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A STUDY OF ALLEY CROPPING MAIZE AND GREEN GRAM WITH LEUCAENA LEUCOCEPHALA (LAM) DE WIT AT MTWAPA, COAST PROVINCE, KENYA

BY

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This thesis has been submitted for examination with our approval as University supervisors.

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PROF. D.N. NGUGI DATE

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DR. AMARE GETAHUN DATE

To my beloved parents

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ABSTRACT

Crop yields in the Kenya Coastal lowlands are low because of poor soil fertility and high weed infestation. The sandy soils (92% sand), deficient in all major nutrients N,P,K, are highly leachable and fertilizer application is necessary for good crop yields.

Green leaf Manure (GLM) from Leucaena leucocephala hedgerows (alleys) established in a split-plot systematic design with 5-replications were incorporated to boost soil fertility, by cutting them down to 0.5m from the ground level 2 weeks before maize crop planting. Two additional cuttings were made during the cropping season for additional GLM and to minimize Leucaena shading on the crop.

Assessment of crop yields and monitoring of soil fertility trends was carried out over a period of four years (1982-1985). It was observed that the usual trend of soil fertility decline that normally results with continuous cropping was reversed with the use of Leucaena alley farming. The system was even able to increase maize yield by 38% after four continuous cropping years, except for the period of tree establishment and pruning during which crops were significantly reduced due to excessive shade effect.

Soil tests also showed a gradual increase in soil % organic carbon, phosphorus, potassium, calcium, magnesium and pH over the control plot's. This was due to the high organic N-additions, up to 283Kg N/ha from Leucaena GLM, nutrients release from tree root death and decomposition, and finally, nutrients savings from uptake by weeds. In general, the higher the tree density/ha, the higher the concentration of soil nutrients including an increase in soil pH.

Significant weed control of upto 90% was achieved due to the fallow effect preceding the alley cropping. Besides, most of the difficult to control grass weeds were reduced in favour of the easier to control broad-leaved, non-grass weeds.

The Financial returns and savings from the sale and use of Leucaena fuelwood and GLM to the system were also remarkably high. Leucaena cuttings during one cropping season yielded 28.3 t/ha of fresh GLM.

CHAPTER ONE

1.0 INTRODUCTION

Maize yields at the sub-humid Coastal strip of Kenya are low, averaging only 900-1000Kg/ha (Anon, 1983b), despite good rainfall in the area. Similarly yields of green gram, a popular rotation crop of the area in the short rains with maize are also low, 400Kg/ha (Muturi, 1981). The major reasons for the low yields are poor soil fertility levels (with high leaching rates) and weed problems. Because of the hot humid conditions, weeds grow fast and cause more crop loss (42%) than pests and diseases combined (Michieka, 1981). The soils are sandy loam with 92% sand, and are deficient in all the major nutrients (N,P, and K). Therefore, fertilizer application is critical for high maize yields. However, fertilizer costs and the poor facilities (supply of fertilizers and access roads problems) existing in the area, at times prevent efficient distribution and use of fertilizers. Besides, even when fertilizers are used in the area, they have low residual effect as they are leached fast. Thus, the fertilizer adoption rate in the area is indeed very low, only 2% (Muturi, 1981). Farm yard manure could potentially be used to improve soils, but since the amounts required, 7.4t/ha/year (Grimes and Clarke, 1962), or equivalent N,P,K, are prohibitively large, it is not an easy alternative.

In addition, firewood (the major source of energy for the area) is increasingly becoming deficient, especially in and close to urban settings. Over 80% of the rural population in Kenya use fuelwood as their source of energy (Anon, 1984c). It was against this background of crop production problems and projected fuelwood shortages that alley cropping with leguminous multi-purpose trees such as <u>Leucaena leucocephala</u>, L. Salvadorian-K28 variety, hereafter simply referred to as Leucaena, was identified as an important research topic. It was felt that such a system could improve soil fertility levels through atmospheric nitrogen-fixation and mulch/green leaf manure production, control weeds through shading effect (when there is no crop in the field i.e. dry season), and provide firewood/staking materials as by-products of tree management practices.

1.1 JUSTIFICATION FOR THE EXPERIMENT AT THE COASTAL BELT:

The coastal belt of Kenya is an important agro-ecological zone with characteristics peculiar to itself. The climatic conditions, soils, crops and the agricultural pests prevailing in the belt are very different from those found in the Kenya highlands (Muturi, 1981) and the arid/semi-arid lands. The soils of the coastal belt range from loamy to sandy-clay loam and are generally heavily leached, acidic, pH 4.2 - 6.7 in nature, and have low cation exchange capacities. Consequently, fertilizer application is a must for high crop yields. Yet fertilizers are expensive and have low residual value compared to organic manures. The high rainfall, temperatures and relative humidity (over 60%) (Appendix 8.1) also favours pests, diseases, and weed infestation, the latter causing as much 40-42% crop loss (Michieka, 1981, Anon, 1984a).

Despite these negative crop production factors, the coastal belt is quickly becoming densely populated compared to other drier parts of the Coast Province. The pressure on the land is further increased by movement of landless people from other densely populated areas e.g. Central Province, in search of farming land and employment.

About one-third of the Coast Province (28,000Km^2) is considered suitable for agriculture (Warui, 1982). Land pressure is gradually breaking the traditional systems where trees and limited food crops are intercroppd, a system stable enough to balance the chemically and physically poor soils. The system allows slow mineralization of potassium and phosphorus besides providing effective protection from soil erosion. On clearing, however, the soil may not stand intensive arable cropping for long (Muturi, 1981). Besides, fuelwood demand and consumption in the area are gradually having increased impact on the land (Getahun, 1982). Since integrated tree-crop farming has long been the agricultural practice of the area, it is envisaged that a continuation of the same with the added emphasis on multi-purpose trees such as Leucaena, could ameliorate, both food production problems (e.g. soil fertility decline and weed control) and also provide useful products (food, fodder, and fuelwood).

1.2 SPECIFIC OBJECTIVES

The specific objectives of the experiment were two-fold:-

(a) To determine the effect of different row and within-row spacings of Leucaena leucocephala on yields of intercropped maize and green gram crops.

(b) To determine biomass yield (green leaf manure/fodder and firewood/staking materials) from the intercropped Leucaena alleys under the different tree management factors imposed.

CHAPTER TWO

2.0 LITERATURE REVIEW

The positive role of multipurpose trees (MPTs) in mixed farming systems that have been infrequently studied may prove themselves to be very valuable for agroforestry. This arises out of the experience with traditional shifting cultivation and the subsequent fallow period and lands thereafter created. Environmental resources, both in spatial and temporal terms, and both above and below ground, can usually be better shared between a mixture of species than by sole cropping. This is one of the advantages of mixed cropping (Huxley, 1985). Yadav (1982) investigating the nitrate-N profile of soil in sole and parallel multi-cropping system of maize and beans in India observed that there was nitrate-N in the deeper horizons due to leaching from inter-row spaces of single crop system, whereas the nitrate-N content beyond 30cm depth was drastically reduced in multi-parallel cropping because it was better utilized by the crops.

Legume intercropping in cereals has also been reported to reduce N-leaching (Singh et al., 1978), and its positive effect in the conservation of soil N has also been demonstrated by Yadav (1981). The practice of intercropping, particularly with MPTs, besides reducing nutrient leaching, could also reduce the long fallow cycle of traditional agriculture to one-year period, which could mean an increase in arable crop land and therefore crop(s) produced.

Agroforestry therefore, a form of planned fallow lands, has been suggested as a substitute for the fallow lands of shifting cultivation in modern sedentary agriculture due to increasing human population pressure.

Scattered examples of the preservation and use of naturally occurring leguminous trees for fertility maintenance in indigenous farming systems (Okigbo and Lal, 1978) and the results of early research on planted fallows and 'alley cropping' systems for cereal and root crop production between rows of leguminous trees (Pareira, 1978, Benge, 1979, Wilson 1979) have demonstrated the potential of such systems to maintain high soil nitrogen levels (Raintree, 1980).

Alley cropping is a system in which the crops are grown in the interspaces (or alleys) between rows of woody shrubs, which are pruned periodically during the cropping season to prevent shading and to provide green manure and/or mulch to the arable crops (Getahun, 1980, Kang et al., 1981, Anon, 1982a, Balasubramanian, 1983, Nair, 1984). The larger branches are used for poles or fuelwood. In the dry season, the trees are allowed to regrow and draw nutrients from deep soil levels (Kang et al., 1984), aiding in the recycling of leached nutrients from the sub-soil back to the surface, by means of leaf drop and/or foliage pruning, where they can be used by shallow rooting arable crops such as maize (Raintree, 1980).

Alley cropping is an adaptation and a refinement of the bush fallow system commonly practised by small scale farmers in Africa (Wilson and Kang, 1981). Encouraging results have been obtained from alley cropping studies conducted at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria (Hartmans, 1981, Wilson and Kang, 1981,) where the practice originally acquired its name. The choice of deep rooting leguminous trees such as Leucaena not only lends a measure of the much needed drought resistance to the system, but also the canopy developed during the dry season could also control weeds (Kang et al., 1984)

Species selected for alley cropping must however be easy to establish, fast growing, deep rooted, coppicious, have the ability to withstand frequent prunings and be able to produce heavy and easily degradable foliage (Wilson and Kang, 1981). These properties as well as biological nitrogen fixation (BNF) are possessed by Leucaena (Guevarra, 1976).

2.1 PROPERTIES OF LEUCAENA LEUCOCEPHALA

Leucaena is a multipurpose plant with a large number of uses, e.g., fodder (mainly for ruminants), fuelwood (24-100m3/ha) (Anon., 1980b) and wood (pulp, paper, construction). It also provides service roles such as soil conservation and fertility improvement through Biological Nitrogen Fixation (BNF) and green leaf manure. Besides, it helps break impervious sub-soil layer, improve water percolation and prevent surface runoff (Anon, 1980b, Nair, 1984). Salvadorian-type Leucaena is a deep rooted plant, with an aggressive tap root that can penetrate deep into the soil and thus enable the plant to withstand drought (Jiang, 1982).

Leucaena is a fast growing species and has a range of varieties from tall and slender (to 20m tall) to bushy types (to 5m), with deep roots of upto 2.5m (Djikman, 1950).

Leucaena coppices well. Its coppicing ability allows repeated harvests for firewood, timber and foliage (Brewbaker, 1984). Stumps from plants of almost any age, variety, quickly resprout new shoots. Coppice regrowth is much more vigorous than seedling growth because the new shoots are served by a well developed root system.

New shoots of giant varieties are said to reach 6m in 12 months from cutting (Djikman, 1950). Leucaena can grow in a wide range of environments ranging from semi-arid low rainfall (250mm in Hawaii) to areas of high rainfall (600-1700mm), with heavy clay and alkaline soils. Once Leucaena is established, it has several advantages such as:-

(a) Leached plant nutrients are recycled from sub-soil,

(b) Provide biologically fixed nitrogen to the companion crop,

(c) Provide favourable conditions for soil macro- and micro-organisms,

(d) Provide prunings, applied as mulch, and shade during the fallow period to suppress weeds,

(e) Protect soil against erosion, especially if planted along contours, and

(f) Provide an inexpensive source of stakes for yam vines, provide fuelwood and fodder and its seeds are often used as human food (Ngambeki and Wilson, 1983).

2.2 EFFECT OF LEUCAENA AS ORGANIC FERTILIZER IN MAIZE PRODUCTION

Scientists have investigated the use of Leucaena hedgerows/alley cropping with maize as an alternative low nitrogen input system, in which maize yields can be sustained at a relatively low level without nitrogen inputs (Guevarra, 1976, Kang et al., 1981, Ngambeki et al., 1983). Such a system would not only be sustainable in terms of nitrogen requirements, but it could also contribute to reduction of both soil erosion in the uplands (hedges are planted along contour lines) and help to reduce the ever increasing fuelwood shortage (Torres, 1983).

Kang et al., (1981) investigated the effectiveness of Leucaena prunings, what they referred to as Green Leaf Manure (GLM) as nitrogen source for maize, using both field and pot trials, in sandy Apomu soil (Psemmentic Usthorthent) at Ibadan, Southern Nigeria. The GLM significantly increased N-uptake of seedlings and N-percentage in ear and leaves of maize. High maize grain yield was obtained with application of 10 tons fresh GLM and N at 50Kg/ha. With no N-application or removal of the Leucaena tops after each prunings, maize grain yields were significantly lowered by a total of about 46 per cent compared to those in which the prunings were retained.

The prunings (GLM) as N-source appeared most effective when incorporated than when applied as surface mulch. This can be explained in terms of faster rate of mineralisation of the incorporated GLM, within 1-3 weeks, (Weeraratna, 1982) and possibly reduced loss of N due to volatilization than with surface mulch (Evensen, 1982). Likewise, the lower efficiency of broadcast prunings, could partially be attributed to ammonia-N volatilization loss during decomposition under high temperature conditions in the field (Messan, 1980). Largely because of these losses, only about 65% of nitrogen in Leucaena is available for the crop growth (Brewbaker and Evensen, 1984).

Evensen, (1982), further showed that Leucaena GLM surface mulching to be only 41.2% as efficient in supplying N to maize as in urea. These efficiencies were however higher than Guevarra's (1976) 38% value because

Guevarra used chopped whole Leucaena foliage including the woody fraction. Woody materials would release N slowly during their decomposition and therefore decrease total available-N.

In the pot trials, pruning applied two weeks before planting was more effective than when applied at time of planting maize. Under green house conditions, the apparent N-recovery from maize with early pruning about equalled that of fertilizer N. IITA studies (Anon, 1982a) also showed that, at equal N-rates, the prunings are less effective than inorganic fertilizer. This effect, may in part, be due to the fact that applying the prunings only once at planting may not be as effective as the inorganic fertilizer-N which was split applied.

Crop yields and the growth of Leucaena from two year-old study plots showed no serious disadvantage from the establishment of Leucaena through intercropping (Table 1).

Table 1: Effect of application of Nitrogen and Leucaena prunings on Grain yield of Maize variety TZPB grown in alleys between Leucaena hedgerows*:

Nitrogen rates (Kg/ha)	Leucaena prunings added at time of planting (fresh weight, t/ha)		
	0*	5**	10***
0	2109	2732	3221
50	2572	3166	3256
100	3377	3450	3432
LSD 0.05	296		

(Adapted from Kang <u>et</u> <u>al</u>., 1981)

* Leucaena tops from two prunings carried out during maize-growing season were applied as mulch to all treatments.

** Prunings were removed from this treatment at planting.

*** Supplemented with Leucaena prunings from outside the experimental area.

The use of Leucaena tops maintained maize yields at a reasonable level; even with no additional nitrogen input on low fertility sandy inceptisoils. An increase of 40% in maize yields from two-year alley cropping with Leucaena over control plot of maize alone at IITA which had the same basal fertilizer rate and maize population density has also been reported (Anon, 1982a). The effect of nitrogen contributed by the

Leucaena mulch on maize grain yield was about 100Kg N/ha for every 10 t/ha of fresh prunings. Other studies at IITA showed higher N-yields of 189-250Kg/N/ha from 5,000-8,000Kg/ha dry leaves with 3.2-3.5% N-content (Table 2) (Kang et al., 1981).

Table 2: Nitrogen contribution by various leguminous woody species interplanted with maize in alley cropping trials at IITA, Ibadan, Nigeria

Shrubs	Leaf yield (dry weight) (Kg/ha)	N-Content	
		%	Kg/ha
Gliricidia sepium	2,300	3.7	84
Tephrosia candida	3,067	3.8	118
Cajanus cajan	4,100	3.6	151
Leucaena leucocephala	5,000-8,000	3.2-3.5	180-250

(Adapted from Kang et al., 1981, Wilson and Kang, 1981)

The use of "Giant Hawaiian" Leucaena as green manure for maize applied on the soil surface has also been studied by Guevarra (1976). Plots receiving Leucaena leaves yielded 4.2 t/ha compared to check plots, which gave 1.8t/ha only. The former even yielded more than those plants treated with inorganic fertilizer at the rate of 75Kg/N/ha.

Besides GLM, biological nitrogen fixation (BNF) is yet another important attribute of Leucaena. Under favourable year-around growing conditions, nitrogen fixation rates as high as 500-600Kg/ha/year have been measured (Guevarra, 1976) in Hawaii. However, lower yields of 100-200Kg/N/ha/year (equivalent to 50-100Kg Ammonium phosphate/ha/year) have similarly been measured (Halliday, 1984) in Hawaii.

In principle, nitrogen fixation occurs only if the correct rhizobium strain is present in the soil. However, Leucaena has the ability to form a symbiotic relationship with a variety of rhizobium types. But the rhizobium strains that Leucaena has a symbiotic relationship with is not specific to the plant. Seed inoculation is therefore not normally needed, especially if other leguminous species such as Mimosa, Sesbania, Gliricidia and Calliandra grow in the area (Anon, 1984d).

In addition to Rhizobium, the fine roots and root hairs are also usually infected with beneficial mycorrhizal fungus whose vast network of hyphae aids the plant in obtaining and making more efficient use of mineral nutrients. This helps Leucaena to grow in soils low in minerals such as phosphorus (Anon, 1984d). Mycorrhiza has been found helpful in increasing the uptake of phosphorus, particularly in soils with low P-levels. Phosphorus helps improve root nodulation and increased plant height and dry matter yield (Hedge, 1982).

The stimulation of regrowth in Leucaena and other legumes following pruning has recently been shown to activate nitrogen fixation (Rachie, 1983). Leucaena is therefore, more efficient both in growth and nitrogen fixing ability following topping as compared with normal growth (Evensen, 1982). Leucaena pruned at one metre high at three months intervals can yield 500-600Kg N/ha per year (Escalada, 1980).

Leucaena provides more than just nitrogen; mineral elements such as phosphorus and potassium, absorbed by the roots from deep soil become incorporated into the foliage. This helps Leucaena grow in soils low in minerals such as phosphorus (Brewbaker, 1984). In Hawaii, Leucaena foliage harvested from one hectare after one years growth contained 44Kg of phosphorus and 187Kg of potassium, as well as calcium and micronutrients (Anon, 1984d). Similar studies in the Phillipines (Anon, 1977) have demonstrated that a well grown Leucaena plot can yield around 87.3Kg of Phosphorus and 375Kg/ha/year of Potassium. Significant amounts of calcium and other minerals will also be included.

Though the efficiency of N-utilization by maize from Leucaena leaf mulch is low - 38%, perhaps due to fast rate of decomposition to humus, (after only 2 weeks), the maize - Leucaena alley cropping can still be utilised as a low-input system (Guevarra, 1976). Addition of Leucaena GLM from full grown hedgerows was able to sustain maize grain yield at about 3.8 t/ha year for two consecutive years with no N-addition, while with no addition of prunings, maize grain yields declined. Higher maize grain yields were obtained by supplementation with low N-rates of 20-80Kg N/ha depending on variety and soil (Kang et al., 1981). However, Evensen (1982) reported yields of maize grain of almost 5.0 t/ha was obtained by incorporation of 150Kg GLM N/ha and with no supplemental fertilizers. (Table 3).

Table 3: Maize growth and yield response to various N-treatments in Hawaii

Treatment N(Kg/ha)	Grain yield 15.5% moisture (Kg/ha)	Total Dry Matter	% of ears < 10cm	Mean plant height to top of tassel (cm)
Urea 100	5490 a*	10,500	2.1	238
GLM INC. 150	4870 a	9,620	6.4	215
Urea 75	3840 b	8,180	18.3	225
GLM INC. 100	3430 bc	7,260	20.1	215
Urea 50	2950 bcd	6,190	34.0	212
Urea 25	2540 cd	6,240	28.7	209
GLM MUL. 100	2180 d	5,560	36.6	188
GLM INC. 50	2100 d	5,050	45.4	184
NO NITROGEN	415	2,730	87.6	167

(Adapted from Evensen, 1983)

Note: GLM INC. = Green Leaf Manure Incorporated.
GLM MUL. = Green Leaf Manure Mulch.

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Other studies (Rachie, 1983) of intercropping in comparatively fertile soils at Centro Internacional de Agricultura Tropica (CIAT), Cali, Colombia, have shown that maize yields varied only slightly under various treatments of Leucaena population and espacements as shown in Table 4 and 5.

Table 4: Maize height reduction and grain yield in association with Leucaena at CIAT, Colombia

Leucaena population (plants/ha)	Planting distance (cm)	Height reduction* %	Maize Yield**t/ha
13,000	24 x 300	16	5.4
20,000	25 x 200	16	5.5
40,000	25 x 100	25	4.9
40,000	50 x 50	29	4.5

(Adapted from Rachie, 1983)

* Forty days after planting compared to check.

** Adjusted to 15 per cent moisture content.

Table 5: Maize heights reductions and grain yields when grown in association with Leucaena at CIAT, Colombia

Leucaena population (plants/ha)	Maize population, (plants/ha)	Height* reduction %	Maize Yield**t/ha
0	25,000	0	4.6
0	50,000	0	5.2
10,000	25,000	2	4.7
10,000	50,000	11	4.6
20,000	25,000	0	4.2
20,000	50,000	12	4.9
40,000	25,000	10	3.5
40,000	50,000	15	4.9

(Adapted from Rachie, 1983)

* Forty days after planting compared to check

** Adjusted to 15 per cent moisture content

These studies indicated very little competition by the Leucaena with maize, when cut-topped to 10-20cm, and GLM and branches used as organic manure.

The slight decrease in maize yields grown in association with Leucaena is understandable since CIAT soils are relatively highly fertile, and therefore little response from nutrients re-cycled by Leucaena foliage was expected at the outset (Rachie, 1983). However, some reduction, in plant height occurred in maize intercropped with Leucaena, although this effect was not reflected in the final yields. From these studies, Leucaena population of 10,000 to 20,000 plants/ha at CIAT appeared adequate to provide sufficient foliage to cover soil and supply sufficient quantities of nutrients without competing with maize. The effects however depend on site conditions (soil's fertility and climatic conditions prevailing) and cannot therefore be generalized.

In the CIAT experiment, mulch from dry season Leucaena pruning and toppings, and tree management practice such as pruning 4-6 weeks after crop is sown was instituted as a measure to support the maize crop.

In Morogoro, Tanzania, trials were laid out in 1980-1981 with Leucaena (intercropped with maize and beans in separate plots) to evaluate its potential in food and fodder production under various regimes of lopping, and a variety of weeding regimes (Maghembe et al. 1980). The yield of maize and bean crops was improved. The mean yield of maize was 1645Kg/ha and was greater than twice the national average yield of maize in Tanzania (i.e., 670Kg/ha) (Acland, 1981). The mean yield of beans was 401Kg/ha, an average yield by farmers' standards (Acland, 1981). Tree growth was similarly enhanced because of the nursing effect of the crop against weed competition, protection from browsing by both domestic and wild animals and the creation of favourable micro-climate for the trees (Redhead et al., 1983). The fact that the food crops are weeded has a beneficial effect on the young trees, even more than the 'spot' weeding carried out as normal Tanzanian forest practice (Redhead et al., 1983).

In some parts of Asia, Leucaena and Sesbania grandiflora are among legumes recognized as efficient soil fertility restorers (Guevarra, 1976, Anon 1977). Gill et al., 1982 investigated the effect of Leucaena foliage compared to Sesbania foliage as source of green manure. The results demonstrated the usefulness of Leucaena foliage as a source of green manure (though actual yields were not given by the author) and subsequently an important source of manuring the crops for tropical and sub-tropical climatic conditions. Besides increasing crop production, Leucaena provided organic matter that improved the soil's properties - increasing aeration, water retention, and cation exchange capacity.

Intercropping studies of Leucaena in India showed that the production potential of Leucaena appears to be much higher when associated with a crop (sorghum) than when sown alone (Gill, 1985) - perhaps because of complimentarity effects rather than competition.

In Brazil, Leucaena used as green manure at the rate of 5t/ha increased bean yields (Phaseolus vulgaris) from 1.4t/ha for the unfertilized control to 2.2 t/ha (Kluthcouski, 1980).

Torres (1983) for example, used information available to formulate quantitative hypothesis on the impact of intercropping Leucaena hedgerows with maize upon the physical productivity of grain and fuelwood in the lowland tropics. Torres observed that data available would indicate that the production of organic nitrogen (N) by Leucaena hedgerows cut approximately every 8 weeks at a height of 15-30cm and planted at a distance between rows wider than 150cm is 45gm yr^{-1} per line or meter hedgerow. In addition, Torres deduced from the published data that "the impact of hedgerow intercropping on maize productivity, although substantial, would be limited to systems where existing production levels of maize are lower than 1500Kg/ha. As expected, production per hectare decreases as spacing of Leucaena hedgerows increases".

This latter hypothesis of Torres is supported by Alvarez et al. (1984) studies in the Phillippines. They observed that a higher grain yield of maize was obtained in plots where Leucaena intercrop was established in single hedgerows spaced two metres apart than in plots with triple hedgerows spaced five meters apart. The maize yields were higher in the single as opposed to triple because the fresh herbage yield from subsequent growth over four cutting periods and applied to the maize crop as organic fertilizer were consistently higher in plants established in single hedgerows as compared to those of the triple hedgerows. Soil organic matter content, pH and exchangeable K were not significantly affected by Leucaena herbage nor by inorganic fertilization.

Torres (1983) further noted from the information collected that "at the close spacing, hedgerows would produce enough fuelwood per hectare to satisfy the yearly needs of approximatley 4 people, assuming a specific gravity for Leucaena wood of 0.46 and per capita consumption of 0.85 cubic metres". Torres' deduction, however are for a given ecological condition, Leucaena variety used and above all management practices instituted (e.g. pruning height at 15-30cm) and cannot be generalized.

Other studies in the Philippines have shown that Leucaena contains 20-36Kg of N/ton, 1.5-5.0Kg P/ton and about 13-24Kg K/ton of dry matter (Fori, 1976). Brewbaker (1975) observed that the fertilizer equivalent of a years harvest per ha of "Hawaiian Giant" Leucaena is estimated to be more than 550Kg N, 225Kg P_2O_5 and 550 Kg K_2O .

In Torres' analysis, shading effect on the crop by the tree was discarded because of the low cutting height (15-30cm) used. But production of intercropped maize could also be affected by the competition arising from the adjacent Leucaena hedgerow. Kang, et al., (1981) studied this competitive effect and concluded that shading from Leucaena hedges was the main factor affecting yield of the adjacent maize rows (in their experiment, hedges were cut at 1-1.5m high).

In assessing the quantity of dry matter and nitrogen that can be produced from Leucaena, Pallad et al., (1983) reported that the highest total dry matter production and nitrogen per hectare was obtained from high tree/crop ratio. If such green manures can be produced during the course of the normal cropping season without affecting crop yields, it may be possible to supply, at least partially, the nitrogen requirement of subsequent crops.

Other experiments in Hawaii and the Philippines have also shown that Leucaena foliage placed around maize can boost maize yields with increases similar to those achieved with manure or inorganic fertilizers (Guevarra, 1976). A yield increase of 1.0 ton of maize required only 1.0 ton (dry weight basis) of GLM, the equivalent of 4.0 tons of freshly harvested foliage with 4% nitrogen (Guevarra, 1976).

Similarly, it was observed in India that Leucaena leaves used as a source of manure recorded the highest plant height, number of leaves/tiller and fresh weight of fodder oats as compared to controls of urea, Sesbania sesban and Desmanthus virgatus (Gill and Patil, 1984). It was also observed that maize crop manured with herbage from intercropped Leucaena produced as much grain (3.0 t/ha) as pure stand of maize (without Leucaena intercrop) fertilized with 60-30-30Kg/ha NPK.

Mendoza et al., (1981) also recorded good responses of maize to Leucaena fertilization in Taiwan, where yield of green maize increased from 1.48t/ha in unfertilized check plots to 4.06t/ha from plots with incorporated foliage. Good maize yields from land fertilized with Leucaena cuttings were also reported by Granert (1980). He obtained maize grain yields of 2090Kg/ha compared to the Philippines national average of 840Kg/ha.

Other researchers such as Pathak and Patil (1982) studied the value of Leucaena as green manure on red, gravely murram soils at Jhansi, India. Leucaena planting (40,000 plants/ha) of different durations were established and were followed by a cereal fodder crop. They found that, compared with control plots, 30Kg/N/ha gave a 36% increase in the yield of the first crop but no increase in the successive crop of grass. However, with increasing periods under Leucaena plantings, there were increasing levels of improvements in the first cereal fodder crop and also in the second crop. The Leucaena GLM improved yields by as much as 150% for the first crop and 84% for the second crop when soil fertility was allowed to regenerate under Leucaena plantings for 2 years.

2.3 TREE MANAGEMENT: SIMULTANEOUS FODDER AND FUELWOOD PRODUCTION

The giant *Leucaena leucocephala* varieties are known to produce substantial biomass (fodder and fuelwood) (Brewbaker and Hutton, 1979). At Ibadan, a well established hedgerow of *Leucaena leucocephala* variety K-28 grown on a sandy Entisol at 4m inter-row spacing produced between 15 and 20 tons of fresh prunings (5.0 to 6.5 tons dry matter) per hectare with 5 prunings per year (Kang et al., 1984). When allowed to grow uninhibited for one year in the Ibadan trials, the Leucaena hedgerow easily reached a height of over 7.5m and produced more than 88 tons of wood per hectare.

For the Salvadorian varieties, e.g., K28, harvesting should be done leaving a taller stump than other varieties so that several axillary buds are retained (Hedge,1982). The higher cutting requirements of the Salvador types are apparent from a study in which a uniform height (5cm) was maintained for both Hawaiian and Salvadorian types; the former markedly out-yielded the latter (Guevarra, 1976).

Takahashi and Ripperton (1949), studying the Hawaiian type, obtained the highest yield (50.9t/ha) of green forage when Leucaena was cut at 5cm above ground. At 38cm and 76cm, yields were 43.40t/ha and 40.28t/ha respectively. However, Pereira (1982) observed that periodic pruning at higher points, 75-80cm, prevents Leucaena from becoming weeds, which they do at lower heights, a practice making them unacceptable to farmers.

In a trial conducted in the Philippines (Mendoza et al., 1975), highest annual dry-matter yields (23.6 t/ha) were obtained when plants were maintained at 3m high and the leaves were plucked. Also yields were maximized when 25% of the foliage were left on the plants (Mendoza et al., 1975). A cutting height of 30-50cm has been recommended in Hawaii (Kinch and Ripperton, 1962) while in india, harvesting at 90-100cm produced good yields as well as minimizing the labour cost for weeding and manual harvesting (Hedge, 1982).

Other studies suggest that plants can frequently be coppiced but will have a longer and more productive life if stems are allowed to reach 3cm thick in diameter before the first cutting and are cut at 0.3-1.0m height, and allowed to regrow for 3 months in the rainy season and 4 months in the dry season (Prussnar, 1981). In many cases, poor performance of hedgerow can be traced to too early pruning (Pereira, 1980). Moreover, the trees can be cut back and kept pruned during the cropping period and leaves and twigs applied to the soil both as mulch and as nutrient source with the bigger branches used as stakes or firewood.

Guevarra (1976) and Ferraris (1979) in Hawaii and Australia respectively found out that harvesting at monthly intervals brought down the yield of fodder as well as the nutritive value. Sampet and Pattaro (1979) also reported that frequent harvests (every 4-6 weeks) in Thailand reduced the woody yield. In Papua New Guinea, under adequate moisture conditions, the crop was ready for fuelwood harvest in 6 weeks during the summer months (Hill, 1971).

Leucaena, however, can only serve one main purpose at a time. For example, the most leaves are produced when the tree is frequently coppiced and, hence does not continuously produce seeds or wood. If both seeds and leaves are desired from one plant the production of both will be lower than if only one product (i.e. seeds or leaves) is regularly harvested.

The supply of fuelwood from the system therefore depends on the effect of interval and intensity of cutting of the tree. Das (1981) reported from a drought prone area of India that cutting at one metre height above ground and at interval of 60 days yielded more foliage compared to those cut at other intervals, while cutting at one metre height under 90 days interval yielded more fuelwood. Osman (1981) in Mauritius investigating the effects of cutting interval on relative dry matter production of 4 cultivars of Leucaena reported that a cutting height of between 45 and 90cm is recommended for maximum yields of dry matter.

Therefore, it seems that the choice of cutting height and interval will be determined by the users' priority needs from that system (food, fodder and fuelwood considerations), and the coppicing ability of the variety under the given set of environment (rainfall, temperature and soil) and management conditions. For example, in the IITA studies, the system was designed with alley widths of 2m for hand tools and 4m for tractor oriented maize production (Wilson and Kang, 1981).

2.4 <u>WEED CONTROL BY LEUCAENA ALLEY CROPPING</u>

Leucaena alley cropping has the potential to reduce weed infestation through shading during the dry season (Anon, 1984b, unpublished data, Kang <u>et al</u>., 1984). The early ground cover of Leucaena achieves good weed control through shading (Hedge, 1982).

The understorey of Leucaena plantations often carries very few weeds, although a substantial number of Leucaena seedlings may be present (Wildin, 1980). Although an allelopathic mechanism has been proposed to explain mature Leucaena's ability to suppress other plants, and although mimosine has been shown to be allelopathic in vitro, shading is a more plausible explanation, as weeds thrive in stands with mature, but partially opened canopies (Anon, 1982b).

Caution however is needed in the use of Leucaena for erosion control. Planting solid stands of Leucaena at high populations on steep slopes is not recommended because ground cover will usually be shaded out, more so when the foliage is cut for forage or green manure. The result is exacerbated erosion, as water flows freely down the slopes between the trees (Anon, 1982b). The tap-root system of Leucaena makes it unsuitable for binding surface soil, a situation leading to excessive soil erosion especially under dense pure Leucaena stands (Pound et al., 1983). It has therefore been suggested that interplanting or strip planting of a second species or planting a shade tolerant "live mulch" grown under Leucaena crop (Tergas et al., 1978) could be a solution. Low profile legumes such as Centrosema pubescens or Psophocarpus palustris would seem possible candidates (Pound et al., 1983). Nevertheless, the aggressive and deep rooting system break up and aerate impervious soils (Djikman, 1950), allowing greater water infiltration and surface runoff and soil erosion are thus decreased (Anon., 1980b). Moreover, the litter and the humic layers on the soil surface act as a cushion against erosion (Nair, 1984). Loppings and prunings could also provide mulch to aid in preventing sheet erosion between trees.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL DESIGN AND TREATMENTS

Leucaena leucocephala (Lam) de Wit, Salvadorian variety K28 seedlings, 20-35cm tall, raised in polythene tubes in sunken nursery beds were planted in single rows in May, 1982 in an area which had been ploughed and harrowed by tractor. The area had previously been a cattle grazing paddock. The planting was in a split-plot systematic design with row spacing (2, 4 and 8m) forming the main plots, while within row spacing (0.5, 1.0, 2.0 and 3.0M) constituted the sub-plots. Each of the tree spacing combinations (treatments) was replicated five times within the main plots. The soil was a homogeneous sandy loam with a 0-1% slope.

The experimental sites measured 65 x 70m (Appendix 8.2) and the plots were surrounded on all sides by 4m strip planted with crop only (green gram during October-December 1984 and maize during March-August 1985), to serve as the external guard rows. The internal rows of trees formed internal guard rows between treatments.

Experimental variables under test were 12 different tree row and within row spacing combinations (Appendix 8.3), giving 8 different plant population densities (Appendix 8.4). These were intercropped with maize (Zea mays L.) or green gram (Phaseolus aureus Roxb.) .

Maize (Coast Composite variety) was planted at 90 x 30cm., (one plant per hill, approximately 37000 plants/ha) in the long rain seasons

(April-August), while green gram was planted at 45 x 15cm in the short rain seasons (October-December) as per the agricultural recommendations of the area (Muturi, 1981). A control plot (no trees), also replicated 5 times was maintained with the same crop managements practices as the intercropped plots.

Cassava (Manihot esculentus) was intercropped with the trees during the first year. Cassava was used as nurse crop for the young trees against excessive radiation and weeds. Yield performance of the cassava crop was not measured.

Leucaena trees performance (% survival and mean heights) after 8 months were recorded during the tree establishment phases.

Systematic designs (Bleasdale, 1967) are not randomized and therefore statistical analysis requiring randomization are not appropriate (Huxley, 1983). Even so, such analysis are often used on non-randomized data and so are used here, one of my justification for this being the homogeneity of the soils in the experimental plots. The homogeneity aspect of the soils minimizes the need for randomization. The statistical analysis in this thesis must then be taken with this in mind. Duncan's Multiple Range Test (DMRT) was used to test the significant differences between treatment means. Significance levels were expressed at P = 0.05 and alphabetical letters are used in Tables to denote significant differences by DMRT, while standard errors (S.E.) of means and % coefficient of variance (C.V.) are displayed at the bottom of the Tables. The Analysis of Variance (Anova) of the reimposed split-plot design (Snedecor and Cochran, 1972) of the tree spacing (treatments) results is shown in Appendix 8.5.

3.2 TREE MANAGEMENT PRACTICES AND DATA COLLECTED

The tree management phases viz: establishment, pruning and coppicing determined what critical data for the tree/crop were collected.

3.2.1 Tree establishment phase (May 1982-September 1984)

This was a phase of no tree management and in which cassava formed the initial nurse crop. No crop data on cassava was collected. The critical data however collected during this phase was:-

(a) tree % survival during the dry months, 8 months after planting and

(b) tree heights (m), as a measure of growth.

Tree heights were taken from the bottom to the tip of the tallest branch, using a scaled pole. This method was used for tree height measurements at all later management phases.

3.2.2 Tree pruning phase (October 1984-February 1985)

During this phase, pruning the 2.5 year old trees to single stem was carried out in October 1984 in order to reduce excessive shade for the companion green gram crop. Plate 1 indicates the growth rate and extent of canopy closure of 2.5 year old Leucaena leucocephala while Plate 2 shows the extent of side pruning instituted during the second management phase. Side pruning was also done to determine the amounts of fodder and fuelwood available from such trees. An additional side pruning was carried out in December 1984 to reduce shade effect on the crop.

Plate 1. Shade and canopy closure from 2.5 years old Leucaena trees before green gram sowing, September 1984

Plate 2. Extent of Leucaena pruning before and during the green gram crop season, October 1984

The tree/crop parameters monitored and data collected during this phase included:-

(a) Fresh fodder/Green Leaf Manure (GLM) yield. Fodder was taken to be all leaves and any woody material (twigs) less than 5mm diameter. Fodder/GLM was weighed with a field spring balance immediately after separating from the fuelwood, and then incorporated, as much as possible, into the soil.

(b) Fuelwood yield after sun-drying for 3 months when moisture content would be approximately 15-20% was determined. A portable moisture metre was used to assess moisture content.

(c) Green gram yield after shelling and drying in the sun.

(d) Crop yield components which might correlate with grain yields such as:-

(i) Green gram plant heights (m), 60 days after planting.

(ii) Mean number of leaves per metre square quadrat per treatment.

(iii) Leaf Area Index (LAI), 60 days after crop sowing. Total leaf area was computed after the method of Tosso, (1978) using the formula: $A = 0.35 + 0.063 LW$ where
A = total leaf Area
L = leaf length at midrib of five top leaves/plant from each square quadrat.
W = leaf width

LAI was then computed as total leaf area divided by unit area of ground surface.

(iv) Mean pod length (cm) of plants for each of the random metre square quadrats.

(v) Weeds per metre square viz:-

(a) Types and

(b) Fresh weight in October 1984 and and January 1985.

Percent weed reduction was then calculated using the control plot as a baseline with 100% weeds.

Other parameters assessed during this phase were:-

(a) Incident radiation on the green gram crop, approximately one meter away from the trees, between 11.30 a.m. to 1.00 p.m. (overhead sun). This was done with a solar sensor SS-100 (100mw/sq. cm = 100 mv) attached to a digital solar integrator, model SI 377. Percent incident radiation on the crop was then calculated using the control plot (no trees with 100% of available incident radiation).

(b) Soil (chemical) fertility changes. Soil sampling per plot: top soil (0-15cm) was analysed at National Agricultural Laboratories (NAL), Nairobi for nutrients to determine soil fertility changes over time. These levels are expressed as adequate (ad) or deficient (d) according to N.A.L. standards. Soil parameters analysed and specific methods used were as follows:-

(i) Texture - hydrometer method

(ii) pH in water (1:1 soil solution suspension)

(iii) Organic Carbon: Walkeley-Black method

(iv) Exchangeable cations such as Na, Mg, Mn, and available P were determined by the North Carolina double acid extraction method (Nelson, et al., 1953) using an acid mixture of 0.1N HCL and 0.03N H_2SO_4 for extraction.

This soil fertility study was continued also during the third tree management phase, coppicing.

3.2.3 Tree coppicing phase (March-September 1985)

During this phase, coppicing the 3 year old trees to 0.5m above ground (see Plate 3) was carried out in March 1985 in order to reduce excessive shade on the maize crop.

Maize was planted as described earlier on 15th April, and given 100Kg/ha Triple Superphosphate (TSP) fertilizer (46% P_2O_5) for root establishment, and 150Kg/ha Calcium Ammonium Nitrate (CAN) (26%N) in two split applications, at knee-high and at tasselling.

Crop parameters monitored were:-

(a) Maize yield expressed at 13% moisture content.

(b) Maize plant heights at different physiological growth stages (42, 62 days after sowing and also at harvest) and at various distances from Leucaena rows.

(c) Leaf Area Index (LAI), 62 days after crop was sown. Total leaf area was estimated from leaf length multiplied by the greatest width, multiplied by a constant 0.75 (Watts, 1973, Moll and Kamprath, 1977). Leaf Area Index (LAI) was then computed as total leaf area divided by unit area of ground (Evans, 1972, Fakorede and Mock, 1978).

(d) Mean length (cm) and width (cm) of cobs

(e) Mean shelling percentage:- i.e., weight of shelled dry maize divided by weight of dry maize with cob multiplied by 100.

(f) Dry matter yield (t/ha) of maize stover after grain harvest. Ten plants in the middle of the rows were used to estimate the maize stover yield, t/ha of each treatment.

(g) Tree root density (g/m^3/tree) measurements to provide an indication of level and density of rooting (and therefore extent of tree root nodulation, and/or competition with maize). This was done by digging a hole next to 5 randomly selected trees for each spacing combination after crop harvest. The hole size dug next to each tree was 25cm deep long, 60cm wide and 20cm deep. The sampling distances away from the randomly selected tree bases were 0-25cm, 25-50cm, 50-75cm, 75-100cm.

Plate 3. Heights (0.5m) at which Leucaena was cut back to in March 1985 and at which it was maintained at later coppicing phases, April 1985

(h) Net financial returns from the sale of fuelwood. This was computed following the sale of Leucaena firewood (at KSh1.50 per Kg, 4km away from the experimental site) harvested in March in 1985 less labour requirements (mandays/ha) and KSh/ha for harvesting and stacking the fuelwood which was computed based on 5 minutes per tree and at KSh18.0 per manday of 8.0 hours. The cost of fuelwood transportation (being subject to negotiation from place to place) was not included in the overall costs.

(i) Nitrogen contribution to the soil from Leucaena GLM.

This was calculated by multiplying the total GLM weight of the 3 coppicings done during the 1985 maize crop season with the dry weight % nitrogen content (4.4) of the Leucaena leaves and twigs.

Contribution of N directly to soil by biologically N-fixing bacteria in the root nodules was not quantified and therefore ignored in these computations.

(j) Financial earning from use of Leucaena GLM as an alternative to purchase of inorganic fertilizers. The financial earnings/ha are the product of the 1985 unit price (Kshs174.25) of a bag of CAN (26% N) fertilizer and the resultant equivalent CAN bags from the GLM nitrogen contributions (given that a bag of CAN has 13Kg N), less the total cost of the recommended CAN application rates (3 bags/ha) for maize in the area.

Assumptions on which this financial earning from use of Leucaena GLM as an alternative to inorganic nitrogenous fertilizers were based on were:-

(i) That Leucaena green leaf manure decomposition is over in 2 weeks (Anon. 1984d);

(ii) That the Leucaena green manure is incorporated into the soil instead of broadcasting;

(iii) That the cost of incorporation of GLM into the soil is covered by the land preparation exercises i.e. no direct cost was involved in the incorporation of the green leaf manure into the soil.

CHAPTER FOUR

4.0 RESULTS

In this section, results are presented largely in chronological order based on the cropping sequence used in the experimental period. Thus, data from the initial tree establishment phase are presented first, followed by the tree pruning phase in 1984, and lastly tree coppicing phase in 1985.

4.1 LEUCAENA ESTABLISHMENT PHASE: MAY 1982-OCTOBER 1984

During this phase, no management (pruning or coppicing) was done on the trees; the objectives being to get baseline data on crop and tree performance in the unmanaged system for comparison to later phases of different management techniques. The 1983 crops (maize and green gram) and 1984 maize crop are presented in the Appendix 8.6, 8.7, and 8.8 to give a picture of the crop situation during this period.

However, there were interesting factors studied during this phase. These were the effect of tree row and within-row spacings on % survival and height of the trees. These are presented in sections 4.1.1 and 4.1.2 below.

4.1.1 Per cent tree survival (%)

Percentage Survival of the trees was studied to see if there were differences under the different row and within-row spacings combinations. These trees were growing under a uniform cassava crop stand. Survival count of all plants in each spacing was done 8 months after planting and actual mean survival % of the number initially planted is shown in Table 6.

Table 6. Effect of Treatments on Survival(%) of Leucaena, 8 months after planting while intercropping with cassava, December 1982.

Row Spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	89.0b*	100.0c	100.0abc	93.0abc	96.0
4.0	93.0bc	96.0bc	98.0bc	82.0a	92.0
8.0	64.0a	80.0b	88.0b	56.0a	72.0
Means	82.0	92.0	95.00	77.0	

S.E. of row spacing means = 7

S.E. of within row spacing means = 14

C.V. (%) row spacing = 32

C.V. (%) within row spacing = 26

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

The wider row spacings (8m) % survival were significantly lower than the 2.0 and 4.0 metres, the latter two not differing significantly in their % survival. Similarly, the wide within row spacing (3.0m) % survival were significantly lower than the closer spacing (0.5, 1.0 and 2.0 metres) which showed no significant differences in their % survival.

Though interaction on % survival was not significant , however, there was a common trend that the closer 2m, 4m between and within-row spacings had higher % survival as opposed to the wider 8m inter-row spacing with any within-row spacing.

4.1.2 Tree heights

The mean tree heights (m), 8 months after planting are shown in Table 7.

Table 7. Mean height (m) of Leucaena, 8 months after planting while intercropping with cassava, December 1982.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	2.6e*	2.5e	2.1d	2.0cd	2.3de
4.0	1.8c	1.6bc	2.2d	2.1d	1.9c
8.0	1.1a	1.4b	1.7c	1.4b	1.4b
Means	1.8	1.8	2.0	1.8	

S.E. of row spacing means = 0.35
S.E. of within row spacing means = 0.12
C.V. (%) Row spacing means = 22
C.V. (%) Within row spacing means = 16

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Though row and within-row spacings on Leucaena plant height interactions was significant, it was however not consistent. Therefore, the results were difficult to interpret.

4.2 LEUCAENA PRUNING PHASE, OCTOBER 1984-MARCH 1985

This was the first tree management phase when pruning the trees to one main stem was carried out in October 1984. Results of this phase are presented in this order viz: green gram yield, sunlight penetration, green gram yield components (pod length, number of leaves/plant, leaf area index, plant heights), weed reduction and finally Leucaena growth and biomass yield (fodder and fuelwood).

4.2.1 Green gram yield, January 1985

Yield of green gram yield planted in October 1984 and harvested in January 1985 is shown in Table 8.

Table 8. Mean effect of treatments on green gram yield (Kg/ha), January 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	128.0cd*	32.0a	28.5a	49.7b	59.6
4.0	33.0a	69.5b	35.0ab	138.8d	69.1
8.0	197.5e	109.8c	101.8c	204.4f	179.1
Means	119.5	70.4	55.1	165.3	
Control plot mean					331.6g

S.E. of row spacing means = 14.9
S.E. of within row spacing means = 18.69
C.V. (%) Inter-row spacing = 52
C.V. (%) Intra-row spacing = 46

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

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significant interaction between treatments on green gram yield was observed. An increase in row and within-row spacing generally led to an increase in yields. The control plot yields were however significantly higher than any of the treatments.

4.2.2. Sunlight penetration

Percentage sunlight reduction to green gram crop as compared to the control plots (100% incident radiation) is shown in Table 9.

Table 9. Sunlight (%) reduction to green gram under different Leucaena spacing, January 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	93.0cd*	98.0d	98.0d	98.0d	97.0
4.0	98.0d	80.0bc	98.0d	48.0b	81.0
8.0	91.0c	85.0c	59.0b	41.0a	69.0
Means	94.0	88.0	85.0	62.0	

S.E. of row spacing = 30.12
S.E. of within row spacing = 25.50
C.V. (%) Row spacing = 36.6
C.V. (%) Within row spacing = 31.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Sunlight penetration was significantly reduced by both row and within-row spacings. Though interaction was not significant, a persistent trend of increase in spacings leading to increase in sunlight penetration was observed. The green gram yield (Table 4.2.1) followed this pattern of sunlight penetration, with higher yields in the wider spacings.

4.2.3 Green gram pod length (CM)

The effect of the treatments on pod length is shown in Table 10.

Table 10. Mean effect of treatments on green gram pod lengths (cm), 60 days after sowing, December 1984.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	8.2d*	7.6c	7.5b	8.0c	7.8
4.0	7.6c	7.2a	7.5b	7.4b	7.4
8.0	8.6e	8.7f	8.3de	8.7f	8.6
Means	8.1	7.8	7.8	8.0	
Control plot mean					9.6g

S.E. of row spacing means = 0.2
S.E. of within row spacing means = 0.3
C.V. (%) Row means = 7.4
C.V. (%) Within row means = 8.3
* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Pod length was significantly affected by row spacing. The 8m row spacing green gram plants had significantly longer pod lengths than either the 2 and 4m row spacings which did not differ significantly in their pod lengths. The control plot green gram pod lengths were however significantly longer than the ones in the intercropped plots (Table 10).

Within row spacing pod lengths did not differ significantly from each other.

4.2.4 Number of leaves/plant of green gram

The mean effect of treatments on a number of leaves/green gram plant is shown in Table 11.

Table 11. Mean effect of treatments on number of leaves per green gram plant, 60 days after sowing, December 1984.

Row spacing (m)	Within row spacing (m) 0.5	1.0	2.0	3.0	Means
2.0	173.0a	136.0a	251.0bc	220.0abc	195.0
4.0	262.0bcd	231.0abc	229.0abc	257.0bcd	245.0
8.0	229.0abc	232.0abc	235.0bc	252.0bc	245.0
Means	221.0	200.0	238.0	243.0	
Control plot mean					356.0e

S.E. of row spacing means = 29.11
S.E. of within row spacing means = 15.95
C.V. (%) row spacing = 12.5
C.V. (%) within row spacing = 13.0
* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significant differences in row or within row spacing on mean number of leaves/plant were noticed for any of the treatments. However, the control plot had significantly higher number of leaves/plant than the other treatments.

4.2.5 Leaf area index

The mean effect of treatments on LAI is shown in Table 12.

Table 12. Mean effect of treatments on Leaf Area Index (LAI) of green gram crop, 60 days after sowing, December 1984.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	0.5 dc*	0.4 c	0.6 fe	0.5 dc	0.5
4.0	0.6 fedc	0.6 fedc	0.6 fedc	0.7 fe	0.6
8.0	0.6 fedc	0.6 fedc	0.6 fedc	0.6 fedc	0.6
Means	0.6	0.5	0.6	0.6	
Control plot mean					0.7 f

S.E. of row spacing means = 0.04

S.E. of within row spacing means = 0.02

C.V. (%) row means = 18.0

C.V. (%) within row means = 17.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between row and within-row spacing on LAI was noticed, though a persistent trend was not detectable. Row spacing 4.0m in combination with 3.0m within-row spacing showed higher LAI, but not significantly different from many of the treatments e.g. 2 x 1.0, 4 x 0.5, 8 x 1.0 and 8 x 2.0. The control plot's LAI was not significantly different from these treatments; though it had higher green gram yield (Table 8).

4.2.6 Green gram plant heights

The mean effect of treatments on green gram plant heights is shown in Table 13.

Table 13. Mean effect of treatments on green gram plant heights (m) in Leucaena intercrop, 60 days after sowing, December 1984.

Row spacing (m)	Within row spacing (m)				
	0.5	1.0	2.0	3.0	Means
2.0	0.9b	0.8ab	1.0b	0.8ab	0.9
4.0	0.9b	0.8ab	0.9b	1.0b	0.9
8.0	0.8ab	0.9b	0.9b	0.9b	0.9
Means	0.9	0.8	0.9	0.9	
Control plot mean					0.8ab

S.E. of row spacing means = 0.34

S.E. of within row spacing means = 0.23

C.V. (%) row means = 8.6

C.V. (%) within row means = 10.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Mean green gram plant heights (m) showed that the intercropped green gram were significantly taller than the control plants. No significant differences existed between row spacings (m) or within row spacings on mean green gram plant heights.

4.2.7 Weed reduction

4.2.7.1 Reduction in Weed Types

The mean effect of treatment on weed types present in October 1984 are shown in Table 14.

Table 14. Mean effect of treatments on weeds (types/m^2) in Leucaena/green gram intercrop, October 1984.

Row spacing (m)	Within row spacing (m) 0.5	1.0	2.0	3.0	Means
2.0	1.7 a*	1.8 a	1.2 a	2.4 b	1.8
4.0	1.4 a	2.0 a	2.8 b	5.2 c	2.9
8.0	4.0 bc	4.0 bc	8.2 d	13.4 e	7.4
Means	2.3	2.6	4.1	7.0	
Control plot mean					14.8 f

S.E. of row spacing means = 0.26
S.E. of within row spacing means = 0.14
C.V. (%) row means = 48
C.V. (%) within row means = 54

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

A significant interaction between treatments on weed types present was observed. An increase in both row and within row spacings led to a corresponding increase in weed types present. The control plot's weed types were however significantly higher than the intercropped plots, an indication that, the higher weed reduction in the intercropped plots was due to the alley cropping shade effect.

4.2.7.2 Reduction in biomass yield of weeds

The mean effect of the treatments on weed fresh weights is shown in Table 15.

Table 15. Mean effect of treatments on weed fresh weights (g/m^2) in Leucaena/green gram intercrop, October 1984.

Row spacing (m)	Within row spacing (m) 0.5	1.0	2.0	3.0	Means
2.0	10.0a*	10.0a	10.0a	20.0ab	10.0
4.0	10.0a	30.0ab	30.0ab	110.0c	40.0
8.0	80.0c	110.0c	270.0cd	450.0cd	270.0
Means	30.0	50.0	100.0	260.0	
Control plot mean					490.0e

S.E. of row spacing means = 0.26
S.E. of within row spacing means = 0.14
C.V. (%) row spacing = 17.5
C.V. (%) within row spacing = 13.0
* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction effect between treatments on weed fresh weights was noticed. Biomass yields decreased with decrease in both row and within-row spacings. The control plot's yields were significantly higher than any of the intercropped plots.

4.2.7.3 Percentage weed fresh weights reduction

Reduction of weed fresh weights (%) (Table 4.2.7.2) during the October 1984 sampling compared to the control plot's fresh weights (i.e. no weeds reduction) are shown in Table 16.

Table 16. Percent weed fresh weights reductions (%) compared to control, October 1984.

Row spacing (m)	Within row spacing (m)				Means
		1.0	2.0	3.0	
2.0	98.0a	98.0a	96.0a	97.5a	97.5
4.0	98.0a	94.0ab	78.0b	91.0ab	91.0
8.0	84.0cb	45.0c	71.0ab	53.8d	63.5
Means	93.0	90.0	81.67	60.7	
Control plot mean					0%e

S.E. of row spacing means = 0.04

S.E. of within row spacing means = 0.02

C.V. (%) Row spacing = 4.9

C.V. (%) Within row spacing = 2.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between treatments on % weed fresh weights reduction was noticed. A decrease in both row and within row spacings led to a higher % weed fresh weights reductions, an indication of better control. This differential weed biomass reductions (Table 16) are shown in Fig.1.

4.2.7.4 Cumulative reduction in weed types

Following green gram harvest in January 1985, 2.5 years after Leucaena establishment, weed species reduction in intercropped and control plots was evaluated. This was done by noting the species that were present or absent. This is shown in Table 17.

Fig. 1. PERCENT WEED BIOMASS REDUCTIONS UNDER LEUCAENA, OCTOBER 1984

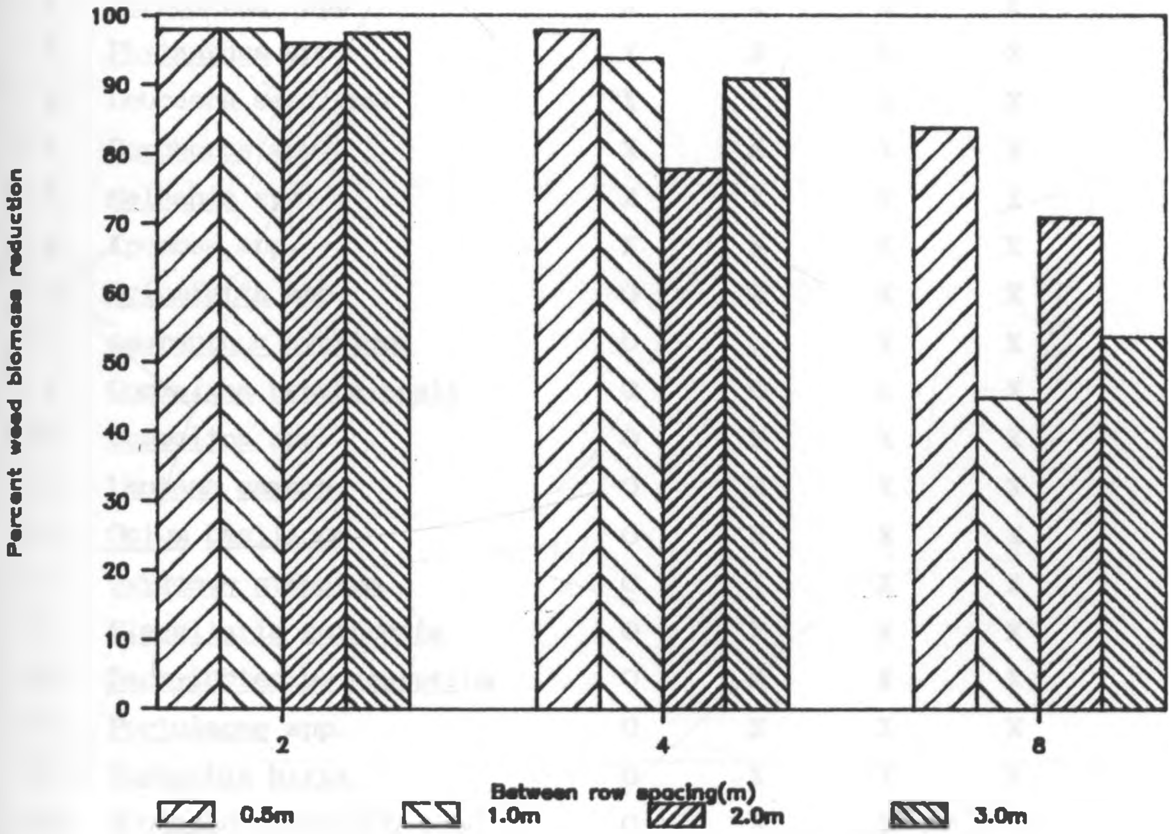


Table 17. Weed Species recorded in January 1985 after 2.5 years of continuous cropping under Leucaena.

Weed Species	Present/Absent in row spacings (m) 2	4	8	Control Plot
Grass Species				
1. Eleusine indica	X	X	X	X
2. Cynodon dactylon	X	X	X	X
3. Digitaria spp.	X	X	X	X
4. Imperata cylindrica	X	X	X	X
5. Cyperus rotundus	O	X	X	X
6. Digitaria velutina	O	X	X	X
Broad Leaved species				
1. Acrocarpus spp	X	X	X	X
2. Phylanthus spp.	X	X	X	X
3. Leucaena seedlings	X	X	X	X
4. Corchorus spp.	X	X	X	X
5. Melhania spp.	X	X	X	X
6. Ipomoea spp.	X	X	X	X
7. Triumfetta spp.	O	X	X	X
8. Amaranthus hybridus	O	O	X	X
9. Commelina benghalensis	O	O	X	X
10. Commelina spp.	O	X	X	X
11. Lantana camara	O	X	X	X
12. Ocium basilicum	O	X	X	X
13. Oxygonum sinuatum	O	X	X	X
14. Flagellaria guinensis	O	X	X	X
15. Dactyloctenium aegyptium	O	X	X	X
16. Portulacae spp.	O	X	X	X
17. Euphorbia hirta	O	X	X	X
18. Acalypha volkensis	O	X	X	X
19. Amaranthus spp.	O	O	X	X
20. Boerhavia diffusa	O	O	X	X
21. Vigna parkeri	O	O	X	X
22. Vigna spp.	O	O	X	X
23. Perargonium quinquelobatum	O	O	X	X

X - Present

O - Absent

General observations from Table 11 showed that a 63% and 28% reduction in weed types in the 2 and 4m row spacings respectively has been achieved compared to the control plot. The reduction (3%) in the 8m row spacing was however insignificant.

4.2.8 Leucaena biomass production

Tree heights, fodder and fuelwood yields from the tree side prunings instituted in October and December 1984 were used as indicators of Leucaena biomass production. Each of these parameters are discussed in sections 4.2.8.1 to 4.2.8.5 below.

4.2.8.1 **Trees heights**

Tree heights after pruning to single stems (Plate 2.0) twice during the green gram growing period were taken in January 1985. These heights, after 2.5 years of trees growth are shown in Table 18.

Table 18. Mean Leucaena tree heights (m) at green gram crop harvest, January 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	5.6ab*	6.2bcd	7.2cd	6.8cd	6.5
4.0	5.9bc	6.0bc	7.0cd	6.8cd	6.4
8.0	4.5a	5.7bc	5.6ab	6.4bcd	5.5
Means	5.3	6.0	6.6	6.7	

S.E. of row spacing means = 0.33

S.E. of within row spacing means = 0.25

C.V. (%) row spacing = 8.0

C.V. (%) within row spacing = 12.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significant differences in row or within row spacing on tree heights were noticed for any of the treatments.

4.2.8.2 Fodder/Green Leaf Manure Production

As a result of trees side pruning in October and December, substantial amount of fodder/Green Leaf Manure (GLM) was realised. Tree side prunings were done after 2.5 years of establishment. These yields are shown in Tables 19 and 20 for October and December 1984 prunings respectively.

Table 19. Mean yield (t/ha) of fresh fodder from Leucaena side pruning, October 1984.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	63.9d*	32.9cd	24.5bc	28.1bcd	37.4
4.0	34.3cd	20.7bc	12.1a	14.8b	20.5
8.0	19.4b	13.4ab	10.6a	11.7a	13.8
Means	39.2	22.3	15.7	18.2	

S.E. of row spacing means = 2.62
S.E. of within row spacing means = 2.03
C.V. (%) row means = 25
C.V. (%) within row means = 33

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction effect between treatments on fresh fodder yields was observed. A decrease in both row and within-row spacing generally led to an increase in fresh fodder yields. For instance, 2m row spacing and 0.5m within row spacing had the highest yield compared to 8m row spacing and 3.0m within row spacing which had the least yield.

Table 20. Mean Yield (t/ha) of fresh fodder from Leucaena side pruning, December 1984.

Row spacing (m)	Within row spacing (m)				Means
	5.0	1.0	2.0	3.0	
2.0	13.3f*	5.3e	4.0d	3.6cd	6.5
4.0	6.4e	2.8c	1.6b	1.7b	2.5
8.0	4.3d	2.0bc	1.1a	1.2a	2.2
Means	8.0	3.3	2.2	2.2	

S.E. of row spacing means = 2.31
S.E. of within row spacing means = 2.76
C.V. (%) row means = 32
C.V. (%) within row means = 23
* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

A similar interaction effect of treatments on fresh fodder yields of October 1984 (Table 19) was found also for the yields of December 1984 (Table 20). Treatment combination 2x0.5 had the highest yield of fodder compared to 8 x 3.0 which had the least.

4.2.8.4 Fuelwood Yield

Following the October 1984 tree side pruning, considerable fuelwood was produced, after 2.5 years growth. The mean yields (t/ha) of sun-dried wood are shown in Tables 21 and 22 for October and December 1984 prunings respectively.

Table 21. Mean fuelwood yield (t/ha) from first side pruning of Leucaena, October 1984.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	62.8d*	30.0c	28.1c	14.3b	33.8
4.0	28.6c	19.3cb	11.7b	6.1a	16.4
8.0	13.1b	7.1ba	7.6ba	8.5b	9.1
Means	34.8	18.5	15.8	9.6	

S.E. of row means = 2.62
S.E. of within row spacing means = 2.03
C.V. (%) row means = 32.0
C.V. (%) within row means = 40.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction effect between treatments on October 1984 fuelwood yield was noticed. An increase in both row and within row spacing led to decrease in fuelwood yield.

Tree spacing at 2 x 0.5m (10,000 trees/ha) gave yields significantly higher than the rest. At 2 x 1.0m, 2 x 2.0m, 4 x0.5m and 4 x 1.0m spacings which were not significantly different in their yields followed it closely. The lowest yield was from the 4 x 3.0m module which was only 9.7% of the 2 x 0.5 module (62.8 versus 6.1 t/ha). No significant difference existed in the yields of the remaining modules. This trend was partially repeated in the yields of the second pruning in December 1984 (Table 22).

Table 22. Mean fuelwood yield (t/ha) from second Leucaena side pruning, December 1984.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	6.e*	3.0d	2.4cd	1.2ba	3.3
4.0	3.0d	2.3cd	1.3ba	0.7a	1.8
8.0	1.3ba	1.1a	1.2ba	0.9a	1.1
Means	3.6	2.1	1.6	0.9	

S.E. of row spacing means = 0.37
S.E. of within row spacing means = 0.24
C.V. (%) row spacings = 35.5
C.V. (%) within row spacings = 40.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant row and within row spacing interaction on fuelwood yield (t/ha) was observed. An increase in both row and within row spacing led to a decrease in fuelwood yield.

4.3 LEUCAENA COPPICING PHASE (MARCH-SEPTEMBER 1985)

The next tree management practice imposed was one in which the trees were cut (coppiced) to 0.5m above ground in March 1985 to reduce tree shade on the companion crop and produce GLM for fertilizing the 1985 long rains maize crop. Besides, the difficulties and risks of side pruning tall trees proved the pruning management practice imposed earlier to be unfeasible.

4.3.1 Maize grain yield

Maize planted on 15th April 1985 was harvested on 23rd August, and grain yields expressed at 13% moisture content are shown in Table 23.

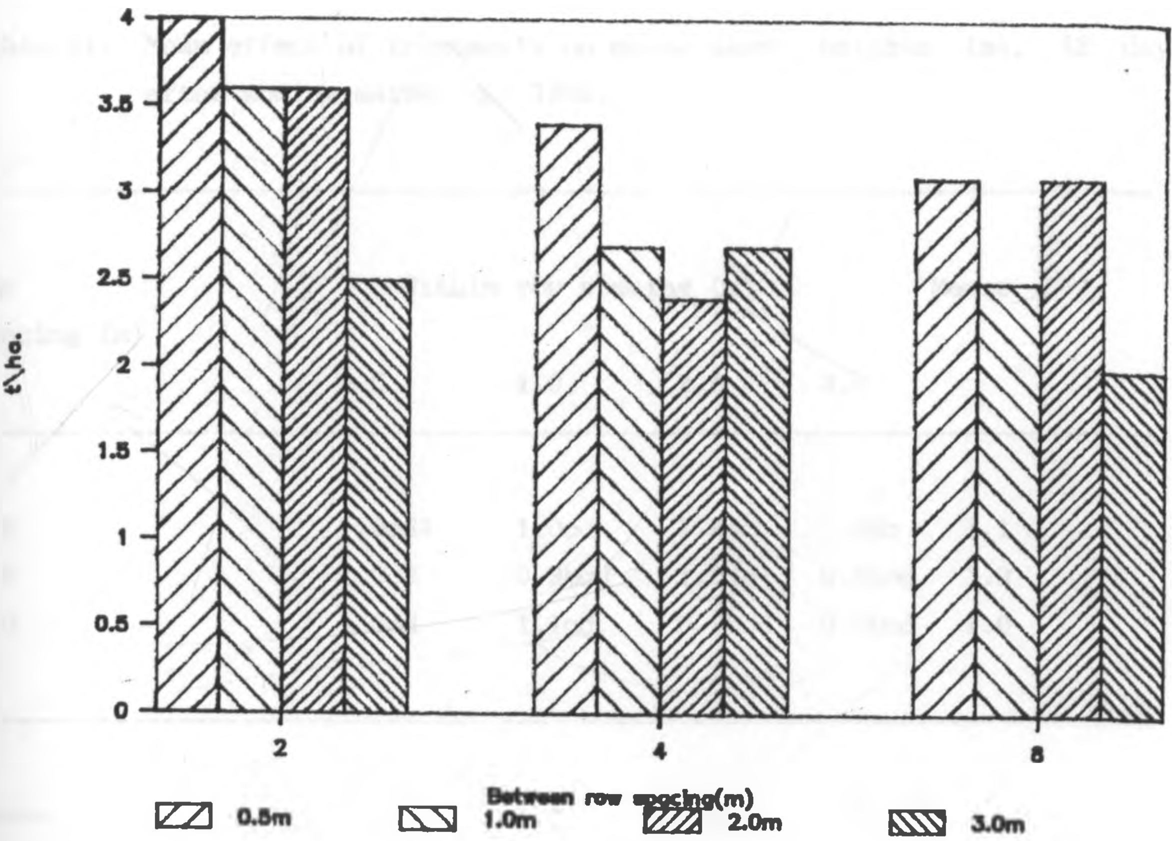
Table 23. Mean effect of treatments on yield of shelled maize yield (Kg/ha), August 1985. (x 1000Kg/ha)

Row spacings (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	2.0	
2.0	4.0e	3.6de	3.6de	2.5b	3.4
4.0	3.4cd	2.7c	2.4b	2.7c	2.8
8.0	3.1c	2.5b	3.1c	2.0a	2.7
Means	3.5	2.9	3.0	2.5	
Control plot mean					2.5

S.E. of row spacing means = 0.16
S.E. of within row spacing means = 0.21
C.V. (%) row spacing = 12
C.V. (%) within row spacing = 28

Both row and within row spacings differed significantly in their shelled maize yields. The 2.0m row spacing yielded significantly higher than both the 4.0 and 8.0m row spacings and the control plot (Fig.2). Though there was no significant difference in the yields of the 4.0 and 8.0m rows, they were nevertheless higher than the control plot. Among the within row spacings, the 0.5m spacings yielded significantly higher than the rest which did not differ significantly in their maize grain yields. No significant interaction in between and within row spacing was noticed.

Fig. 2. EFFECT OF LEUCAENA ROW SPACING ON MAIZE YIELD (T/HA), AUGUST 1985



4.3.2 Maize yield components

4.3.2.1 Maize plant height, 42 days after sowing

Maize plant heights, 42 days after sowing were taken, and the mean heights are shown in Table 25. Plates 5 and 6 similarly show maize performance under Leucaena intercrop in 2 and 4m row spacings, 42 days after sowing. A similar plate for the 8.0m wide alleys was not made available due to the limitation (lack of wide angle lens) of the camera equipments available to the author at the time of photographing.

Table 24. Mean effect of treatments on maize plant heights (m), 42 days after sowing maize, May 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	1.0cd*	1.0cd	1.2dc	1.2dc	1.1
4.0	1.0cd	0.9bcd	1.2dc	0.9bcd	1.0
8.0	1.0cd	1.1cd	0.9bcd	0.9bcd	1.0
Means	1.0	1.0	1.0	1.0	
Control plot mean					0.7a

S.E. of row spacing means = 0.31
S.E. of within row spacing means = 0.11
C.V. (%) row spacing = 8.2
C.V. (%) within row spacing = 14.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significance differences in maize plant heights between row and within row spacings were noticed. Similarly, interaction between treatments on maize heights was not significant. All the Leucaena spacing combination were however significantly taller than the control plot's.

Plate 4. Maize performance under Leucaena intercrop 2m row spacing, 42 days after sowing, May 1985.

Plate 5. Maize performance under Leucaena intercrop 4m row spacing, 42 days after sowing, June 1985

4.3.2.2 Maize plant heights, 62 days after sowing

Maize plant height measurements at 100% tasselling was done after it was observed that maize rows close to Leucaena trees were taller than those away from the trees. Hence maize heights 65cm away from the trees and 130cm away from the trees were measured, and the mean treatment effects on these maize heights are shown in Tables 25 and 26 respectively.

Table 25. Mean maize plant heights (m), 65cm away from Leucaena trees, 62 days after sowing maize, June 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	3.5d*	3.5d	3.6d	3.6d	3.6
4.0	3.2c	2.8ab	2.7a	3.2c	3.0
8.0	3.0b	3.1bc	3.0b	3.0b	3.0
Means	3.2	3.1	3.1	3.3	
Control plot mean					2.7a

S.E. of row spacing = 0.13
S.E. of within row spacing means = 0.96
C.V. (%) row spacing = 8.7
C.V. (%) within row spacing = 11.2

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Maize heights (m) were significantly affected by row spacing. The 2m row spacing maize heights were significantly taller than the 4.0 and 8.0m row spacing; the heights of the latter two were not significantly different from each other.

Table 26. Mean effect of treatments on maize plant heights (m) 130cm away from Leucaena trees, 62 days after sowing maize.

Row spacings (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
4.0	3.0a*	2.8ab	2.6a	3.2c	2.9
8.0	2.9ab	3.0b	2.8ab	1.9a	2.7
Means	3.0	2.9	2.7	2.6	
Control plot mean					2.7a

S.E. of row spacing means = 0.74

S.E. of within row spacing means = 1.07

C.V. (%) row spacing = 9.3

C.V. (%) within row spacing = 13.2

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significant differences between treatments on maize heights away from the Leucaena trees was observed. These maize heights from the 4.0 and 8.0m row spacing with any within row spacing combination were found to be shorter than those of Table 25, though this difference was not significant.

The 2m row spacing maize plant heights are missing from Table 26 because there were only two maize rows in each Leucaena 2m row spacing, both of which were adjacent to the tree rows. These were however seen from Table 25 to be significantly taller than any combination of row and within row spacing of the 4 and 8 metres.

4.3.2.4 Leaf area index

Leaf Area Indices (LAI) of maize plants leaves, 62 days after sowing were taken and mean treatments effects are shown in Table 27.

Table 27. Mean effect of treatments on LAI of intercropped maize, 62 days after sowing.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	2.4bc*	2.8cd	2.5cd	2.1b	2.5
4.0	2.4bc	2.8cd	2.5cd	2.1b	2.5
8.0	2.8cd	3.0cd	3.2d	3.3d	3.1
Means	2.5	2.9	2.7	2.5	
Control plot mean					2.0a

S.E. of row spacing means = 0.27
S.E. of within row spacing means = 0.12
C.V. (%) row spacing = 22.2
C.V. (%) within row spacing = 8.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between row and within row spacing on LAI was observed, though it was not consistent. However, it was clear that LAI of the 8m row spacing were consistently higher than the rest. The control plot's LAI was significantly lower than any of the treatments.

4.3.2.5 **Maize ear heights**

It has been observed from parameters assessed (Tables 24, 25 and 26) that maize plants in the intercropped plots were significantly taller than control plot's. Maize plant ear height measurements (height of maize stalk from ground to bottom of ears) was also felt necessary to elucidate any treatment effects. The mean maize ear heights are shown in Table 28.

Table 28. Mean effect of treatments on maize plant ear heights (m) at 100% tasselling (101 days after sowing), July 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	1.0 fe*	1.1 f	1.1 f	0.8 dcb	1.0
4.0	0.9 edc	0.8 dcb	0.9 fed	0.7 b	0.8
8.0	0.7 cb	0.8 dcb	0.9 edc	0.7 b	0.8
Means	0.9	0.9	1.0	0.7	
Control plot mean					0.6

S.E. of row spacing means = 0.21
S.E. of within row spacing means = 0.35
C.V. (%) row spacing = 5.4
C.V. (%) within row spacing = 16.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

It was observed from Table 28 that significant differences existed in row and within row spacing on maize plant ear heights (m) at 100% tasselling, though their interactions showed no significant differences. The 2m. row spacing maize ear heights were significantly higher than either the 4 or 8 metres and even the control plot's. The 4 and 8 metre row spacing showed no significant differences, though their ear heights were significantly higher than the control plot's. The within row spacings 0.5, 1.0 and 2.0 metres were not significantly different in their maize ear heights, but higher than the 3.0 metre within row spacing.

4.3.2.6 Maize plant heights at harvest

Maize plant heights at harvest were taken and the mean heights are shown in Table 29.

Table 29. Mean effect of treatments on maize plant heights (m) at harvest, August 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	2.0	
2.0	2.3cd*	2.5d	2.5d	1.9b	2.3
4.0	2.1c	1.9b	2.4d	1.7a	2.0
8.0	1.8b	2.1c	2.0c	1.6a	1.9
Means	2.0	2.2	2.3	1.7	
Control plot mean					1.7a

S.E. of row spacing means = 0.31
S.E. of within row spacing means = 0.71
C.V. (%) row spacing = 15.2
C.V. (%) within row spacing = 13.8

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

It was observed from Table 29 that there were significant differences in row and within row spacing on maize plant heights at harvest. The 2m row spacing maize plants were significantly higher than the 4.0m which were also significantly taller than the 8.0 and the control plot. The control plot had the least maize plant heights at harvest. Among the within row spacings, no significant differences existed between 0.5, 1.0 and 2.0m in their maize heights, but the 3.0m within row spacing maize plants were significantly shorter than the rest. Interaction between row and within row spacing on maize plant heights at harvest was found to be insignificant.

4.3.2.7 Maize cob lengths at harvest

Treatment effects on maize cob lengths (cm) at harvest was assessed (Table 30).

Table 30. Mean effect of treatments on length (cm) of maize cobs at harvest, August 1985.

Row spacing (m)	Within row spacings (m)				Means
	0.5	1.0	2.0	3.0	
2.0	16.9bc*	17.9c	16.7bc	18.7c	17.6
4.0	17.2c	17.2c	16.5abc	15.4abc	16.6
8.0	16.3abc	17.1bc	17.7c	16.4abc	16.9
Means	16.8	17.4	17.0	16.8	
Control plot mean					16.4abc

S.E. of row spacing means = 0.34
S.E. of within row spacing means = 0.39
C.V. (%) row spacing = 4.5
C.V. (%) within row spacing = 9.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significant difference was noticed in mean maize cob lengths between any of the treatments (row and within row spacing, interaction and the control plot).

4.3.2.8 Maize cob diameters at harvest

Maize cob diameters at harvest was assessed, and the mean treatment effects are shown in Table 31.

Table 31. Mean effect of treatments on diameter (cm) of maize cobs at harvest, August 1985.

Row Spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	4.4b*	2.9a	3.4a	4.5b	3.8
4.0	4.8c	4.9d	4.7c	4.8c	4.8
8.0	4.2ab	4.5b	4.4b	4.4b	4.4
Means	4.5	4.1	4.2	4.6	
Control plot mean					4.6bc

S.E. of row spacing means = 0.14
S.E. of within row spacing means = 0.17
C.V. (%) row spacing = 7
C.V. (%) within row spacing = 16

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

The 4.0, 8.0 row spacings and the control plot had significantly wider mean cob diameters than the 2.0m row spacing. The former two were not significantly different from each other in their diameters nor from the control plot's. Within-row spacings or treatment interactions showed no significant differences on maize cob diameters.

4.3.2.9 Maize % shelling

Percentage shelling (Table 32) was calculated as the weight of the shelled dry maize (expressed at 13% moisture content) over the weight of dry maize with cobs times 100.

Table 32. Mean effect of treatments on % shelling of maize at harvest, August 1985.

Row spacing (m)	Within row spacing (m)				Means
2.0	77.6de*	71.8bcde	73.2bcde	70.0abcde	73.1
4.0	73.3bcde	68.9abcde	65.2abcde	74.8cde	70.5
8.0	74.5cde	74.1cde	76.4de	91.1e	79.1
Means	75.2	71.6	71.6	78.7	
Control plot mean	78.7de				

S.E. of row spacing means = 2.75
S.E. of within row spacing means = 2.74
C.V. (%) row spacing = 8.3
C.V. (%) within row spacing = 14

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

No significant differences existed in row and within row spacing and the control plot in mean % shelling at harvest.

4.3.2.10 **Maize stover yields**

Maize stover yields (t/ha) at harvest was assessed (Table 33).

Table 33. Mean effect of treatment on stover yield (t/ha) at harvest, August 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	23.7cd*	27.4e	28.9e	14.8b	23.7
4.0	20.0c	20.7c	24.4de	17.0bc	20.5
8.0	20.0c	20.0c	25.2de	14.8b	20.0
Means	21.2	22.7	26.2	15.5	
Control plot mean					14.1a

S.E. of row spacing means = 1.51
S.E. of within row spacing means = 1.29
C.V. (%) row spacing = 16.0
C.V. (%) within row spacing = 23.2

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

The 2m row spacing yielded significantly higher maize stover than the 4 and 8m row spacings which did not differ significantly from each other in their yields. The control plot yielded significantly the least stover. Significant differences were noticed among the within row spacings stover yields. The maize stover yields of the closer within row spacings (0.5, 1.0 and 2.0) were significantly higher than the wider 3.0m within row spacing. The 2m within row spacing yielded significantly higher than either 0.5 or 1.0m within row spacings. No interaction effect between treatments on maize stover yield was noticed.

4.3.3 Soil chemical fertility changes

Changes in soil chemical properties under different treatments are shown in Table 34.

Table 34. Mean effect of treatments on chemical fertility of top soil (0-15cm) from Leucaena plots.

Row Spacing	Sample Dates	pH	K m.e.%	Ca m.e.%	Mg m.e.%	P p.p.m.	C %
2M	April '84	6.10	0.16d	2.00d		24.00ad	0.49d
	Aug. '84	6.08	0.24ad	2.58ad	1.55ad	18.00ad	0.45d
	Jan. '85	5.80	0.26ad	3.60ad	0.48d	66.75ad	0.97d
	Sept. '85	6.52	0.31ad	2.30ad	0.85d	90.50h	0.23d
4M	April '84	5.90	0.14d	1.60d	-	22.00ad	0.26d
	Aug. '84	6.30	0.22ad	2.20ad	1.38ad	22.00ad	0.24d
	Jan. '85	5.98	0.24ad	3.40ad	0.80d	31.75ad	0.87d
	Sept. '85	6.02	0.32ad	1.90d	0.60d	68.50ad	0.25d
8M	April '84	6.10	0.12d	2.40d	-	37.00ad	0.35d
	Aug. '84	6.32	0.24ad	2.78ad	1.80d	29.00ad	0.40d
	Jan. '85	5.78	0.25ad	3.70ad	0.73d	30.25ad	0.94d
	Sept. '85	6.05	0.27ad	1.60d	0.55d	44.00ad	0.20d
control	April '84	-	-	-	-	-	-
	Aug. '84	5.83	0.23ad	3.10ad	0.40d	32.25ad	0.49d
	Jan. '85	5.83	0.23ad	3.10ad	0.40d	32.25ad	0.49d
	Sept. '85	6.01	0.25ad	1.50d	0.60d	26.00ad	0.21d

NB: ad = adequate
d = deficient

In general, the concentration of % C, P, K, Ca and Mg in the intercropped plots showed substantial increments as compared to their respective control plots, even though the same types and rates of fertilizers were applied to all. Soil pH also increased in the intercropped plots as compared to the control. Besides, these increases in nutrients tended to increase with increase in tree density, 2m row spacing generally having the highest nutrient levels as compared to the 4 and 8m row spacings.

4.3.4 Weeds reduction

Both weed types and biomass yields assessment (Table 35 to 36) were done in May 1985 and are shown in Tables 35 to 36..

Table 35 Mean effect of treatments on weed types/m^2, May 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	4.8abc*	6.6d	6.0c	3.6a	5.3
4.0	5.8c	4.0a	5.0bc	5.4bc	5.1
8.0	5.8c	5.6bc	5.0bc	6.0c	5.6
Means	5.5	5.4	5.3	5.0	
Control plot mean					14.2e

S.E. of row spacing means = 0.47
S.E. of within row spacing means = 0.44
C.V. (%) row spacing = 20.0
C.V. (%) within row spacing = 33.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction effect (though the trend was not consistent) between treatments on weed types reduction was noticed. Therefore data was difficult to interpret.

However, the control plot's weed types were significantly higher than the intercropped plots, an indication that intercropping reduced weed types.

Table 36. Mean Effect of treatments on weed biomass yields (g/m^2), May 1985

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	58.0ab*	75.0cd	60.0b	45.0a	59.5
4.0	70.0bc	43.0a	45.0a	80.0cd	59.5
8.0	83.0d	53.0ab	45.0a	85.0d	66.5
Means	70.3	57.0	50.0	70.0	
Control plot mean					135e

S.E. of row spacing means = 7.24
S.E. of within row spacing means = 9.70
C.V. (%) row spacing = 28.3
C.V. (%) within row spacing = 35.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

As in Table 35, significant treatments interaction on weed biomass yield (g/m^2) was observed. The yields of the control plot were significantly higher than intercropped plots.

Table 37 Mean effect of treatments on weed types/m^2, August 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	3.0b*	1.2a	3.4cd	3.8de	2.9
4.0	3.2b	3.4cd	4.4e	3.4cd	3.6
8.0	4.2de	3.4cd	4.4e	3.4cd	3.9
Means	3.5	2.7	4.1	3.5	
Control plot mean					7.0f

S.E. of row spacing means = 0.09

S.E. of within row spacing means = 0.10

C.V. (%) row spacing = 16.8

C.V. (%) within row spacing = 33.8

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Weed types were significantly affected by row spacing. The 2m row spacing had significantly lower types than the 4 and 8m which were not significantly different from each other in their number. No significant difference between within row spacing weed types was noticed. The control plots counts were however significantly higher than intercropped plots.

Table 38 Mean effect of treatments on weed biomass, (fresh weight) yields (g/m^2), August 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	68.0a*	38.0a	30.0a	54.0a	47.5
4.0	70.0b	60.0b	170.0bc	130.0bc	107.5
8.0	230.0c	132.0bc	163.3bc	146.7bc	168.2
Means	122.7	76.9	121.1	110.2	
Control plot mean					650.0d

S.E. of row spacing means = 57.98
S.E. of within row spacing means = 37.57
C.V. (%) row spacing = 35.2
C.V. (%) within row spacing = 24.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

The weed biomass yields of all the row spacings were significantly different from each other. No significant differences were noticed among the within row spacing, except for the 1.0m within row spacing yields which were significantly lower than the rest. The yields of the control plot were however significantly higher than the intercropped plots, an indication of better weed control in the latter.

4.3.5 Leucaena biomass production

4.3.5.1 Fodder/GLM production

Fodder (leaves and woody materials less than 5mm diameter) yields from the first 1985 tree coppicing to 0.5m above ground are shown in Table 39. Subsequent coppicing yields within the cropping season, and the periodicity of coppicing are shown in Table 40, 41 and 42.

Table 39. Mean effect of treatments on fresh fodder yields (t/ha) of first 1985 coppicing at 0.5m height, March 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	15.4e*	8.6cd	8.1cd	7.3cb	9.8
4.0	11.7d	5.1b	4.4b	6.2cb	6.8
8.0	7.5c	4.4a	3.4a	3.6a	4.7
Means	11.5	6	5.3	5.7	

S.E. of row spacing means = 0.85
S.E. of within row spacing means = 0.51
C.V. (%) row spacing means = 18.6
C.V. (%) within row spacing means = 19.6

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Fodder yields were significantly affected by interaction between row and within row spacings. A decrease in both row and within row spacing generally led to an increase in fodder yields. The 2 x 0.5m treatment combination gave the highest yields, followed by 4 x 0.5m whose yields were significantly lower than the 2 x 0.5m spacing combination. This was followed by the set 2 x 1.0, 2 x 2.0, 2 x 3.0 and 8 x 0.5m which were not significantly different from each other in their fodder yields. The least fodder yields came from the 8 x 2.0m and 8 x 3.0m treatment combinations.

Table 40. Mean effect of treatments on fresh fodder yields (t/ha) of second coppicing at 0.5m height (30 days after the first coppicing), April, 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	4.6d*	3.6d	2.7de	2.3c	3.3
4.0	2.4c	1.4bc	0.7b	1.1bc	1.4
8.0	2.4c	0.7b	0.6a	0.7b	1.1
Means	3.1	2.0	1.3	1.7	

S.E. of row spacing means = 0.5
S.E. of within row spacing means = 0.6
C.V. (%) row spacing means = 23.6
C.V. (%) within row spacing means = 39.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Both row and within row spacing significantly differed in their fodder yields, though there was no significant interaction between these variables. Yields of 2m rows were significantly higher than either 4.0 or 8.0m row spacings. Fodder yields of 0.5m within row spacing were significantly higher than the rest, while the remaining within row spacings yields (1.0, 2.0 and 3.0m) were not significantly different from each other in their fodder yields.

Table 41. Mean fresh fodder weights (t/ha) of third tree cutting back to 0.5m height (35 days after the 2nd coppicing), May 1985.

Row Spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	8.3e*	5.2d	3.1dc	1.7bc	4.6
4.0	4.2dc	2.1bc	1.4b	0.9a	2.1
8.0	2.2c	1.1b	0.6a	0.5a	1.1
Means	4.9	2.8	1.7	1.0	

S.E. of row spacing means = 0.16

S.E. of within row spacing means = 0.21

C.V. (%) row spacing = 9.6

C.V. (%) within row spacing = 21.8

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between treatments on fodder yields of third pruning was noticed. A decrease in both row and within row spacing generally led to an increase in fodder yields. Spacing modules 2 x 0.5, 2 x 1.0, 2 x 2.0 and 4 x 0.5m yielded significantly higher fodder than the rest. These modules were also significantly different in their respective fodder yields. The rest (except 8 x 3.0m which had the least yield) were not significantly different from each other in their respective fodder yields.

Table 42. Mean effect of treatments on fresh fodder yields (t/ha) from fourth coppicing to 0.5m height after maize harvest, (3.5 months after the third cutting back to 0.5m height), September 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	21.1e*	11.3d	9.3c	9.6c	12.8
4.0	12.3d	6.8bc	4.5b	6.5bc	7.5
8.0	7.1bc	4.5b	3.0a	3.7ab	4.6
Means	13.5	7.5	5.6	6.6	

S.E. of row spacing means = 0.88
S.E. of within row spacing means = 0.62
C.V. (%) row spacing = 16.8
C.V. (%) within row spacing = 20.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Interaction in row and within row spacing on fodder yields (t/ha) was found to be significant. An increase in both row and within row spacing led to a decrease in fodder yields.

The 2 x 0.5m (10,000 trees/ha) spacing combination had significantly the highest yield, followed by 2 x 1.0 and 4 x 0.5m which did not differ significantly in their fodder yields. The 8 x 2.0m spacing combination had the least yield.

4.3.5.2 Fuelwood production

Substantial amount of fuelwood (t/ha) was harvested after cutting back the trees to 0.5m above ground, nearly 3 years after planting. Pruning to one trunk was done in October 1984 (Plate 1). This main trunk was harvested in March 1985, and the fuelwood yield realised is shown in Table 43 and partly in Plate 7.

Table 43. Mean effect of treatments on Leucaena fuelwood yield (t/ha), March, 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	105.5 f*	29.8 ed	18.8 ed	25.1 ed	44.8
4.0	83.5 f	43.3 e	21.9 ed	15.7 d	41.1
8.0	28.5 ed	15.4 d	8.3 d	8.3 d	15.2
Means	72.5	29.5	16.4	16.5	

S.E. of row spacing means = 10.79
S.E. of within row spacing means = 11.73
C.V. (%) row spacing = 46
C.V. (%) within row spacing = 49

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between treatments on fuelwood yield was observed. An increase in both row and within row spacing led to a decrease in fuelwood yield. Areas of significant differences in Table 43 are shown by DMRT in alphabets.

The spacing combination (2 x 0.5m and 4 x 0.5m) yielded significantly the highest fuelwood, though no significant difference was noticed between them. The least yield was obtained from 8 x 2m and 8 x 3.0m spacing combination.

Plate 6. A sample of the fuelwood yield, harvested in March 1985, stacked ready for turning into charcoal.

No fuelwood was realised from the second and third coppicing of the trees back because of the short-interval between the two.

A substantial amount of fuelwood (t/ha) was however realised from the fourth coppicing (Table 44), 3.5 months after the third cutting back. This fuelwood harvest was done in the process of land preparation (after a short fallow period) for the subsequent 1985 short-rains crop.

Table 44. Mean effect of treatments on Leucaena fuelwood yield (t/ha), September, 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	8.0f*	5.0e	2.2c	1.9cb	4.3
4.0	3.5d	1.7cb	1.6b	1.6b	2.1
8.0	1.6b	0.7a	1.0ab	1.0ab	1.1
Means	4.4	2.5	1.6	1.5	

S.E. of row spacing means = 0.5
S.E. of within row spacing means = 0.3
C.V. (%) row spacing = 32.0
C.V. (%) within row spacing = 33.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between row and within row spacing on fuelwood yield was realised. A decrease in both row and within row spacing led to an increase in fuelwood yield. The 2 x 0.5m treatment gave the highest yield while 8 x 1.0m gave the least.

4.3.5.3 Tree heights

Tree heights before the fourth pruning were recorded to indicate rate of growth (Table 45).

Table 45. Mean effect of treatments on tree heights (m) at maize harvest, August 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	3.8e*	4.2d	4.0d	3.7cd	3.9
4.0	3.7cd	3.4ab	3.5ab	3.6abc	3.5
8.0	3.3a	3.5ab	3.4ab	3.7cd	3.5
Means	3.6	3.7	3.6	3.7	

S.E. of row spacing means = 0.14
S.E. of within row spacing means = 0.11
C.V. (%) row spacing = 6.0
C.V. (%) within row spacing = 9.5

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Tree heights (m) were significantly affected by row spacing. The 2m row spacing heights were significantly taller than the 4.0 and 8.0m; the latter two were not significantly different from each other in their heights.

4.3.5.4 Tree root densities (g/m^3/tree)

Tree root density measurements (Table 46) were carried out in August 1985.

Table 46. Mean effect of treatments on tree root density (g/m^3/tree), April, 1985.

Row Spacing (m)	Root Sampling from tree base (cm)	Within row Spacing (m) 0.5	1.0	2.0	3.0	Sampling distance mean	Row spacing means
	0-25	8.4de	3.2b	6.3d	5.9cd	6.0	
	25-50	7.8de	4.3c	3.4b	4.7c	5.1	
2.0	50-75	3.2b	2.7b	2.3b	5.2cd	3.4	4.4
	75-100	4.0c	3.9bc	1.7a	3.1b	3.2	
	0-25	10.6e	4.8c	7.1d	2.5b	6.3	
	25-50	3.9bc	2.9b	2.4b	2.2a	2.9	
4.0	50-75	5.0cd	4.5c	7.3d	6.0cd	5.7	5.1
	75-100	3.9d	6.9d	6.9d	3.5b	5.3	
	0-25	8.9de	8.2de	9.4e	0.8a	6.8	
	25-50	7.6de	9.1e	12.7f	10.2e	9.9	
8.0	50-75	1.1a	12.5f	7.8de	8.6de	7.5	6.8
	75-100	1.5a	4.7c	5.2cd	1.1a	3.1	
Within row means		5.5	5.6	6.0	4.5		

S.E. of row spacing means = 0.64
S.E. of within row spacing means = 0.74
S.E. of sampling distance means = 0.74
C.V. (%) row spacing = 25.2
C.V. (%) within row spacing = 14.3
C.V. (%) sampling distance = 32.3

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Tree root density was significantly affected by interaction between row spacing and root sampling distance from tree, but not by within row spacing. Nevertheless, the trend of interaction was difficult to establish from the data of Table 46. It appeared however that a decrease in root sampling distance from the tree coupled with an increase in row spacing led generally to an increase in tree root density. It was however observed that there were differences in the root types at each sampling distance. The closer to the tree sampling distance viz 0-25cm and 0-50cm, generally had fine root-hair like roots, while the 50-75cm and 75-100cm sampling distances had a mixture of both fine and coarse roots, though the proportion of coarse roots was more pronounced.

4.4 FINANCIAL RETURNS FROM USE AND SALE OF LEUCAENA BIOMASS PRODUCTS

Financial returns from use of Leucaena fodder/GLM as organic fertilizer and sale of fuelwood harvested before the 1985 cropping was computed. These financial returns are discussed below.

4.4.1 Use of Leucaena fodder/GLM as organic fertilizer

Organic nitrogen (Kg/ha) added to the soil from incorporated fodder/GLM in one cropping season based on nitrogen levels (4.4%) of leaves and twigs harvested in March 1985, and on a conversion ratio of 1:4.4 dry weight to fresh weighed was computed.

The mean nutrient composition of the March 1985 fodder/GLM is shown in Table 47 while Table 48 shows the mean nitrogen contributions (Kg/ha) of the fodder/GLM yields of Tables 39 to 41 (on dry weight basis) to the intercropped plots.

Table 47. Mean nutrient composition (on dry weight basis) of Leucaena leaves and twigs, March 1985.

Percent						PPM			
N	P	K	Ca	Mg	S	Cu	Zn	Mn	Fe
4.4	0.3	2.2	2.2	0.2	0.3	11.9	21.0	51.0	216.0

Table 48 Mean Nitrogen contributions (Kg/ha) from Leucaena leaves and twigs, March 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	283.0e*	174.0dc	140.0dc	114.0d	178.0
4.0	183.0d	87.0c	65.0bc	82.0c	104.0
8.0	122.0d	63.0b	47.0a	48.0a	70.0
Means	196.0	108.0	84.0	81.0	

C.V. (%) row spacing = 28.2

C.V. (%) within row spacing = 25.0

* Means with the same letter do not significantly differ at the 0.05 level of probability according to Duncan's Multiple Range Test.

Significant interaction between treatments on organic nitrogen contribution to the intercropped plots was observed. A decrease in both row and within row spacing generally led to an increase in nitrogen contributions. The 2 x 0.5cm treatment combination gave the highest yield while the 8 x 2.0m treatment combination gave the least.

4.4.2 Financial earnings from use of Leucaena organic Nitrogen

Organic nitrogen contributions (Table 48) from one cropping season's fodder/GLM harvests could be translated into financial earnings i.e what is excess of the cost of the recommended CAN (26%N) fertilizers total cost (Table 49).

Table 49. Financial earnings (KShs/ha) from use of Leucaena fodder/GLM as an alternative to purchase of nitrogenous (CAN) fertilizers.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	3270.0	1810.0	1883.0	1006.0	1992.0
4.0	1931.0	644.0	349.0	577.0	875.0
8.0	1113.0	322.0	108.0	121.0	416.0
Means	2105.0	925.0	780.0	568.0	

The financial earnings (Table 49) that were calculated as CAN equivalent of N contributed by Leucaena GLM as was explained in section 3.2.3 (i) of the materials and methods were a reflection of the nitrogen contributions of the different tree spacing treatments (Table 48). The highest earning was from 2 x 0.5m spacing treatment combination while the 8 x 2.0m gave the least.

4.4.3 Financial returns from sale of fuelwood

The fuelwood yield (Table 43) harvested in March 1985 after 2.5 years growth was substantial. This yield was a bonus from the intercropping system since its production received no direct costs (e.g. fertilizer application, weeding etc.). The only direct cost involved in the production of the fuelwood was the cost of harvesting.

The mean labour requirements (Mandays/ha) for harvesting and stacking the fuelwood harvested in March 1985 (Table 43) and the corresponding harvesting and stacking costs are shown in Tables 50 and 51. The financial earnings (KSh/ha) from these fuelwood is shown in Table 52.

Table 50. Mean labour requirements (mandays/ha) for harvesting fuelwood, after 2.5 years growth, March 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	104.0	52.0	26.0	17.4	49.9
4.0	52.0	26.0	13.0	8.6	24.9
8.0	26.0	13.0	6.5	4.3	12.5
Means	60.0	30.3	15.2	10.1	

The 2 x 0.5m treatment combination with 10,000 trees/ha required the highest mandays/ha for harvesting and stacking the fuelwood. The 8 x 3.0 treatment combination required the least mandays/ha.

Table 51. Mean labour cost (KSh/ha) for harvesting and stacking fuelwood, March 1985.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	1872.0	936.0	468.0	313.2	897.3
4.0	936.0	468.0	234.0	154.8	448.2
8.0	468.0	234.0	117.0	77.4	224.1
Means	1092.0	546.0	273.0	181.8	

The costs of the 2 x 0.5 treatment combination were the highest, the 8 x 3.0 treatment combination with 416 trees/ha required the least cost/ha for fuelwood harvesting and stacking.

Table 52. Mean net financial earnings (KSh/ha) from sale of fuelwood harvested in March 1985 after 2.5 years growth.

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	15,628.0	4,030.7	2,665.3	3,870.1	6,548.5
4.0	12,980.6	6,748.6	3,416.0	2,461.9	6,401.8
8.0	4,282.0	2,322.6	1,266.3	1,305.9	2,294.2
Means	10,963.5	4,367.3	2,449.2	2,546.0	

The 2 x 0.5m treatment combination gave the highest financial returns from the sale of fuelwood while the 8 x 2.0m treatment combination gave the least returns.

CHAPTER 5

5.0 DISCUSSION

This section is presented according to the biological stages of experimental period and/or Leucaena growth and management imposed from May 1982-September 1985. Data collected from the tree, crop(s), weeds etc. is then presented respectively for discussion under each of the three management phases of the experiment.

5.1 LEUCAENA ESTABLISHMENT PHASE (MAY 1982-SEPTEMBER 1984)

This was a phase felt necessary not to impose any management (pollarding or coppicing) to the trees in order to get baseline data on the tree and the companion crops in these unmanaged system for comparison to later phases of different management techniques.

Cassava was used as the initial intercrop, and seemed to be a good companion crop for the Leucaena in this early establishment phase.

The sequence and yields of subsequent maize and green gram crops are shown in Appendix 8.6 to 8.8. Crop yield were greatly reduced during this phase because of excessive tree canopy effect developed.

The critical factors monitored at this phase, however, were effects of row and within-row spacing on percent tree survival and heights after 8 months of growth. Though no significant interaction between treatments on % survival was noticed, generally the percentages of the wider (8m) row spacings with any within row spacing were lower than those of the closer (2.0 and 4.0m) row spacings, again with any within-row spacing.

Similarly, though significant but inconsistent treatment interaction on plant heights was observed, plant height of Leucaena increased with increase in plant population. Similar observations have been reported by Mohatkar ~~et al.~~ and Relwani, (1985) in India.

The higher % survival and growth in the closer row and within row spacings could be attributed to an early canopy development and rapid ground cover which might have made favourable micro-environment (eg. weed suppression due to canopy effect) and more photosynthetic activity due to more leaf area exposure to radiation than in the wider spacing.

Redhead *et al*., (1983) in Tanzania also established that tree growth was enhanced because of the nursing effect of the crop against weed competition, protection from browsing by both domestic and wild animals and the creation of favourable micro-climate for the trees. The fact that food crops are weeded has a beneficial effect on the young tree's growth and survival rates (Readhead *et al*, 1983). Besides, the inorganic fertilizers applied to the companion crop indirectly benefits the trees The beneficial effect of applied nitrogenous fertilizers on the early growth of Leucaena has also been reported by Hill (1970).

Maghembe *et al*., (1980) at Morogoro, Tanzania, also found that maize compared to beans had profound effects on inter-planted Leucaena; which produced taller (1.6m) straight and unbranched stems after only 13 weeks an advantage if the objective was to produce a large proportion of poles This effect on Leucaena height was attributed to maize shade effect which forced the trees to grow taller initially, by precluding heavy branching and multiple leaders near the base of the tree.

Though shading increases plant heights at the initial stages of establishment, it however reduces root growth as well as forage yield (Egara and Jones, 1977). Djikman (1950) reported that the rate of growth of Leucaena is optimum under full sun, more so under high temperatures once it has become established (Savory, 1979).

5.2 LEUCAENA PRUNING PHASE (OCTOBER 1984-FEBRUARY 1985)

At this phase of management, pruning to single stem was imposed on the trees to partially reduce the canopy effect on the 1984 short-rains season green gram crop. Lawson (1984) showed that incident radiation on cowpea crop intercropped with Leucaena was significantly increased by pruning.

5.2.1 Green gram yield

Inspite of the two similar tree side prunings (Plate 2) instituted during the green gram growing season, green gram yields under pruned Leucaena were however still significantly reduced by 38-68% as compared to the control plots. The control plot yields were significantly higher than any of the intercropped plots.

The significant interaction between spacing treatments on green gram yield with increase in both row and within row spacings leading to an increase in green gram yield, suggested that a growth factor e.g. sunlight was limiting in the narrower row and within row spacings. This suspicion was confirmed by sunlight (%) reduction measurements which showed that the narrower row and within row spacings had significantly lower sunlight penetrations than the wider spacings. This indicated that pruning of the trees to single stems did not significantly reduce shade effect on the crop, more so for the crop rows close to the trees. Besides, competition for moisture and nutrients between the trees and the crop could in addition to incident radiation reduction also have contributed to the low green gram yields in the intercropped plots. However, the high yields of the 0.5m within row spacing with any row spacing (except 4 x 0.5m) was due to the extra sunlight penetration of these plots due to their position at the eastern end of the Leucaena alleys.

Lawson (1984) showed that percent incident radiation on cowpea was significantly lower close to the trees than in the middle of the alleys, and that % radiation incident on the crop was however tremendously improved (45%) by pruning, implying subsequent increment in the yield of the crop. The significant reduction in sunlight penetration in the narrow spacings than in the wider ones was due to the dense canopy developed in the former.

The significantly high fodder/GLM and fuelwood yields obtained from narrow spacings as compared to the wider spacings was a reflection of the dense canopy effect that had a possible contribution in the reduction of the green gram yields.

East-West orientation of the plots, a layout recommended (Anon, 1984b) and used in this experiment to minimize shading of the tree on the companion crop, led to differences in percent incident radiation between plots especially in the morning and evening, when the angle of the sun is reduced. This phenomenon subsequently led to differences in green gram yields between plots. The yields of plots at the end of the alleys (e.g. 2 x 0.5, 4 x 0.5, 8 x 0.5, 2 x 3.0, 4 x 3.0 and 8 x 3.0) were generally higher than the rest which fell in the middle of the 65m long alleys. When shading was however removed in the next season's crop, some of the plots at the eastern and western ends of the alleys did not however yield significantly higher than those in the middle of the alleys (Table 23). This observation indicated that the higher green gram yields in some of the plots at the eastern and western ends of the alleys was due to more incident radiation that they were receiving than those plots in the middle of the alleys.

5.2.2 Green gram yield components

The significantly longer pod lengths of the control plot (no trees) over the intercropped plots corresponded with the high green gram yields (Table 8) of the control plot, an indication that pod length, which in this case was a good indicator of high green gram grain yields, was affected by sunlight penetration. This sunlight penetration to the green gram was significantly affected by between row spacings more than within row spacings.

The control plot produced significantly higher number of green gram leaves/plant than those of the intercropped plots, and this corresponded positively with the high green gram grain yields obtained from the control plot. However the observation that the LAI of the control plot was not significantly higher than some of the intercropped which yielded significantly lower green gram yields than the control suggested that high LAI was not always an indication of high green gram yields. The high green gram yield of the control plot was therefore due to the more leaves/plant, which might have been well oriented to incident radiation for high photosynthetic activities, leading to higher green gram grain yields.

Mean green gram plant heights in the intercropped plots were significantly taller than the control plots. These increased heights were however due to excessive canopy effect, that caused etiolation despite the tree side pruning instituted earlier.

5.2.3 Weed reduction

The significant interaction of tree spacing treatments on the analysis of weed types and biomass yields of weeds corresponded with significant reductions in weeds. Significant reductions in weeds were observed as in both tree row and within row spacings were reduced. This was due to reduced sunlight penetration in the narrow spacings that had higher densities of trees/ha as compared to the wider spacings. This was confirmed by reduced sunlight penetration measurements (Table 9) from these modules, as well as by similar studies conducted by Kang *et al*., (1981).

The absence of problematic weeds such as *Oxygonum sinuatum* in the intercropped plots of the 2m between row spacing of trees (Table 17) could be an indication of control of herbaceous weeds as a result of the shading effect of the dense tree canopy. The control of obnoxious herbaceous weeds as well as grasses under Leucaena, the latter of which generally have longer reproductive cycle and therefore stay in the field for a longer period than the former (Ivens, 1982), could mean a significant saving on soil nutrients and therefore gradual build-up of soil fertility.

Although volunteer Leucaena seedlings/wildlings in the narrower 2 and 4m row spacings were observed because of heavy tree seeding, their adverse effects however, on the companion green gram crop was felt negligible as has been shown by other studies (Anon, 1984d).

5.2.4 Leucaena biomass production

were noticed between tree heights, however, biomass (fodder and fuelwood) yields were significantly affected by the interaction between row and within row spacings. A decrease in both row and within row spacings generally led to an increase in both fodder and fuelwood yields because of the increase in tree density/ha. Though yields of individual plants from high density modules could be low (Hedge, 1982), these losses were however compensated by the increased number of plants, as shown by the higher yields of fuelwood and fodder.

The significant differences in yields of fodder and fuelwood from spacing with the same tree densities/ha but with different tree spacing arrangements e.g. 2 x 2.0, 4 x 1.0 and 8 x 0.5 (Table 4.2.8.2 and 4.2.8.4), all with 2500 trees/ha, and with the additional observation that spacing with lower rectangularities (Huxley, 1984) yielded more than those with higher rectangularities suggested the availability of more feeding areas in all directions as opposed to the higher rectangularities which had their feeding areas limited by intra-row competition.

5.3 LEUCAENA COPPICING PHASE (MARCH-SEPTEMBER 1985)

This was a phase of alley cropping as defined by Wilson and Kang, (1981) in which the trees were coppiced to 0.5m height above ground level to reduce shade on the companion maize crop in the alleys created by the tree rows.

Earlier crop yields (Table 8 and Appendix 8.6 to 8.8) were significantly reduced by canopy effect as a result of the reduced incident radiation in the intercropped plots.

5.3.1 Maize yield

The significantly higher maize yields (Table 23) of some of the intercropped plots as compared to the control plot suggested the beneficial effect of Leucaena trees on the crop. An increase of 37% in maize yield was attained by the highest yielding intercropped plot (2 x 0.5) as compared to the control. Kang (1981) however reported an increase of 46% in maize yield at Ibadan, Nigeria. Flores (1975) and Leviste (1976) citing the work of Brewbaker also reported that maize yield was increased by 133% when fertilized with Leucaena GLM as compared to the control plots.

In general, maize yields were higher when intercropped under high density Leucaena plants than under low density. The findings of de la Rosa (1980) is also in conformity with the results of this experiment. He reported that the intercropping of maize under high Leucaena population/ha increased the grain yield of maize per plant. Similar findings have also been reported by Rachie (1983) who observed that highest maize yields was obtained under Leucaena populations of 10,000-20,000 plants/ha.

The most possible reason for the higher yield of maize attained when planted under high density Leucaena than under low density and the control was due to improved soil fertility as a result of the higher GLM, BNF, leaf dropping and root decomposition.

Brewbaker (1984) observed that Leucaena provides more than just nitrogen; mineral elements such as phosphorus and potassium absorbed by the roots from deep soil also become incorporated into the foliage. This foliage upon falling or incorporation into the soil lead to an increase in soil nutrient levels and therefore enhanced crop performance. Besides, the improved crop performance could be due to reduced N-leaching under legume intercropping as opposed to single crop system (Singh et al., 1981; Yadav, 1981).

5.3.2 Maize yield components

The significant increase in maize plant heights over the control plots only 42 days after sowing and at later stages, of tasselling and harvesting in the absence of shade in the intercropped plots due to frequent Leucaena pruning to 0.5m height above ground, suggested the beneficial effects of coppicing Leucaena on the intercropped maize, as discussed earlier.

In addition to maize plant heights, other growth components such as LAI, ear heights and stover yields of the intercropped plots were also significantly higher than those of the control plots. However, treatment effects on cob length, cob diameter and maize shelling percentage were not significant. Nevertheless, other studies by de la Rosa (1979) showed that both cob length and diameter as well as cob weights were significantly increased by Leucaena GLM as compared to the control, an improvement he attributed to the better performance of maize under Leucaena alley cropping. However, he reported that age to tasselling, plant height, ear height, number of cobs per plant and shelling percentage of maize under Leucaena were not significantly increased as compared to control.

Other studies by Ssekabembe (1984) at Machakos, Kenya on effect of multipurpose trees GLM on maize yield components and grain yield also showed number of leaves/plant, leaf area index and maize plants heights were consistently higher than the control plot's maize, though the differences were not statistically significant.

The superior performance of intercropped maize yield components as compared to the control plot could also be partly attributed to reduced weed incidences, mainly due to the canopy effect of the previous tree management phases (establishment and pollarding), that smothered most of the weeds.

The contribution of nutrients from soil incorporated Leucaena GLM, and particularly the high organic nitrogen yields could also have significantly affected these maize yield components as has been shown by Ssekabembe (1984), resulting subsequently in higher maize grain yields, though the efficiency of Leucaena N-utilization by maize has been reported to be as low as 38% (Guevarra, 1976) due to the fast rate of Leucaena GLM decomposition to humus. Evensen (1982), however showed efficiencies as high as 65% when Leucaena leaves and small twigs were used instead of chopped whole Leucaena foliage including the woody fraction which Guevarra used.

Maize planted closer to the Leucaena trees (65cm away) (Table 25) were significantly taller than those planted further away (130cm) (Table 26), despite the uniform treatments at all points. This could be due to the possibility of additional nutrients from the tree roots whose density has been shown (Table 46) to be highest within 50cm distance from the trees.

Leucaena has been observed to nodulate profusely in the sandy soils, and N-fixation by these nodules and/or subsequent release of nutrients by the roots upon death and decomposition to humus could also have led to the superior performance of maize plants closer to Leucaena trees.

5.3.3 Soil fertility improvements

Significant increases in % organic carbon, phosphorus, potassium calcium, magnesium and pH levels in the top soil (0-15cm depth) of the intercropped plots as compared to their respective control plots was obtained, even though the same types and rates of fertilizers were applied to all plots. This phenomenon suggested the beneficial effect of the trees in increasing soil fertility.

The higher the tree density/ha, the higher the concentration of soil nutrients (Table 34) generally, with soil reaction (pH) becoming less acidic. These trends will perhaps be more conspicuous in the long run because processes of soil nutrients build up are generally of long term duration. Hu Tai-wei et al., (1984) in China reported that soil nutrient reserve (0-30cm) content under Leucaena increased in available nitrogen, phosphorus, potassium, calcium and magnesium at the rate of 5.52, 1.67, 13.94, 676.71, 125.53Kg/ha/year on average, respectively after 4.5 years of growth. Besides, the high biomass yields (maize grain and wood) exported out of the system meant that a lot of nutrients have been taken out too, recycled from deeper soil layers. Even after this 'export', still there was substantial nutrients build-up in the top soil, inspite of improved plant nutrition from these soils due to reduced soil acidity.

In acidic soils, a substantial amount of P applied as fertilizer could be converted into insoluble Fe and Al phosphate that are unavailable to plants. Troug (1946) and Thomson and Troeh (1978) reported that P formed low solubility compounds of iron and aluminium phosphates when the soil pH was below 6.0.

The reason for the improvement of the soils in the intercropped plots was due to the more GLM applied, therefore more humus than the control plot. This humus increases the nutrients retentive capacity of the soils, thereby reducing their leaching rates. Due to their organic nature, nutrients in green manures are often released over a longer period than is the case with inorganic fertilizers, and they are less likely to be lost (fixed, bound or leached) as soils are better buffered and complex organic compounds are formed which protect the nutrients (Pound and Martinez, 1983). The slight decrease in soil pH in January 1985 as compared to 1984 (Table 34) in the intercropped plots as well as the control plot was due to the nitrogenous fertilizers applied as was also reported by Kang et al. (1983).

A remarkable increase in soil carbon was noticed at the end of the pruning phase (January, 1985) as a result of the very low growth and yield of green gram due to the shading effect of the remaining tree canopy. The very low growth and yield of green gram indicated that there was very little extraction of nutrients from the soil and hence the soil showed increment in carbon build up as in the cases of soils that are left fallow. Moreover, the shading effect of the canopy reduces soil temperatures thereby minimizing the decomposition rates of organic matter in soils and making it gradually available. However the significant drop in soil carbon in September 1985 despite the large amount of GLM added (Tables 39, 40 and 41) to the soil was because of the fast rate of decomposition of Leucaena GLM within 2-3 weeks (Anon, 1984d) especially in the open Leucaena alleys as compared to the shaded alleys of the pollarding phase. The fast rate of mineralisation of Leucaena has been noted by several workers (Guevarra, 1976, Kang et al. 1981, Balasubramanian, 1983; Ssekabembe, 1984). This fast rate of decomposition in the open Leucaena alleys was due to the higher intensity of sunlight that raised the soil temperatures as a result of the open canopy that enhanced soil microbial activity. This is true of tropical soils generally of which, Kanwar (1976) observed that, although much organic matter is produced, it decays rapidly.

Nevertheless, the increased levels of soil nutrients indicated to-date have undoubtedly contributed to increased maize yields realised in August 1985. Though alley cropping e.g., with Leucaena has been described as a low input crop production system (Torres, 1983), the maize yields of this experiment, as well as by other investigations carried out in Nigeria (Anon, 1982a, 1983a, Kang et al., 1981, 1983) have clearly demonstrated that it can as well be considered for high technology inputs such as mineral fertilizers and irrigation. These studies, however, have indicated more than anything else the benefits of chemical fertilizer use in supplementing the yield advantages of alley cropping.

5.3.4 Weed reduction

Significant reduction in both weed types and biomass yields in the intercropped plots was achieved as compared to the control. For instance, a significant reduction in biomass yields of weeds (72%) from 2m row spacing was obtained as compared to the control in August 1985 due to the differences in canopy closure rates between row spacings (Table 38).

This weed control effect could also be attributed partly to the earlier management phases (establishment and pruning) canopy effect on weeds.

That the shade factor was responsible for the weeds reduction was confirmed by lower percentage weed reductions in May 1985 during the active alley cropping stage (Tables 35 and 36) as compared to the crop ripening/harvesting period when canopy developed and significantly reduced weed yields (Tables 37 and 38). Hedge (1982) also observed that the early ground cover of Leucaena achieves good weed control through shading, although allelopathic mechanism as being involved has also been suggested by others (Anon, 1982b). Kuo et al. (1982) observed that both mimosine, and the aqueous extracts of air-dried Leucaena leaves were strongly phytotoxic to a number of test plants, and to inhibit their germination and radial growth. Six phenolics and several unknown flavonoids were obtained from the extracts of air-dried Leucaena leaves. These, together with mimosine, are likely to be responsible for the allelopathic action of Leucaena (Kuo et al., 1982).

The reduced weed incidences in the intercropped plots positively contributed to the high maize yields of the intercropped plots as compared to the control plot, which at all times had significantly more weeds than other treatments, and subsequently, lower yields of maize (Table 23) than most of the intercropped plots. Besides, most of the weeds in the intercropped plots were broadleaved species, and were easy to remove/dislodge as opposed to the more difficult grassy species such as Cyperus esculentus that were abundant in the control plot. In the Philippines and Fiji, similarly difficult to control grasses such as Imperata cylindrica and Chromolaena odorata have effectively been controlled through shading by Leucaena, the latter at a Leucaena spacing of 1.5 x 1.5m (Pound and Martinez, 1983, Castillo et al., 1977, Benge and Curan, 1976).

5.3.5 Leucaena biomass production

The biomass production (fodder and fuelwood) during this coppicing phase was significantly affected by the tree density. Highest yields occurred at modules with high tree density/ha. The lowest yields of both fodder and fuelwood were constantly observed from the 8m row spacing with any within row spacing combination.

Tree heights during this phase were significantly affected by between row spacing as was the case in the earlier management stages. It was observed from Table 39, 40 and 41 that spacing treatments with the same density of trees per hectare, but different arrangements such as 2 x 1 and 4 x 0.5 had significantly different biomass yields of fodder and fuelwood. This observation suggested the effect of rectangularity (Huxley, 1983), although the actual cause of these differences were not clearly understood. The observation that maize yields (Table 23) were also highest in these high tree density modules indicated enhanced soil fertility and weed control.

The superior tree heights in the narrower spacings as compared to the wider ones was attributed firstly to the significant reduction of weeds in the narrower spacings which could have resulted in moisture and nutrients savings and, secondly, to the large amounts of nitrogen from GLM added to these plots.

The increase in root density, g/m^3/tree (Table 46) close to the trees (0-50cm) compared to the distance ones (50-100cm), and the superior maize performance close to the trees (Table 25) suggested the beneficial contributory effect of the roots to the GLM effect on soil N-status. This effect could be either due to biological nitrogen fixation by rhizobium bacteria on root nodules or N-release upon decomposition of dead roots. Similar studies by Kang et al. (1981) on root distribution of Leucaena plants when arranged in hedgerows showed that there were only small amounts of Leucaena roots in the surface soil beyond a distance of 100cm from the rows. However the high root weights at 25cm distance recorded in Kang et al. (1981) experiment was caused mainly by coarse woody roots, which would not compete for nutrients.

5.3.6 Financial returns from use and sale of Leucaena biomass products

The use of Leucaena GLM as organic fertilizer, whose percent nitrogen content (4%) and potential nitrogen yield/ha were observed to be high (Tables 47 and 48) could significantly contribute to the farmers' income. For example, potential nitrogen additions of up to 70-283Kg/ha to the companion maize crop were realized which could mean a reduction in the purchase of inorganic fertilizers. However, due to the high volatilization losses of added organic-N, especially under high temperatures in the field (Messan, 1980), only about 65% of this nitrogen is available for the crop growth (Brewbaker and Evensen, 1984). More losses could further occur due to sub-optimum timeliness of application (Pound and Martinez, 1983). Although the efficiency of utilization of the nitrogen is therefore low, it is suggested that on a long-term basis, its content of other elements and the improvement of soil properties due to the addition of organic matter as Leucaena meal will probably prove beneficial (Pound an Martinez, 1983).

The beneficial effect of this additional nitrogen on the maize was apparent from the generally increased yields of the intercropped plots as compared to the control plot. Other studies at Ibadan, Nigeria also reported nitrogen contribution of 189-250kg/ha from Leucaena mulch with 3.2-3.5% N content (Kang, 1981).

Besides GLM, biological nitrogen fixation (BNF) is yet another important attribute of Leucaena. Guevarra (1976), for example, under favourable year-round growing conditions reported nitrogen fixation rates as high as 500-600kg/ha/year. However, lower nitrogen yields of 100-200kg/ha/year have also been measured in Hawaii (Halliday, 1984).

Similarly, the computed financial returns/ha (Table 49) from the extra Calcium Ammonium Nitrate 'C.A.N.' fertilizer equivalent bags resulting from the GLM of three coppicings in one cropping season was quite significant. Financial returns/ha of up to Ksh3,270 was obtained after deducting the recommended CAN (26% N) fertilizer costs used by the maize crop.

The significant fuelwood yields (Tables 43) after two and half years of tree establishment represents an important source of income to the system. Though the labour requirements for harvesting and other respective costs were highest for the high tree density modules, the financial returns from sale of the fuelwood were also highest for the high tree density treatments.

CHAPTER SIX

CONCLUSION

Both survival and growth of Leucaena was observed to be highest in high tree density treatments (10,000 trees/ha). This was attributed firstly to competition for light and therefore fast growth, and secondly to early canopy closure which controlled weeds more effectively than wider spacings. The crop husbandry practices (fertilizer application and weeding) also had beneficial effects on the growth and survival rates of the trees since their deep roots recycle and use for their growth nutrients leached beyond the reach of the arable crops.

Crop yields were however significantly reduced after only 8-12 months of Leucaena growth largely due to excessive shade effect developed, suggesting introduction of early management practices (pruning or coppicing). Pruning thereafter to single stem after 2.5 years growth was not effective in reducing canopy effect on the companion crop. However, a significant improvement in maize yield (38% increase compared to the control) was achieved particularly in the narrower alleys, when the trees after 3 years growth were coppiced to 0.5m high. This resultant increase in yields in a place characterized by low crop productivity is therefore remarkable.

The improved crop performance after tree coppicing (alley cropping) was attributed firstly to the significant levels of weed control (at times up to 90%) due to the previous canopy effect, and secondly to the gradually improving soil fertility levels such as % organic carbon, potassium, phosphorus, calcium, magnesium and pH which were all higher in the intercropped plots as compared to the control, even though all plots received the same types and rates of inorganic fertilizers.

The gradually improving soil fertility was attributed to the effect of the fallow period (establishment/pruning phase of 2.5 years) in terms of reducing both weed biomass and composition (the gradual reduction in the number of grass species and the dominance of the broad leaved species being a commonly noted feature), tree root decomposition and nutrient release, leaf litter/GLM fall or incorporation in the soil, and lastly to nutrients recycled from deeper soil layers by the trees.

Up to 28.3t/ha of GLM from tree coppicings at approximately monthly intervals, with potential N yield of 284Kg/ha was realised and incorporated into the soil of the highest tree density plot (2 x 0.5m). The prunings (GLM) as N-source are most effective when incorporated into the soil than when applied as surface mulch as has been shown in other studies (Kang et al., 1981). Large amounts of biologically fixed nitrogen (though not quantified in this experiment) could also have contributed to the enhanced crop yields under Leucaena.

The woody biomass yield and the associated GLM during the period of tree establishment prior to the initiation of the alley cropping treatment were significant and eclipsed the decline in crop yields during this period. The financial returns from the sale of such GLM and fuelwood were also significant; up to Ksh3,270 and KSh15,628 respectively as compared to the control which had no such extra advantages, except for the returns from the sale of the crops only.

This experiment has therefore elucidated the beneficial effects of alley cropping maize with Leucaena leucocephala, leading to improved crop yields due to improved soil fertility status and enhanced weed control. The resultant fuelwood obtained during the fallow period (between one cropping season and the next) could substantially improve household's energy requirement, and help reduce environmental degradation of trees for fuelwood.

RECOMMENDATIONS FOR FUTURE RESEARCH

This study has shown the levels of crop loss and gain that can occur under single rows of Leucaena in an unmanaged (fallow), partially managed (pruning) and managed (alley cropping) systems at the coastal sandy soils of Kenya.

However the beneficial effects of the tree in terms of soil fertility improvement and therefore increased crop yields was compounded by the application of the recommended fertilizer rates for the area.

It is therefore recommended that future research:

a) Separate the compound effects of inorganic fertilizer and Leucaena GLM on crop (Green gram and Maize) yields.

b) Determine the biomass (GLM) yield of single and double hedge row Leucaena alley cropping system at different heights and frequencies of coppicing.

c) Determine the effect of (b) above on the companion crops.

d) Establish trends in soil nutrient levels, and quantify levels of biologically fixed nitrogen under such systems as (b) above.

It is also recommended that shorter alley lengths than 65m are used to avoid unequal distribution of incident radiation among plots/treatments, and that the alleys be aligned in East-West direction to maximise harvest of morning and afternoon incident radiations.

From the findings of this study, it is also recommended that high density planting of Leucaena for increased biomass/GLM production be used for higher crop yields/Green Leaf Manure/woodfuel at the farm level.

A periodic pruning at lower points (e.g., 0.5m above ground) which prevents Leucaena excessive seeding and shading is also recommended to make Leucaena acceptable to farmers.

CHAPTER SEVEN

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CHAPTER EIGHT

APPENDIX

Appendix 8.1: Climatic data for Mtwapa from January 1982 to September 1985

1982	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
RAINFALL (mm)	1.4	NIL	38.2	281.3	660.4	118.2	193.3	72.5	110.1	176.7	57.6	28.0
EVAPORATION (mm)	6.3	7.0	7.5	4.8	3.5	4.4	4.3	4.9	5.6	5.2	5.8	5.8
MEAN MAX. TEMP.	31.7	31.9	32.5	30.4	27.9	28.3	27.4	27.5	28.3	28.9	30.6	31.4
MEAN MIN. TEMP.	22.4	22.3	22.8	23.3	22.5	21.9	21.1	20.8	21.2	22.2	21.9	22.4
% MEAN R.H.	71.0	68.0	69.0	81.0	86.0	82.0	82.0	80.0	79.0	82.0	79.0	78.0

Appendix 8.1 (continued)

1983	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
RAINFALL (mm)	1.4	5.0	67.4	163.9	502.2	234.0	163.0	22.9	64.5	31.6	21.5	10.6
EVAPORATION (mm)	6.2	6.4	6.7	5.7	5.3	5.2	4.4	5.1	5.7	5.9	6.3	6.3
MEAN MAX. TEMP.	13.3	31.8	32.6	30.8	28.3	28.2	27.8	27.8	28.1	29.6	30.8	32.0
MEAN MIN. TEMP.	22.3	22.7	23.0	24.1	22.0	21.6	20.6	20.6	20.7	20.2	20.7	21.5
% MEAN R.H.	72.0	71.0	69.0	81.0	82.0	84.0	82.0	80.0	77.0	75.0	73.0	72.0

Appendix 8.1 (continued)

1984	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
RAINFALL (mm)	.2	NIL	24.4	297.8	321.5	169.6	117.3	18.6	90.9	299.4	163.5	28.1
EVAPORATION (mm)	6.8	7.4	7.5	7.6	6.3	5.4	4.8	4.2	5.3	5.0	5.6	5.7
MEAN MAX. TEMP.	31.4	30.9	32.3	31.1	29.0	27.3	26.5	26.9	27.8	28.5	29.6	30.7
MEAN MIN. TEMP.	21.5	21.3	33.1	24.2	22.4	21.3	20.5	20.0	20.4	21.9	22.4	2.8
% MEAN R.H.	68.0	67.0	70.0	76.0	80.0	81.0	84.0	81.0	78.0	80.0	83.0	73.0

Appendix 8.1 (continued)

1985	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
RAINFALL (mm)	20.3	50.6	48.3	209.9	277.5	540.0	146.8	91.3	38.3	-	-	-
EVAPORATION (mm)	5.6	5.3	6.1	6.0	4.4	4.2	4.5	5.0	5.7	-	-	-
MEAN MAX. TEMP.	31.3	31.0	31.4	30.0	28.5	27.6	27.0	26.6	27.9	-	-	-
MEAN MIN. TEMP.	22.7	22.9	22.4	23.8	22.8	18.6	20.0	21.1	21.5	-	-	-
% MEAN R.H.	74.0	77.0	75.0	79.0	82.0	77.0	81.0	79.0	76.0	-	-	-

Appendix 8.2: Field Layout of Leucaena Experimental Plots at Mtwapa

Appendix 8.3: Leucaena Experimental Plots Planting Modules in Parallel Systematic Design

Row spacing (m)	Within row spacing (m) 0.5m	1m	2m	3m
2m	2A 1m	2B 2m	2C 4m	2C 6m
4m	4A 2m	4B 4m	4C 8m	4D 12m
8m	8A 4m	8B 8m	8C 16m	8D 24m

Appendix 8.4: Leucaena Plant Population/ha, Area/Plant and Plant Arrangements

Tree density per ha.	$1m^2$ 10,000	$2m^2$ 5,000	$4m^2$ 2,500	$6m^2$ 1,666	$8m^2$ 1,250	$12m^2$ 823	$16m^2$ 625	$24m^2$ 416
	2A	2B	2C	2D				
	4A	4B			4C	4D		
		8A			8B		8C	8D

Appendix 8.5: Analysis of Variance (Anova) of Leucaena spacing treatments

Source of Variation	Degrees of Freedom
Sub-plot total	59
Blocks	4
Row Spacings	2
Error (a)	8
Within Row Spacings	3
Row and Within Row Spacings Interaction	6
Error (b)	36

Appendix 8.6: Dry weights (Kg/ha) of shelled maize under Leucaena leucocephala intercrop, August 1983

Row spacing (m)	Within row spacing (m) 0.5	1.0	2.0	3.0	Means
2.0	0.0	0.0	21.0	210.0	57.8
4.0	210.0	240.0	50.0	1050.0	387.5
8.0	1190.0	1130.0	1520.0	2120.0	1490.0
Within row means	466.7	456.6	530.3	1126.7	
Control plot mean					2990

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Appendix 8.7: Dry weights (Kg/ha) of Green gram crop under <u>Leucaena leucocephala</u> intercrop, December 1983

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	0.0	0.0	0.00	0.00	0.0
4.0	0.0	0.0	0.00	0.00	0.0
8.0	0.0	0.0	0.75	0.00	1.6
				5.80	
Within row means	0.0	0.0	.20	1.93	
Control plot mean					367

Appendix 8.8: Dry weights (Kg/ha) of shelled maize under <u>Leucaena leucocephala</u> intercrop, August 1984

Row spacing (m)	Within row spacing (m)				Means
	0.5	1.0	2.0	3.0	
2.0	0.0	0.0	0.0	16.0	4.0
4.0	90.0	0.0	15.0	192.0	74.0
8.0	250.0	205.0	619.0	107.0	295.2
Within row means	113.0	68.0	211.0	405.0	
Control plot mean					2750