PLANT NUTRIENT ASPECTS OF MULCHING IN ALLEY CROPPING TRIALS AS AFFECTED BY MICRO-CLIMATOLOGICAL FACTORS OF THE SEMI-ARID AREAS OF MACHAKOS DISTRICT, KENYA

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

To my beloved wife, Beatrice Wangari

and

my daughter, Lydia Murugi

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ABSTRACT

Experiments on plant nutrient status and yield of maize in relation to mulch nutrient composition were conducted at Katumani, in Machakos from 1987 to 1989. In all the seasons apart from the Short Rains of 1988, Katumani composite B was sown. During the SR'88 Hybrid 511 was mistakenly planted.

Cassia siamea had been grown as the tree species forming the hedges. Between the hedges, 3 maize rows were sown parallel to the hedges. The hedges were lopped periodically at a height of 50 cm and the loppings fully incorporated into the soil within the hedges (alleys) before the beginning of each season. In the control plots, each hedge row was replaced by a row of maize and therefore no mulch was incorporated in the control plots.

Nutrient analysis was performed for *Cassia* loppings, maize leaves, maize grains and maize stovers for nutrient analysis. Maize yield (grains) in g/row and weed biomass were also assessed. Decomposition for *Cassia siamea* loppings using standard litter bags was also monitored.

The results indicated that incorporation of mulch increased the nutrient concentrations of maize leaves, grains, and stovers as revealed by higher levels of nutrient concentrations in the treated plots relative to the controls. Although there was a relatively higher yield in the treated plots as compared to the controls on per row basis, the differences were not significant. The weed biomass in the treated plots was more than in the control plots. Decomposition experiments indicated that approximately 70-90% of *Cassia* mulch dry matter could be lost within 60 days.

It has been observed that, the most limiting factor to the alley cropping technology in the semi-arid areas is the competition for water and nutrients in the soils. Water and nutritional status of the soil, will therefore determine to a large extent, the success or otherwise of such a system in these areas.

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CHAPTER ONE

1. INTRODUCTION

Kenya's population growth rate is approximately 4% per year and it requires doubling of food production if this increasing population is to be adequately fed (Mwangi & McCarthy, 1982). Two ways of achieving this are stabilizing food production and by opening up new areas for arable farming in marginal and medium agricultural potential areas. Kenya's arid and semi-arid areas cover approximately 80% of the country while the semi-arid areas with marginal to medium agricultural potential comprise about 20% of the country's land area. It is from these areas that one third of the projected increase in agricultural production is expected to come from (Anon, 1983).

Major constraints in the semi-arid areas include low and unreliable rainfall, and very low organic matter in the soils. The repetitive maize/bean intercrops and low agricultural inputs into the soil have led to degradation and impoverishment of most soils in these areas resulting in very low crop yields. At times total crop failure, necessitating expensive intervention in the form of famine relief, has been experienced (Mungai, 1987).

In the traditional systems, farmers mainly relied on long fallow periods to regenerate the fertility of the land exhausted during the cropping period. The bush fallow - crop production rotation is known to be an ecologically stable system since a long fallow period is feasible. When the fallow period becomes too short, as observed in areas with high population densities, either artificial fertilizers have to be used to improve soil fertility or other alternatives which are economically attractive to small farmers have to be included in the production system. High costs and/or lack of inorganic fertilizers in many developing countries exclude or limit their use by many small farmers. In addition, low clay Alfisols and related soils which are widely distributed in the tropics, are known to be prone to soil acidification due to continuous use of high rates of artificial fertilizers (Kang & van der Heide, 1985).

In order to reduce the dependency on artificial fertilizers and at the same time respond adequately to the problems of food production in the semi-arid areas, a technically feasible and economically viable technology which can sustain crop production and offer other benefits to the farmer needs to be developed. Agroforestry has been proposed as one such alternative in these areas. Young (1985 & 1989) has defined agroforestry as a collective term for land use systems in which trees are deliberately grown on the same land management unit as agricultural crops or pastures, and in which there is both an economic and ecological interaction between the tree and non-tree components. Agroforestry can be both a low-input as well as a self-sustaining technology. According to Nair (1984), it has the most apparent potential in 'marginal' and in resource-limited small holder systems where monocultural agriculture or forestry may not be most feasible or even desirable.

In order to maximise the benefits brought about by agroforestry systems, scientists at IITA have developed an alley cropping system. This is essentially an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees or shrubs (Kang et al., 1981b; Wilson & Kang, 1981).

The hedgerows are cut back (lopped) at or close to planting and are kept pruned during crop growth period to prevent shading and to reduce other competitions with food crops. The loppings provide mulch which acts as green manure for the food crops and in this way plant nutrients are recycled in the soil layers where tree-roots are active. The mulch also provide favourable conditions for soil macro-and micro-organisms.

The Dryland Agroforestry Research Project (DARP) sited in the semi-arid areas of Machakos which is a joint venture between KEFRI, KARI, ICRAF, NDFRS and MIDP (See appendix I for abbreviations used) aims at developing agroforestry technologies for the semi-arid areas of Kenya and other East African countries with a view to improving the quality of life of the inhabitants through maintaining or increasing the productivity of the cropping and animal production systems.

The results from the DAFP alley cropping trials conducted at Katumani National Dryland Farming Station (1983-1986) indicated between-row yield differences in Cassia siamea/maize intercrops whose interpretation appeared incomplete (Sang & Hoekstra, 1986b). The authors found that during the development period of the alley cropping system, the maize rows adjacent to the hedgerows performed better than the centre rows. When the hedges were better developed, a negative impact was noted on the maize rows closest to the hedges which they explained as being likely due to moisture competition between the hedges and the adjacent rows of maize. The picture was different again in the first two seasons of the operational phase (Sang & Hoekstra; 1987b), where the two different Cassia siamea spacing gave different results and where the eastern outer rows outperformed the western ones. They suggested that the latter effects might be explained by a moisture and nutrient "harvesting" effect due to the slightly sloping terrain. The better performance of the outer rows as compared to centre rows during hedgerow establishment was suggested to be due to an improved availability of growth factors like moisture and nutrients for manure was used during the hedgerow establishment, though these factors were not quantified. The yield interpretation of the maize rows remain therefore difficult and it would appear very useful to quantify aspects of plant nutrient inputs from the mulch as one possible factor contributing to the above mentioned anomalies.

Information on the nutrient composition of the Cassia siamea that is incorporated in the soils as a mulch and its rate of decomposition is not well understood. It is therefore necessary to know and understand the decomposition rates and release patterns of nutrients into the soil and their subsequent availability and uptake by the maize crop.

The overall objective of this study was therefore to assess the plant nutrient aspects of mulching in DAFP's Cassia siamea alley cropping trials as affected by micro-climatological factors and their subsequent effect on maize yield after nutrient release into the soil through mineralization. Information on these factors and of rainfall patterns of the area would assist in working out the timing of lopping the hedgerows for optimum release of nutrients. In order to realize the above objective, the following specific investigations were undertaken;

(a) The nutrient composition of loppings of *Cassia siamea*.

(b) The rate of decomposition of *Cassia siamea* loppings.

(c) The foliar analysis of maize leaves.

(d) The nutrient analysis of maize grains.

(e) The dry matter determination of weeds.

The plant nutrients assessed in this study were the macro nutrients like Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca) Magnessium (Mg), Sulphur (S), and Sodium (Na) which are essential nutrients and constitutents of a variety of organic compounds related to the structure and metabolism of plants. Some like N, P & K are more mobile in plants whereas others like Ca are less mobile (Cooke 1982, Sutcliffe & Baker, 1978). Carbon (C) content was also analysed.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. General

Budelman (1988) mentions that in the past few years the interest of the scientific community in leguminous shrubs and trees capable of fixing nitrogen has grown significantly. This increased interest is attributed to the increasing awareness that nitrogen fertilizers are becoming very expensive, particularly in the context of food crop production. When these leguminous trees and shrubs are selected correctly and integrated in cropping systems, they can produce cheap and accessible nitrogen and can be used for other purposes. Gliricidia sepium and Leucaena leucocephala are some of the species used widely in the cropping systems by farmers in Nigeria. According to Budelman (1989), such systems when developed should be able to replace the need for shifting cultivation and must accommodate the following four basic considerations:

(a) Create the lowest possible financial threshold, so that the technology is accessible to resource - poor farmers;

(b) Pay heed to management strategies that cater for maximum possible soil protection;

(c) Match tree and crop species that are mutually compatible, and

(d) Select tree species with a high degree of user-friendliness and a good capacity for regrowth after pruning.

In addition to their nitrogen fixing abilities, trees/shrubs can be periodically lopped and the loppings provide mulch which acts as green manure when incorporated into or put on to the soil. According to Stigter (1984), a mulch is a shallow layer that appears at the soil/air interface, with properties that differ from the original soil surface layer.

Mulching with crop residues and other vegetative matter has been a consistently successful practice in traditional shifting cultivation (Kang & van der Heide, 1985). In IITA, Nigeria, it has been shown experimentally that maize respond positively to mulch and the yield increases represent the net effect of a number of favourable effects on growth (Kang et al., (1981b). Moreover, the presence of organic cover on the soil not only reduces the raindrop impact effect on the soil, but it also improves both the physical conditions and fertility status of the soil (Nair, 1984). Mulching has been readily and profitably adopted in horticultural and plantation husbandry. Kang et al., (1984), reports several benefits which have been attributed to the practice of adding mulch. For example, it has been shown experimentally that the yield responses of maize at IITA, were 46, 55 and 22 percent more for the mulched plots, over the period 1970, 1971 & 1972 respectively. Six years of alley cropping of Leucaena with maize and cowpeas on low fertility Entisols helped to maintain higher soil nutrients and organic matter through periodic additions of Leucaena prunings. Plots which received prunings contained twice the amount of soil organic matter as the plots which did not. Repeated application of inorganic nitrogen fertilizer increased soil acidity whereas the addition of Leucaena prunings did not affect soil acidity. Plots receiving the prunings also maintained higher soil moisture compared to those that did not. The mulch from the prunings lowered soil temperature and enhanced biological activity.

Loppings from fast-growing and quickly regenerating woody perennials grown with agricultural crops in either zonal or mixed cropping schemes could be added as mulch on crop production fields. Hedgerow intercropping (alley cropping) is an excellent illustration of this possibility. Wilson and Kang (1981) have defined alley cropping as a crop production system whereby food crops are planted in spaces created by hedgerows of selected trees or shrubs. The loppings from the hedgerows supply nutrients and organic materials to the crop and recylce leached nutrients. In a recent agroforestry diagnostic survey of the farming system practices in Machakos district, conducted by ICRAF, the likely benefit from mulching was identified as one of the important aspects of the agroforestry approach to land management in the semi-arid, low-input crop production systems of that region (Nair, 1984). Kang et al., (1984) enumerated the following as possible benefits of trees and shrubs in an alley cropping system:

(a) Providing green manure or mulch for companion food crop. In this way plant nutrients are recycled from deeper soil layers.

(b) Providing prunings, which when applied as much during fallow suppress weeds.

(c) Providing favourable conditions for soil macro- and micro-organisms.

(d) When planted along the contours of sloping land, they provide a barrier to soil erosion.

(e) Providing prunings for browse, staking material and firewood.

(f) Providing biologically fixed nitrogen to the companion crop, if N fixing.

A major feature assigned to alley cropping is the ability of deep rooted species to absorb soil moisture and nutrients not available to annual crops from the lower soil strata. This moisture allows them to remain functional in the dry season. The deep roots enable them to pump and restore mineral nutrients to the surface soil. The shade they provide reduces soil temperature and evaporation and thus produce favourable environment for beneficial soil organisms (Wilson, et al., 1986). High soil temperatures have been found to inhibit germination and retard early growth of maize but when mulch was applied on the surface, soil temperatures were reduced and germination and early growth were improved (IITA, 1984).

2.2 The effects of mulch on crop and soil effects

When mulch was incorporated into the soil, Sang & Hoekstra (1986a) reported a significant, positive increase in maize yield in the range of 36 to 122% between the treated plots (where mulch was incorporated) and the untreated ones (control) on per row basis. In the reports on the experiment (Sang, et al., 1985; Sang & Hoekstra, 1986b; Sang & Hoekstra, 1987a&b), it has been shown that there was a consistent difference between the control and treatment plots. Treated plots were significantly higher in grain, cob weight and stover yields than the controls, and there were indications of cummulative effects with the number of years after the establishment of the experiment.

In a study on the effect of the application of the leaf-mulch of Gliricidia sepium on the early development, leaf nutrients and tuber yields of water yam (Dioscorea alata), Budelman (1989) showed that the mulch if strategically placed, can shorten the period needed for the yams to sprout by approximately 20% as well as increase yam production. One tonne dry matter mulch of per hectare raised the yam tuber yields by about two tonnes.

The use of loppings from leguminous trees and shrubs as green manure is a very old practice. Loppings of Sesbania grandiflora for example are commonly used as green manure source in rice production in Asia. Farmers in the Savanna region of West Africa have utilized the litter-fall under the canopy from Acacia albida as nitrogen source for peanuts and millets (Dancette & Poulain, 1969; Felker, 1978). In the intercropping studies in Hawaii, Guevarra (1976) observed a large increase in maize grain yield with the application of Leucaena prunings. The maize yield in control plots averaged 1.9 tonnes/ha, while the application of Leucaena prunings (half incorporated prior to planting and half as side-dressing) equivalent to 150 kg N/ha increased the yield to 6.6 tonnes/ha. Kang et al., (1981a) also observed significant increases in maize grain yield from 1.3 tonnes/ha to 3.2 tonnes/ha when Leucaena prunings were applied.

Young loppings from leguminous trees and shrubs are good sources of easily decomposable materials because of their relatively narrow carbon-nitrogen ratio (Kang & van der Heide, 1985). They observed rapid decomposition of Leucaena leaves as compared to maize stover and stated that, buried in the soil, fresh Leucaena leaves have a half life (time taken for half of the material to decompose) of about 10 days.

Although, much nitrogen can be obtained from the prunings of hedgerows of woody legumes such as Leucaena and Gliricidia in alley cropping, on low fertility soils application of supplemental nitrogen may still be required to obtain maximum yields (Kang & van der Heide, 1985). This may in part be attributed to lower efficiency of nitrogen from the prunings as was also reported by Guevarra (1976), who observed that the direct benefit from nitrogen added with the prunings to the immediate maize crop was about 36%. According to this author, several causes could be suggested to account for this lower efficiency such as; delayed release of minerals, application of prunings as mulch being less effective and possible loss of nitrogen by volatilisation and sometimes pruning is done mainly to reduce shading rather than to supply nutrients to companion crops.

Despite the low efficiency of nitrogen from Leucaena prunings, it still contributes a significant portion of the crop requirement (Kang et al 1981b & 1985). These authors, from the results of six years observation on a low fertility loamy sand at Ibadan, showed that grain yield of maize in alleys cropped with Leucaena could be maintained at 2.0 tonnes/ha with only the addition of Leucaena prunings i.e. with no application of fertilizer nitrogen. Maize yields in the control plots (without application of Leucaena prunings) declined to a low level of about 0.5 tonnes/ha during this period. In the same study, the maize plants in the control plots that grew adjacent to the Leucaena hedgerows showed better growth compared to those growing in the middle of the alleys. This, they reported was mainly due to nitrogen contribution from the leaf litter fall in areas adjacent to the hedgerows. Yamoah et al., (1986b) observed that in the plots where inorganic N fertilizer was not applied as well as the prunings not added maize plants near the hedgerows performed better than those in the middle alleys. They attributed this to the accumulation of litter fall which was observed to be greater nearer the hedgerows than in the middle of the alleys resulting in an improvement in soil fertility nearer the hedgerows.

Although the nutrient aspects have been emphasized above, the effects of mulching are infact rather complex. Reporting on traditional mulch as a method of micro climatic management and manipulation, Stigter (1984) reviewed the following effects of mulch application;

(a) Soil temperatures become different because of influences on the energy balance at the surface. The amount of absorbed solar radiation is affected by changes in mulch layer and colour. Exchanged long-wave radiation differs because of the new cover on top layer composition and geometry. Heat and mass transfers in the air boundary-layer and the soil top-layer differ because of the material applied or the land cultivation practised.

(b) Soil Moisture conditions become different as water available for evaporation becomes less. Moreover, under the most organic mulches, more water will enter into the soil or be retained by it because of structural changes near the surface.

(c) Soil Physical Properties, such as infiltration, water retention, and percolation capacity, soil aeration, mechanical and aggregation conditions of the soil, will differ because of structural consequences of mulch applications. Also the rate at which soil erosion takes place from rain, hail, water and wind impact (often worsened by preceding high solar radiation impact) is reduced by mulching because of the protective properties of a mulch layer against destructions from splashing, runoff and other mechanical factors (and radiation).

(d) Soil Chemical Properties, such as acidity, salt concentration and nutrient contents will change because of indirect effects of soil water movements and direct effects of decomposition of mulch material.

(e) Soil Microbial Activities, and occurence of other microfloral and fauna impacts within the soil, will be influenced by the other parameters mentioned above, which create differences in the micro-climates and other living conditions of these organisms.

(f) Aerial Physical Properties, such as radiation flux distribution, temperature, humidity and air flow, differ because of mulch influences on the air within and just above the mulch. This modifies the climate of aerial plant parts.

(g) Mechanical impact of rain, hail and wind, is reduced by the protective capacities of a mulch layer in respect to seedlings and near-surface plant parts as aerial roots.

(h) Weed Growth, is influenced by modified soil and air conditions. It may be greatly reduced because of reduced light. Pests and diseases are influenced as well. These intensity aspects are complex and at times the data conflicting as there may have beneficial as well as damaging effects due to applications of mulch.

The net effect of mulch used on plant growth and development in terms of yield quantity and quality, will be the sum of all the above mentioned factors.

Application of Leucaena prunings resulted in higher soil moisture retention, organic matter, exchangeable K, Ca, Mg, and also nitrate levels in the soil solution (Kang et al., 1985). Also, Yamoah et al., (1986c), reported improved soil chemical properties in the alley cropped sites relative to the controls. They observed that soils under Cassia had the highest content of N, P, K and organic carbon. Bulk density, mean aggregate diameter and water holding capacity were better in the cropped sites. Gravimetric moisture content was generally higher in the cropped sites and highest under Cassia.

However, the benefits resulting from application of mulch are not always easy to demonstrate but, as Johnston (1986) suggests, they may be related to water holding capacity of the soil due to extra organic matter and raising the concentration of nitrogen in the grain which is an important aspect of grain quality.

2.3 Time and method of applying prunings

Surface application of Leucaena leaves as mulch delayed its decomposition (Wilson et al., 1986, & Kang & van der Heide, 1985). Despite the slower decomposition rate of dried Leucaena leaves, Read (cited by Kang & van der Heide, 1985) could not find any differences in maize yield from application of fresh as opposed to dried materials in the field. However, Kang et al (1981a) have suggested that, because of the faster decomposition rate of Leucaena prunings when incorporated in the soil, its direct manurial effect is therefore better when buried in the soil. Indeed, results of investigations carried out in Hawaii showed higher maize grain yield from incorporation of the prunings as compared to surface application (Kang et al., 1981b). Results of studies using Gliricidia sepium prunings also showed higher maize grain yield with incorporation or banding of the prunings than by broadcast application (Kang & van der Heide, 1985). Holland and Coleman (1987), observed that surface placement of straw resulted in higher maximum net N immobilization and slower rate of decomposition as compared to incorporation.

The time when prunings are apllied is inevitably influenced by the frequency of cuttings. The results of Alferez (cited in Nyamai, 1987) indicate that, for upland rice, it is beneficial to apply Leucaena prunings 25 days before planting. In an experiment with IR-36 rice variety grown under upland conditions (non-flooded), evidence was obtained on the superiority of applying Leucaena leaves as organic fertilizer by incorporating them into the soil during land preparation 25 days before seeding. The grain yield of corn was also reported to be higher when Leucaena was cut and incorporated at the early growth stage of the crop.

Evenson (cited in Nyamai (1984) in explaining the above observations, again offered an explanation that there must be faster mineralization with incorporation into the soil of green mulch and possibly reduced loss of nitrogen by volatilisation compared with surface application. The yield of maize grain with an application rate of 150 kg/ha of green leaf manure was almost 5 tonnes/ha with incorporation, 4 tonnes/ha with surface mulch application and only about 0.4 tonnes/ha with no mulch application. Ssekabembe (1985) reported that incorporation of Leucaena was estimated to be 20% more efficient in supplying N to maize compared to surface application.

On the other hand however, results on alley cropping in Nigeria reported by Atta-Krah (cited in Nyamai, 1987) indicated that the growth of maize (plant weight and number of leaves) was slightly better when land was not tilled and the pruning not incorporated into the soil. This finding is the opposite to those reported by Kang et al., (1981b) and Evenson (cited in Nyamai, 1984). These workers obtained better maize yield when the prunings were incorporated into the soil as opposed to when applied on the surface as mulch. The discrepancy can be understood from the remarks of Ahn (cited in Nyamai, 1987), Stigter (1984), and Budelman (1988), who stated that the benefit of mulch, when applied on the surface, may lie in its effects on reducing soil water losses, soil temperatures, erosion and weed growth rather than in the addition of nutrients. Mulching may be of particular importance where water supplies are marginal (Ahn, 1970).

Complete incorporation into the soil as well as the burning of crop residues are widely accepted practices for their disposal. However, burning destroys much of the nitrogen contained in the residues and can result in severe soil erosion problems. Burning also destroys soil conditioning effects, modifies the soil microflora and causes the soil surface to be hydrophobic which could reduce infiltration and water storage. Incorporation of crop residues containing low nitrogen is likely to prevent maximum benefits of the residues to the soil structure as compared to surface managed residues (Elliott & Papendick, 1986). However, Skidmore et al., (1986) suggested that appropriate management of crop residues might retard degradation of soil physical properties and sometimes improves the soil. It had been observed that organic matter increased and the soil was less compacted where wheat straw had been incorporated into the soil for 12 years compared to where it had been baled and removed or burned.

2.4 Rate of mineralization

Application timing and the rate of mineralization of mulches as soil organic matter control the release of nutrients. Since nutrients are subject to leaching, fixation and other losses, it is advantageous if their release can be effected at the same time as the major uptake by plant roots. The main possible management control over timing of nutrient release is the period when plant residues are applied to the soil. Other parameters which affect nutrient release are the quality of such residues, how they are applied (e.g. to the surface or buried), chemical and physical soil properties, especially mositure content and temperature, and the soil fauna (Young, 1985 & 1989). According to Budelman (1989), knowledge of the specific decomposition rate of the mulch used is important when performing mulching experiments. The decomposition rate determines the speed with which the nutrients in the mulch material are released, as well as the period during which the mulch can be considered to be actively supplying nutrients to the soil. The rate refered to here is a specific decomposition rate, covering decomposition periods measured in days. Budelman (1989), concluded from experiments in which Gliricidia mulch, at a rate of 4 tonnes dry matter per hectare, was left to decompose that, the decomposition process can be adequately decribed by the exponential equation:

$$Y_{(t)} = Y_{(o)} . e^{-ct} \qquad (1)$$

in which,

$Y_{(t)}$ represents quantity left after period t in days (for example in Kg/ha).

$Y_{(o)}$ is the initial quantity applied.

c is the constant decomposition rate (or decomposition constant)

Budelman's Gliricidia experiment cove-ed 70 days, with 6 sampling dates. The losses of carbon, nitrogen, phosphorus and potassium in the decomposing mulch were followed and it was observed that the release rates from the mulch of carbon, nitrogen and phosphorus were remarkably similar. Since carbon makes up the bulk of the elements present in dried mulch, (if the above results may be generalized) the decomposition rate related to the release of carbon can be applied as a general indicator of the resistance to decomposition of the mulch. Potassium was rapidly lost from the mulch, the reason being that it is found as an ion in the cell fluid, and consequently can easily be leached from the organic matter for it is not part of the building units in tissue structures. He modified the equation (1) to obtain the nutrient-release function as follows:

$$R_{(t)} = D. P. (1-e^{-ct}) \qquad (2)$$

Where

R represents the amount of specific nutrient released in kg per hectare after a certain period of time (t in days).

D represents the mulch treatment in kg dry matter per hectare and is comparable to Y(o) in equation (1)

P represents the presence of specific nutrient in the mulch expressed as a percentage on a weight basis. This of course is only true for those elements to which a certain C value applies.

Yamoah et al., (1986a) conducted decomposition studies in a field under alley cropping with Gliricidia sepium, Cassia siamea and Flemingia congesta as the hedgerow plants. The mulches were placed on the soil surface. They reported the dry matter loss of the cutbacks (first pruning after the shrubs had been established for two years) to be 96%, 58% and 46% for Gliricidia, Flemingia and Cassia respectively, during a period of 120 days and for the subsequent prunings to be 100%, 85%, 73% for Gliricidia, Cassia and Flemingia for a period of 120 days. The fast decomposition rate of Gliricidia probably resulted from its high N content and its succulent nature. The cutbacks and prunings of Gliricidia, Cassia and Flemingia released 252, 120 & 75 kg N/ha, respectively during the decomposition period. The mulches increased maize grain yield by 15% for Gliricidia, 22% for Flemingia and 50% for Cassia. They suggested that, the mulch effects of the persistent Cassia leaves, perhaps through moisture conservation and weed control was more beneficial than the Gliricidia's high N content.

These studies were all carried out in the humid tropics. There is therefore a need to get a deeper insight of the nutrient composition of Cassia siamea and its rate of decomposition in relation to maize yield under the semi arid conditions of Machakos where it is currently being incorporated into the soil as a mulch.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Experimental site

The experimental work for this study was carried out at the Katumani National Dryland Farming Research Station (NDFRS) site. The experimental site and layout was already designed and established under Dryland Agroforestry Research Project (Sang & Hoekstra, 1986b).

The site is adjacent the ICRAF's (International Council for Research in Agroforestry) Field Station which is approimately 7km South-West of Machakos town (approximately 1°,30'S, 37°,15'E; altitude, 1560m). According to the soil survey agroclimatic zonation (Sombroek et al., 1982), the climate of the area is sub-humid to semi-arid. The annual rainfall/annual potential evaporation ratio, r/Eo, is 0.4-0.5 with an average annual rainfall of about 700mm and potential reference crop evapotranspiration of about 1800mm. The average seasonal rainfall is about 350mm for each of the two seasons i.e. the 'Long Rains' (March-May) and the 'Short Rains' (October-December). By extrapolation from the detailed soil survey of the ICRAF experimental farm, the soils of this site are luvisols. They are well drained and deep (18 - 20 cm) with friable clay over murram (Kibe et al, 1981).

3.1.1 Experimental layout

The established experimental layout is a completely randomised design with two treatments (excluding the control) each replicated 4 times (see appendix 6).

3.1.2 Planting materials

Cassia siamea had previously been selected as the tree species for the hedgerows. Within each plot (except control plots) four hedges were established in November 1983, at between-row spacing of 3.6 m. and in-row spacing of 0.25 m for treatment 1 (C 0.25) and 1.0 m for treatment 2 (C 10). This study was concerned with the nutrient aspects and decomposition of loppings of Cassia in relation to maize yield. Between hedgerows, 3 rows of maize were sown parallel to the hedges at a spacing of 90 cm between rows and 30 cm within-rows. In the control plots, each hedge row was replaced by a row of maize (appendix 6). Maize was planted twice a year with regard to rainfall pattern of the area (Sang & Hoekstra, 1986b).

3.2 Analysis of plant materials

3.2.1 Sampling

Twenty maize plants from each plot were randomly selected and sampled before noon. One leaf per plant was sampled. The sampling was done at the end of the tasseling period close to cob setting and the leaf opposite the cob was sampled. All the twenty leaves from one plot were mixed together to form one sample. There was a limitation of one sample per plot since the sampling was destructive and more intensive sampling could have adversely affected the final yields. Advice on sampling was obtained from Ir. F.C.T. Guiking (Wageningen Agricultural University, The Netherlands, private communication, 1986).

Sampling of Cassia siamea was done at lopping. The loppings from each plot were weighed, thoroughly mixed, chopped into smaller pieces, a sub sample taken and its remainder incorporated as mulch. The sampling was done on per hedge basis, and in all cases the western most hedge was always the first to be sampled (number 1) and the eastern most the last (number 4). In total there were 16 samples (4 from each plot). After sampling the loppings from each hedge were spread evenly into the adjacent alley, and those of hedge 4 (viz the eastern hedge) were equally divided amongst the three alleys. Each alley (and therefore plot) received different amounts of mulch (see appendix 4) depending upon the biomass production of each hedge. The amounts of mulch obtained also varied from season to season.

The sampling of weeds was done before the first weeding took place. They were sampled by randomly establishing plots of 1m² between the maize rows. They were hand plucked, cleaned carefully and dried at 100°C in the oven for 24 hours after which the dry weights were taken. Six samples were taken from each plot.

The maize grains were sampled after the crop was harvested and threshed. Two kinds of sampling were done i.e. (a) a 20 grain subsample randomly selected from each row, were composited together to form one composite sample for each plot, and (b) 100 grains, randomly selected also, were sampled for each row from some selected rows in each plot. All the rows could not be sampled in this last way as the cost of analysis was a limiting factor.

3.2.2 Sample handling

The leaf samples were packed loosely in paper bags and in most cases were not stored for more than 2 days before drying. To remove all traces of surface contamination the samples were washed with a wet sponge using demineralized water followed by rinsing twice in distilled/demineralized water. After rinsing, the samples were transfered to small paper bags and dried at 70°C for 48 hours in an oven. The maize grains were put in paper bags and also dried at 70°C for 48 hours.

The dried material was ground using a 1mm seive mill. This ensured homogeneous ground sample. The powder was thoroughly mixed, packed in polythene bags, and stored under dry and cool conditions prior to chemical analysis.

3.2.3 Chemical analysis

The following elements were analyzed in all the samples taken, Nitrogen (N), Potassium (K), Phosphorus (P), Sodium (Na), Magnesium (Mg), Calcium (Ca), Sulphur (S) and Carbon (C). Total nitrogen was determined using the Kjeldahl method (Black et al., 1965) and carbon by Walkley-Black method (Black et al, 1965), Potassium and sodium were determined flamephotometrically, phosphorus colorimetrically and magnesium and calcium spectrophotometrically. Sulphur was determined using a turbidimetric method (Evenhuis & De Waard, 1978, IITA, 1979, NAL 1986, Ahn 1975).

3.2.4 Nitrogen

Some 0.2g of air dried plant material was weighed and transfered into a Kjeldahl digestion tube, and 1g of the catalyst (mixer of selenium powder, copper sulphate and potassium sulphate) was added. 10ml of concentrated sulphuric acid (conc. H_2SO4) was added and mixed. The resultant solution was heated gently on a digestion stand for one hour after which the tubes were removed (ensuring that no undigested plant material were left sticking on to the sides of the tube) and cooled. The resultant digest was carefully transferred into 100ml volumetric flask using a clean funnel and the tube washed three times with small amounts of distilled water into the volumetric flask. Distilled water was added to make to the mark. This formed solution A.

10ml of 1% boric acid was transfered into 100ml conical flask and 3 drops of mixed indicator (bromocresol green/blue and methyl red in ethanol) added. The flask was placed under the condenser of the distillation apparatus in such a way that the tip of the condenser was below the surface of the solution. 10ml of the digested solution (solution A) and 10ml of 40% sodium hydroxide (NaOH) were both pipetted into the distillation flask and rinsed with small amounts of distilled water. After the first distillate drops reached the boric acid indicator solution, the colour changed from pink to green. Distillation continued for another 2 minutes after which the conical flask was lowered (the tip being above the liquid) and distillation continued for another minute. The tip of the condenser was rinsed with distilled water and the solution was titrated with 0.01N H_2SO4 until the colour changed from green to pink as end point. With each series of determinations a blank and a standard sample was run.

Calculations:

$$\% N = \frac{(T-B) \times N \times 1400}{S}$$

where:

T = Sample titration (ml)

B = Blank titration (ml)

N = Normality of H_2SO_4

S = Sample weight (mg)

3.2.5 Dry ashing

2.5g of air-dried plant materials were weighed into crucibles, which were placed in a muffle furnace and ashed at 400-500°C for 3 hours. An empty crucible was placed and used for a blank. After the ash was white or nearly so the samples were removed from the furnace and allowed to cool The ashes were moistened with 5ml concentrated nitric acid (con. HNO_3) and evaporated to dryness on a hot water bath after which they were ashed again in the muffle furnace at 400°C for 30 minutes. They were removed and allowed to cool and 10ml of 2.5 N Hydrochloric acid (HCl) was added cautiously down the walls of the crucibles to prevent spattering and heated on a hot water bath. The samples were filtered through filterpapers into 50 ml volumetric flasks and the crucibles washed 3 times with distilled water. These ash solutions (solution B) were then used for the determination of P, K, Na, Ca, Mg and S.

3.2.6 Phosphorus

5ml of the ash solutions (solution B) was pipetted into 50 ml volumetric flasks, and 15ml of the mixed reagent solution (Nitric solution, Ammonium metavanadate solution and molybdate solution) added. Distilled water was added to make to the mark and mixed thoroughly. The optical density was measured at 450nm using a colorimeter and the concentration of P in ppm read off from the calibration curve.

Calculations

$$\% \text{ P in sample} = \text{P ppm in solution} \times \frac{\text{ml.ash solution} \times \text{ml.solution} \times 100}{\text{weight of sample} \times \text{ml. aliquot} \times 1{,}000{,}000}$$

$$\% \text{ P} = \text{ppm} \quad \left(\frac{50 \times 50 \times 10^2}{2.5 \times 5 \times 10^6} \right)$$

3.2.7 Potassium and Sodium

1ml of the sample solution (ash solution B) was pipetted into 50ml volumetric flasks and 5ml of the buffer solution (Cesium chloride and Aluminium nitrate) was added and made to mark with diluted hydrochloric acid. The standard series and samples for both K and Na were measured (in ppm) at corresponding wavelengths as was indicated in the flame emission spectrophotometer.

Calculations

$$\% \text{ K or Na in sample} = \text{K or Na ppm in sol.} \times \frac{\text{ml. ash sol.} \times \text{ml.Sol} \times 100}{\text{sample weight} \times \text{ml. aliquot} \times 1{,}000{,}000}$$

$$\% \text{ K or Na} = \text{ppm} \quad \frac{(50 \times 50 \times 10^2)}{2.5 \times 1 \times 10^6}$$

3.2.8 Calcium and Magnesium

5ml of ash solution (solution B) was pipetted into 50ml voluntaric flasks and 1ml of 5% Lanthanum chloride solution added and made to the mark with distilled water. After mixing well, calcium and magnessium concentrations were measured (in ppm) at wavelengths 422.7nm by atomic absorption spectrophotometer. An air/acetylene flame and appropriate lamps for Ca and Mg were used in each case.

Calculations

$$\% \text{ Ca or Mg in sample} = \text{Ca or Mg ppm in sol.} \times \frac{\text{ml. ash sol.} \times \text{ml.sol} \times 100}{\text{sample weight} \times \text{ml. aliquot} \times 1{,}000{,}000}$$

$$\% \text{ Ca or Mg} = \text{ppm} \quad \frac{(50 \times 50 \times 10^2)}{2.5 \times 10 \times 10^2}$$

3.2.9 Sulphur

10ml aliquots of ash solutions, blanks and standard series were pipetted into 50ml volumetric flasks and 1ml of 0.5% gum acacia added. One scopp (about 0.1g) of $BaCl_2$ crystals was also added. The resultant solution was mixed thoroughly and left to stand for one hour. The optical density was measured at 580nm and the concentrations (in S ppm) were read off from the concentration curve.

Calculations

$$\% \text{ Sulphur} = \text{Sppm in sol.} \times \frac{\text{ml.ash sol.} \times \text{ml. sol} \times 100}{\text{sample weight} \times \text{ml aliquot} \times 1000{,}000}$$

$$\% \text{ S} = \text{ppm} \quad \frac{(50 \times 10^2)}{2.5 \times 10^6}$$

3.2.10 Carbon

0.025g of air dried plant material was weighed accurately and transferred to 300ml erlenmeyer flasks. 10ml of 1N potassium dichromate ($K_2Cr_2O_7$) was added accurately into each flask. 20ml of conc. H_2SO4 was rapidly added using an automatic pipette or measuring cyclinder directing the stream into the mixture. The flasks were swirled immediately but gently to start with, then vigorously for one minute and allowed to cool on asbestos sheets for about 30 minutes. 100 ml of distilled water was added and also 5ml of Orthorphosphoric acid (gives an environment necessary to obtain a clear end point during titration). 3-4 drops of the indicator (diphenylamine) was added and titrated with 0.5N Ferrous sulphate solution. As the end point was approached, the turbid dark blue colour became greenish, changing to a clear pale green quite sharply at the end point. The blank titration was treated in the same manner but without the plant material, to standardize the dichromate.

<u>Calculations</u>

$$\% \text{ organic C in sample} = \frac{(me\ K_2\ Cr_2\ O_7 - me\ Fe\ SO4)}{\text{weight of sample}} \times 0.399$$

3.3 Rate of mulch decomposition

This was investigated by the use of litter bags. The litter bags were made of exuded polyvinyl with a 7 mm mesh and measured approximately 30cm by 30cm by 2.5cm deep. The sides could be bent to retain the shape of a shallow box-line container which would prevent compression of the enclosed litter and allow free access to most groups of macrofauna, (Anderson & Ingram, 1989).

The amount of the loppings put into the bags was 50g (which was on average approximately equal to the weight of the loppings incorporated in per unit area equivalent to the litter bag). The loppings from each plot were chopped into small pieces, thoroughly mixed and representative samples weighed and put into the bags. The two open hedges of the bags were then sealed with nylon thread and the loppings spread evenly within the bags.

The bags were placed (buried) in the ground at a depth of 0-20cm (in the plough layer) Twelve litter bags were each placed in the three <u>Cassia</u> <u>siamea</u> treated plots (C 0.25) i.e. plot no. 3, 8 and 10 (See appendix 6 for plot numbers) for the short rains of 1988 and fifteen for the long rains of 1989 respectively. In all the cases, one alley in each plot was selected for the placement of the bags. Equal number of bags were each placed in the western, middle and eastern side of the alley.

Those that, for example, were placed on the western side, were buried 45cm from the *Cassia* hedge and 45 cm from the maize row, i.e. in between the maize row and the *Cassia* hedge and the same applied for those buried on the eastern side of the edge. Those buried in the middle were placed in between the two *Cassia* hedges. They were placed between the middle maize row and the adjacent maize rows (see appendix 6 for litter bags placement).

In a row the bags were buried at equal distance from each other. Three bags were randomly unburied from each alley (one bag from each of the western, middle and eastern positions) after 10, 20, 30, 60 and 90 days.

The litter bags were then untied and the contents transfered to paper bags. Later the soil was carefully washed off and the litter was taken into the oven and dried at 100°C for 24 hours, after which the dry weights were taken. These weights were expressed as % sample weight remaining undecomposed (appendix 2, m & n).

3.4 Statistical analysis

The results of the available nutrients in the *Cassia siamea* loppings, maize leaves, maize grains, maize stovers, soils and the dry weight of weeds were statistically analysed using INSTAT programme. The analysis of variance (ANOVA) tables are presented in the appendix 3. Significance was taken at the 5% level.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

The results presented in this chapter are mostly for the long rains (LR) and short rains (SR) of 1988 which represent the two seasons investigated.

In the case of Cassia siamea loppings, some preliminary analysis of nutrients had been conducted during the SR'87 (see appendix 2, a). These loppings (SR'87) were distinguished on the basis of the lopping height of the Cassia hedge, which is normally 50 cm. Those above the 50cm (>50 cm) were relatively younger shoots as compared to those below the mark which were older. In the proceeding seasons, this distinction was not found necessary since the loppings are not distinguished before incorporation. The nutrient composition for the LR'89 (appendix 2, d) was carried out to try and gain understanding of the decomposition experiment of Cassia siamea loppings of the same season using the litter bags. It was not possible to carry out the decomposition experiment during the LR'88 since the litter bags arrived when the season had started and the incorporation of the loppings had already been done.

Only the means are presented in most of the tables that follow, the actual data is contained in appendix 2. The analysis of variance tables (ANOVA) is contained in appendix 3. Figures in brackets represent the standard deviation (STD).

4.1 Nutrient composition for loppings of Cassia siamea

The nutrient composition for the Cassia siamea loppings for the two seasons of 1988 are presented in Table 1.

Table 1. Means of nutrient composition for the loppings of Cassia siamea (n=16)

NUTRIENTS IN %

SEASON	N	P	K	Ca	Mg	S	Na	C	C/N
LR'88	2.63	0.12	1.16	2.25	0.23	0.05	0.18	24.43	9.27
	(0.17)	(0.01)	(0.12)	(0.26)	(0.05)	(0.01)	(0.03)	(10.29)	(3.67)
SR'88	2.21	0.10	0.99	2.84	0.23	0.04	0.20	33.27	15.05
	(0.28)	(0.02)	(0.16)	(0.40)	(0.02)	(0.01)	(0.02)	(3.77)	(2.30)

The results indicate that the nutrients were not significantly different on per plot basis except for Ca & Mg (LR'88) and P & Ca (SR'88) which were significantly different (appendix 3, b & c). Since there were no significant differences between the nutrients on per hedge basis, the reasons for the observed differences are not obvious and therefore not easily explainable other than by natural inhomogeneities.

The nutrient composition for the LR'88 season indicate that there was a higher % concentration of some nutrients e.g. N, P, K & S but lower concentration of Ca, Na, & C as compared to the SR'88 season. These differences were significantly different at 5% level except for S. The Cassia hedges are normally lopped twice a year in March (for LR) and October (for SR). During the LR' season the hedges had been growing over a period of 4 months as compared to 6 months growth for SR. There was therefore, a differential growth period of 2 months between the LR & SR. The interim dry period between October and March is relatively shorter than that between March and October (see appendix 5 for rainfall figures). Hence, the LR'88 season's loppings were younger, more succulent, fresher, greener and more leafy as compared to the SR'88 loppings.

The above explanation suggests why there was a higher % concentration of the more mobile nutrients like N, P & K that are associated with the younger portions of the plant for the LR'88 season and a higher % concentration of the less mobile nutrients, like Ca which get immobilized once deposited for the SR'88. (Cooke 1982, Sutcliff & Baker 1978). The C/N ratio for the LR season was narrower (9.27 + 3.67) than for the SR (15.05 + 2.30). This seems to have been brought about by both the increase of C in the older woody material and decrease of N during the SR season. This, is supported by most of the preliminary analysed data which indicated a higher % concentration of N,P & K in the younger portions and a higher concentration of Ca, & C in the older portions (appendix 2, a). Only for Na, Mg & S whose differences are small do not fully comply with this explanation.

4.2 Nutrient composition for maize leaves

Table 2 gives the average results of the nutrient composition for maize leaves for the long and short rains of 1988.

Table 2. Means of nutrient composition for maize leaves (n=4).

	NUTRIENTS IN %							
SEASON	N	P	K	Ca	Mg	S	Na	C
LR'88 TREATED	3.72 (0.27)	0.28 (0.03)	1.75 (0.28)	0.98 (0.09)	0.38 (0.02)	0.08 (0.01)	0.32 (0.01)	28.72 (4.63)
CONTROL	3.12 (0.07)	0.24 (0.00)	1.25 (0.14)	0.78 (0.04)	0.28 (0.02)	0.07 (0.00)	0.28 (0.02)	27.96 (6.22)
% INCR	19.20	16.70	40.00	25.60	35.70	14.30	14.30	2.70
SR'88 TREATED	2.46 (0.05)	0.17 (0.02)	2.02 (0.06)	0.44 (0.04)	0.23 (0.02)	0.05 (0.01)	0.32 (0.04)	32.75 (1.06)
CONTROL	2.21 (0.08)	0.14 (0.01)	1.82 (0.14)	0.28 (0.03)	0.17 (0.02)	0.04 (0.00)	0.25 (0.01)	32.10 (0.83)
%INCR	11.30	21.40	11.00	57.10	35.30	25.00	28.00	2.00

The maize leaves from the treated plots had a higher concentration of nutrients than the untreated plots as shown on Table 2 in both seasons.

Though positive % figures were observed in all the cases, only N, Ca, Mg (LR) and N, P, Ca, Mg (SR) were significantly different. However, the most important thing observed is that the mulches contributed substantial amounts of all the nutrients in the maize plant. This is clear from the % increase of the treated plots relative to the controls. The nutrients composition of the leaves varied in the two seasons and there is no clear explanation for the non significant differences observed. For N, P, Ca, Mg & S the LR'88 season gave appreciable higher figures whereas K & C were smaller and Na the same as for the SR'88. It is however, important to note that Hybrid 511 was erroneously planted during the SR'88. The number of treatments involved were 2, thereby giving only 1 degree of freedom, and also the number of samples taken (4 in each case) might have meant that if the differences were not of a big magnitude in nature, then after the statistical analysis no significant differences would emerge. The amounts of mulch incorporated during the two seasons that averaged 0.5 kg/m² (depending upon the biomass production of each hedge, see appendix 4) could have been too little to bring about a big difference in magnitude between the treated and control plots.

4.3 Nutrient composition for maize grains

Means of nutrient composition for maize grains for the long and short rains of 1988 are presented in table 3.

Table 3. Means of nutrient composition for Maize grains (n=24)

NUTRIENTS IN %

SEASON	N	P	K	Ca	Mg	S	Na	C
LR'88 TREATED	1.47 (0.07)	0.18 (0.04)	0.22 (0.03)	0.18 (0.01)	0.14 (0.02)	0.00 (0.00)	0.06 (0.02)	37.97 (3.59)
CONTROL	1.22 (0.09)	0.14 (0.03)	0.17 (0.04)	0.16 (0.02)	0.12 (0.03)	0.00 (0.00)	0.04 (0.02)	36.87 (3.09)
%INCR	20.50	28.60	29.40	12.50	16.70	0.00	50.00	3.00
SR'88 TREATED	1.53 (0.08)	0.22 (0.04)	0.23 (0.02)	0.15 (0.01)	0.13 (0.01)	0.01 (0.00)	0.05 (0.01)	37.61 (2.16)
CONTROL	1.41 (0.05)	0.19 (0.02)	0.20 (0.02)	0.16 (0.01)	0.11 (0.01)	0.01 (0.00)	0.04 (0.01)	36.73 (2.51)
%INCR	8.51	15.79	15.00	6.67	18.18	0.00	25.00	2.39

As in the case of the maize leaves, the grains also indicated a higher concentration of nutrients in those plots that received mulch as compared to those that did not. The % increase of treated plots over controls could therefore be attributed to mulch application though not all of them were significantly different. N, P, K, Ca, Mg & Na were significantly different for the LR'88 and so were N, P, K, & Mg for the SR'88 (appendix 3, g & n).

It was explained previously (c.f 3.2.1) that two different kinds of sampling were employed in respect to grains i.e. composite sampling and row basis sampling. This was done due to the fact that data was needed to establish whether there were any differences between the maize rows in terms of nutrient composition. It had been observed that the two outer maize rows (eastern and western) outperformed the middle row in terms of yield with the eastern row outperforming the western row (See 4.5). Establishing whether this was as a result of higher concentration of nutrients in these outer rows needed to be quantified.

However, when the grain nutrients from these rows were statistically analysed, they were found not to be significantly different (appendix 3, l & m).

It has been pointed out that hybrid 511 was planted during the SR'88. The results for the two seasons indicate that the differences between the treated and control plots in terms of all the nutrients except Mg were less for the Hybrid maize (SR'88) compared to the Katumani composite B. Hybrid 511 is a long maturing variety compared to the Katumani variety and is usually grown in the wetter areas. The rainfall received during this season was, however, higher than the normal expected average of 350 mm and was well distributed throughout the growing season (appendix 5). This ensured that the hybrid maize grew to maturity and yielded well. It was observed that this cultivar grew taller and had an increased above ground biomass compared to the Katumani cultivar. If this extra shoot height and biomass could be reflected in a greater root biomass and deeper root system than the Katumani cultivar, then it is possible that the Hybrid maize roots exploited new and deeper mineral reserves which allowed it to perform better (Mungai et al. unpublished, Coulson., et al 1989),. The narrower differences in nutrients between the treated and control plots of the hybrid maize as compared to the Katumani could be explained by the fact that, prior to the SR'88, the experimental plots had always been planted with Katumani maize. It is likely that those successive maize crops had extracted nutrients down to a certain depth of soil, and the soil in that depth had become denuded of nutrients compared to the soil below it. When the deeper rooted hybrid maize was introduced, it is possible that its roots exploited new mineral reserves at lower levels and hence the observed increase in the nutrients and yields (4.5). The magnitude of the increase was however, bigger for the controls than treated plots. The reason for this could be that there was competition between the maize and Cassia in the treated plots for both nutrients and water and also because there was less mulch incorporated (appendix 4) during this season than the previous season, (Coulson et al 1989).

4.4 Nutrient Composition for Maize Stovers

Initially analysis of the nutrient for maize stovers was not in the proposal. To gain some understanding of what happens to the levels of concentrations of nutrients in the maize leaves once the grains form, it was considered important to perform this analysis. The results of LR'88 could not give this trend since this analysis was not carried out. The same technique as that for sampling the maize leaves was used.

Table 4. Means of nutrient composition for maize stovers (n=4)

	NUTRIENTS IN %							
SEASON	N	P	K	Ca	Mg	S	Na	C
SR'88 TREATED	0.43 (0.03)	0.04 (0.01)	1.23 (0.10)	0.33 (0.02)	0.19 (0.05)	0.04 (0.00)	0.35 (0.04)	34.95 (0.65)
CONTROL	0.28 (0.06)	0.03 (0.00)	1.08 (0.09)	0.24 (0.02)	0.14 (0.01)	0.04 (0.00)	0.24 (0.03)	32.50 (0.85)
%INCR	53.57	33.33	13.88	37.50	35.71	0.00	45.83	7.54

From these results, it was noted that there was a significant difference with respect to N, P & Na (appendix 3, i). However the results, (just as those of Tables 2 and 3) clearly show the trend that the plots that received mulch had a higher concentration of nutrients than those that did not. It is also observed that the stover contained a lower concentration of nutrients when compared to mature maize leaves analysed at the tasseling stage (Table 2). From this comparison N indicated the highest magnitude of decline followed by P and K. These nutrients are mobile in the plant and may have been translocated from the leaves to other plant organs like the grain before the leaves became senile, (Mwangi, 1989, Cooke 1982, Sutcliff & Baker, 1978). The magnitude of the decline for the other elements was saml1 and this may be explained by their low mobility in the plant.

4.5 Yields (grains) in g/row

Table 5 shows the maize yields in g/row for the long and short rains of 1988 epressed on per row basis and not in tonnes/ha. This is due to the fact that the yield will depend on plot dimensions and the amounts of mulch applied on per unit of surface.

Table 5. Mean yields (grains) in g/row.

SEASON	TREATED PLOTS		CONTROLS	
	Plot No.	g/row	Plot No.	g/row
LR'88	2	3047.2	1	2281.5
	3	3787.7	5	2099.1
	8	2675.9	7	1794.3
	10	2925.2	12	3272.9
	AVG	3109.0	AVG	2362.0
		(414.0)		(554.0)
SR'88	2	4589.6	1	4199.9
	3	3486.5	5	3916.2
	8	4563.3	7	3309.4
	10	4531.0	12	3899.9
	AVG	4292.6	AVG	3831.4
		(465.9)		(324.1)

The treated and control plots consisted of a total of 9 and 13 rows respectively. This was becaause each hedge row was replaced by a row of maize in the control plots (appendix 6). The yields in each treated plot was therefore, an average of 9 maize rows while in the control it was an average of 13 rows. On a per row comparison, the results reveal that the treated plots out-performed the control plots by approximately 32% for the long rains of 1988 and 12% for the short rains of the same year. There were however no significant differences between the yields from the control and those from the treated plots (appendix 3, n).

Hybrid 511 planted during the SR'88 did better than Katumani B composite of LR'88. However, the differences between the treated and control plots for the Hybrid was less (12%) than that for Katumani (32%). This was due to the fact that there was a greater increase in the hybrid controls of 62% from the LR to SR as compared to the treated plots of 38%. Thus, the yields in the control plots increased more than those of the treated plots when the LR and SR were compared. These observations support the inference previously made (c.f.4.3) that the root competition caused by rain and/or crop phenotypic differences could strongly influence the crop yield. This concept is further supported in the season that followed the Hybrid planting (LR 89) when Katumani composite B was planted again. In this situation the controls did worse than expected. The treated plots out yielded the controls by 229%. This could have been the result of extra extraction of nutrients as a result of Hybrid 511 during the previous season (Coulson et al 1989).

The two maize rows (eastern and western) next to the Cassia siamea performed better than the middle row with the eastern row out performing the western row in both seasons (Table 6).

Table 6. Mean maize yields (g/row) for the 3 maize rows inside the Cassia alleys.

	WESTERN	MIDDLE	EASTERN
LR'88	3150.3	2902.6	3334.5
SR'88	4336.2	3723.6	4756.3

With respect to row positions, it was only the middle row of SR'88 that was significantly lower than the other two outer rows (appendix 3, q). This phenomenon was similar to what Sang & Hoekstra (1987b) had observed. They attributed this to downward movement of nutrients and water due to slopy terrain benefiting the crop at the lower level immediately above the hedge. Statistical analysis of maize grain nutrients with respect to these positions did not however, show thi superiority of the outer rows as compared to the middle row. Soi sampled at the end of the LR'88 growing period indicated that there ma be a cummulative effect of the previous years mulch application becaus there was an overall increase in nutrients in the treated plots a compared to the controls (appendix 2, j). Though all the nutrient (except S) were significantly different (appendix 3, j), superiority o the eastern and western positions in terms of soil nutrients was no observed. It is important however, to mention that this dat represented only one sampling depth and at the end of a growing perio (LR'88 season). It might be possible that soil nutrient gradient from Ogaro's & V.d. Kooi's (unpublished) soil nutrient studies carrie out through the growing season and at different sampling depths coul help explain the yield differences between rows. According to Munga (unpublished) the lower yields of the middle row could be explained b the fact that the temperature profiles he has observed indicate tha the middle row has higher temperatures than the eastern and the wester rows and that the western row's temperatures are higher than th eastern row's. Because these temperatures are a consequence o differences in solar radiation received (shading of the soil by Cassi hedge), it could be that there is differential evaporation within th alleys, especially earlier in the season with the midlle row losin more water to the atmosphere followed by the western and lastly by th eastern row. Mungai et al. (1989a), indicated that water an nutrients seem to be the most limiting factor to the growth an performance of maize in Machakos. Nutrients could be important sinc it was observed that there was a greater accumulation of litter nea the Cassia hedges than in the middle row during the growing period. This litter was as a result of litter fall (leaves) from the Cassia shrubs before they were lopped. This then would mean an overall increase in the nutrients near the hedges resulting in a better performance of the maize rows next to the hedges as compared to the midlle row.

4.6 Maize performance as affected by Cassia siamea green manure

Investigations into the effects of Cassia siamea green manure on maize performance showed that there was a differential response between the controls and the treated plots. Visual observations indicated a marked difference between the controls and the treated plots, especially during the early stages of maize growth and development. It was noted that, during the first month after planting, the maize in the treated plots was taller, greener and thicker stemmed than that in the controls (Mungai et al., 1989b). This might have been as a result of more nutrients in the leaves of the maize in the treated plots (See Table 2) as compared to the controls. Tables 2, 3 & 4 reveal that there was an increase of all the nutrients in the leaves, stovers and grains in the treated plots compared to the controls except for sulphur in the grains. This suggests that, the nutrients in the Cassia loppings when released into the soil after mineralization might have led to the increased total available soil nutrients for the crop uptake. This increased availability could have been reflected in the leaves and grains and ultimately in the higher yields of the treated plots over the controls on a per row basis.

It was observed that all the nutrients in the maize leaves were higher than in the grains and stovers (see Tables 2, 3 & 4) except for nutrients like sulphur and calcium which as stated earlier are immobile in plants and become immobilized once deposited. Thus, it would appear that there was translocation of nutrients from the leaves and other plant organs to the grains as they filled. Indeed, Boyer and McPherson (1975) stated that, the most active uptake of nitrogen (and other nutrients) in maize occurs in the first half of the growth period. According to Mwangi (1989) the protein of the grains (which can be measured by the percent nitrogen content of the grain) must be derived primarily from the nitrogen that was previously part of the vegetative plant proteins. Thus as the grain fills, it would appear that considerable amounts of grain protein N are derived from nitrogenous compounds which are translocated from the vegetative tissues as senescence takes place. This situation would result in the decline of %N content in the maize stover relative to the leaves. A similar phenomenon has been noted in the beans (D'souza & Coulson 1985).

Earlier results from the same DARP experiments revealed that incorporating mulch into the soil did improve the maize performance in terms of grain yields among other factors that were investigated (Nyamai, 1987, Sang & Hoekstra, 1985, 1986a&b, 1987a&b). Sang & Hoekstra (1987b) reported an increase in dry weight of grains of the treatment plots as compared to controls of about 20% for C 1.0 & 12% for C 0.25 during the 6th cropping season. They, however, noted that, such an increase was still insufficient to compensate for the loss in maize crop production under the alley cropping system because of the decline in the cropped area, since 4 maize rows had been taken up by Cassia hedges in each plot. Nyamai (1987) observed an increase in yield of maize by between 11 & 22% due to Cassia mulch application. He reported that the soil N and organic carbon were either sustained or slightly increased following the partial incorporation, whereas the control plots showed a progressive decline in soil N and organic carbon with subsequent cropping. He argued further that the fresh manures (of which it was estimated that 2/5 were completely buried and 3/5 remained as surface mulch) helped in the conservation of soil moisture and in the reduction of soil surface temperature hence reducing water loss through evaporation. This he suggested could have been an important contributory factor to the better performance in the treated plots compared with the controls. Mungai et al (1989a) have pointed out that soil moisture as determined by the amount and distribution of rainfall and the nutrient availability appear to be the most important in determining the growth and yield of maize in Machakos. Soil data collected at the end of the LR'88 growing season (appendix 2.i) revealed an overall increase of nutrients in the treated as compared to control plots. This increase in soil nutrients would seem to indicate that, even with the increased yield of the maize the crop did not take all the extra soil nutrients. This seems to indicate the cummulative effect of the soil nutrients over the years as a result of decomposition of the leaf mulches since SR'85. Mwangi (1989) observed a progressive increase in soil nutrients with time in mulched plots, although the plots were not those used here. The lower grain yields in the control plots seem attributable to the low nutrients brought about by the removal by harvested plant parts without any replacement although the influence of other factors such as soil moisture cannot be ruled out.

In his comparison of two extreme seasons, Mwangi (1989,) reported that. the rate (amount) of application anc the type of mulch were important in determining the yield of maize, but more important was the soil water as dictated by rainfall. The nutrients added to the soil by mulch decomposition and mineralization were appreciably less useful to the plant when the water conditions in the soil were not favourable. When water supply was adequate he observed a higher grain yield with significant differences among the treatments. In the present investigation, the yields in the treated plots were not significantly higher than those of the control plots on per row basis. But, unlike in the case of Mwangi, in this experiment the Cassia siamea hedges have been established in the experimental plots and these do compete for water and nutrients with the maize crop (Mungai et al., 1989a, Coulson et al., 1989). Also, the amounts of mulch applied within the alleys were small (average 0.8 kg/m^2) compared to those of 2 & 1 kg/m^2 that were applied in the case of Mwangi (1989).

Additional data from Mungai (unpublished), on the same fields and in the same TTMI/DARP collaboration confirm that the productivity of Maize/Cassia alley cropping system is greatly influenced by both rainfall and soil nutritional status. From his data, it appears that above a certain rainfall level, the per row maize yield in the alleys is greater than that of the controls and as rainfall increases above this figure, the increase of the treatment yield becomes larger than that of the control. Conversely, as the rainfall decreases below this figure, the productivity of the maize in the alleys declines more and more below that of the control due to the competition for water with Cassia. Thus, it would appear that, the benefits of the added mulch are very much dependent on soil water availability as governed by rainfall and moisture competition (Coulson et al., 1989). In a recent preliminary study of the root distribution of Cassia siamea in this same experiment, Mungai et al (1989) indicated that at distances of 75 cm & 40 cm from the tree, 56% & 63% of the roots occured in the top 40 cm of soil respectively. This shallow rooting depth would then suggest that there is appreciable competition for water by Cassia, especially if the soil water, which is a function of rainfall, is limiting. This argument could be supported by the yield results of SR'87 (Mungai et al., 1989) where the controls out performed the treated plots when the rainfall was low and poorly distributed.

4.7 Dry matter determination of weeds

Table 7 gives the results of dry matter determination of weeds in g/m² for the short rains of 1988 and long rains of 1989.

Table 7. Dry weight determination of weeds in g/m² (n=48)

SEASON	TREATED PLOTS	CONTROL PLOTS
SR'88	12.3 + 6.2	4.8 + 2.2
LR'89	38.3 + 61.1	28.8 + 27.9

The results indicate that there were more weeds in the treated plots than in the controls for the two seasons. The treated plots for the SR'88 season had significantly more weeds than the controls whereas those for LR'89 were not significantly different (appendix 3,k).

It is expected that the mulches enhanced the weed growth by facilitating an improved physical and fertility status of the soil as also suggested by Mwangi (1989).

According to Akobundu (1980) weed control alone constitutes over 40% of the total cost of production of most arable crops in the tropics. If weeds are not checked in time they can adversely affect crop production by competing for the nutrients released into the soil by the decomposing mulches. For maximum utilization of these nutrients by the crop, constant weeding would have to be practised. Earlier observations by Sang & Hoekstra (1986b & 1987b) revealed that the controls had more weeds than the treated plots though the difference was were not significant. The explanation advanced for this phenomenon was that, the mulch suppressed weeds in the treated plots. This was especially so during the 6th cropping season (Sang & Hoekstra, 1987b) when treatment C.0.25, which received the highest application of mulch had the lowest weed biomass. It is important to note that during this period, it was not the practice to fully incorporate mulch into the soil as was the case during SR'88 and LR'89. Nyamai (1987) approximated that in the earlier experiments, 2/5 of the mulch applied was incorporated and 3/5 was left on the surface. Sang et al., (1985) reported more weed biomass in the _Leucaena_ microplots where the mulches were fully incorporated as compared to the controls. This was attributed to the quick release of nutrients from _Leucaena_. This adds weight to the earlier suggestion that a cummulative effects of nutrients in the soil occurs due to continous mulch application over successive years resulting in enhanced fertility of treated plots relative to controls. Thus promoting the observed superior growth of weeds in the treatments as compared to controls.

4.8 Decomposition of Cassia siamea

The results of the Cassia siamea decomposition are presented in Figures 1 to 5 and appendix 2, m & n. It was observed that decomposition was more rapid in the first few days and gradually decreased over time for both seasons. Decomposition was faster for the softer leaves and slower for the more lignified branch parts and twigs as stated by Ezcurra and Becerra (1987). Also, Phenolic compounds associated with Cassia which are resistant to decomposition could have contributed to the observed trends (Nyamai, 1987). Decomposition rates with respect to positions were generally similar for the two seasons (Fig 2 & 4) for the observed differences were not statistically significant (appendix 3, p & q). However, decomposition was faster for the LR'89 as compared to SR'88 (Fig. 5). The mulches for SR'88 were relatively older by about 2 months as compared to those for LR'89 (cf. 4.1). Therefore, the older and more lignified materials for SR'88 decomposed slower than the softer and younger materials for LR'89 (Ezcurra & Becerra 1987). According to Russel (1973), plant materials with C/N ratios of 20:1 or smaller have sufficient N to supply the decomposing micro-organisms and also release N for plant use. Allison (1973) gives that critical ratio as 30 and the critical % N content as 1.4 - 1.7. The % N content of Cassia, for the two seasons investigated, averaged 2.21 + 0.28 (for SR'88) and 2.39 + 0.23 (for LR'89) and the C/N ratios of 15.05 + 2.30 and 7.75 + 1.35, respectively. These figures meet the critical values given by Allison and Russel and explain why decomposition was faster for the LR'89 as compared to the SR'88. Soil moisture and temperature may not have played a very important role in the observed differences between and within seasons because rainfall was sufficient and well distributed throughout the two seasons (appendix 5).

The rate of decomposition was rather low, taking into account the C/N ratios observed since at day 90 all the Cassia had not yet completely decomposed (3.7% for LR'89 and 29.4% for SR'88 at day 60 remained). Nyamai (1987) states that the most likely reason for the slow rate of decomposition is that Cassia siamea, like other members of the Caesalpinoideae, have phenolic compounds which are known to inhibit their association with the decomposing and nitrogen fixing bacteria and fungi. The implication of this is that although the amount of N in Cassia loppings is not particularly low, its release and subsequent availability may be slowed by the presence of these compounds. Because of this, the exponetial equation described by Budelman (c.f. 2.4) for Gliricidia mulch may not adequately fit in the present case.

The rate of nutrients release from crop residues or mulches depends on factors like the type of residue or mulch, C/N ratio, and other various soil parameters such as moisture, temperature, aeration, and pH. In general, incorporation of residues low in N would lead to N immobilization (Fu et al., 1987). Mwangi (1989) states that whether a mulch will increase or decrease soil N depends upon its ease of decomposition and its C/N ratio. He suggested that, the narrower C/N ratio of both Leucaena leucocephala and Cassia siamea would give a more rapid decomposition and mineralization of N when the leaf mulches were buried in the soil as compared to Terminalia brownii which had a wider C/N ratio.

The C/N ratio of an organic material as an index of biodegradability could be complicated by a number of factors particularly the physical and chemical characteristics of substrate (Agbim, 1987). Yamoah et al., (1986a) found out that the dry matter loss of the Cassia cutbacks and prunings was 46% and 85% respectively during a period of 120 days. They suggested that the slow rate of decomposition of Cassia when applied at the surface may be important for soil moisture conservation, soil temperature regulation and weed control. Also, perhaps the potential of alley cropping systems could be better exploited by using a fast decomposing species like Gliricidia or Leucaena along with Cassia in order to provide both N and organic materials on a sustained basis.

On the other hand, a relatively slow decomposition and mineralization of mulches like the one potrayed by Cassia siamea might be advantageous to the crop in that it may prevent excessive nutrient loss through leaching of the nutrients that have not been taken up by the plant. 70 to 90% of the Cassia had decomposed within 60 days. Young (1989) has described Cassia siamea as having an intermediate rate of decomposition releasing most of its nitrogen within 60 days of application into the soil.

An earlier investigation into the effects of decomposition during the dry period indicated that nearly 50% of the incorporated Cassia could be lost within a period of 60 days (appendix 2, p). The loss in the dry season could mostly be attributed to termite activity as evidenced by their gullies and their congregating in and around the litter bags. The termites are very predominant in this areas. They are very mobile, hence, lopping the Cassia and incorporating it into the soil too long before the onset of rains may mean risking the nutrients being carried away from the plots once the termites start to feed on the loppings. In addition, fungi could also have played a role in the process of decomposition for the mulch inside the litter bags was frequently embedded in fungi's mycelial mass. Agbim (1987) carrying out a study on dry season decomposition of leaf litter from five common plant species of West Africa observed a loss ranging from 35.6 to 63.2% under field moisture stress and concluded that possibly the main agents of decomposition in dry season are fungi. They achieve this by growing and ramifying into the substrate with their mycelial (Swift et al., 1979).

These observations were not entirely exclusive to the dry season, for during the wet seasons the same observations were made but it would be assumed that, as Agbim (1987) suggested, bacteria might have had a more important role to play in decomposition during the wet than the dry season. The traditional time adopted by DARP Project for lopping the Cassia of 0 to 2 weeks before the onset of rains (i.e. before crop planting) may therefore seem justified under these conditions. Scientists at IITA (1987) observed that prunings applied during the period three weeks before planting up to planting had an effect on N content of maize that was equivalent to that of applying N fertilizer at 90 kg/ha for Gliricidia and 60 kg/ha for Flemingia and Cassia and that for Cassia and Gliricidia. Nitrogen released by the decomposing materials was more effectively used by the crop when the prunings were applied close to the time of planting.

Due to its slow rate of decomposition, it would therefore appear that Cassia siamea loppings are not suitable for side dressing, when one has in mind the benefits of nutrients for the growing crop, but should always be incorporated prior to planting.

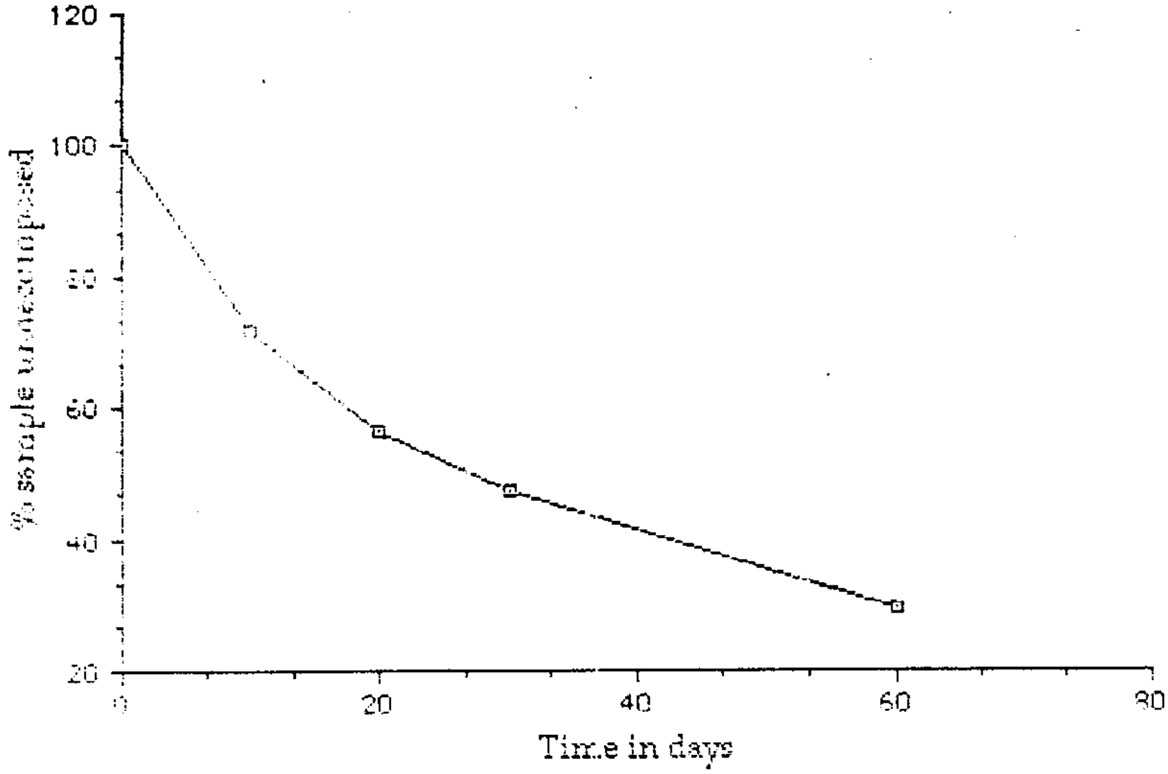

Fig 1 : Decomposition of *C. siamea* short rains 88

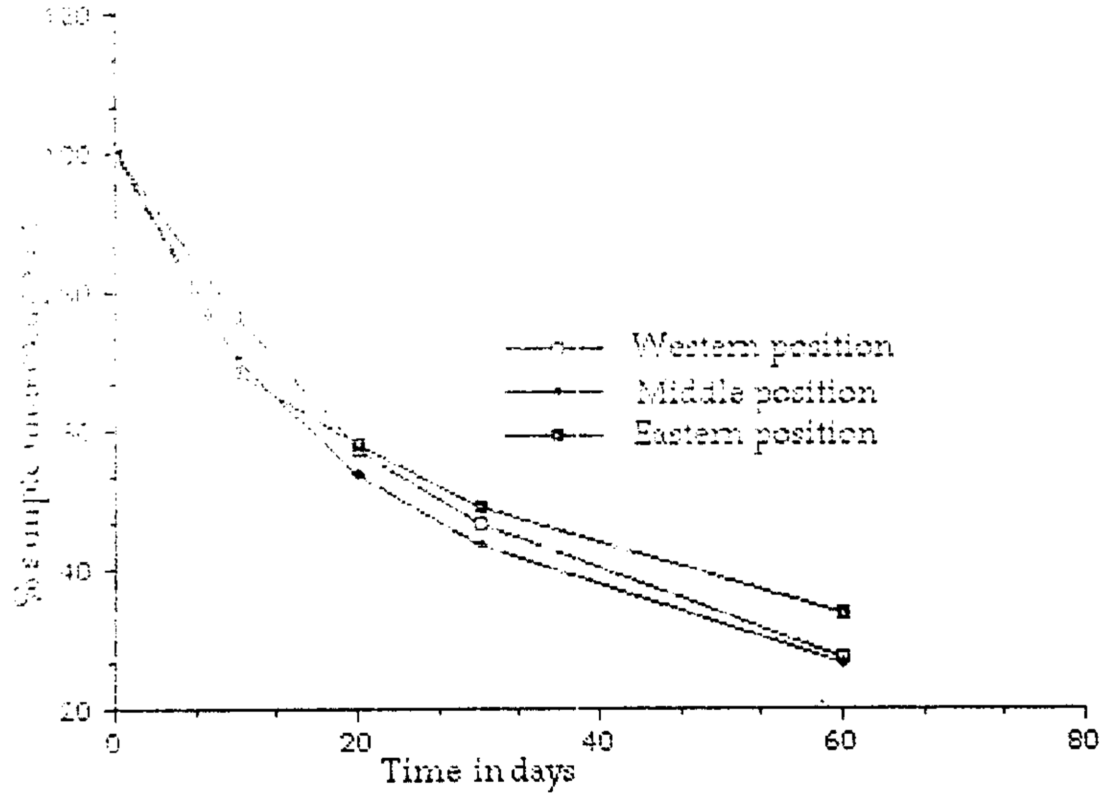

Fig. 2 : Decomposition of *C. siamea* short rains 88 (in the three positions within the alley)

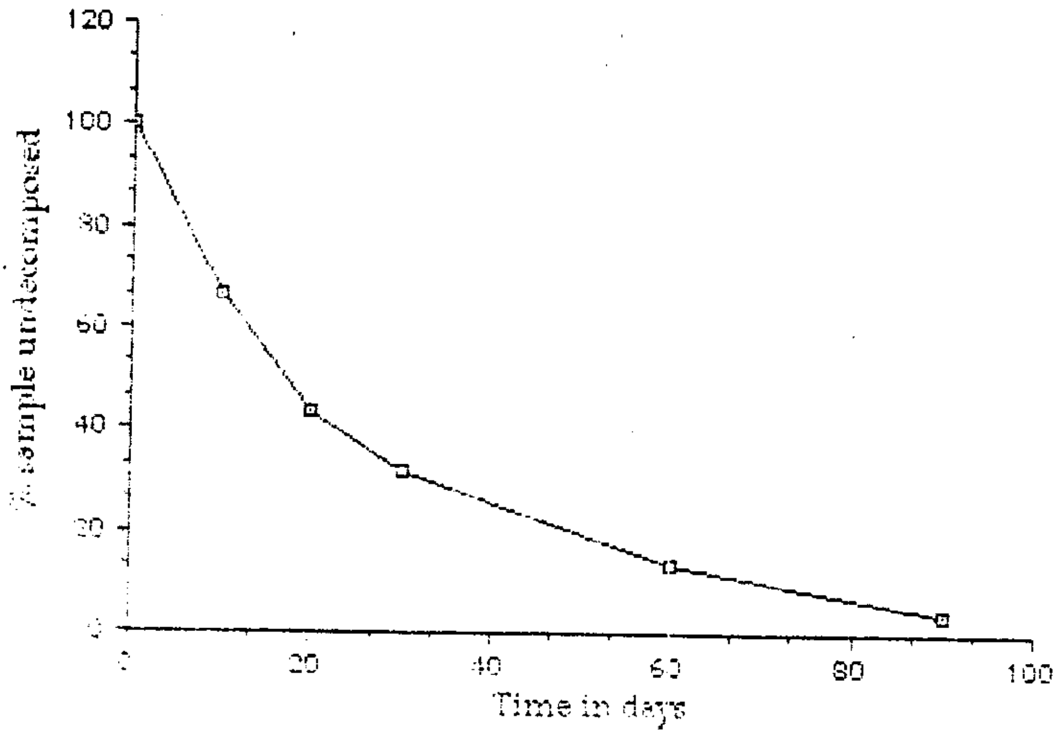

Fig. 3 : Decomposition of *C. siamea* long rains 89

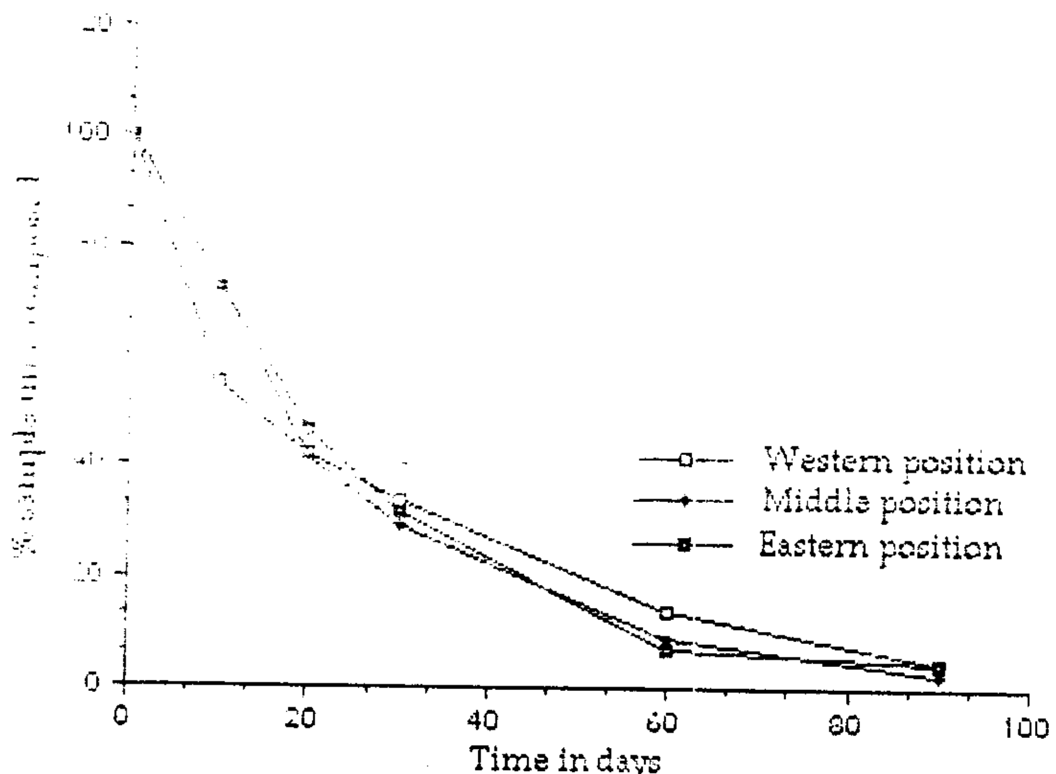

Fig. 4. : Decomposition of *C. siamea* long rains 89 (in the three positions within the alley)

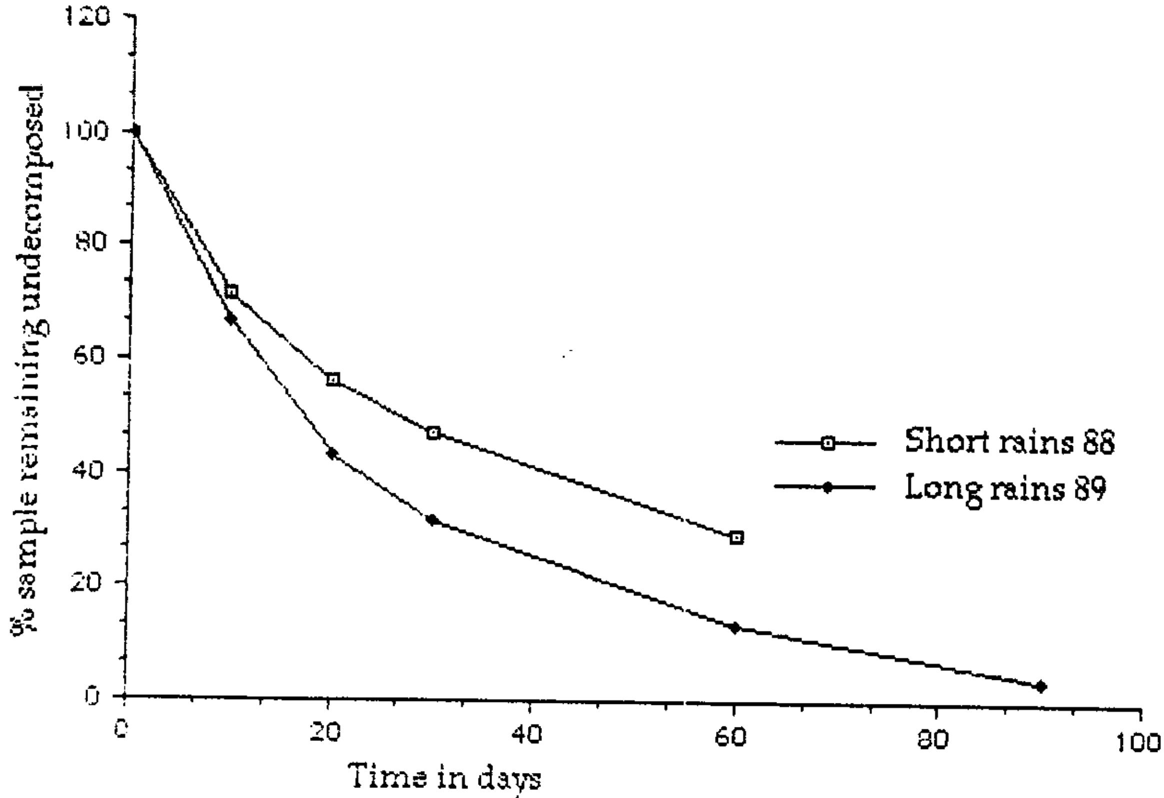

Fig. 5 : Decomposition of *C. siamea* short rains 88 versus long rains 89.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

The study has shown that using *Cassia siamea* loppings as green manure does improve the yields and the mineral nutritional value of maize. This system of management can contribute significant amounts of nutrients to the companion crop which may lead to higher yields without the use of costly fertilizers which most farmers cannot afford in these areas. The practice can also maintain and even improve the fertility of the soil. There were more nutrients in the treated plots compared to the controls with respect to maize leaves, stovers and grains. The yields were higher on per row basis of the treated plots as compared to the controls. However, when the total areas were taken into account, the relative advantage of mulch incorporation seemed to barely make up for the area occupied by the hedges. It is therefore necessary to undertake more trials on multi-purpose trees (MPT)/shrubs for alley cropping trials in order to improve the net value of alley cropping under semi-arid conditions.

The decomposition rate of *Cassia siamea* was rather slow. For the full benefits of nutrient release into the soil and subsequent uptake by the maize crop, it is suggested that, the loppings should be incorporated in the soil 0-2 weeks before planting (seeding). However, a systematic study to determine the optimum time for mulch incorporation in relation to mineralization both for *Cassia* and other agroforestry species commonly used for alley cropping in these semi-arid areas like *Leucaena* and *Gliricidia* is recommended. In addition to the litter bag technique, available N in the soil should be assessed to determine the N flux dynamics during the period of mineralization. A study of the role of soil macro and micro organisms in relation to soil moisture and soil temperature in decomposition and mineralization is recommended.

To be able to come up with an accurate determination of what happens to the nutrients of the loppings once mineralized, it would be necessary to establish a balance between what is taken up by plants and what is left in the soil. To achieve this it is recommended that sampling should be done simultaneously for both the above and below ground parameters.

There is appreciable competition for water by Cassia hedge and maize crop in the system especially if soil water which is a function of rainfall is limiting. More research geared at understanding the facets of roots competition patterns should be encouraged. To avoid soil moisture and nutrient competition in the system, deeper rooted trees which would act as nutrient pumps should be grown. Research into the different management regimes to bring this about and the choice of species is recommended.

The magnitude of the increase of the yield on per row basis of the treated plots over the controls was approximately 32% & 12% for the LR & SR'88. The drop during the SR'88 as compared to LR'88 may have been due to the different cultivar (Hybrid 511) planted during the SR'88 as opposed to the Katumani composite B that is normally planted in Machakos. The Hybrid did better than the Katumani composite in terms of total yields, but the controls of the Hybrid increased more than the treatments when the LR & SR are compared. The Hybrid was apparently able to exploit the control area more effectively.

Alley cropping may result in the additional nutritional value of the grains as evidenced by higher concentrations of nutrients in the maize grains of the treated plots as compared to controls. It might also result in other beneficial factors like soil erosion control, improved infiltration, nutrient and water harvesting and a better micro-climate environment as evidenced by the superiority of the maize rows next to the Cassia siamea hedge in terms of final grain yield.

Incorporation of mulch was found to enhance the growth of weeds. The weed biomass was higher in the treated plots as compared to the control though the differences were only significant for one season. This might have been as a result of more available nutrients in these treatment plots due to the decomposition and mineralization of the incorporated mulch. It is recommended that weeding should always be done promptly to ensure that the crop benefits maximumamly from whatever advantages the incorporated mulch might bring into the soil.

Alley cropping in the semi-arid areas aimed at increasing yields with a degree of sustainability is not as clear cut as in the more humid areas, for rainfall and nutritional status of the soil seem to dictate to a large extent the success of the system. However, with proper management and use of appropriate MPTs may lead to better use of unrealible rainfall (soil moisture) and available nutrients in soil for yield sustainability and improvement in these areas.

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APPENDIX 1

LIST OF ABBREVIATIONS USED

DARP	Dryland Agroforestry Research Project (Machakos).
ICRAF	International Council for Research in Agroforestry (Nairobi).
IDRC	International Development Research Centre Nairobi
IITA	International Institute of Tropical Agriculture (Nigeria).
KARI	Kenya Agricultural Research Institute (Muguga).
KEFRI	Kenya Forestry Research Institute (Muguga).
MIDP	Machakos Integrated Development Project (Machakos).
NAL	National Agriculture Laboratories Nairobi.
NDFRS	National Dryland Farming Research Station (Katumani).
TTMI	Traditional Techniques of Microclimate improvement (The Netherlands).

APPENDIX 2

NUTRIENT TABLES

(a) CASSIA SIAMEA HEDGEROWS SAMPLED ON 14/10/87 (SR'87)

NUTRIENTS IN %

PLT.NO.	POSIT.	N	P	K	Ca	Mg	S	Na	C	C/N
2	YOUNG	2.64	0.16	1.52	1.96	0.18	0.07	0.20	42.33	16.03
	OLD	1.96	0.11	1.22	3.40	0.21	0.08	0.18	51.00	26.02
3	YOUNG	2.23	0.12	1.38	1.57	0.15	0.08	0.26	48.00	21.52
	OLD	2.00	0.11	1.24	3.02	0.18	0.07	0.27	50.63	25.32
8	YOUNG	2.24	0.14	1.56	1.74	0.18	0.07	0.28	34.50	15.40
	OLD	1.92	0.12	1.10	2.84	0.21	0.09	0.19	43.00	22.40
10	YOUNG	2.80	0.13	1.66	1.64	0.18	0.08	0.24	50.25	17.95
	OLD	1.85	0.10	1.29	2.54	0.20	0.06	0.20	69.38	37.50
AVARAGE	YOUNG	2.48	0.14	1.53	1.73	0.17	0.08	0.25	43.77	17.65
	OLD	1.98	0.11	1.21	2.95	0.20	0.08	0.21	53.50	27.02
STD	Y	0.25	0.01	0.10	0.15	0.01	0.00	0.03	6.08	2.38
	O	0.06	0.01	0.07	0.31	0.01	0.01	0.04	9.71	5.76

YOUNG = TOP PARTS>50CM
OLD = LOWER PARTS<50CM

(b) CASSIA SIAMEA HEDGEROWS SAMPLED ON 23/3/88 (LR'88)

NUTRIENTS IN %

PLT.NO.	HR NO.	N	P	K	Ca	Mg	S	Na	C	C/N
2	1	2.31	0.11	1.34	2.08	0.16	0.04	0.19	17.00	7.49
2	2	2.47	0.10	1.36	2.30	0.13	0.04	0.18	38.88	15.74
2	3	2.61	0.12	1.24	2.36	0.19	0.07	0.24	16.50	6.32
2	4	2.63	0.12	1.24	2.68	0.17	0.05	0.17	20.25	7.70
3	1	2.99	0.13	1.30	2.28	0.24	0.06	0.19	33.38	11.16
3	2	2.82	0.14	1.16	2.44	0.25	0.06	0.12	45.75	16.22
3	3	2.54	0.11	1.18	2.36	0.26	0.05	0.16	12.75	5.02
3	4	2.62	0.12	1.12	2.64	0.26	0.05	0.21	17.60	6.72
8	1	2.68	0.12	1.34	1.88	0.30	0.05	0.18	34.50	12.87
8	2	2.71	0.11	1.08	2.04	0.28	0.04	0.16	15.75	5.81
8	3	2.57	0.11	1.12	1.80	0.27	0.04	0.17	19.50	7.59
8	4	2.50	0.10	0.97	2.08	0.28	0.04	0.14	21.00	8.40
AVERAGE		2.63	0.12	1.16	2.25	0.23	0.05	0.18	24.43	9.29
STD		0.17	0.01	0.12	0.26	0.05	0.01	0.03	10.29	3.67

(c) CASSIA SIAMEA HEDGEROWS SAMPLED ON 5/10/88 (SR'88)

		NUTRIENTS IN %								
PLT.NO.	HR NO.	N	P	K	Ca	Mg	S	Na	C	C/N
2	1	2.16	0.08	0.69	3.64	0.23	0.02	0.14	29.27	13.55
2	2	2.36	0.06	1.00	2.90	0.21	0.04	0.20	34.56	14.64
2	3	2.25	0.06	0.96	3.70	0.25	0.04	0.20	39.85	17.71
2	4	2.70	0.09	1.06	3.04	0.23	0.05	0.20	37.24	13.79
3	1	2.00	0.11	1.08	3.04	0.21	0.06	0.22	38.98	19.49
3	2	2.81	0.12	1.35	2.56	0.20	0.06	0.23	30.02	10.68
3	3	1.88	0.12	1.13	2.40	0.21	0.04	0.20	36.21	19.26
3	4	1.89	0.13	0.81	2.90	0.21	0.04	0.19	27.69	14.65
8	1	2.28	0.11	0.81	3.04	0.24	0.04	0.17	31.32	13.74
8	2	2.05	0.12	0.80	2.90	0.27	0.04	0.18	35.50	17.32
8	3	2.10	0.12	1.00	2.84	0.25	0.04	0.20	29.67	14.13
8	4	1.89	0.12	1.13	2.28	0.20	0.04	0.20	28.54	15.10
10	1	2.28	0.09	0.92	2.32	0.21	0.04	0.19	37.17	16.30
10	2	1.93	0.08	0.98	2.66	0.23	0.03	0.19	32.40	16.79
10	3	2.16	0.09	1.06	2.66	0.25	0.03	0.21	36.47	16.88
10	4	2.53	0.12	1.08	2.52	0.24	0.03	0.22	33.27	13.15
AVERAGE		2.21	0.10	0.99	2.84	0.23	0.04	0.20	33.27	15.05
STD		0.20	0.02	0.16	0.40	0.02	0.01	0.02	3.77	2.30

(d) CASSIA SIAMEA HEDGEROWS SAMPLED ON 22/3/89 (LR'89)

		NUTRIENTS IN %								
PLT.NO.	HR NO.	N	P	K	Ca	Mg	S	Na	C	C/N
2	1	2.61	0.14	1.36	1.63	0.16	0.05	0.25	24.30	9.31
2	2	2.47	0.15	1.42	1.36	0.18	0.05	0.27	26.40	10.69
2	3	2.58	0.20	1.30	1.11	0.17	0.06	0.24	29.90	11.59
2	4	2.97	0.19	1.24	1.29	0.17	0.05	0.25	26.60	8.96
3	1	2.41	0.16	1.30	1.36	0.17	0.05	0.26	24.90	10.33
3	2	2.50	0.18	1.20	1.23	0.15	0.05	0.24	22.60	9.04
3	3	2.58	0.19	1.18	0.95	0.13	0.06	0.22	23.80	9.22
3	4	2.61	0.18	1.51	1.61	0.18	0.06	0.26	29.30	11.23
8	1	2.96	0.16	0.99	1.16	0.15	0.05	0.18	23.80	8.04
8	2	2.99	0.19	1.74	1.43	0.20	0.05	0.30	26.40	8.83
8	3	2.32	0.19	1.38	1.52	0.22	0.05	0.28	30.20	13.02
8	4	2.86	0.18	1.24	1.36	0.20	0.06	0.25	25.60	8.95
10	1	2.98	0.14	1.36	1.30	0.20	0.05	0.26	29.10	9.77
10	2	2.80	0.14	1.20	0.87	0.20	0.04	0.22	27.30	9.75
10	3	2.92	0.19	1.40	0.91	0.20	0.06	0.26	22.50	7.71
10	4	2.37	0.17	1.42	1.43	0.17	0.03	0.26	26.00	10.97
AVERAGE		2.68	0.17	1.33	1.28	0.18	0.05	0.25	26.17	9.75
STD		0.23	0.02	0.16	0.23	0.02	0.01	0.03	2.41	1.35

N.B.

HR NO. FROM WEST TO EAST

(e) **MAIZE LEAVES SAMPLED ON 21/5/88 (LR'88)**

PLT.NO.	POSIT.	N	P	K	Ca	Mg	S	Na	C
1	CONT	3.22	0.24	1.44	0.80	0.25	0.06	0.25	36.75
5	CONT	3.11	0.23	1.14	0.82	0.29	0.07	0.30	23.50
7	CONT	3.04	0.24	1.16	0.72	0.30	0.07	0.28	23.63
2	TREAT	3.35	0.27	1.88	0.92	0.35	0.08	0.37	26.25
3	TREAT	4.04	0.32	1.98	1.12	0.38	0.07	0.37	22.38
8	TREAT	3.58	0.27	1.26	0.98	0.37	0.09	0.27	33.65
10	TREAT	3.92	0.24	1.86	0.87	0.41	0.06	0.26	32.63
	AVG.C	3.12	0.24	1.25	0.78	0.28	0.07	0.28	27.96
	AVG.T	3.72	0.28	1.75	0.98	0.38	0.08	0.32	28.72
	%INCREASE	19.20	16.70	40.00	25.60	35.70	14.30	14.30	2.70
	STD C	0.07	0.00	0.14	0.04	0.02	0.00	0.02	6.22
	STD T	0.27	0.03	0.28	0.09	0.02	0.01	0.05	4.63

(f) MAIZE LEAVES OF 9/1/89 (SR'88)

PLT.NO.	POSIT.	NUTRIENTS IN %							
		N	P	K	Ca	Mg	S	Na	C
1	CONT.	2.24	0.15	1.94	0.32	0.19	0.05	0.27	31.30
5	CONT.	2.10	0.13	1.80	0.26	0.15	0.04	0.23	31.30
7	CONT.	2.17	0.13	1.60	0.24	0.14	0.05	0.25	32.30
12	CONT.	2.31	0.15	1.94	0.31	0.18	0.04	0.26	33.30
2	TREAT.	2.38	0.18	1.97	0.42	0.20	0.05	0.30	33.90
3	TREAT.	2.51	0.20	2.00	0.48	0.23	0.04	0.39	33.70
8	TREAT.	2.45	0.16	1.98	0.46	0.26	0.06	0.29	31.50
10	TREAT.	2.49	0.15	2.12	0.38	0.24	0.05	0.28	31.90
	AVG.C	2.21	0.14	1.82	0.28	0.17	0.04	0.25	32.10
	AVG.T	2.46	0.17	2.02	0.44	0.23	0.05	0.32	32.75
	%INCREASE	11.30	21.40	11.00	57.10	35.30	25.00	28.00	2.00
	STD C	0.08	0.01	0.14	0.03	0.02	0.00	0.01	0.83
	STD T	0.05	0.02	0.06	0.04	0.02	0.01	0.04	1.06

N.B.
Control(CONT) plots recieved no mulch treatment
Treated(TREAT) plots had mulch inco-orporated before planting

(g) MAIZE GRAINS SAMPLED ON 21/9/88 (LR'88)

NUTRIENTS IN %

PLT.NO.	POSIT.	N	P	K	Ca	Mg	S	Na	C
CONT.1	WHOLE	1.27	0.16	0.20	0.16	0.14	0.00	0.03	40.82
CONT.1	ROW 6	1.23	0.14	0.20	0.18	0.13	0.00	0.03	38.95
CONT.1	ROW 7	1.27	0.14	0.18	0.14	0.13	0.00	0.04	37.89
CONT.1	ROW 8	1.31	0.15	0.16	0.18	0.14	0.00	0.02	39.20
CONT.5	WHOLE	1.12	0.16	0.18	0.16	0.13	0.00	0.03	33.61
CONT.5	ROW 10	1.07	0.11	0.17	0.18	0.12	0.00	0.02	35.67
CONT.5	ROW 11	1.15	0.18	0.20	0.18	0.12	0.00	0.03	34.35
CONT.5	ROW 12	1.11	0.10	0.17	0.20	0.10	0.00	0.02	39.96
CONT.7	WHOLE	1.16	0.09	0.14	0.18	0.08	0.00	0.03	33.04
CONT.7	ROW 2	1.18	0.14	0.12	0.16	0.12	0.00	0.02	41.62
CONT.7	ROW 3	1.18	0.16	0.13	0.14	0.10	0.00	0.03	36.55
CONT.7	ROW 4	1.11	0.16	0.11	0.12	0.10	0.00	0.02	32.02
CONT.12	WHOLE	1.30	0.12	0.10	0.16	0.08	0.00	0.04	34.32
CONT.12	ROW 6	1.36	0.18	0.16	0.14	0.11	0.00	0.07	41.26
CONT.12	ROW 7	1.25	0.17	0.26	0.14	0.20	0.00	0.06	33.42
CONT.12	ROW 8	1.35	0.15	0.23	0.14	0.10	0.00	0.07	37.17
TREAT.2	WHOLE	1.46	0.16	0.22	0.18	0.14	0.00	0.03	39.34
TREAT.2	ROW 1	1.43	0.16	0.20	0.16	0.15	0.00	0.04	42.02
TREAT.2	ROW 2	1.42	0.18	0.20	0.18	0.14	0.00	0.04	35.66
TREAT.2	ROW 3	1.46	0.20	0.24	0.18	0.13	0.00	0.05	32.26
TREAT.3	WHOLE	1.53	0.27	0.28	0.20	0.15	0.00	0.06	43.93
TREAT.3	ROW 7	1.48	0.24	0.26	0.18	0.15	0.00	0.05	31.67
TREAT.3	ROW 8	1.68	0.24	0.24	0.18	0.15	0.00	0.05	36.86
TREAT.3	ROW 9	1.52	0.25	0.26	0.20	0.15	0.00	0.05	37.27
TREAT.8	WHOLE	1.54	0.16	0.20	0.18	0.14	0.01	0.06	41.59
TREAT.8	ROW 4	1.42	0.21	0.19	0.16	0.20	0.01	0.07	39.34
TREAT.8	ROW 5	1.41	0.18	0.23	0.18	0.13	0.00	0.08	34.52
TREAT.8	ROW 6	1.48	0.14	0.21	0.18	0.15	0.01	0.08	40.10
TREAT.10	WHOLE	1.47	0.16	0.19	0.18	0.16	0.00	0.08	41.89
TREAT.10	ROW 7	1.47	0.14	0.18	0.16	0.12	0.00	0.08	39.82
TREAT.10	ROW 8	1.37	0.15	0.18	0.20	0.13	0.00	0.06	36.45
TREAT.10	ROW 9	1.40	0.11	0.20	0.18	0.10	0.00	0.07	34.86
AVG CONT		1.22	0.14	0.17	0.16	0.12	0.00	0.04	36.87
AVG TREAT		1.47	0.18	0.22	0.18	0.14	0.00	0.06	37.97
%INCREASE		20.50	28.60	29.40	12.50	16.70	0.00	50.00	3.00
STD C		0.09	0.03	0.04	0.02	0.03	0.00	0.02	3.09
STD T		0.07	0.04	0.03	0.01	0.02	0.00	0.02	3.59

(h) MAIZE GRAINS SAMPLED ON 30/5/89 (SR'88)

NUTRIENTS IN %

PLT.NO.	POSIT.	N	P	K	Ca	Mg	S	Na	C
CONT.1	WHOLE	1.45	0.19	0.19	0.16	0.12	0.01	0.04	38.90
CONT.1	ROW 6	1.43	0.17	0.17	0.14	0.10	0.01	0.03	37.20
CONT.1	ROW 7	1.53	0.19	0.21	0.17	0.13	0.01	0.05	36.80
CONT.1	ROW 8	1.41	0.19	0.19	0.14	0.12	0.01	0.06	40.20
CONT.5	WHOLE	1.38	0.19	0.23	0.16	0.12	0.01	0.05	37.50
CONT.5	ROW 10	1.42	0.16	0.21	0.14	0.10	0.01	0.06	35.90
CONT.5	ROW 11	1.41	0.16	0.21	0.14	0.10	0.01	0.03	38.10
CONT.5	ROW 12	1.39	0.19	0.19	0.16	0.10	0.01	0.04	33.70
CONT.7	WHOLE	1.36	0.16	0.21	0.14	0.10	0.01	0.04	33.40
CONT.7	ROW 2	1.35	0.16	0.23	0.14	0.10	0.01	0.05	32.60
CONT.7	ROW 3	1.32	0.17	0.19	0.16	0.10	0.01	0.06	35.30
CONT.7	ROW 4	1.42	0.19	0.19	0.15	0.10	0.01	0.04	36.70
CONT.12	WHOLE	1.43	0.23	0.24	0.16	0.13	0.01	0.04	37.80
CONT.12	ROW 6	1.47	0.20	0.21	0.15	0.12	0.01	0.03	33.00
CONT.12	ROW 7	1.42	0.22	0.21	0.14	0.12	0.01	0.06	39.30
CONT.12	ROW 8	1.40	0.19	0.19	0.16	0.10	0.01	0.03	41.20
TREAT.2	WHOLE	1.60	0.25	0.24	0.16	0.14	0.01	0.05	34.60
TREAT.2	ROW 1	1.66	0.22	0.23	0.17	0.13	0.01	0.06	35.30
TREAT.2	ROW 2	1.61	0.25	0.23	0.15	0.13	0.01	0.04	38.20
TREAT.2	ROW 3	1.51	0.22	0.21	0.14	0.12	0.01	0.05	33.10
TREAT.3	WHOLE	1.48	0.29	0.26	0.16	0.14	0.01	0.05	36.80
TREAT.3	ROW 7	1.51	0.27	0.24	0.16	0.14	0.01	0.05	39.20
TREAT.3	ROW 8	1.42	0.27	0.24	0.17	0.14	0.01	0.04	40.60
TREAT.3	ROW 9	1.42	0.16	0.23	0.18	0.12	0.01	0.06	39.60
TREAT.8	WHOLE	1.55	0.21	0.23	0.16	0.13	0.01	0.06	38.30
TREAT.8	ROW 4	1.63	0.20	0.24	0.16	0.13	0.01	0.05	37.90
TREAT.8	ROW 5	1.53	0.27	0.26	0.17	0.14	0.01	0.06	34.60
TREAT.8	ROW 6	1.62	0.19	0.21	0.16	0.12	0.01	0.06	39.30
TREAT.10	WHOLE	1.50	0.19	0.23	0.15	0.12	0.01	0.04	39.10
TREAT.10	ROW 7	1.48	0.19	0.21	0.14	0.12	0.01	0.03	40.50
TREAT.10	ROW 8	1.60	0.19	0.23	0.15	0.12	0.01	0.04	37.90
TREAT.10	ROW 9	1.41	0.19	0.21	0.17	0.12	0.01	0.05	36.80
AVG CONT		1.41	0.19	0.20	0.15	0.11	0.01	0.04	36.73
AVG TREAT		1.53	0.22	0.23	0.16	0.13	0.01	0.05	37.61
%INCREASE		8.51	15.79	15.00	6.67	18.18	0.00	25.00	2.39
STD C		0.05	0.02	0.02	0.01	0.01	0.00	0.01	2.51
STD T		0.08	0.04	0.02	0.01	0.01	0.00	0.01	2.16

CONT: For control plots
TREAT: For treated plots (Mulch was inco-orporated)
WHOLE: For composits sample representing the whole plot
ROW:For one maize line (No. of line given e.g 1)

(i) MAIZE STOVER SAMPLED ON 21/3/89 (SR'88)

PLT.NO.	POSIT.	N	P	K	Ca	Mg	S	Na	C
		NUTRIENTS IN %							
1	CONT.	0.35	0.03	1.07	0.25	0.14	0.03	0.22	33.00
5	CONT.	0.23	0.02	1.02	0.22	0.12	0.04	0.25	32.00
7	CONT.	0.22	0.02	0.99	0.21	0.13	0.04	0.20	31.40
12	CONT.	0.33	0.03	1.24	0.26	0.15	0.03	0.28	33.60
2	TREAT.	0.42	0.04	1.28	0.33	0.21	0.04	0.32	35.20
3	TREAT.	0.42	0.06	1.29	0.36	0.11	0.05	0.37	35.80
8	TREAT.	0.49	0.03	1.07	0.32	0.19	0.04	0.29	34.00
10	TREAT.	0.40	0.04	1.26	0.31	0.24	0.04	0.40	34.80
	AVG.C	0.28	0.03	1.08	0.24	0.14	0.04	0.24	32.50
	AVG.T	0.43	0.04	1.23	0.33	0.19	0.04	0.35	34.95
	%INCREASE	53.57	33.33	13.88	37.50	35.71	0.00	45.83	7.54
	STD C	0.06	0.00	0.10	0.02	0.01	0.00	0.03	0.85
	STD T	0.03	0.01	0.09	0.02	0.05	0.00	0.04	0.65

N.B.
Control(CONT) plots recieved no mulch treatment
Treated(TREAT) plots had mulch inco-orporated before planting

(j) SOIL SAMPLED ON 30TH SEPTEMBER 1988: DEPTH = 0-20CM (LR'88

PLT NO	POSIT.	PH	Na	K	Ca	Mg	Mn	Pppm	N%	C%	Sppm
			IN m.e %								
1	CONT	5.90	0.20	0.66	5.80	1.30	0.35	18.00	0.07	0.70	3.00
1	CONT	6.20	0.18	0.60	6.20	1.20	0.36	12.00	0.07	0.80	3.00
1	CONT	6.50	0.18	0.62	5.40	1.00	0.32	19.00	0.08	0.64	1.00
5	CONT	5.90	0.11	0.44	2.00	0.70	0.31	12.00	0.04	0.67	3.00
5	CONT	5.80	0.08	0.42	2.20	0.80	0.28	8.00	0.07	0.42	3.00
5	CONT	5.80	0.08	0.42	2.20	0.80	0.36	8.00	0.04	0.53	4.00
7	CONT	5.80	0.11	0.52	2.30	1.00	0.28	12.00	0.05	0.67	4.00
7	CONT	5.70	0.11	0.50	2.20	1.80	0.34	12.00	0.03	0.23	4.00
7	CONT	5.80	0.13	0.52	3.20	1.00	0.28	10.00	0.02	0.24	4.00
12	CONT	5.90	0.14	0.63	2.50	1.10	0.39	10.00	0.07	0.76	4.00
12	CONT	6.30	0.18	0.65	3.10	1.00	0.28	10.00	0.07	0.76	3.00
12	CONT	6.40	0.18	0.70	3.50	1.20	0.34	14.00	0.06	0.81	3.00
2	TREAT	6.30	0.24	0.90	6.40	2.80	0.36	20.00	0.07	0.79	2.00
2	TREAT	6.40	0.26	0.88	6.20	1.60	0.39	16.00	0.08	0.88	3.00
2	TREAT	6.30	0.20	0.88	5.60	2.00	0.39	18.00	0.09	0.60	3.00
3	TREAT	6.60	0.20	0.72	7.20	2.20	0.42	19.00	0.08	0.73	4.00
3	TREAT	6.50	0.24	0.66	6.20	2.40	0.42	20.00	0.09	0.82	3.00
3	TREAT	6.40	0.26	0.72	6.80	1.80	0.59	21.00	0.09	0.92	3.00
8	TREAT	6.00	0.16	0.66	5.30	1.50	0.38	18.00	0.08	0.94	4.00
8	TREAT	5.80	0.18	0.60	5.90	1.80	0.36	18.00	0.07	0.92	4.00
8	TREAT	5.90	0.23	0.60	4.30	1.40	0.46	18.00	0.09	0.87	3.00
10	TREAT	6.00	0.21	0.60	5.80	1.50	0.34	18.00	0.09	0.72	3.00
10	TREAT	6.10	0.18	0.63	5.00	1.50	0.39	16.00	0.08	0.82	3.00
10	TREAT	6.00	0.21	0.65	4.80	1.60	0.38	14.00	0.06	0.85	2.00
	CONT.	6.00	0.14	0.56	3.38	1.08	0.32	12.08	0.06	0.60	3.25
	TREAT.	6.20	0.21	0.71	5.79	1.84	0.41	18.00	0.08	0.82	3.08
	%INCREASE	3.30	50.00	26.80	71.30	70.30	28.10	49.00	33.30	36.70	5.30
STD C		0.26	0.04	0.09	1.47	0.28	0.04	3.33	0.02	0.20	0.83
STD T		0.25	0.03	0.11	0.81	0.41	0.06	1.87	0.01	0.10	0.64

(k) **WEED SAMPLES TAKEN ON 18/11/88** (SR'88)

PLT.NO.	POSIT.	DRY WGT IN GMS	PLT.NO.	POSIT.	DRY WGT IN GMS
1	CONT	4.4	2	TREAT	5.2
1	CONT	3.9	2	TREAT	13.8
1	CONT	3.9	2	TREAT	8.8
1	CONT	1.4	2	TREAT	7.4
1	CONT	2.6	2	TREAT	12.4
1	CONT	5.6	2	TREAT	11.7
1	CONT	3.7	2	TREAT	11.6
1	CONT	4.9	2	TREAT	11.0
1	CONT	5.8	2	TREAT	10.4
1	CONT	4.3	2	TREAT	10.7
1	CONT	4.8	2	TREAT	10.6
1	CONT	2.5	2	TREAT	12.6
5	CONT	6.8	3	TREAT	15.6
5	CONT	8.4	3	TREAT	12.3
5	CONT	7.3	3	TREAT	11.8
5	CONT	2.9	3	TREAT	11.6
5	CONT	2.0	3	TREAT	16.0
5	CONT	3.3	3	TREAT	15.1
5	CONT	6.3	3	TREAT	18.3
5	CONT	1.6	3	TREAT	15.1
5	CONT	7.6	3	TREAT	19.1
5	CONT	9.0	3	TREAT	16.8
5	CONT	3.6	3	TREAT	37.8
5	CONT	1.9	3	TREAT	16.5
7	CONT	7.4	8	TREAT	8.3
7	CONT	4.4	8	TREAT	12.2
7	CONT	1.0	8	TREAT	4.3
7	CONT	7.6	8	TREAT	6.2
7	CONT	1.0	8	TREAT	16.4
7	CONT	8.2	8	TREAT	8.6
7	CONT	1.2	8	TREAT	5.8
7	CONT	3.0	8	TREAT	8.3
7	CONT	4.1	8	TREAT	27.4
7	CONT	7.4	8	TREAT	12.0
7	CONT	6.8	8	TREAT	15.5
7	CONT	6.0	8	TREAT	7.9
12	CONT	8.2	10	TREAT	13.2
12	CONT	6.4	10	TREAT	8.4
12	CONT	8.9	10	TREAT	11.4
12	CONT	5.9	10	TREAT	30.4
12	CONT	3.7	10	TREAT	15.4
12	CONT	4.2	10	TREAT	7.1
12	CONT	2.4	10	TREAT	12.2
12	CONT	5.4	10	TREAT	5.5
12	CONT	4.4	10	TREAT	14.2
12	CONT	7.3	10	TREAT	5.7
12	CONT	3.9	10	TREAT	8.2
12	CONT	4.2	10	TREAT	9.8
	AVG C	4.8		AVG T	12.3
	STD C	2.2		STD T	6.2

(1) WEED SAMPLES TAKEN ON 29/4/89 (LR'89)

PLT.NO.	POSIT.	DRY WGT IN GMS	PLT.NO.	POSIT.	DRY WGT IN GMS
1	CONT	1.9	2	TREAT	12.3
1	CONT	4.9	2	TREAT	2.4
1	CONT	1.9	2	TREAT	1.1
1	CONT	0.8	2	TREAT	1.3
1	CONT	3.5	2	TREAT	1.2
1	CONT	0.4	2	TREAT	1.8
5	CONT	5.7	3	TREAT	21.9
5	CONT	18.3	3	TREAT	6.8
5	CONT	12.3	3	TREAT	2.9
5	CONT	8.0	3	TREAT	7.5
5	CONT	10.6	3	TREAT	13.4
5	CONT	33.0	3	TREAT	42.7
7	CONT	45.4	8	TREAT	248.0
7	CONT	37.5	8	TREAT	132.3
7	CONT	24.8	8	TREAT	1.5
7	CONT	39.8	8	TREAT	17.1
7	CONT	19.0	8	TREAT	11.1
7	CONT	18.2	8	TREAT	133.2
12	CONT	70.9	10	TREAT	146.4
12	CONT	80.3	10	TREAT	33.4
12	CONT	87.4	10	TREAT	39.2
12	CONT	81.2	10	TREAT	12.4
12	CONT	65.9	10	TREAT	19.8
12	CONT	18.9	10	TREAT	8.7
	AVG C	28.3		AVG T	38.3
	STD C	27.9		STD T	61.1

(m) DECOMPOSITION OF CASSIA SIAMEA FOR SHORT RAINS '88

% SAMPLE REMAINING UNDECOMPOSED

		TIME				
PLOT	ROW NO.	0	10	20	30	60
3	1	100.0	95.4	71.1	46.7	41.1
3	2	100.0	76.8	58.8	51.4	31.1
3	3	100.0	65.4	60.7	55.3	36.8
8	1	100.0	66.9	48.4	46.3	15.8
8	2	100.0	64.6	51.1	39.5	31.6
8	3	100.0	70.2	52.6	44.7	30.9
10	1	100.0	67.5	51.9	47.0	25.6
10	2	100.0	68.4	51.9	46.1	17.9
10	3	100.0	70.2	60.4	47.5	33.7
	AVERAGE	100.0	71.7	56.3	47.2	29.4
	STD	0.0	9.0	6.7	4.1	7.8
ROWS	1-W	100.0	76.6	57.1	46.7	27.5
(AVG)	2-M	100.0	70.6	53.9	43.7	26.7
	3-E	100.0	68.6	57.9	49.2	33.8

1-W = AVG OF WESTERN ROWS
2-M = AVG OF MIDDLE ROWS
3-E = AVG OF EASTERN ROWS

(n) DECOMPOSITION OF CASSIA SIAMEA - LONG RAINS '89

% SAMPLE REMAINING UNDECOMPOSED

		TIME					
PLOT	ROW NO.	0	10	20	30	60	90
3	1	100.0	61.0	54.9	36.0	10.4	5.5
3	2	100.0	72.0	35.4	34.8	4.9	4.3
3	3	100.0	75.0	56.7	26.8	7.9	4.9
8	1	100.0	59.1	36.0	34.1	11.6	3.7
8	2	100.0	73.8	45.1	26.8	6.1	3.0
8	3	100.0	79.3	39.6	31.7	15.2	3.7
10	1	100.0	44.5	36.0	31.1	19.5	3.7
10	2	100.0	70.7	43.9	26.8	15.9	0.6
10	3	100.0	62.8	43.3	37.2	28.0	4.3
	AVERAGE	100.0	66.5	43.2	31.7	13.3	3.7
	STD	0.0	10.1	7.5	3.9	6.9	1.3
ROWS (AVG)	1-W	100.0	54.9	42.3	33.7	13.8	4.3
	2-M	100.0	72.2	41.5	29.5	9.0	2.6
	3-E	100.0	72.4	46.5	31.9	17.0	4.3

1-W = AVG OF WESTERN ROWS
2-M = AVG OF MIDDLE ROWS
3-E = AVG OF EASTERN ROWS

(p) PRELIMINARY DECOMPOSITION OF C. SIAMEA DONE DURING A DRY PERIOD (11/8/88 - 11/10/88)

TIME IN DAYS	% SAMPLE UNDECOMPOSED
0	100.0
10	85.3
20	75.1
30	66.2
40	60.2
60	53.9

APPENDIX 3

ANOVA TABLES

(a) CASSIA SIAMEA SAMPLED ON 14/10/87 (SR'87)

NUTRIENT	DF	ERROR	SS	MS	F
N	1	6	0.5941	0.5941	13.7*
P	1	6	0.0015	0.0015	8.4*
K	1	6	0.2016	0.2016	20.2*
Ca	1	6	2.9890	2.9890	37.8*
Mg	1	6	0.0015	0.0015	7.1*
S	1	6	0.0000	0.0000	0.0
Na	1	6	0.0025	0.0025	1.7
C	1	6	189.44	189.44	2.2
C/N	1	6	203.11	25.866	7.9*

(b) CASSIA SIAMEA SAMPLED ON 23/3/88 (LR'88)

NUTRIENT	DF	ERROR	SS	MS	F
N	2	9	0.1282	0.0641	2.5
P	2	9	0.0005	0.0003	2.4
Ca	2	9	0.5334	0.2667	7.8*
Mg	2	9	0.0312	0.0156	53.5*
S	2	9	0.0003	0.0002	1.8
Na	2	9	0.0023	0.0012	1.2
C	2	9	52.630	26.315	0.2
C/N	2	9	2.4963	1.2482	0.1
K	2	9	0.0573	0.0287	2.5

(c) CASSIA SIAMEA SAMPLED ON 5/10/88 (SR'88)

NUTRIENT	DF	ERROR	SS	MS	F
N	3	12	0.1841	0.0614	0.7
P	3	12	0.0059	0.0020	12.8*
K	3	12	0.0713	0.0238	0.9
Ca	3	12	1.3569	0.45238	4.6*
Mg	3	12	0.0024	0.0008	2.2
S	3	12	0.0008	0.0003	2.9
Na	3	12	0.0017	0.0006	1.4
C	3	12	39.1470	13.0490	0.8
C/N	3	12	3.4182	1.1394	0.2

(d) CASSIA SIAMEA SAMPLED ON 22/3/89 (LR'89)

NUTRIENTS	DF	ERROR	SS	MS	F
N	3	12	0.1706	0.05687	1.0
P	3	12	0.0009	0.00003	0.7
K	3	12	0.0054	0.0018	0.1
Ca	3	12	0.142	0.0473	0.8
Mg	3	12	0.0036	0.0012	2.9
S	3	12	0.0003	0.0001	1.4
Na	3	12	0.0046	0.0015	2.7
C	3	12	6.1969	2.0656	0.3
C/N	3	12	0.8101	0.2703	0.1

(e) MAIZE LEAVES SAMPLED ON 21/5/88 (LR'88)

NUTRIENTS	DF	ERROR	SS	MS	F
N	1	5	1.2440	1.2440	19.6*
P	1	5	0.0025	0.0025	3.7
K	1	5	0.4200	0.4200	5.6
Ca	1	5	0.0640	0.0640	8.0*
Mg	1	5	0.0163	0.0163	24.9*
S	1	5	0.0001	0.0001	1.1
Na	1	5	0.0029	0.0029	1.2
C	1	5	0.9900	0.9900	0.0

(f) MAIZE LEAVES SAMPLED ON 9/1/89 (SR'88)

NUTRIENTS	DF	ERROR	SS	MS	F
N	1	6	0.1275	0.1275	22.3*
P	1	6	0.0021	0.0021	6.8*
K	1	6	0.0780	0.0780	5.1
Ca	1	6	0.0465	0.0465	26.9*
Mg	1	6	0.0091	0.0091	15.3*
S	1	6	0.0001	0.0001	1.0
Na	1	6	0.0078	0.0078	5.5
C	1	6	0.8450	0.8450	0.7

(g) MAIZE GRAINS OF 21/9/88 (LR'88)

NUTRIENTS	DF	ERROR	SS	MS	F
N	1	22	0.5305	0.5305	77.5*
P	1	22	0.0123	0.0128	9.0*
K	1	22	0.0176	0.0176	12.4*
Ca	1	22	0.0032	0.0032	10.0*
Mg	1	22	0.0048	0.0048	7.5*
S	1	22	0.0000	0.0000	3.5
Na	1	22	0.0055	0.0055	17.5*
C	1	22	7.9302	7.9302	0.7

(h) MAIZE GRAINS OF 30/5/89 (SR'88)

NUTRIENTS	DF	ERROR	SS	MS	F
N	1	22	0.0852	0.0852	15.8*
P	1	22	0.0077	0.0077	8.6*
K	1	22	0.0043	0.0048	19.0*
Ca	1	22	0.0042	0.0042	3.2
Mg	1	22	0.0024	0.0024	23.5*
S	1	22	0.0000	0.0000	0.0
Na	1	22	0.0001	0.0001	0.8
C	1	22	7.0417	7.0417	1.1

(i) MAIZE STOVERS OF 21/3/89 (SR'88)

NUTRIENTS	DF	ERROR	SS	MS	F
N	1	6	0.045	0.045	14.9*
P	1	6	0.0006	0.0006	6.4*
K	1	6	0.0421	0.0421	3.6
Ca	1	6	0.0000	0.0000	0.1
Mg	1	6	0.0055	0.0055	3.4
S	1	6	0.0001	0.0001	3.9
Na	1	6	0.0231	0.0231	12.6*
C	1	6	12.005	12.005	1.7

(ii) SOIL SAMPLED ON 30/9/88 (DEPTH 0-20 CM) (LR'88)

NUTRIENT	DF	ERROR	SS	MS	F
Zn	1	22	0.2204	0.2204	3.1
Na	1	22	0.0330	0.0330	23.1*
K	1	22	0.1330	0.1330	12.0*
Ca	1	22	34.800	34.800	22.6*
Mg	1	22	3.5267	3.5267	26.1*
Mn	1	22	0.0408	0.0408	14.0*
P	1	22	210.04	210.04	26.4*
N	1	22	0.0038	0.0038	15.9*
C	1	22	0.2882	0.2882	11.1*
S	1	22	0.1667	0.1667	0.3

(k) WEEDS

SEASON	DF	ERROR	SS	MS	E
Short rains '88	1	94	1354.5	1354.5	61.6*
Long rains '89	1	47	1081.1	1081.1	0.5

(1) MAIZE GRAINS OF 21/9/88 (LR'88)
TREATMENT ROWS COMPARED

NUTRIENTS	DF	ERROR	SS	MS	E
N	2	9	0.0008	0.0004	0.1
P	2	9	0.0004	0.0002	0.1
K	2	9	0.0008	0.0004	0.5
Ca	2	9	0.0041	0.0020	0.7
Mg	2	9	0.0012	0.0006	1.0
S	2	9	0.0000	0.0000	0.5
Na	2	9	0.0001	0.0000	0.1
C	2	9	16.856	8.428	0.7

(m) MAIZE GRAINS OF 30/5/89 (SR'88)
TREATMENT ROWS COMPARED

NUTRIENT	DF	ERROR	SS	MS	E
N	2	9	0.0131	0.0066	0.8
P	2	9	0.0061	0.0030	2.3
K	2	9	0.0012	0.0006	3.8
Ca	2	9	0.0001	0.0000	0.1
Mn	2	9	0.0004	0.0002	3.3
S	2	9	0.0000	0.0000	0.0
Na	2	9	0.0002	0.0001	1.1
C	2	9	2.1350	1.0675	0.2

(n) YIELDS (GRAINS) IN GMS/ROW

SEASON	DF	ERROR	SS	MS	F
LR'88	1	6	1.15E6	1.15E6	3.5
SR'88	1	6	4.26E6	4.26E6	2.0

(o) YIELDS (GRAINS) IN GMS/ROW
EASTERN, MIDDLE & WESTERN ROWS COMPARED

SEASON	DF	ERROR	SS	MS	F
LR'88	2	33	1.13E6	5.64E5	2.0
SR'88	2	33	6.57E6	3.29E6	5.8*

(p) DECOMPOSITION OF CASSIA SIAMEA - LR'89

SAMPLING DAYS	DF	ERROR	SS	MS	F
10	2	6	44.127	22.063	0.7
20	2	6	8.9867	4.4933	0.2
30	2	6	6.3756	3.1878	0.4
60	2	6	28.829	14.414	0.6

(q) DECOMPOSITION OF CASSIA SIAMEA - LR'89

SAMPLING DAYS	DF	ERROR	SS	MS	F
10	2	6	16.247	8.1233	5.8*
20	2	6	1.2022	0.6011	0.3
30	2	6	0.7400	0.3700	0.8
[illegible]	2	6	2.7022	1.3511	0.9
[illegible]	2	6	8.9533	4.4756	0.9

* Significant at the 5% level.

APPENDIX 4

BIOMASS PRODUCTION FROM CASSIA SIAMEA HEDGES IN KGS/HEDGE

	PLT	ROW1	ROW2	ROW3	ROW4	TOTAL
LR'88	2	9.8	14.7	12.5	13.0	50.0
	3	15.4	20.1	18.7	19.0	73.2
	8	14.5	29.0	17.9	18.3	79.7
	10	12.1	16.6	17.4	21.8	67.9
SR'88	2	10.2	9.7	7.5	10.0	37.4
	3	12.5	8.4	11.7	20.0	52.6
	8	17.3	20.7	15.3	17.8	71.1
	10	11.8	10.3	11.6	20.5	54.2
LR'89	2	27.9	21.5	17.3	26.7	93.4
	3	34.9	21.6	25.3	35.6	117.4
	8	42.0	40.1	30.9	35.7	148.7
	10	29.9	20.3	20.5	40.3	111.0

NB The loppings from each row were appliec to the alley adjacent to it and those from row 4 were equally shared amongst the 3 alleys.

APPENDIX 5

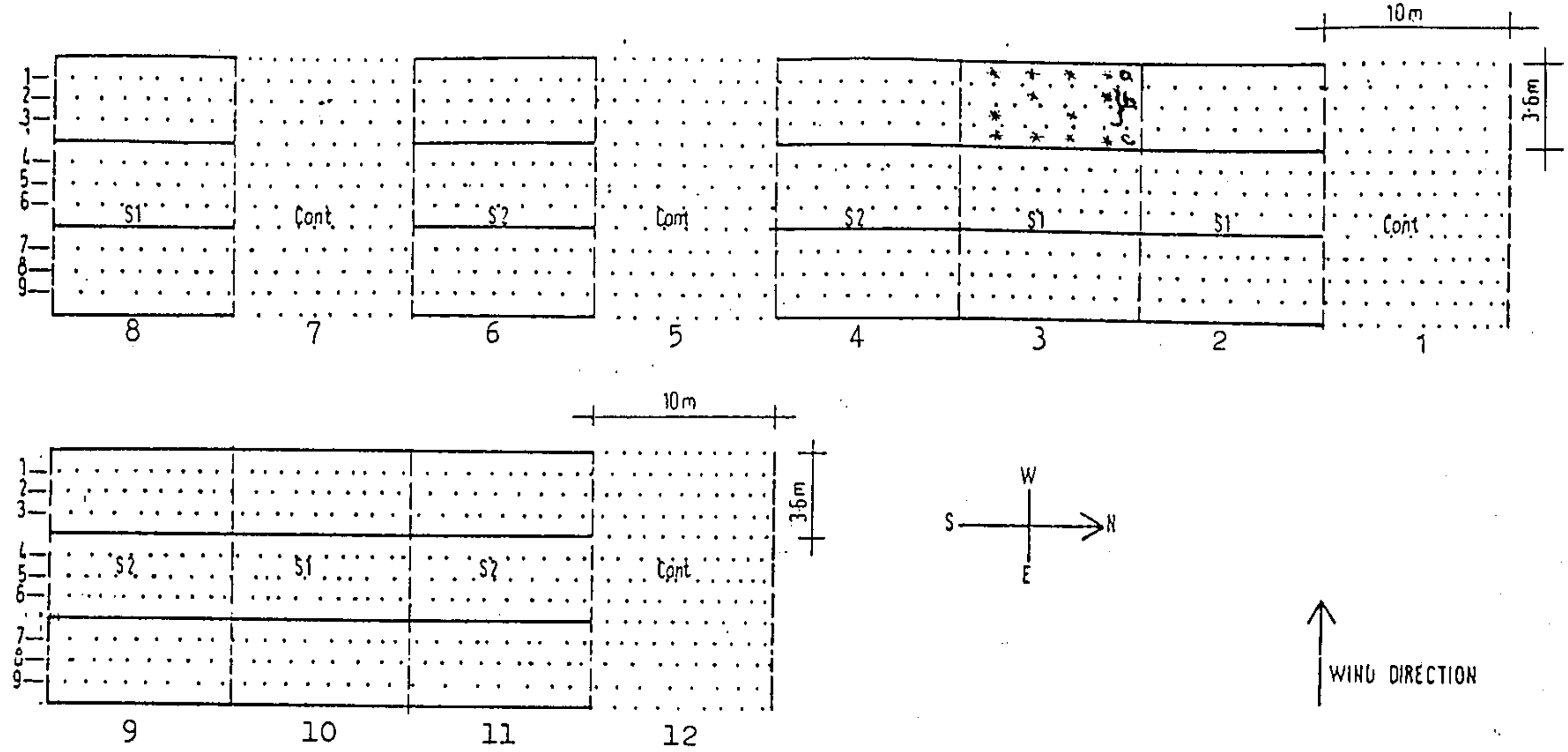
MONTHLY AVERAGE RAINFALL IN MM FOR THE EXPERIMENTAL SITE FOR 1988 AND 1989

	1988	1989
January	144.3	127.2
February	28.9	9.1
March	125.7	86.2
April	263.9	134.2
May	15.1	61.9
June	10.8	
July	0.2	
August	6.1	
September	24.7	
October	31.3	
November	147.7	
December	208.7	

NB The data was collected at the ICRAF Field Station which is adjacent to the experimental site.

CASSIA SIAMEA HEDGE-ROW TRIAL

EXPERIMENTAL LAYOUT



* = Litter bags

a – Western position
b – Middle position
c – Eastern position

CONT = CONTROL

________________ CASSIA SIAMEA HEDGE

.... MAIZE ROWS

LEGEND

1 - 9 = ROWS OF MAIZE

S_1 = CASSIA IN ROW SPACING = .25 m

S_2 = = 1.0 m

1 = 12 = Plot Numbers