize)	-	-	7.4	3.5	5.7	5.4	4.7	8.6	10.9	24.4
T3	Calliandra calothyrsus (Guatemala)	-	8.4	-	8.9	5.0	8.8	9.5	13.4	17.3	36.7
T4	Gliricidia sepium (Guatemala)	-	-	-	4.2	5.4	5.0	1.8	6.1	4.2	18.3
T6	Sesbania sesban (Kakamega)	12.8	-	-	7.5	5.5	5.3	dead	dead	20.3	10.8
T7	Cassia siamea (Siaya)	-	-	-	8.3	4.2	1.5	1.5	1.7	8.3	8.9
T8	Erythrina caffra (Siaya)	-	-	-	7.5	6.3	2.9	5.6	2.3	7.4	17.1
MEAN		-	-	7.9	6.1	5.5	4.9	4.6	6.7	11.4	20.1
S.E.D		-	-	-	1.19	0.54	0.54	0.32	0.57		
CV%		-	-	-	27.5	13.9	15.5	9.9	12.1		

4.2.4.2 Crops

Crop yields

Beans planted during the first and second seasons of 1988 failed due to heavy rains. The results are therefore not included in this report. The hybrid maize planted together with beans in the first season of 1989 performed well while the intercropped beans failed. The composite maize crop in the second rainy season of 1989 gave similar yields as the first harvest in 1989. However, it should be noted that the second crop of 1989 did not receive any external inputs in the form of fertilizer. The maize yields for two seasons are shown in Table 13.

Table 13. Dry maize grain yield (t/ha) for the first (long rainy) and second (short rainy) season of 1989.

Treatment	Species	First season of 1989	Second season of 1989
T1	Leucaena leucocephal.	4.07	4.35
T2	Leucaena leucocephala	3.18	3.62
T3	Calliandra calothyrsus	2.56	3.80
T4	Gliricidia sepium	3.46	3.49
T5	No hedge	2.53	3.05
T6	Sesbania sesban	4.68	4.29
T7	Cassia siamea	4.84	3.36
T8	Erythrina caffra	4.29	4.21
Mean		3.70	3.77
S.E.D		0.94	0.51
C.V.%		24.5	19.3

During the first (long rainy) season of 1989, no significant differences ($p < 0.05$) were found in maize yield between alley cropping treatments, except *Calliandra calothyrsus*, which gave a low yield, which was comparable to the control. The yield of the control plot with pure maize gave the lowest yield of 2.53 t/ha, which was significantly lower than most alley cropping treatments. The highest yields were achieved in the alley cropping plots with *Cassia siamea* and *Sesbania sesban*.

The local, unfertilized maize composite planted in the second (short rainy) season of 1989 was harvested in January 1990 and the yields in some alley cropping plots were again significantly higher than in the control plot ($p < 0.05$). The control plot gave 3.05 t/ha and the best yield (4.35 t/ha) was achieved in the *Leucaena leucocephala* (China) alley cropping plot, closely followed by the *Sesbania sesban* plot with 4.29 t/ha.

The preliminary conclusion is, that during these first two cropping seasons, a clear positive correlation between the amount of leafy tree biomass applied to the food crop plot and maize crop yield was not observed. However, alley cropping treatments consistently performed better than the control "maize only" treatment.

4.3 The effect of *Leucaena leucocephala* mulch and DAP/CAN fertilizer applications on the productivity of maize and maize/bean systems

4.3.1 Objectives

- to study the effect of Leucaena mulch on the yield of maize and maize + beans systems;
- to study the effect of different levels of fertilizers alone and in combination with mulch on the yield of maize and maize + beans systems.

4.3.2 Experimental design and methodology

The study evaluated four different cropping systems and three different levels of fertilizer in a split-plot design and was replicated four times. The main plot and sub-plot treatments are as follows:

Main plot	Sub-plot
(Cropping Systems)	(Fertilizer Levels)
S1 - Pure maize	Fo - No fertilizer
S2 - Maize + beans	F1 - 30 kg N + 30 kg P_2O_5/ha
S3 - Maize + Leucaena	F2 - 60 kg N + 60 kg P_2O_5/ha
S4 - Maize + beans + Leucaena	

Each main plot measures 15 by 7.5 m and was made up of three subplots of 5.0 by 7.5 m. In plots with the Leucaena, two parallel hedges of trees were planted 3.75 m apart with in-row plant spacing of 0.25 m. Tree density in Leucaena plots was therefore 10,667 trees/ha. All sub-plots were separated by small earth bunds in order to minimise the surface flow of fertilizer and Leucaena mulch from one plot to the next.

Before the experiment was established in April 1988, the area was mainly covered by couch grass (*Digitaria sacalarum*) mixed with pasture grasses. The site was ploughed twice using a disc plough and thereafter harrowed twice. Subsequently, couch grass was removed manually and *Leucaena leucocephala* hedgerows planted in April 1988. The trees were established with 1 tablespoon of di-ammoniumphosphate, equivalent to 4.5 g N and 11.5 g P_20_5 per tree. This is equivalent to 267 kg/ha of DAP.

The Leucaena trees were first cut back to the standard hedge height of 0.5 m in February 1989 when most of the trees had attained a height between 2 and 2.5 m and a root collar diameter between 2.5 cm and 3.0 cm. Although the height criterium was not fully met by all trees in March 1989, they were all cut back at that point in order to be able to incorporate tree leaves before the start of the long rainy season of 1989. Subsequently, hedges have been pruned every 2 to 4 months. Hedge biomass harvested during the first cutting of each season was incorporated in the soil; during subsequent cuttings it has been mulched on the plot between the lines of maize and beans.

The alley between hedges was planted with 4 rows of maize and half alleys on either side of the plot with two rows of maize. In plots without Leucaena hedges 10 rows of maize were planted at 0.75 m between rows and 0.25 m in the row, giving a plant population of 53,000 plants/ha. In alley cropping plots, the maize plant population is 42,400 plants/ha. Bean plant population is the same in Leucaena plots and pure maize/bean plots. Beans are spaced at 0.75 by 0.20 m (66,666 plants/ha).

A cover crop of beans was planted in April 1988 but it failed due to heavy rains. During the short rainy season of 1988, beans were again planted as cover crop with a uniform DAP dose of 100 kg/ha. Commencing with the long rainy season of 1989, the 12 experimental treatments, comprising four different cropping systems times three fertilizer levels were implemented. Maize Hybrid 512 and beans 'Roscoco' GLP-2 have been used in this experiment in both growing season in 1989.

In March 1989, the first experimental crop of maize and beans was sown. At maize planting, fertilizer was applied as per treatments; DAP at planting time and CAN top dressed when plants had reached knee height, where used as sources of N and $P_2 0_5$. All $P_2 0_5$ was applied at planting time via DAP; 39% of N was applied at planting time via DAP and 61% was applied at top dressing via CAN. Beans were planted with DAP at the rate of 100 kg/ha. Maize stalk borer, the most common maize pest was controlled by application of Fenitrothion 3% dust into the plant funnel (whorl) at the rate of 11 kg/ha per application.

During the establishment phase of the trial (April 1988 - February 1989), the measurement of standard tree growth parameters, such as height and root collar diameter increment, were carried out. From the time of first cutting, the leafy biomass production of the Leucaena hedges was monitored per cutting, season and year. Starting with the long rainy season of 1989, data were gathered on a seasonal basis about maize and bean yields in the alley cropping and control plots.

4.3.3 Site description

The site was used as pasture before the experiment was established. Couch grass (*Digitaria sacalarum*) is the predominant weed species at the site. The soil (loam to clay loam) is classified as lixisols (tropical luvisols). From the soil surface towards the deeper soil layers, the colour changes gradually from dull reddish brown towards more orange/yellow reddish brown. The profile is uniform with no abrupt changes in texture. The slope of the experimental site is less than 2% in north to south direction. At the onset of the experiment, the soil was strongly acidic with an estimated pH in water of 5.1. The soil depth exceeded 120 cm. At the start of the experiment in April 1988, soil samples were taken and analyzed for the following chemical components:

Average soil pH (in CaCl2; 1:2.5 ratio)....:	4.6
Organic Carbon (%)....................................:	1.61
Total available Nitrogen (%)......................:	0.13
Phosphorus (P) (Bray no.2a) (ppm)..........:	(not yet available)
Sodium (Na) (me/100 g)............................:	0.52
Potassium (K) (me/100 g)..........................:	1.12

4.3.4 Results and discussion

4.3.4.1 Trees

Survival

The Leucaena provenance from the 'Hengchun Tropical Botanical Gardens' in China (PRC) has proven to be well adapted to the Maseno climate. There has been hardly any mortality due to establishment failure during the initial stage of the experiment.

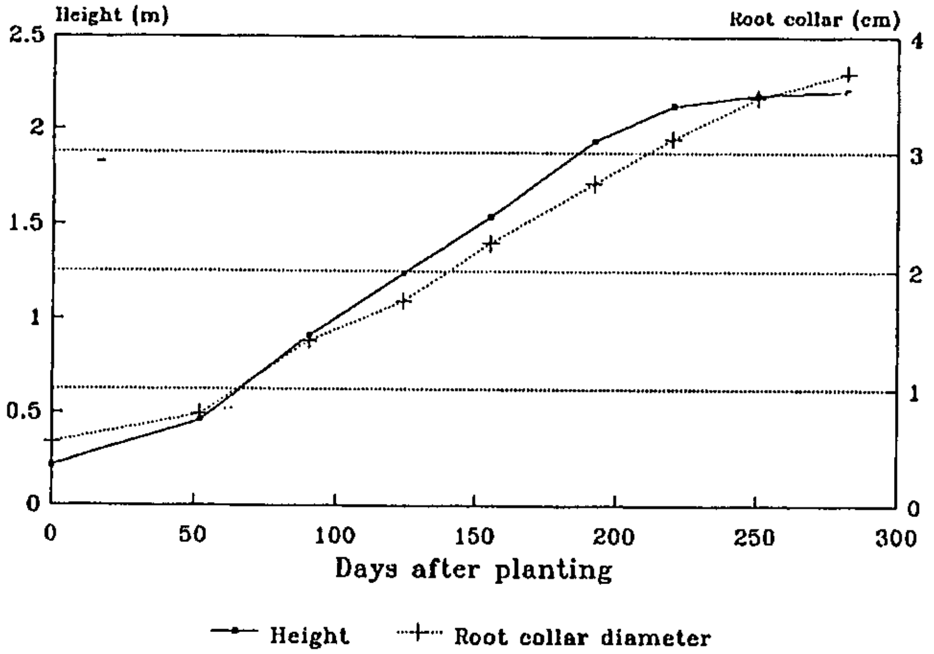
Pest and diseases

The trees were first cut down for hedge formation on 9-3-1989, 10.5 months after their establishment. During the first two months of hedge establishment, there were isolated attacks of white ants, especially of trees with a root collar diameters of less than 5 cm, which caused death. Beating up was done in all such cases and chemical control was taken up to avoid further damage. The compound used was Aldrex (48%) at the rate of 1100 ml/100 *l* of water. Due to the fast growth of the trees during 1988, combined with several heavy hailstone storms, there were signs of bark cracking which caused concern by late 1988 because the trees became brittle and side branches could be broken off easily. However, at the time of harvesting, the problem was no longer serious and most bark cracking had appeared on side branches above the hedge cutting height of 0.5 m. Two years after establishment of the experiment, the Leucaena hedges are healthy, disease and pest free and steadily producing abundant amounts of leafy biomass suitable for mulching.

Height and root collar diameter increment

Height growth increment of Leucaena was measured on a monthly basis from two months after planting up to the time of first cutting. The mean monthly height increment between April 1988 and February 1989 was 20 cm. However, height growth was not linear during the first 10.5 months of growth (see Figure 1). At establishment, the trees had an average height of 21 cm. Between April and July 1988, the trees established their roots and grew on average 15 cm/month. Increased height increment of more than 32 cm/month was achieved between July and December 1988. Thereafter, height growth slowed down considerably and had virtually come to a standstill by February 1989. This significant reduction in height increment coincided with the onset of flowering and the production of seed between December 1988 and February 1989. By late 1988, the trees had switched from vegetative towards reproductive growth. This change in growth strategy coincided with the onset of the dry season between December 1988 and February 1989. Figure 1 also shows the root collar development between April 1988 and February 1989. The growth curve indicates that the root collar diameter developed at a fairly constant rate of approximately 0.5 cm per month throughout the growing period except for the first month after planting when the trees were establishing themselves more slowly.

Figure 1. Height and root collar diameter growth of *Leucaena leucocephala* (Hengchun, China) planted in hedgerows, between planting time (April 1988) and time of first harvest (February 1989).



Biomass yield

When the hedges were first cut in March 1989 to a uniform height of 0.5 m, the biomass was harvested by product type, comprising leaves, twigs, pods and stem wood. At harvest time, most trees had developed into healthy, multi-stemmed shrubs with an abundance of leaves and seed pods. The harvested fresh biomass yield amounted to 8.11 t/ha of stem wood and twigs; 7.12 t/ha of leaves, and 5.87 t/ha of seed pods. Therefore, only 34% of the total fresh biomass harvested during this first cutting was incorporated in the plots as leafy biomass. In Table 14, the amount of fresh leafy biomass harvested at each cutting is summarized as well as the total biomass production between April 1988 and December 1989.

Table 14. Average fresh Leucaena yield (t/ha) from alley cropping plots, planted in April 1988 and regularly harvested between March and December 1989.

DATE	7/3/89	13/6/89	29/9/89	30/11/89	TOTAL 1989
Leaves	7.12	5.31	4.89	3.89	21.21
Stem wood	8.11	-	-	-	8.11
Pods/seeds	5.87	-	-	-	5.87
TOTAL	21.10	5.31	4.89	3.89	35.19

4.3.4.2 Crops

Crop yields

The bean crop of the first rains of 1988 was planted too late in the season and coincided with an exceptionally wet year (1988). No meaningful yield data were collected. The second bean crop was successful and a comparison was made between bean yields in alley cropping plots and control plots. Dry bean grain yields were significantly lower in alley cropping plots than in control plot and measured 987 kg/ha and 1,307 kg/ha respectively ($p < 0.001$). The most plausible reason for the reduced bean yield in alley cropping plots was that the beans were growing under an increasingly heavy cover of shade created by Leucaena before it was cut back to hedge height. No significant differences were found for bean yield within control plots and within alley cropping plots when their yields were compared within comparable cropping systems.

In 1989, two cropping seasons with maize and beans were realised and the first results were obtained about the performance of the four different cropping systems while they were subjected to different levels of fertilizer and leucaena leaf mulch.

Table 15. Maize yields (t/ha), grown in an annual system and in alley cropping with Leucaena, at three fertility levels, first rains (March-July) of 1989.

	FERTILITY LEVELS (N/P_2O_5, kg/ha)			
CROPPING SYSTEM:	0-0	30-30	60-60	MEAN
ANNUAL SYSTEMS				
Sole maize	7.18	8.65	8.67	8.17
Maize/bean intercrop	8.51	9.05	9.06	8.88
ALLEY CROPPING				
Sole maize	6.7	8.28	7.99	7.66
Maize/bean intercrop	8.23	8.39	8.56	8.39
MEAN	7.66	8.59	8.58	
S.E.D				0.24(a)
CV %				8.3
S.E.D		0.189(b)		
CV %		4.6		

a = S.E.D. for comparing maize yield across fertility treatments within the same cropping system
b = S.E.D. for comparing maize yield across cropping systems within the same fertility treatments

The following observations are made on the first season results. Maize yields were extremely high and ranged from 6.7 - 9.1 t/ha. These levels are explained by the fact that the experiment was laid out on fertile pasture land. Secondly, two cover crops of beans were sown in the preceding seasons of 1988 with 100 kg/ha of DAP. Thirdly, appreciable amounts of nitrogen-rich green manure was incorporated in the alley cropping plots, shortly before the first maize crop was sown (7.12 t/ha fresh leaves equal to 1.78 t/ha dry matter, equal to approximately 60 kg/ha of nitrogen). Finally, the bean intercrop in the long rainy season of 1989 received 100 kg/ha of DAP separate from the fertilizer gift to maize, as pretreatment. It should be noted that the additional fertilization of beans (100 kg/ha of DAP) in the maize + bean and maize + bean + Leucaena treatments largely explains the higher absolute yields obtained in these treatments, when they are compared with non-bean treatments.

Probably because of this rather high initial fertility status of the soil, the alley cropping system did not show any impact during the first experimental season. In fact, on the whole, lower yields were obtained in the alley cropping system as compared to the annual systems. The latter is probably due to the fact that the plant population in the alley cropping plots was lower than in the annual plots. Also, response to fertilizer was limited, particularly at the 60 kg level. This could, in part, be attributed to the high fertility status of the soil, but also to inappropriate fertilizer application at the 60 kg level.

Table 16: Bean yields (t/ha), intercropped with maize in an annual system and in alley cropping at three fertility levels, first rains (March-July) of 1989.

	FERTILITY LEVELS (N/P_2O_5, kg/ha)			
CROPPING SYSTEM	0-0	30-30	60-60	MEAN
ANNUAL SYSTEMS	0.21	0.21	0.23	0.22
ALLEY CROPPING	0.10	0.19	0.21	0.17
MEANS	0.16	0.20	0.22	
S.E.D	0.014 (between cropping systems)			
S.E.D	0.024 (between fertilizer levels)			
S.E.D	0.031 (cropping system x fertilizer level), except when comparing mean(s) with the same level of Leuceana.			
S.E.D	0.034			
CV % (treatment level)	25.1			

The following conclusions are drawn, based on the bean yield data from the first (long rainy season) harvest of 1989 (Table 16). The difference in mean bean yield between cropping systems (main plots) with and without Leucaena hedges is significant ($p < 0.05$). Mean yield in the maize bean intercrop is 220 kg/ha and in the Leucaena alley cropping system it is 170 kg/ha. However, when mean bean yields are compared between treatments with varying fertilizer levels (sub-plots), then differences in yield were (just) not significant ($p = 0.053$). The mean bean yield of no-fertilizer, 30/30 and 60/60 plots was 156, 202 and 222 kg/ha respectively. Finally, the bean yields at cropping system x fertilizer level were not found to be significantly different and averaged 194 kg/ha. Although the bean yield from plots with maize and beans and plots with maize, beans and Leucaena were rather poor (102 to 233 kg/ha), they should not be discarded since they represent a nutritional bonus to the farmer who practices intercropping with beans and the beans are established and maintained at very little extra cash cost and labour input.

Table 17. Maize yields (t/ha), grown in an annual system and in alley cropping with Leucaena at three fertility levels, second rains (September - November) of 1989.

	FERTILITY LEVELS (N/P_2O_5, kg/ha.)			
CROPPING SYSTEM	0-0	30-30	60-60	MEAN
ANNUAL SYSTEMS				
Sole maize	2.07	2.13	2.14	2.11
Maize/bean intercrop	2.34	2.03	2.14	2.17
ALLEY CROPPING				
Sole maize	3.04	3.43	3.28	3.25
Maize/bean intercrop	3.04	3.63	2.80	3.16
MEAN	2.62	2.81	2.59	
S.E.D				0.172(a)
CV %				18.3
S.E.D		0.252(b)		
CV %		18.8		

a = S.E.D. for comparing maize yield across fertility treatments within the same cropping system
b = S.E.D. for comparing maize yield across cropping systems within the same fertility treatments

The following conclusions are based on the maize yield data from the second (short rainy season) harvest of 1989 (Table 17). While comparing cropping (main plot) systems, it is observed that: i) mean maize yields in alley cropping treatments are significantly higher ($p < 0.01$) than in annual system treatments; ii) maize yields in bean treatments are not significantly higher or lower than in plots without beans. While comparing maize yields at fertilizer (sub-plot) treatment level, it is observed that: i) maize yields in plots with medium levels of fertilizer are in three out of four cases higher than in plots without fertilizer. However, the difference in yield is not significant at $p = 0.05$; ii) additional fertilization from the medium level (30-30) to the higher level of fertilizer (60-60) does not give any extra maize yield. In fact, in some cases maize yield is slightly lower at high fertilizer rates. The overall conclusion about maize yields during the second rainy season of 1989 is that: i) maize yields in absolute terms were lower than in the first rainy season of 1989; ii) maize yields were significantly higher in alley cropping plots than in annual crop plots. These promising yield increases in alley cropping plots were achieved with only 80% of the maize plant population found in the annual (intercrop) plots. During the second (short rainy) season of 1989, the benefits of the alley cropping plots may have begun to show. However, the apparent lack of positive response of maize yield to the fertilizer treatments is unexplained.

Table 18. Bean yields (kg/ha) intercropped with maize in an annual system and in alley cropping at three fertility levels, second rains (September - November) of 1989.

	FERTILITY LEVELS (N/P_2O_5, kg/ha.)			
CROPPING SYSTEM	0-0	30-30	60-60	MEAN
ANNUAL SYSTEMS	420	480	433	444
ALLEY CROPPING	213	287	307	269
MEAN	317	384	370	
S.E.D	25.5 (between cropping systems)			
S.E.D	37.0 (between fertilizer levels)			
S.E.D	49.7 (cropping system x fertilizer), except when comparing mean(s) with the same level of Leucaena)			
S.E.D	52.3			
CV % (treatment level) 20.7				

The following conclusions are drawn, based on the bean yield data from the second (short) rainy season of 1989 (Table 18). The difference in mean bean yield between cropping systems (main plots) with and without Leucaena hedges is highly significant ($p < 0.01$). Mean yield in the maize bean intercrop is 444 kg/ha and in the Leucaena alley cropping system it is 269 kg/ha. Mean bean yields between treatments with varying fertilizer levels (sub-plots) were not significant. The mean bean yield of no-fertilizer, 30/30 and 60/60 plots was 317, 384 and 370 kg/ha respectively. The bean yields at cropping system x fertilizer level were not found to be significantly different and averaged 357 kg/ha, which was already a significant yield improvement compared to the average yield of the first rainy season of 1989 (194kg/ha).

4.4 The effect of varying the density of *Leucaena diversifolia* in hedgerows and proximity of the food crop to the hedge on hedge biomass productivity and maize yield

4.4.1 Objectives

- to study the effect of varying the within-row and between-row spacing and the number of tree rows in a hedge on the production of tree biomass and the yield of the associated food crop;

- to study the effect of varying the distance of the first crop row from the hedge on tree biomass production and the yield of the associated crop.

4.4.2 Experimental design and methodology

The study evaluated eight different hedge designs for *Leucaena diversifolia* (Origin: Arboretum de Ruhande, Butare, Rwanda) combined with two distances at which the first row of maize was planted from the hedges. This results in 16 different treatments, as listed below.

<u>Hedge plant density, within- and between-rows (D):</u>

D1 - single row hedge, plants at 25 cm.
D2 - single row hedge, plants at 50 cm.
D3 - two rows hedge at 25 cm and plants within-row at 50 cm.
D4 - two rows hedge at 50 cm and plants within-row at 25 cm.
D5 - two rows hedge at 50 cm and plants within-row at 50 cm.
D6 - three rows hedge at 25 cm and plants within-row at 50 cm.
D7 - three rows hedge at 50 cm and plants within-row at 25 cm.
D8 - three rows hedge at 50 cm and plants within-row at 50 cm.

<u>Distance between the hedge and the first crop row (S):</u>

S1 - 75 cm.
S2 - 37.5 cm.

The study was laid out in a randomized complete block with 3 replications on a practically level piece of land at the Veterinary Farm in Maseno. Each plot consisted of the hedge according to the treatment and four rows of maize on either side, so the net experimental size varied from treatment to treatment. However, the maize cropping area is the same for each treatment (30 m^2). Therefore, the smallest plots consist of a single hedge (with varying in-row spacing of individual trees) combined with the first maize row planted at 37.5 cm away from the hedge, resulting in a net plot size of 5.0 m x 6.0 m (D1S2 and D2S2). The largest plots consist of a triple row of three hedges, spaced at 0.5 m and the first crop row planted at 0.75 m away from the two peripheral hedges (5.0 m x 7.75 m) (D7S1 and D8S1). There are other 12 treatment combinations, resulting in intermediate net plot sizes. Each of the 16 treatment combinations is indicated above.

Leucaena diversifolia was planted in October 1988 and each seedling was given one tablespoon of di-ammoniumphosphate (DAP) at planting, equivalent to 4.5 g of N and 15 g of P_2O_5 per plant. Due to the different hedge designs and tree and crop planting densities, it is not possible to express the fertilizer application in terms of one standard figure in t/ha, but all trees received the same starter dose of DAP. The hedges were left to grow freely without competition from food crops in 1988. But beginning with the first (long) rainy season of 1989, maize (hybrid 512) was planted at the recommended spacing of 0.3 m in the row and 0.75 m between-rows (44,444 plants/ha). This first experimental maize crop received 130 kg/ha of DAP (60 kg/ha P_2O_5 and 23 kg/ha N) and was later top dressed with 142 kg/ha of CAN (37 kg/ha of N). Therefore, the total amount of fertilizer given to maize was equivalent to 60/60 kg/ha of N and P_2O_5. In the short rains of 1989, maize was again planted (locally selected cv. 'Hamisi Double Cobber') but it was not fertilized.

Hedges were cut to a standard height of 0.5 m in March 1989, five months after they were planted. Subsequent cuttings were carried out at 2 to 3 months interval and synchronized with the needs of the food crop component to reduce competition for light and moisture at the critical growth periods. At each cutting, the entire 5 m hedgerows were harvested. During the first harvest the cut material was separated into leaves and stem wood. All material was then weighed and the leafy biomass incorporated in the plots. In subsequent harvests, the cut material, which consisted primarily of leaves on young coppice shoots, was weighed as one product. It was placed between the four rows of experimental maize on either side of the hedge.

4.4.3 Site description

This experiment is situated directly south and east of experiment 3 within the same enclosure that was previously used as pasture for several years. The site characteristics for both experiments are similar. Although no soil samples were taken at the start of experiment 5 in October 1988, it is reasonable to assume that the same soil conditions prevail in general in both experiments. The initial chemical soil analytical data from experiment 3 may therefore serve as a reference for experiment 5 when it was started in October 1988.

4.4.4 Results and discussion

4.4.4.1 Trees

Survival, pests and diseases

The *Leucaena diversifolia* grew well in this climate; establishment was near 100% and there were no noticeable problems of stand mortality or pests and diseases during the first one and a half years after planting.

Initial height and root collar diameter increment

At harvest in February 1989, the trees measured on average 1.7 m and the root collar diameter was 2.1 cm. This provenance of *Leucaena diversifolia* grew on average 32 cm/month, despite the fact that it was planted late in the second (short) rainy season of 1988. It is important to note that the trees received more than 1,000 mm of rainfall between planting and harvest, compared to 937 mm which fell during the first (usually called 'long') rainy season of 1988 (April to August). The trees were already harvested 4.5 months after planting because it was felt necessary to start the experiment with hedges and food crops during the first rains of 1989. This very early harvest apparently did not influence the subsequent hedge productivity negatively, although the average root collar diameter of the hedges was initially smaller (see data experiments 1 & 3) than in other alley cropping experiments in Maseno.

Biomass productivity

In Table 19, the cumulative fresh leafy biomass yield per meter of hedge is given for different treatments. It is observed that the marginal biomass increase diminished with increase in population and/or rows within the hedge, pointing towards increasing within and between hedgerow competition, when the hedge design becomes more complicated.

The results of biomass productivity data from 1989 permit to make interesting comparisons between the various hedge designs. The different hedge designs can be grouped into densely populated (D1; D4; D7) versus sparsely planted (D2; D3; D5; D6; D8) hedgerows.

For hedges with wide spacing, a further comparison can be made between hedges with closely spaced hedge lines (D3; D6) against those with widely planted hedge lines (D5; D8). (D2 does not fit in this latter comparison because it consists of only one hedge line).

Based on the individual hedge biomass yields from five cuttings in 1989, significant differences in biomass productivity were found between treatments at each cutting ($P < .001$).

Analyzing the total hedge biomass yield for 1989 (last column), the following is observed. For hedges with an in-row plant spacing of 0.25 m and hedge lines 0.5 m apart (D1; D4; D7), adding another hedge line (two line hedge vs. single line hedge) led to a yield increase of 54% (D4S1) to 65% (D4S2). Adding another line of hedge (three line hedge vs. two line hedge) gave an additional yield increase of 23% (D7S1) and 30% (D7S2). The overall yield increase from D1 to D7 was 90% in treatments where the first maize was planted at 0.75 m from the hedge (S1) and 114% in treatments where the first maize was planted at 0.375 m from the hedge. It should be realized that these three line hedge treatments (D7) have three times the number of plants of D1 treatments but yield increase was only of the order of 100%.

Table 19. Biomass yield of *Leucaena diversifolia* in eight different hedge designs associated with food crops planted close to the hedge (first line at 37.5 cm) and away from the hedge (first line at 75 cm)

Hedge Design:	Date Feb.89	Fresh Biomass Yield (kg/m hedge) Apr.89	Jun.89	Oct.89	Dec.89	Total 1989
D1S1	1.42	0.36	2.61	1.79	1.29	7.47
D1S2	1.38	0.36	2.01	1.56	1.00	6.31
D2S1	1.17	0.40	1.82	1.29	1.01	5.69
D2S2	1.13	0.40	1.77	1.25	0.89	5.44
D3S1	1.42	0.36	2.60	1.67	1.45	7.50
D3S2	1.82	0.36	2.12	1.48	1.18	6.96
D4S1	2.72	0.58	3.39	2.74	2.08	11.51
D4S2	2.58	0.58	2.89	2.41	1.92	10.38
D5S1	1.82	0.36	3.19	2.28	1.01	8.66
D5S2	1.88	0.36	2.74	2.19	1.63	8.80
D6S1	1.96	0.59	3.19	3.23	1.69	9.82
D6S2	1.96	0.59	3.17	2.09	1.59	9.40
D7S1	2.35	0.53	5.29	3.68	2.33	14.18
D7S2	2.65	0.53	4.53	3.39	2.39	13.49
D8S1	2.26	0.59	4.21	2.68	2.01	11.75
D8S2	2.54	0.59	4.09	2.97	1.88	12.07
MEAN	1.94	0.47	3.10	2.24	1.58	9.34
S.E.D	0.24	0.05	0.39	0.30	0.18	-
CV(%)	15.1	11.8	15.4	16.3	13.3	-

For hedges with an in-row spacing of 0.5 m and hedge lines spaces at 0.25 m apart (D2; D3; D6), adding one extra hedge line increases productivity with 32% (D3S1) and 28% (D3S2) respectively. Adding another line to D3 treatments gives an additional yield of 31% (D6S1) and 35% (D6S2) respectively. The productivity increased by 73% from D2 to D6. This is achieved by a three times the plant population of D2. The conclusion earlier drawn regarding diminishing marginal biomass returns on adding hedge lines in comparable designs is again valid.

Another comparison can be made between D2, D5 and D8, whereby one and two hedge lines are added respectively, but with 0.5 m between the hedge lines. Except for different in-row spacings, this comparison is similar to the comparisons made for D1, D4 and D7 treatments. The increase in biomass when one line is added is 52% (D5S1) and 62% (D5S2) respectively. Adding a third line to the hedge gives 36% (D8S1) and 37% (D8S2) extra yield, compared to the D6 treatments. The average total yield increase from D2 to D8 is 107% (D8S1) and 122% (D8S2) respectively. The conclusion that, within similar hedge designs, a 100% yield increase can be achieved by establishing three times the number of plants is again confirmed.

It is also worth comparing D5 with D3 and D6 with D8 in order to estimate the competition effects and resultant yield losses when hedges are placed close together at 0.25 m between row spacing rather than further apart at 0.5 m. Comparing D3 with D5, it is found that placing the hedges closer together (D3S1 and D3S2) leads to a 15% loss in biomass yield. A similar comparison for the triple hedges gave 16% (D6S1) and 22% (D6S2) yield losses compared to double hedges of equal design (D8).

In Table 20, the cumulative biomass yield for different hedge designs are compared with the basic hedge design of a single line with individual plants spaced at 0.5 m (D2S2). It is observed that a maximum yield increase of 161% (or 2.6 x the basic yield) was achieved in a design which had six times the number of plants of the basic hedge design.

It is further noted that the cumulative (1989) biomass productivity of hedges with the first maize row planted close to the hedge was on average 5% lower than the productivity of the hedges where the first row of maize was planted at 0.75 m. The difference in biomass productivity ranged from -15.5% in D1S2, compared to D1S1 to +2.7% in D8S2 versus D8S1.

Table 20. Cumulative biomass yield (Feb-Dec 1989) for different hedge designs of *Leucaena diversifolia* hedges in an alley cropping experiment (kg/m)

Hedge Type	Pl/m	Fresh Yield	Yield Incr. over D2S2	Yield Ranking (high/low)	Land allocation in each treatmei Crop : Hedge
D2S1	2	5.69	+ 5%	15	89 : 11
D2S2	2	5.44	---	16	100 : 0
D1S1	4	7.47	+ 37%	12	89 : 11
D1S2	4	6.31	+ 16%	14	100 : 0
D3S1	4	7.50	+ 38%	11	86 : 14
D3S2	4	6.96	+ 28%	13	96 : 4
D5S1	4	8.66	+ 59%	10	83 : 17
D5S2	4	8.80	+ 62%	9	92 : 8
D6S1	5	9.82	+ 81%	7	83 : 17
D6S2	5	9.40	+ 73%	8	92 : 8
D8S1	5	11.75	+116%	4	77 : 23
D8S2	5	12.07	+122%	3	86 : 14
D4S1	8	11.51	+112%	5	83 : 17
D4S2	8	10.38	+ 91%	6	92 : 8
D7S1	12	14.18	+161%	1	77 : 23
D7S2	12	13.49	+148%	2	86 : 14

Although the conclusions presented are preliminary because they are only based on 1989 data, the indications about proper hedge design from this experiment are rather clear and can be summarized as follows:

- Doubling the in-row plant population does not lead to proportional increases in biomass production. For example, in D1-designs, the increase in productivity compared to D2-designs is only 20%.

- Adding one or two additional hedge lines to an existing design leads in most designs to significant biomass yield increase(s). However, the relationship is not linear due to increased between-row competition in the multi-line hedges.

- From data obtained on food crop yields, it is evident that the land loss resulting from establishing more complicated and wider hedge designs are so far not compensated for by proportional food crop yield increases associated with the higher amounts of Leucaena mulch applied in these plots.

4.4.4.2 Crops

Crop yields

The maize yield data for the first (long) rainy season of 1989 were gathered in such a way that a comparison could be made between the mean grain yield of the first pair of rows on either side of the hedge against the mean grain yield of the three subsequent maize row pairs lying further away from the hedge. In Table 21, the average dry grain yield (kg/plot) and maize yields converted to t/ha, taking into account the differences in plot sizes between treatments, are summarized. The yields obtained during the first rainy season of 1989 (1,000 mm) were high and ranged from 5.68 - 7.90 t/ha. These generally high yields in the first experimental cropping season are explained by three factors. Approximately six months before cropping started, the experimental site was ploughed out of relatively fertile pasture land. Secondly, the maize crop was fertilized uniformly with 60/60 kg/ha of N and P_20_5. Thirdly, appreciable amounts of Nitrogen-rich green manure from the hedges were applied to the plots shortly before the food crop was sown (Avg. 2.84 t/ha fresh leafy mulch, equal to 0.71 t/ha dry matter, equal to 25 kg/ha N). In none of the 16 treatments could a significant difference be detected between maize grain yield between the first line next to the hedge and the average of the three subsequent lines on both sides of the hedge.

When differences in maize grain yield are expressed on a t/ha basis, they take into account the differences in land occupied by the hedge. The land loss ranges from 0 - 23%. It is observed that hedge designs (D1S2 and D2S2) that did not take up any of the land, normally used by the crop, yielded more maize than treatments where the hedge took up a substantial portion of the land (D7S1 and D8S1). The relationship between land loss, due to hedge type, and maize yield loss was found to be as follows. A land loss of 4% gave a yield loss of 2.4%. Subsequent land loss: yield loss ratio's were: 8% - 2.7%; 11% - 13.0%; 14% - 16.3%; 17% - 9.2%, and 23% - 20.0%.

Therefore, the higher amounts of mulch applied from multiple line and/or high density hedges did not have any significant positive effect on grain yield so far. In fact the reverse happened; grain yield was almost uniform throughout the experiment, leading to decreased yields on t/ha basis in treatments with wide hedges.

The results obtained during the second (short) rainy season of 1989 indicate the substantial decline in maize yield in the experiment as a whole when a local maize cultivar (HDC) was used without addition of any artificial fertilizers, combined with a lower level of rainfall (Sept-Dec 1989: 685 mm). Maize yield dropped to the level of 2.5 to 3.6 t/ha. The differences in yield between individual lines of maize, planted closer or further away from the tree hedges were not significant. To appreciate the data presented, it is important to note that the quality of the food crop was generally poor and it is reasonable to assume that treatment differences were masked to a large extend by external factors, such as the maize seed source, lack of any external inputs (fertilizer) and a lower amount of rainfall than usual.

Table 21. Maize grain yield (13% mc.); first (long) and second (short) rainy season of 1989, associated with sixteen different hedge designs of *Leucaena diversifolia*

Hedge Type:	Pl/m	Land allocation ratio Crop : Hedge	First rains 1989 Mean grain yield (kg/line)	First rains 1989 Mean grain yield (t/ha)	Second rains 1989 Mean grain yield (kg/line)	Second rains 1989 Mean grain yield (t/ha)
D1S1	4	89 : 11	2.57	6.09	1.18	2.81
D1S2	4	100 : 0	2.78	7.41	1.36	3.63
D2S1	2	89 : 11	2.93	6.95	1.30	3.08
D2S2	2	100 : 0	2.86	7.63	1.27	3.38
D3S1	4	86 : 14	2.76	6.31	1.31	3.00
D3S2	4	96 : 4	2.88	7.37	1.37	3.50
D4S1	8	83 : 17	3.32	7.33	1.47	3.24
D4S2	8	92 : 8	2.96	7.29	1.26	3.11
D5S1	4	83 : 17	2.86	6.31	1.27	2.80
D5S2	4	92 : 8	2.75	6.77	1.36	3.35
D6S1	5	83 : 17	3.07	6.78	1.38	3.05
D6S2	5	92 : 8	3.21	7.90	1.27	3.14
D7S1	12	77 : 23	3.09	6.38	1.23	2.55
D7S2	12	86 : 14	2.51	5.74	1.28	2.93
D8S1	5	77 : 23	2.75	5.68	1.28	2.64
D8S2	5	86 : 14	3.00	6.86	1.56	3.57
MEAN			2.89	6.80	1.32	3.11
S.E.D			0.35	--	0.19	--
CV % (maize rows)			11.0	--	20.1	--

5. FODDER PRODUCTION TRIALS

5.1 Justification

The natural fodder supply in many highland landuse systems is usually inadequate in quantity and quality, particularly during the dry seasons. Farmers interested in improving their fodder supply have addressed the problem by planting grasses such as *Pennisetum purpureum* (Napier grass), either as a fodder bank or on terrace bunds. Although this has improved the fodder situation, protein shortages in livestock diets are still experienced since most grasses drop in nutritional value during the dry season. The introduction of a woody perennial to provide supplementary, protein rich fodder is therefore being examined. Two experiments have been established to address these fodder production and quality related problems. In the first experiment, the relative productivity of different tree/grass combinations, planted on contour bunds is studied. In the second experiment, the productivity of Leucaena hedges, when managed at different cutting heights for fodder production in an alley cropping system is studied. In both experiments, the effect of the tree and/or grass component on the productivity of the companion food crops is also monitored.

5.2 Combination of grasses and tree hedges on field bunds for fodder production

5.2.1 Objectives

- to determine the fodder yields of *Pennisetum purpureum*, *Leucaena leucocephala*, *Sesbania sesban* and *Calliandra calothyrsus*, planted on terrace bunds in pure arrangements and in tree-grass mixtures;

- to determine the effect of the different treatment combinations on the performance of the companion food crops.

5.2.2 Experimental design and methodology

The following treatments were included in the experiment:

TREATMENT	TREE/GRASS SPECIES	ORIGIN/PROVENANCE
T1	Leucaena leucocephala	Melinda, Belize
T2	Sesbania sesban	Kakamega, Kenya
T3	Calliandra calothyrsus	Guatemala
T4	Pennisetum purpureum	Vet. Farm, Maseno
T5	Leucaena + Pennisetum	---
T6	Sesbania + Pennisetum	---
T7	Calliandra + Pennisetum	---

The experiment was laid out as a complete randomized block design with four replicates. Each treatment consisted of a 4 m long and 1 m wide section of the bund and a food crop terrace below and above the bund. Within each half food crop plot a minimum of two rows of experimental maize next to the bund were studied. The total experimental plot size therefore consisted of a field bund of 1 x 4 m and two food crop terraces of 1.5 x 4 m each. The total net plot size is 16 m^2, of which 25% is bund area and 75% is cropping area. Each bund section had two parallel lines of trees and/or grass. The two lines were 0.5 m apart and the within-row spacing for trees was 0.25 m. Trees and/or grasses were planted in staggered lines in order to increase the effectiveness of the planted combination on the bund against soil erosion. Trees received 25 g of DAP at planting time, equivalent to 4.5 g of N and 11.5 g of P_2O_5. The pure tree treatments (T1-T3) and the grass in the pure grass (T4) treatment were established in April 1988 together with the tree component in the mixed treatments (T5-T7). The grass in the mixed treatments was established between August and November 1988. Trees were managed as hedges and cut back to 0.5 m. Cutting frequency and timing of cutting between treatments initially (between August 1988 and January 1989) varied depending on the coppice growth. With effect from April 1989, all treatments were cut at the same date and this was carried out at least twice every growing season at the time of sowing the food crop and around two months later. Four crops were grown since the start of the trial, i.e. beans in the first and second seasons of 1988, maize (hybrid 512) and beans intercropped in the first season of 1989 and a locally selected composite maize (cv. HDC) in the second season of 1989. Fertilizer was applied to the bean crops in 1988 at a rate of 100 kg/ha of DAP. The intercrop during the first rainy season of 1989 was fertilized with 130 kg/ha of DAP at planting time and top dressed with 142 kg/ha of CAN, equivalent to 60/60 kg/ha of N and P_2O_5. The maize in the short rainy season of 1989 (cv. HDC) was not fertilized.

5.2.3 Site description

The experimental site was initially covered with small bushes and couch grass. Contour bunds of 30 cm high and 1 m wide were physically constructed, simulating the existing farmer's practice locally known as "fanya juu". The dug out soil from ditches was used to level the terraces between the bunds. The minimum terrace width between bunds was 4 m. Soils vary from clay loam to sandy clay with a depth exceeding 1.5 m. The colour is reddish brown. The slope was about 5% and it is tilted both in north-south and west-east direction. The soil is strongly acid with pH (in water) of 4.9.

At the start of the experiment in April 1988, soil samples were taken and analyzed for the following chemical components:

Average soil pH (in CaCl2; 1:2.5 ratio)....:	4.42
Organic Carbon (%).......................................:	0.93
Total available Nitrogen (N) (%)...............:	0.11
Phosphorus (P) (by Bray no.2 method).....:	(not yet available)
Sodium (Na) (me/100 g)..............................:	0.67
Potassium (K) (me/100 g)............................:	0.71

5.2.4 Results and discussion

5.2.4.1 Trees and grass

Tree survival

Leucaena leucocephala showed less than 2% mortality after receiving six cuttings between December 1988 and January 1990. Both in the mixed and pure treatments, *Sesbania sesban* showed 100% mortality after receiving seven cuttings between September 1988 and January 1990. Stand mortality of *Calliandra calothyrsus* reached about 10% after 7 cuttings between October 1988 and January 1990.

Pests and diseases

Sesbania sesban was defoliated by the larvae of the *Mesoplatys ochroptera* beetle, especially during hot dry spells. There was a slight termite attack on *Calliandra calothyrsus*, mostly in the form of root collar girdling and subsequent wilting of the young seedlings.

Initial tree height and root collar increments

Table 22 indicates that *Sesbania sesban* displayed the fastest height and root collar diameter growth from planting until first cutting, followed by *Calliandra calothyrsus* and *Leucaena leucocephala*. It is interesting to note that five months after planting, the pure (two line) treatments (T1-T3), which experienced between-line competition from the planting day onwards, were on average between 7% (*Calliandra calothyrsus*) and 25% (*Leucaena leucocephala*) lower in height than the single tree line treatments, which grew free of any competition from their adjacent grass line during the same 5 months period from April to August 1988. The height of *Sesbania sesban* in double line planting was reduced by 13%. When *Leucaena leucocephala* was cut after eight months and the mixed treatment had grown together with grass for three months, the difference in final height between pure and mixed treatments was marginal. These findings indicate that there is a considerable amount of between row competition during the establishment phase of double hedgerows of trees on bunds. However, some hedge species (Calliandra) appear to cope better with initial between row competition than others (Leucaena).

Table 22. Tree height and root collar diameter increment (cm) between planting and first cutting for *Leucaena leucocephala*, *Sesbania sesban* and *Calliandra calothyrsus* planted on field bunds in pure lines and in mixture with *Pennisetum purpureum*

Treatment	Assessment date at					
	5 months		6 months		8 months	
	Ht.	RCD	Ht.	RCD	Ht.	RCD
Leucaena leucocephala	84	1.2	100	1.4	151	2.0
Sesbania sesban	231	2.6	-	-	-	-
Calliandra calothyrsus	161	1.5	189	1.9	-	-
Leucaena + Pennisetum	112	1.5	122	1.8	155	2.3
Sesbania + Pennisetum	263	3.3	-	-	-	-
Calliandra + Pennisetum	172	1.7	196	2.2	-	-
MEAN	171	2.0	152	1.8	153	2.2

5.2.4.2 Crops

Biomass from fodder on bunds

The biomass produced by different tree species planted in double lines, grass double lines, and the different tree/grass combinations is summarized in Table 23.

In order to be able to make a fair comparison between the different alternatives, the biomass productivity is expressed in kg/m for the upper and lower line on each bund section separately.

The biomass production is divided into two distinct periods; the initial formation stage of the different components on the bunds, and the uniform production stage in 1989. The first period runs from August 1988 up to January 1989 and the second stage started in April 1989 and is still ongoing.

The highest production in the initial stage was achieved by the pure Napier grass treatment. The average productivity per line was 17.5 kg/m. The upper bund section was somewhat more productive than the lower section (+/- 11% from the mean).

An interesting finding during the same initial period was that the total biomass production from double lines of Leucaena and Sesbania were equal to the single line of the same species, which had grown largely free of competition from the companion Napier grass during most of the initial establishment period. Napier in combination treatments was planted only in August-October 1989, allowing a head start for the trees in the mixed treatments. The single line production of Calliandra (in mixture with Napier) was 27% lower than the double line production of Calliandra in the pure treatment.

Table 23. Fresh leafy biomass yield (kg/m) during the initial formation stage of field bunds (august 1988-January 1989) and during the productivity of standard cutting (April-December 1989)

Treat ment	Species combination on bunds	Cutting No. 1	2	3	4	5	6	Sum Aug 88 Jan 89	Cutting No. 7	8	9	10	Sum April-Dec'89	Relative productivity mixed treatments vs pure treatments	
		23/8/88	12/9/88	17/10/88	27/10/88	8/12/88	16/1/89		5/4/89	16/6/89	20/9/89	15/11/89		by line	by treat
T1	Leucaena - upslope	-	-	-	-	1.4	-	1.4	2.0	1.1	1.0	0.6	4.7	)	
	Leucaena - downslope	-	-	-	-	1.3	-	1.3	2.0	1.1	1.0	0.6	4.7	100%)	100%
T2	Sesbania - upslope	-	1.7	-	-	-	1.4	3.1	2.2	1.5	0.3	0.3	4.3	)	
	Sesbania - downslope	-	1.7	-	-	-	1.3	2.7	2.2	1.7	0.3	0.3	4.5	100%)	100%
T3	Calliandra - upslope	-	-	1.0	-	-	1.5	2.5	1.7	1.3	1.4	1.4	5.8	)	
	Calliandra - downslope	-	-	1.0	-	-	1.4	2.4	1.7	1.5	1.5	1.4	6.1	100%)	100%
T4	Napier - upslope	4.4	-	-	6.8	-	8.3	19.5	8.8	11.9	8.6	6.4	35.7	100%)	
	Napier - downslope	3.2	-	-	4.8	-	7.4	15.4	8.8	10.6	7.5	6.4	33.3	100%)	100%
T5	Napier - uplsope	-	-	-	-	-	-	-	5.3	12.6	9.9	9.2	37.0	+ 4%	-46%
	Leucaena - downslope	-	-	-	-	2.8	-	2.8	4.2	1.2	1.7	0.9	8.0	+70%	-15%
T6	Napier - upslope	-	-	-	-	-	-	-	5.8	11.7	10.2	9.8	37.5	+ 5%	-46%
	Sesbania - downslope	-	3.3	-	-	-	2.3	5.6	3.1	1.8	0.3	0.2	5.4	+20%	-39%
T7	Napier - upslope	-	-	-	-	-	-	-	3.7	7.7	6.2	6.5	24.1	-33%	-65%
	Calliandra - downslope	-	-	1.8	-	-	1.8	3.6	2.5	1.5	1.6	0.9	6.5	+ 7%	-45%
MEAN	Tree component							2.8	2.4	1.4	1.0	0.7	5.6		
MEAN	Grass component							17 5	6.5	10.9	8.5	7.7	33.5		

These early findings clearly indicate that there is considerable competition between hedge lines of MPTs in the initial stages of hedge formation. Similar tendencies were observed for hedge lines in the experiment described in section 4.4. The average production of one line of trees (all species combined) over the period of August 1988 to January 1989 was only 2.8 kg/m, or 16% of the initial grass production (17.5 kg/m).

Since April 1989, all treatments received uniform cutting management and were cut on a 2 to 3 month cycle up to the end of 1989. The data presented in Table 23 for the period April-December 1989 can be analyzed at two levels; i.e. the total combined (double line) productivity of each treatment over a standard bund length of 1 m and the comparative productivity of separate single line components on the bund.

It was found that:

The highest fresh biomass productivity was achieved again in the pure double line grass treatment with 69 kg/m of bund or on average 34.5 kg/line/m. This level of production was significantly higher than any other combination of trees and grasses, produced on bunds ($P < .001$). The upper line of grass was somewhat more productive than the lower line (+7%).

The combined tree and grass biomass productivity of Leucaena-Napier and Sesbania-Napier were lower than the pure grass treatment at 45 and 42.9 kg/m of bund. These two different combinations were not significantly different in productivity ($P = 0.05$).

Evidently, less productive was the combination of Calliandra with Napier, yielding only 30.6 kg of fodder per metre of bund over the same period, which was significantly less than any of the other combination treatments discussed above ($P < 0.05$). It is interesting to note that especially Napier grass seemed to suffer from the combination with Calliandra. It was 33% less productive than the mean grass productivity in the pure and combined treatments discussed above.

The pure tree treatments were much less productive than the tree-grass treatments and yielded 9.4, 8.8 and 11.9 kg/m of bund for Leucaena, Sesbania and Calliandra, respectively. The differences in productivity of pure hedge treatments were not significant ($P = 0.05$). It is further noticed that single lines of a tree species, combined with Napier grass, did produce more than the expected 50% of the double tree line production in the pure tree treatments. One line of Leucaena produced only 15% less than two lines of the species planted together and single lines of Sesbania produced 39% less than double lines. Single lines of Calliandra produced 45% less biomass than the two lines in pure treatments. The single line production of Leucaena and Calliandra in combination with grass was significantly higher than the corresponding single line production in the pure tree treatments ($P < 0.05$).

These preliminary findings indicate that a hedgerow is better combined with a row of Pennisetum than with another hedgerow of the same species. The same is true for the grass, with the exception of Calliandra. To determine "best" combination requires further analysis of the nutritive content of each of these combinations. Such nutritive values should then be checked against the farmers requirements especially during the dry seasons.

Two points are important in the interpretation of the results. First of all, tree-grass combinations did very well as far as the trees were concerned because they received an initial 4-5 months head start and were strong and tall by the time the grass was established in the companion line. In fact, it was initially difficult to establish the grass under the (uncut) tree cover.

Sesbania sesban died in the second half of 1989 because it does not withstand the repeated cutting back that is practised in this fodder production system. Therefore, it is not a viable fodder production proposition if the system is to function for more than 1½ years. This leaves the Leucaena-Napier combination as most promising in terms of overall combined biomass productivity.

Crop yields

It has been very difficult to obtain crop yield data from this experiment reflecting differences in treatment factors. First of all, some crops failed due to a combination of soil and rainfall conditions and secondly, maize crop yields harvested in 1989 were found to be strongly influenced by site variability within the blocks.

5.3 Effect of cutting height of Leucaena hedgerows on biomass productivity and food crop yields in alley cropping

5.3.1 Objectives

- to study the effect of different cutting heights on the biomass production of hedgerows of *Leucaena leucocephala*;

  to study the effect of hedge height on the yield of the main food crop (*Zea mays*) grown in the alleys.

5.3.2 Experimental design and methodology

The study evaluated five cutting heights (0.1, 0.3, 0.5, 0.7 and 0.9 m) of hedges of *Leucaena leucocephala* (Origin: Melinda Forest Station/Melinda, Belize), a promising species for alley cropping at 1,500 m altitude on acid, leached soils in the bimodal highlands of East Africa. The statistical design of the study was a randomized complete block with five replications. The plot size was 3.5 x 5.0 m with one row of Leucaena in the centre of the plot and two rows of maize on either side of the hedge at a between-row spacing of 0.75 m and in-row spacing of 0.3 m (44,444 maize plants/ha). Leucaena was planted in east-west direction across the slope (<3%) in april 1988 at 0.25 m in the row and 3.5 m between the rows (14,430 trees/ha). A starter dose of 25 g of DAP per tree was applied, equivalent to 65 kg/ha of N and 166 kg/ha of $P_2 0_5$. The annual food crop in the first two rainy seasons (1988) was beans (GLP-2, Roscoco). It was maize (hybrid 512) intercropped with beans (GPL-2) in the first (long rainy) season of 1989 and it was maize (local cv. HDC) in the second (short rainy) season of 1989. Beans were fertilized with 100 kg/ha of DAP at the time of planting. Only maize in the long rains of 1989 was fertilized with 130 kg/ha of DAP and top dressed with 142 kg/ha of CAN, giving a total of 60 kg/ha of P_2O_5 and N. The local maize cultivar grown in the second rainy season of 1989 was not fertilized.

The Leucaena hedges were first cut back in November 1988 to the different management heights, about 7.5 months after planting, when Leucaena was 2.5 to 3.0 m tall and the root collar diameter was 2.5 to 3.0 cm thick. Subsequent cuttings were carried out at 2 to 3 months interval and synchronized to reduce light and moisture competition to the associated food crop. Thus, the hedges were cut shortly before sowing the food crop and again eight weeks later. At each cutting, the entire row was harvested and the side branches were trimmed to keep hedge width to about 0.5 m. During the initial and second harvest, the material was divided into leaves, twigs and stem wood (only at the first cutting). All material was then weighed fresh and removed from the plot.

5.3.3 Site description

The experiment is located within the same area as experiment 1 (MPTs species screening for alley cropping) and the site description given previously applies also to the currently discussed experiment. The site was a relatively flat (<2% slope), sandy area with impeded drainage and poor soil fertility, especially in respect of phosphorus. The soil pH (in water) was 5.0 - 5.2 in early 1988. At the start of the experiment in April 1988, soil samples were taken and analyzed for the following chemical components:

Average soil pH (in CaCl2; 1:2.5 ratio)................:	4.57
Organic Carbon (%)..:	0.68
Total available Nitrogen (%)..................................:	0.10
Phosphorus (P)(Bray no.21)(ppm)..........................:	(not yet available)

5.3.4 Results and discussion

5.3.4.1 Trees

Leucaena established well and grew vigorously in this climate. There have been no noticeable problems of stand mortality or pests and diseases so far. At first harvest, highest wood yield (2.6 kg/m of hedge) was realized when the hedges were cut back to ground level. Cutting at 0.9 m above ground level yielded 1.4 kg/m of stem wood (Table 25). These initial fresh yields are equal to 7.4 t/ha and 4.0 t/ha of firewood or stakes respectively, if hedges are planted 3.5 m apart. Leaf and small twig biomass yields were not significantly different between treatments for the initial harvest in November 1988. The coppice regrowth during the first dry period from November 1988 to February 1989 did not show significant differences between treatments, although the trend was towards the higher yields with increase in cutting heights. It seems that during the first three months after initial cutting, the difference in production potential could not yet come out convincingly, perhaps due to drought stress. As of the first (long rainy) season of 1989, significant differences in leafy biomass production were detected ($P < 0.001$) in three out of four cuttings (Table 25.). The preliminary conclusion is therefore, that hedges cut at higher cutting heights produce significantly more leafy biomass then hedges cut at lower cutting heights, if moisture is not a growth limiting factor.

Table 24. Fresh biomass yield in 1988 (initial) and 1989 (uniform cuttings) of *Leucaena leucocephala* hedges managed at five different cutting heights in an alley cropping system

Cut Ht.	Fresh Biomass Yield (kg/m of hedge) Nov.88	Feb	Apr	Jun	Sept	Nov	Total 88/89
0.1-lf	3.1	1.9	1.3	0.5	0.6	0.8	8.2
-tw	1.1	1.3	-	-	-	-	2.4
-wd	2.6	1.3	-	-	-	-	3.9
0.3-lf	3.0	2.4	1.5	0.7	0.9	1.2	9.7
-tw	1.1	1.7					2.7
-wd	2.1						2.1
0.5-lf	3.1	2.5	1.7	0.7	0.9	1.3	10.2
-tw	1.2	1.6					2.8
-wd	1.7						1.7
0.7-lf	2.8	2.4	1.7	0.8	1.0	1.5	10.2
-tw	0.9	1.6	-	-	-	-	2.5
-wd	1.3						1.3
0.9-lf	3.5	3.0	2.1	1.0	1.3	1.7	12.6
-tw	1.3	1.9					3.2
-wd	1.4						1.4
MEAN:							
-leaves	3.1	2.4	1.7	0.7	0.9	1.3	10.2
-twigs	1.1	1.6					2.7
-wood	1.8	-					2.1
S.E.D:							
-leaves	0.42	0.37	0.12	0.07	0.17	0.08	-
-twigs	0.20	0.25	-	-	-	-	-
-wood	0.42	-	-	-	-	-	-
C.V%							
-leaves	21.1	23.8	11.9	14.5	27.9	10.1	-
-twigs	27.4	24.4	-	-	-	-	-
-wood	37.0	-	-	-	-	-	-

note: lf = leaves; tw = twigs; wd = stem wood

5.3.4.2 Crops

The effect of hedge cutting height on the companion food crop(s) is equally important in choosing a particular hedge height for an alley cropping system. The bean crop planted in both seasons in 1988 and as intercrop under maize in the first rainy season of 1989 failed due to high rainfall early in the season and poor site drainage. It should be noted that hedge biomass was removed as fodder for livestock and manure was not returned to the plots. As a result, rapid nutrient depletion and loss of soil structure is expected which might have affected food crop yields.

Maize yields averaged 2.7 t/ha in the first (long) rains of 1989 and 3.1 t/ha in the second (short) rains (Table 26). Treatment differences were not significant, indicating that cutting heights between 0.1 and 0.9 m did not have any influence on the associated maize crop. However, low initial soil fertility status, rapid site fertility depletion and consequent low maize yields may have masked treatment differences. The coefficient of variation (CV%) was exceptionally high in both seasons; 55 and 38% respectively.

Table 25. Maize grain yield (13% mc) cropped in alley of *Leucaena leucocephala* hedges managed at five different cutting heights (m)

	Maize yield (t/ha)	
	long rains 1989	short rains 1989
Cutting Height (m)		
0.1	3.07	2.97
0.3	1.98	2.90
0.5	2.70	3.04
0.7	3.09	3.21
0.9	2.67	3.40
MEAN	2.7	3.1
S.E.D	0.942	0.746
CV (%)	55.1	38.0

6. NON EXPERIMENTAL ACTIVITIES

The AFRENA project in Maseno is involved in many non experimental activities. The staff members at the research station have developed close links with the local community and officials. Many farmers, teachers and their students, government officers and scientists from the region, as well as from elsewhere, have visited the station. Such visits serve as good occasions of interaction with potential users of the agroforestry technologies developed on the station. The comments received from farmers, scientists and other visitors have been taken particularly seriously because they form the input to new research ideas and may lead to amendments in the on-going work. The Agroforestry Research Centre activities are valued by the community because of their contribution to solving pressing land-use problems in the region, the demonstration function of the trials and the employment opportunities they have created for many people in the area. As such, the Centre and the project have had an impact on the local understanding of land-use issues and the potential of agroforestry.

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Annex 1. Staff List AFRENA on-station project (Maseno)

Staff	Institute/Position	Joined
Scientific staff		
Mr. J.H.O. Otieno	KEFRI - scientists	Feb-Aug. 1988
B.Sc/M.Sc. Forestry	KEFRI-KARI-ICRAF Agroforestry Research Centre Director and on-station project team leader	Nov. 1989
Mr. E.K. Mengich B.Sc. Forestry	KEFRI - scientist	Sept. 1989
Dr. A.D. Olang PhD. Agronomy	KARI - scientists (on-station project team leader: July 1988-Oct. 1989)	July 1988
Mr. A.M. Heineman B.A. social Science MBA Management Science M.Sc. Forestry	ICRAF - associate scientist (Dutch Government funded)	Nov. 1987
Administrative Secretary		
Mr. S. Juma	KEFRI	Oct. 1989
Field Technicians		
Mr. M. Odongo	KEFRI	April 1988
Mr. H. Wandabwa	KEFRI	Aug. 1988
Mr. M. Ng'ethe	KEFRI	May 1989
Mr. R. Cheruiyot	KEFRI	June 1989
Nursery foreman		
Mr. J. Owalo	KEFRI	Nov. 1988
Storekeeper		
Mr. J. Ogutu	KEFRI	Nov. 1988
Driver		
Mr. J. Ngala	KEFRI	April 1988
Typist/Receptionist		
Mr. C.O. Apondi	KEFRI	June 1989
Tea lady/Cleaner		
Ms. J. Kisanya	KEFRI	June 1989
Mrs. H. Mohamed	KEFRI	June 1989
Office messenger/cleaner		
Mr. T. Odhiambo	KEFRI	June 1989
Other staff		
Mr. W. Ochieng	KEFRI	June 1989
Mr. G. Ouma	KEFRI	June 1989

Annex 2. Experiment 10. Species list, treatment allocation and seed supply institution for Leucaena and Calliandra species/provenances, general screening trial

Treatment	MPTS Species and seed source	Seed supplying institution
T1	Leucaena leucocephala (Hengchun, China)	Seed harvested in Exp.3 in 1989
T2	Leucaena leucocephala (K8) Baobab Farm, Mombasa Gen. Coll.	KEFRI/KFSC
T3	Leucaena leucocephala (K28) (as T2)	KEFRI/KFSC
T4	Leucaena leucocephala (K636) (Coahuila, Mexico)	KEFRI/KFSC
T5	Leucaena leucocephala (14198)	ILCA/Ethiopia
T6	Leucaena diversifolia (K156) (Vera Cruz, Mexico)	KEFRI/KFSC
T7	Leucaena diversifolia (14193)	ILCA/Ethiopia
T8	Leucaena revoluta (14201)	ILCA/Ethiopia
T9	Leucaena paniculata (14203)	ILCA/Ethiopia
T10	Calliandra calothyrsus (CC-094-002-88) Patullil, Guatemala	KEFRI/KFSC

Annex 3. The mean height and root collar diameter growth (cm) of different provenances of *Leucaena leucocephala* at 14 months after planting

Treatment	Provenance	Mean height	Mean RCD
Leucaena leucocephala	Kibwezi, Kenya	341.8	7.37
Leucaena leucocephala	Hawaii	384.4	8.23
Leucaena leucocephala	Melinda, Belize	347.1	7.30
Leucaena leucocephala	Hengchun, China	365.0	7.82
Leucaena leucocephala	Yimbo, Siaya, Kenya	326.3	6.48
Grand Mean		352.9	7.44
S.E.D		13.17	0.268
C.V.% (plot)		4.6	4.4
(tree)		10.1	11.3

Annex 4. The mean height and root collar diameter growth (cm) of different provenances of *Gliricidia sepium* at 14 months after planting

Treatment	Provenance	Mean height	Mean RC
Gliricidia sepium	Guatemala	266.2	7.59
Gliricidia sepium	Santa Cruz, Costa Rica	218.0	6.59
Gliricidia sepium	Columbia	266.6	8.16
Gliricidia sepium	Monterrico, Taxisco, Guatemala	239.0	8.43
Gliricidia sepium	Chiquimala, Guatemala	273.3	6.48
Gliricidia sepium	Guyatenago, Guatemala	308.0	8.12
Grand Mean		261.9	7.71
S.E.D		21.39	0.375
C.V.% (plot)		10.0	6.0
(tree)		17.6	13.8

Annex 5. The mean height and root collar diameter growth (cm) of different provenances of *Calliandra calothyrsus* at 14 months after planting

Treatment	Provenance	Mean height	Mean RCD
Calliandra calothyrsus	Guatemala	441.8	9.08
Calliandra calothyrsus	Kibuye, Rwanda	406.8	8.15
Calliandra calothyrsus	Arboretum de Ruhande, Rwanda	427.2	8.80
Grand Mean		425.3	8.68
S.E.D		17.67	1.062
C.V.% (plots)		5.1	15.0
(trees)		12.3	17.5

Annex 6. The mean height and root collar diameter growth (cm) of different provenances of *Sesbania sesban* at 14 months after planting

Treatment	Provenance	Mean height	Mean RCD
Sesbania sesban	Kakamega, Kenya	497.8	8.62
Sesbania sesban	Mukururiati, Kenya	500.1	9.51
Sesbania sesban	Kiambu, Kenya	339.3	5.34
Grand Mean		445.8	7.82
S.E.D		27.24	0.891
C.V.% (plot)		7.5	14.0
(tree)		12.5	21.1

Annex 7. The mean height and root collar diameter growth (cm) of two provenances of *Cassia siamea* and one provenance of *Cassia spectabilis* at 14 months after planting

Treatment	Provenance	Mean height	Mean RCD
Cassia spectabilis	Bugarama, Rwanda	418.9	9.03
Cassia siamea	Bugarama, Rwanda	284.6	6.58
Cassia siamea	Kwale, Kenya	253.4	5.85
Grand Mean		319.0	7.16
S.E.D		25.1	0.42
C.V.% (plot)		9.6	7.2
(tree)		12.5	10.0