EFFECT OF *Leucaena leucocephala*, *Cassia siamea* AND *Terminalia brownii* LEAF MULCH ON MAIZE PERFORMANCE AND SOIL NUTRIENTS UNDER THE SEMI-ARID CONDITIONS IN MACHAKOS, KENYA.

BY

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DECLARATION

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

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

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DEDICATION

This thesis is dedicated
to my mother, Mutika, my
wife,Wangi
&
to my children, Mwangi and
Wairimu.

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ABSTRACT

The influence of three leaf mulches from three tree species on soil nutrients, maize performance and yield and N concentration of maize at variuos growth stages was studied for two very contrasting seasons (very dry 1987 "short rains " and wet 1988 "long rains") in the semi-arid district of Machakos, Kenya. Fresh leaf mulches of *Leucaena leucocephala*, *Cassia siamea* and *Terminalia brownii* were burried in the soil at a depth of 15cm at 1 and 2kg/m^2 rates. The mulching materials were burried in furrows 90cm apart. The design of the experiments was randomised complete block replicated four times. After burying the mulches, Katumani maize was planted on ridges (above the mulch layers), at a spacing of 90x30cm.

Analysis of the leaf mulches for their nutrient composition showed that *Leucaena leucocephala* had the highest concentration of nutrients while *Terminalia brownii* had the lowest concentrations but highest C content. In terms of C/N ratio *Terminalia brownii* had the highest (average of 38.4) while *Leucaena leucocephala* had the lowest (Average of 15.4), indicating a lower decomposition of the former.

Soil analysis showed that the mulches increased soil pH, organic carbon, exchangeable bases, total nitrogen and phosphorus during their decomposition

and even cummulatively over the trials. There was a progressive decline in the soil nutrient status in the unmulched plots, which is likely to be due to nutrient removal by the maize crop and leaching.

Results on the mulches' influence on maize indicated that mulch application significantly increased nitrogen concentration of maize ear leaves (cobbing stage). Maize grain yield was higher in the mulched plots compared to the unmulched, however the differences were not significant (p=0.05). Maize grain yield was significantly and positively correlated with plant height, plant base diameter, leaf area index, cob weight, and grain size in the second trial.

CHAPTER ONE

1. INTRODUCTION

Increasing land pressure, due to rapid population growth in many parts of the tropics, has led into a shortening of the fallow periods which used to restore soil fertility in many traditional farming systems (Torres,1984). Kenya's population growth rate was officialy 4% in the 1979 census (Stewart and Hash,1981).

Consequently the high potential areas are now becoming more and more populated leading to intensive use of land and thus leading to rapid soil degradation and a decline in crop yields.The result of this is a rapid expansion of small holders farming in ever drier zones (Stewart and Hash,1981).These new communities have no farming backgroud of their new areas in terms of crop selection and the agronomic practices most suited for stabilization at a maximum level of food production in these areas.Methods of improving the productivity of traditional farming systems by the introducton of inorganic fertilizers have not been widely adopted by the poor small scale farmers.This is partly because of:-(a) capital scarcity and/or a lack of an effective infrastructure for the production and distribution of these inputs; (b) the uncertainity of the returns after the use of inorgarnic fertilizers especially when rainfall is unreliable.

It is necessary therefore, to develop a low external soil management technology that can sustain crop production at a maximum level.One such possible low external technique is alley cropping. According to Kang *et al.*,(1981) and Wilson and Kang (1981), alley cropping is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees or shrubs.The hedgerows are cut back at crop planting and where necessary kept pruned during the crop cycle to minimize shading and to reduce competition between them and the food crops.

In the semi-arid areas, alley croping of maize with leguminous trees and shrubs has been proposed as an alternative to current practices as it is a low inorgarnic fertilizer input system.

In such a system, it is thought that maize yields could be maintained perhaps at relatively high levels without inorgarnic inputs (Kang *et al.*, 1981).The prunings of the trees act as mulch and also decompose, releasing nutrients into the soil (Yamoah *et al.*, 1986).The trees can also be dual or multipurpose since they may act not only as a source of soil nutrients, but can provide fuelwood,feed for livestock,favourable conditions for soil macro-and micro-organisms, and reduce soil erosion if planted along the contour (Torres, 1984).If leguminous trees are grown they may also contribute to the soil nitrogen through symbiotic nitrogen fixation (Brewbaker and Hutton, 1979).

A major constraint in the semi-arid areas of Kenya is the low and unreliable rainfall (Stewart and Hash, 1981).The soils are low in organic matter (Siderius and Muchena, 1977) and are highly weathered and leached (Okalebo, 1987).Alley cropping is one of the potential methods to replace bush fallow in the semi-arid regions (Kang *et al.*, 1985).

Organic additions acting as plant nutrient source and as a means of improving the soil physical properties deserve examination particularly in light of the very positive effects of mulching documented in western Nigeria (Lal, 1975) and the beneficial effects of green manure observed elsewhere (Hayllet 1961,Vine,1953).

Considering the unstable ecosystems, variability of rainfall, both in terms of the amount and distribution and the low yields that characterise Kenya's semi-arid areas, mulching may have an important role to play in maintaining soil fertility and sustaining yields. However, work on the influence of mulches on soil properties and crop performance in these areas is scanty.

The purpose of this study was therfore to investigate the effect of *Leuceana leucocephala Terminalia brownii* and *Cassia siamea* leaf mulches on soil nutrient status and on performance of Katumani composite maize crop in the semi-arid areas of Machakos District, Kenya.Based on this a study was done by examining the following:-

(1) the composition of leaf mulches with respect to the following minerals :- Nitrogen (N), Phosphorus (P), Calcium (Ca), Carbon (C), Magnesium (Mg), Potassium (K), and Sodium (Na). Mulch vulnerability to decomposition was assessed via their C:N ratios.

(2) the soil nutrient and pH status with respect to mulch application.

(3) the nitrogen content of the maize at various growth stages and total yields as influenced by different leaf mulches.

(4) the influence of the mulches on the various productivity related parameters of maize like grain size, leaf area index, plant height and plant base diameter and the correlation between these parameters and the grain yield.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 GENERAL

Many workers, especially in the humid and subhumid tropics have over the recent past investigated the use of leguminous hedgerows and alley croping. They are perceived as crop production technologies in which crop yields can be sustained at reasonable levels without the addition of large amounts of chemical fertilizers. One of the features of alley croping would seem to be its potential supply of nitrogen and organic matter for soil enrichment. Such a system should be self-sustaining in terms of soil fertility (Yamoah *et al.*, 1986; Torres, 1984).

The use of *Leuceana leucocephala*, *Glyricidia sepium* and *Sesbania rostata* for crop production in alley croping systems have been demonstrated (International Institute of Tropical Agriculture (IITA) annual reports 1978-1983; Kang *et al.*, 1981). Potential dry matter and nitrogen yield of some alley croping shrubs have also been reported.

Emphasis has been placed on the use of herbaceous leguminous tree species. Species such as

Acio baterii, *Anthona macrophyla*, *Glyricidia sepium*, *Sesbania gradiflora* and *Leuceana leucocephala* have been identified as effective in restoring soil fertility (Kang *et al.*, 1981).

Stigter (1984), broadly def nes a mulch as a shallow layer appearing at the soil/air interface with properties that differ from the original soil surface layer. Mulching affects many conditions near the soil/air interface where it is applied. These effects depend on the following :-

(a) method of application, e.g whether the mulch is incoporated into the soil, burried within the soil or left on the surface.

(b) Amounts of the mulch applied.

(c) Time of application.

(d) Nutrient composition and if at the surface, colour of the mulch.

(e) Decomposition rates of the mulch which in turn depend on the form, state of mulch and time of application as well as enviromental and the micro-meteorological conditions in soil.

Mulches may affect soil temperature, soil moisture, soil physical and chemical properties, soil microbial activities, aerial physical properties (radiation), mechanical impact of rain, hail and wind, weed growth, and pests and diseases (Stigter, 1984).

Review by Stigter (1984), indicate that traditionaly many different materials have been used as mulch: tree leaves, grass and straw, crop residues among others.In addition, use is made of chopped maize stalks, weeds, fire ash, animal dung and organic household waste. Acland (1971), also mentions the use of sisal waste, coffee pulp, saw dust as well as (not traditionally applied) polythene.

2.2 EFFECT OF MULCH ON MAIZE YIELD AND NUTRIENT CONTENT.

Mulching with crop residues and other vegetative matter has been reported as a successful practice (Nair, 1984). Lal (1973, 1975) at the International Institute of Tropical Agriculture (IITA) (Nigeria), showed experimentally a 46,55, and 22% positive yield response of maize to crop residue mulch (incoporated into the soil) in a three year period from 1970 to 1972. Similarly Yamoah *et al.*,(1986) reported 15% increase in maize yield for *Glyricidia* mulch, 22% for *Flemingia* and 50% for *Cassia* relative to the control.

An increase in maize yield when *Leceana* leaf mulch was incoporated into the soil at the Kenya coast has also been reported (Bashire *et al.*, 1986). Similarly, Kang *et al.*, (1982,1985),in Nigeria, reported a 40% increase in maize yields when *Leceana* leaf mulch was incoporated into the soil at the rate of 10 tons/ha s compared to control.They reported that the addi ion of *Leceana* leaf mulch was able to sustain maize grain yield at about 3.8 tons/ha per year. Wade and Sanchez (1973) working in the Amazon region of Peru also showed that mulching increased maize yield.

In Zaire a ten year study showed that cotton yields were maintained with mulch but they declined to about 1/10 of mulched levels without residue mulch (Jurion and Henry 1969). Yield increases due to mulching are reported from south America (Sanchez *et al.*, 1982). Experiments conducted at the International Institute of Tropical Agriculture and elsewhere have shown an increase in yield of cowpea, soybeans, cassava and yam due to mulching (Lal,1970; Okigbo and Lal,1979).

Higher maize growth rates and vigour resulting from mulching were also reported by Lal (1973).He observed that there were no chlorotic symptoms or nutritional disorders in mulched maize as compared to unmulched plants.

Leceana leaf mulch has been reported to affect nutrient status of maize.Kang *et al.*,(1981), reported that the removal of prunings in alley cropping lowered N, K, and Ca percentages in ear leaves of maize.They observed that when *Leuceana* prunings were incoporated into the soil at 10 tons/ha of fresh herbage the grain to *Leuceana* nitrogen ratio was 7:1 in the first year and 9:1 in the second. Data obtained by Guevarra (1976) give a ratio of 3:1 in the first year.

2.3 EFFECT OF MULCH ON SOIL

The presence of organic cover on the soil surface reduces raindrop impact on the soil and improves the chemical fertility of the soil (Lawes,1962; Chinwuba,1965; Abuzeid,1973; Lal,1973, 1975,1979; Wade and Sanchez,1975; Stigter 1984) in terms of acidity, base status, nutrient content, organic content and its effect on the soil physical properties.

Located at the air/soil interface a mulch layer will influence the soil/atmosphere coupling and consequently it offers the possibility of manipulating the micro-climate. The effect of mulch is not limited to micro-climate improvement since the mulches also decompose at the soil surface, releasing plant nutrients and thus adding to the nutrient status of the soil (Budelman,1987).

Kang *et al.*, (1985), have reported that the application of *Leuceana* prunings resulted in higher soil moisture, higher organic matter content and higher exchangeable K, Ca, Mg and nitrate levels in the soil.Similarly Kang *et al.*, (1981) reported that the addition of *Leuceana* leaf mulch increased the total nitrogen and organic carbon level of the soil as well as the extractable Mg and Ca.In a similar work in Kenya, Othieno (1978), using grass as mulch showed that the K and Ca content of soil were higher in mulched plots than in unmulched ones except for Mg which was lower.

A release of 252, 75 and 120 kg N per hactare per year by *Glyricidia*, *Flemingia*, and *Cassia* leaf mulches respectively, when incoporated into the soil have been reported (Yamoah *et al.*, 1986). However in this publication there was no mention of the rates used but it is assumed that the mulches were applied at the same rate.

Lal (1973) reported that mulching significantly decreased the maximum soil temperature at 5, 10 and 20cm depth and that temperature differences of as much as 8^{0}C between mulched and unmulched plots at a 5cm depth were recorded.

2.4 NUTRIENT COMPOSITION OF MULCHES

In relation to crop production, Yamoah *et al.*, (1986) reported that *Glyricidia* mulch can release all or most of its N into the soil within a period of 120 days.

The giant *Leuceana leucocephala* varieties have been reported to produce substantial biomass (Brewbaker and Hutton, 1979). The two researchers reported that a well established hedgerow of *Leuceana leucocephala* variety K-28 grown on a sandy Entisol at 4m inter-row spacing produced 15 and 20 tons of fresh prunings (5.0 to 6.5 tons of dry matter) per hactare with five prunings per year. Excluding stakes, these prunings were reported to yield over 160kg N, 15kg P, 150kg K, 40kg Ca and 15kg Mg per hactare per year.

The high nitrogen yield from *Leuceana* is well known (National Academy of sciences, 1977) and its reported to fix atmospheric nitrogen (Guevarra *et al.*, 1978 and Rachie,1983).

The potential nutrient contribution by alley shrubs is important particularly if the nutrients could be made available to the crops at the amount, time and place (depth) they are needed. This implies that for a given shrub, knowledge of the nutrient content of prunings, decomposition and nutrient release from the prunings and the method of incoporation are important.

Analyses of nutrient composition of *Leuceana* prunings show that they contain high levels of P, Ca, Mg, S, Zn, and K (Kang *et al.*,1981) and that large quantities of N can be harvested annually in *Leuceana* prunings.

High leaf N content of *Glyricidia* has been reported by several workers (National Academy of Sciences,1980; Wilson and Kang, 1982; Agboola *et al.*,1981). Yamoah *et al.*,(1986) have reported high P and K content in *Cassia* compared to *Glyricidia* and *Flemingia* with an N content of the prunings averaging 4.04% for *Glyricidia*, 3.17% for *Flemingia* and 2.57% for *Cassia*.

Singh and Mudgal (1967), analysed *Leuceana leucocephala* foliage for a period of one year and found the mean P and Ca to be 0.27 and 1.47% respectively. Other studies have found P to be 0.23% (National research council, 1977) and 0.22% (D'Mello and Taplin, 1978) and Ca to be 2.4 and 1.9% respectively.

Data on micronutrients for *Leuceana leucocephala* are more limited than for macronutients. D'Mello and Taplin (1978) found the following levels in *Leuceana leucocephala* leaves (μg/g); Cu,11;

Fe,907; Zn,19; and Mn,51. Reyes (1983) conducted a greenhouse study and obtained the following composition of *Leuceana leucocephala* leaves: P, 0.16%; K, 1.5%; Mg, 0.18%; Na, 0.001%; Ca, 0.76%; Fe, 59µg/g; Zn,22µg/g; Mn,95µg/g and Cu,2µg/g.

It would seem that all values given here would depend very much on the type of soils and soil conditions under which the trees have been grown.

CHAPTER THREE

3. MATERIALS AND METHOD:

3.1 EXPERIMENTAL SITE

The study was carried out at the National Dryland Farming Research Station field in Machakos. This is in the drier areas of Eastern Province of Kenya. The site is located about 10km south of Machakos town at an altitude of 1575m above sea level and 01^0 35'S latitude and 37^0 14'E longitude. Average annual rainfall ranges between 500-1300mm (Farm management Handbook of Kenya, 1984). The rainfall pattern is bimodal and fairly evenly distributed between the "long" and "short" rainy seasons .

According to FAO-UNESCO soil classification (1975), the soils are ferral Chromic Luvisols. They are deep, well drained and dark brownish in colour. Texturaly they are sandy clay at the top surface changing to clay loams in the subsoil (Siderius and Muchena,1977; Kibe *et al.*,1981).

According to the Kenya soil survey agroclimatic zonation (Sombroek *et al.*,1982), the climate of the area is subhumid to semi-arid.

3.2 MULCHING MATERIALS

Mulching materials included three different leaf mulches from :- *Cassia siamea*, *Terminalia brownii*, and *Leuceana leucocephala*. *Cassia siamea* mulch was collected from trees growing in the machakos municipality while *Leuceana leucocephala* mulch was obtained from the Machakos District Farmers Training Centre. *Terminalia brownii* mulch was obtained from demonstration plots owned by the Ministry of Agriculture at Matuu.

For all the mulching materials only the young easily decomposable twigs and leaves were used. The twigs and leaves were chopped to small pieces of about 10cm length and applied in layers at 15cm depth.

From the chopped pieces, four samples for each species were taken for analysis of thier nutrient composition.

3.3 MAIZE SEEDS

The seeds used in the study were Katumani composite, an early maturing variety. They were obtained from the Kenya Grain Growers Co-operative Union (K.G.G.C.U) stores in Machakos town.

3.4 EXPERIMENTAL LAYOUT

Two experiments were carried out during the 1987 "short" and 1988 "long" rains. The unplanted experimental plots had been previously laid down in 1985 in a randomized complete block design (RCBD) and replicated four times (Figure 1). Data was later subjected to analysis of variance based on this design.

The experimental plots were on a sloping field (about 3% eastwards) and to minimize the influence of slope small ridges had been made aroud each plot.

Previous management reports (Sang *et al.*, 1986) indicated that each plot in which a particular mulch type and rate was applied had been receiving the same mulch type and rate twice a year since 1985. The plots were also being planted with maize twice a year since 1985.

Figure 1. Layout of the experiment (not drawn to scale).

N

(1) CS_1	(8) LL_2	(15) LL_1	(22) TB_1
(2) LL_2	(9) CS_2	(16) TB_1	(23) CS_2
(3) Con.	(10) LL_1	(17) CS_1	(24) Con
(4) TB_2	(11) Con	(18) Con.	(25) LL_2
(5) TB_1	(12) TB_1	(19) LL_2	(26) TB_2
(6) CS_2	(13) CS_1	(20) CS_2	(27) LL_1
(7) LL_1	(14) TB_2	(21) TB_2	(28) CS_1

Key

( ) Number in brackets are plot numbers

Plot size = 3.6 x 7.2

Number of plants per row = 12

Number of rows per plot = 8

CS - *Cassia siamea* leaf mulch

LL - *Leucaena leucocephala* leaf mulch

TB - *Terminalia brownii* leaf mulch

Con - Control (no mulch application)

Subscript 1 = Mulches at $1kg/m^2$ rate

Subscript 2 = Mulches at $2kg/m^2$

3.5 MULCH APPLICATION AND MAIZE PLANTING.

The following practices had been established since 1985 and were continued during the period of this particular study.

During land preparation (at least two weeks before maize planting) furrows of 15cm in depth were dug. Five days prior to maize planting , the chopped leaf mulches were placed in the furrows at 15cm depth and covered with soil. The furrows measured 3.6m in length and 0.5m in width. Each plot had eight of such furrows at a spacing of 90cm from the centre of each furrow.

To ensure the correct mulch application rates and the uniformity of application, fresh mulches were applied on per row basis at the rates of 1.8kg/row (equivalent to $1kg/m^2$) and 3.6kg/row (equivalent to $2kg/m^2$).

Katumani maize was planted in the covered furrows five days after mulch application at a spacing of 90 x 30cm giving a plant population equivalent of a little over 3700 plants /ha.

Two seeds were planted per hill. After germination the plants were thinned to one plant per hill giving 12 plants per row. The plots were kept weed-free by hand weeding throughout the growing period of the maize. The above is somewhat comparable to a placement of fertilizer in "bands" with some of its advantages (De Wit,1953).

3.6 PLANT SAMPLING AND ANALYSIS.

3.6.1 Sampling of the leaf mulches

A pre-plant representative sample of each mulch type was taken and placed in a cool box. A few hours after sampling the materials were washed with de-ionised water, dried (to constant weight) in the oven at 70^0C and then ground (using a micro-mill) and put in plastic containers prior to nutrient composition analysis.

3.6.2 Maize sampling for N determination.

Maize was sampled for %N content determination at the following stages:

1) seedling stage
2) prior to tasselling
3) at cobbing
4) at mturity (grains)
5) post-harvest (stover)

At the seedling stage the whole portion of maize seedlings above the ground was sampled. Then prior to tasselling, the entire first leaf below the central point (where emerging leaves coil or roll together) was sampled. At cobbing, the ear leaf (the one attached to the cob was sampled. At post-harvest a representative sample of grains and stover was sampled from each plot.

3.6.3 Determination of crop performance

The importance of crop yield prediction from quantitative plant parameters cannot be over-emphasized as it ensures greater objectivity in the forecasting of crop yield. In many parts of the world, crop yield forecasts are generaly based on farmers' records and these according to Housemann and Huddleston (1966), are to some degree subject to vicissitude in human judgement. The problem is even more pronounced in developing countries where both official and farmers' yield records, if any are kept, are very unreliable. It is in view of the above that some growth parameters were taken and tested for correlation with the grain yield of the crop with the aim of identifying the significant growth parameters of the crop correlated to its yield. The identified parameters could then perhaps be used to develop a maize yield prediction model.

From the candidate plants of each plot

(figure 2), the following data were taken on per plant basis as an index of crop performances:-

(i) Plant height (cm): This was taken monthly from emergence and was the height from ground level to the tip of the plant.

(ii) Leaf area index (LAI), Monthly data on the number of leaves, leaf length, and leaf breadth of the third leaf and area occupied by each plant were taken for each candidate plant and the LAI calculated according to Sang *et al.*, (1985).

(iii) Plant base diameter. For each candidate plant the diameter of the stem was taken at the base (ground level) in two directions and the average of the two measurements calculated. Other parameters taken as an index of crop performance were from the harvest area (Figure 2) and were:

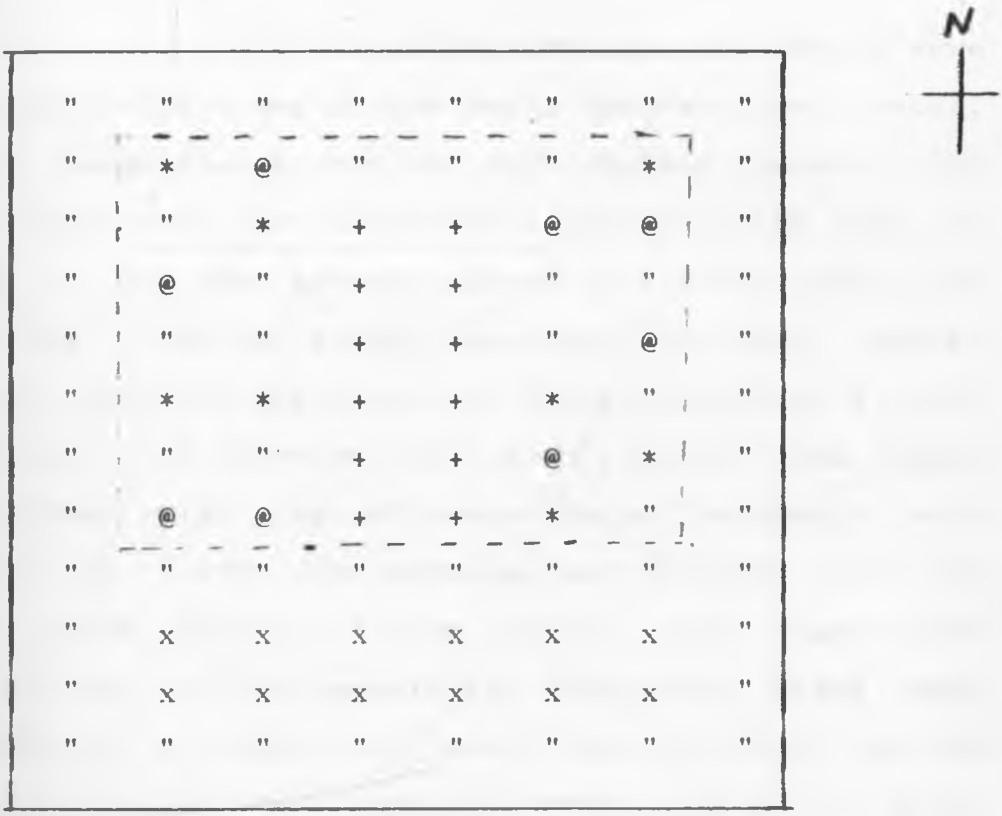
(iv) Grain yield in kg/ha.

(v) Cob weight.

(vi) 1000 grain weight.

(vii) Stover weight.

Figure 2: <u>Sampling pattern per plot (not to scale)</u>



KEY

" A maize plant

\+ Candidate plants

x plants sampled at seedling stage

* plants for which leaves were sampled prior to tasselling

@ plants for which leaves were sampled at cobbing

Harvest area.

3.6.4 Analysis of Maize and Mulching Materials for total N (Kieldahi Method (Jackson 1958)

Shortly after sampling, the leaves were cleaned with a wet sponge using demineralized water. The large leaves were cut into smaller pieces. The material was then dried for 24 hours in the oven at 70^0 C and then ground, placed in plastic bags and sealed. From the ground materials 0.25g sub samples were taken for digestion. To hasten digestion a full spatula of selenium and copper catalyst was added together with 10ml of concentrated sulphuric acid (Sp. Gr. 1.84). The material was digested for one and half hours and then cooled. The digest was distilled over as ammonia gas (NH_3) after being made alkaline by addition of about 20ml saturated sodium hydroxide (40% NaOH) and collected in 2% boric acid. The NH_3 in the boric acid was titrated against a standard acid (0.01N H_2SO_4 and colour change was from green to the pink as the end point. The percentage total nitrogen was calculated according to the formula:-

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

Where:-

T = Titre given by the sample

B = Titre of the blank (no plant material added)

N = Normality of the acid used in the titration

S = Weight of the sample in mg

This determination was replicated four times.

3.6.5 Determination of Ca, Mg, K and P in Mulching Materials (Dry Ashing Method)

Samples of 0.5g of finely ground oven dried mulching material were weighed into a 30ml porcelain crucibles. The samples were then ignited in a muffle furnace for 6-8 hours at 450^0 C to 500^0 C. The samples were cooled and 5ml of 1N HNO_3 solution added and evaporated to dryness on a steam bath at low heat. The samples were returned to the furnace and heated at 400^0 C to 500^0 C for 10-15 minutes until a white ash was obtained, then cooled and 10ml of 1N HCl added. The solution was filtered into 50ml volumetric flask. Phosphorus was determined colorimetrically after colour development with ammonium vanadate - ammonium molybdate solution.

Potassium and Sodium were determined by flame photometry and Ca and Mg by atomic absorption spectrophotometry.

3.7 SOIL SAMPLING

Soil samples were taken twice; prior to planting and after harvesting.

The samples were taken from each trial plot at 0-15, 15-30 and 30-60cm depths. A pit was dug on the ridge previously planted with maize and samples from each depth taken along the direction of the ridge. Sub-samples from each depth were taken and mixed to form a composite sample from which a representative sample for each depth and treatment was taken for analysis.

3.8 SOIL ANALYSIS

Four replicates per sample of each depth and treatment was performed.

3.8.1 Analysis for Total N in Soil (Kieldahl Method). Jackson (1958).

One gram of finely ground dried soil was weighed into a flask and to it 3.5ml of phenol sulphuric acid added.

After fifteen minutes, 0.5g of sodium

thiosulphate was added and after another 15minutes a full spatula of selenium mixture, 0.5g of K_2SO_4 and 3.5ml concentrated H_2SO_4 were added. The mixture was digested for one and a half hours then cooled after which distilled water was adde to prevent solidification. The digest was distilled after being made alkaline by an addition of about 20ml of 40% NaOH.

The ammonia released was collected in 2% boric acid. The collected NH_3 was titrated with 0.01N H_2SO_4 using a mixed indicator.

Total %N in the soil was calculated using the formula:

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

Where:- T = Titre given by the sample

B = Titre of the blank (No soil added)

N = Normality of acid used in titration

S = Weight of sample in mg.

3.8.2 Determination of soil pH (PH 1;2.5KCl and 1:2.5 H_2O)

Ten grams of fine ground (2mm size) air dried soil was weighed into plastic bottles. To the soil sample 25ml of distilled water (for pH 1:2.5 H_2O) and 25ml of 1N KCl (for pH 1:2.5KCl) were added. The bottles were tightly closed and then vigorously shaken using an "end to end" shaker for 30 minutes. The mixture was allowed to stand for 1 hour before pH measurements were taken using a glass electrode pH meter (E350 model).

3.8.3 Determination of organic carbon (Walkley/Black method (Jackson (1958)

One gramme of ground, air dried soil was weighed and put in a conical flask. To it 10ml of 1N $K_2Cr_2O_7$ was added then swirled gently. Twenty ml of concentrated H_2SO_4 was then rapidly added and again swirled until the soil and the reagents were well mixed.The mixture was allowed to cool for 30 minutes after which 100ml of distilled water was added. After cooling 5ml of orthophosphoric acid and 3-5 drops of indicator (diphenylamine) were added. This was titrated with 0.5N $FeSO_4$ solution. A blank (one with no soil sample) was titrated in similar manner to characterise the purity of the reagents used.

The corrected % organic carbon in the soil was calculated using the formula:-

$$\%O.C = \frac{(m.e\ of\ K_2Cr_2O_7 - m.e\ of\ FeSO_4)}{Weight\ of\ air\ dry\ soil\ used\ (g)} \times 0.399$$

3.8.4 Determination of exchangeable bases (percolation method (Jackson, (1958).

A small plug of cotton wool was placed at the bottom of a leaching tube followed by a layer of about 1cm of acid washed quartz sand. A mixture of 5g air dry soil and 10ml of acid washed sand was then put into the leaching tube and another plug of cotton wool on top of the sample. The leaching tube was placed on a rack and 25ml of 1N ammonium acetate (pH7) added. The leaching rate was adjusted using a clip to give 1 drop at every 3 seconds. This leaching was repeated 4 times. After leaching the leachate were made up to 100ml with 1N ammonium acetate (pH7). This solution was used for the determination of the exchangeable bases (Ca, Mg, K, Na) as described below.

(i) <u>Determination of Calcium</u>

A ten ml aliquot of the ammonium acetate leachate was pipetted into a conical flask and 10ml of 10% KOH was added. This was followed by 1ml of triethanolamine and 3 drops of 10% KCN to suppress any other interfering cations.The aliquot of ammonium acetate was titrated with 0.01N EDTA using calcon indicator with colour change from red to blue as the end point. The exchangeable Ca was calculated as follows:-

1ml of 0.01N EDTA is equivalent to 0.01 m.e of Ca ions.

Yml of 0.01N EDTA is equivalent to 0.01Y m.e of Ca ions.

Therefore 0.01Y m.e of Ca ions were in 10ml of the ammonium acetate leachate.

0.1Y m.e of Ca ions were in 100ml of the ammonium acetate leachate.

0.1Y M.e of Ca ions originated from 5g soil.

2Y M.e of Ca ions would originate from 100g soil

Therefore exchangeable Ca content of the soil = 2Y m.e/100g soil.

Where Y = amount of 0.01N EDTA used in the titration.

(ii) <u>Determination of Magnessium</u>

Ten ml of the ammonium acetate leachate

were pipetted into a conical flask. Five ml of NH_4Cl- NH_2OH buffer solution were added followed by 1 ml of triethanolamine and 3 drops of 10% KCN solution. The mixture was titrated with 0.01N EDTA and the colour changed from red to blue as the "end point" using eriochrome black indicator. Here both exchangeable Ca + Mg were determined using the procedure for Ca (see above). Exchangeable Mg was therefore obtained by the difference method, i.e (Ca + Mg) - Ca.

(iii) <u>Determination of Potasium and Sodium</u>

These two elements were determined using a flame photometer by comparing the scale reading of the samples with those of standards of known concentrations. Photometer reading of the ammonium acetate leachate was taken and using a standard curve drawn from the photometer reading of the standard of known concentration, the m.e of exchangeable K and Na were read for each element. Exchangeable K and Na was calculated as follows:-

Y m.e of K or Na are present in 5g soil.

20Y m.e of K or Na are present in 100g soil

Exchangeable K or Na = 20y m.e/100g soil

Where y = K or Na concentration read from the standard curve.

3.8.5 Determination of phosphorus in the soil (Olsen Method (Jackson. (1958).

Two and a half gm of ground air dried soil were weighed and to this 50ml of 0.5N $NaHCO_3$ and a full spatula of activated charcoal were added. The mixture was vigorously shaken for 30 minutes using an " end-to-end" shaker. The filtered 5ml aliquot of the filtrate was pipetted into a 50ml volumetric flask and to this 8ml of reagent B (see below) was added to develop colour.

NB: To make reagent B, 12g of ammonium molybdate (in 250ml distilled water) was added to 0.2908 potassium antimony tatarate (in 100ml of distilled water). All this was made to 2 litres using distilled water. Reagent B was 1.056g Ascorbic acid to every 200ml of above solution.

After colour development for about one hour using reagent B the absorbance of the samples were read using Pye Unicam SP 500 series 2 ultraviolet and visible spectrophotometer. This was compared to the absorbance given by the standards of known P concentration using a standard curve. The concentration of P (in ppm) in the aliquots was read from the standard curve and the soil P content calculated as:-

$$\text{PPM of P} = \frac{\text{Vol. of extractant} \times \text{Vol. of coloured solution}}{\text{weight of soil used (gm)} \times \text{volume of aliquot taken.}} \times \text{PPM of P from}$$

CHAPTER FIVE

RESULTS AND PRELIMINARY DISCUSSION

4.1. NUTRIENT COMPOSITION OF THE LEAF MULCHES

Four representative samples of the three fresh leaf mulches were taken and analysed for their nutrient composition as described in 3.6.4 - 3.6.5. Table 1 shows the mean composition of the leaf mulches.

Table 1: Nutrient content of the leaf mulches determined for the 1987 short rains and 1988 long rains sampling periods.

(a) The 1987 sampling period.

	Mulch type					
Nutrient	*L. leucocephala*	*C. siamea*	*T. brownii*	LSD	CV%	S.E.
%N	3.2±0.28	2.63±0.04	1.43±0.06	0.35	7.0	0.9
%C	47.35±0.6	44.87±0.03	56.83±0.03	0.8	0.7	6.3
C\N	14.89±1.5	17.1±0.3	39.8±1.6	3.4	5.3	13.7
%P	0.22±0.01	0.22±0.02	0.17±0.01	0.03	6.5	0.0
%K	0.039±0.001	0.04±0.001	0.025±0.001	0.07	9.1	0.0
Na	2.99±0.02	1.94±0.001	1.61±0.01	0.03	0.7	0.7
Ca	169.85±4.9	154.05±1.9	107.9±0.0	6.4	2.1	32.1
Mg	60.00±0.6	42.2±0.4	27.1±0.3	0.92	1.0	16.4

	Mulch	type				
Nutrient	*L.leucocephala*	*C.siamea*	*T.brownii*	LSD	CV%	S.E.N-
%N	3.00±0.01	2.48±0.04	1.53±0.01	0.28	5.8	0.75
%C	48.41±0.72	44.89±0.05	56.93±0.04	0.90	0.8	6.19
C\N	16.15±0.49	18.15±0.21	37.15±0.35	0.78	1.6	11.59
%P	0.25±0.01	0.19±0.01	0.18±0.01	0.01	3.5	0.04
%K	0.04±0.00	0.04±0.0001	0.035±0.007	0.01	10.6	0.03
Na	3.04±0.01	1.95±0.01	1.65±0.00	0.01	0.3	0.73
Ca	175.15±0.64	155.95±0.21	109.80±0.00	0.8	0.3	33.59
Mg	61.00±0.71	48.80±0.28	27.90±0.28	0.99	1.0	16.58

The stardard deviations are calculated from 4 replications. Na, Ca, and Mg are in m.e/100g of material.

From Table 1 *L. leucocephala* had the highest %N while *T.brownii* had the lowest. *T.brownii* had the highest C content and the widest C:N ratio. The wider C:N ratio of *T.brownii* suggests a slower decomposition relative to the other mulches (Russel,1973). *L.leucocephala* had the highest percentage of nutrients relative to other leaf mulches and only for K did it share this position with *C.siamea* especially in the first trial. The narrow C:N ratio of both *L.leucocephala* and *C.siamea* suggests a more rapid decomposition and mineralization of N when the leaf mulches are burried in the soil.

Analysis of variance for the mulch nutrient composition data (Appendix 5) indicated that there was no significant difference in %K content of the mulches in both seasons.

In both seasons *L.leucocephala* had significantly more %N, C, Na, Ca and Mg compared to *C. siamea* which had significantly more of these nutrients compared to *T. brownii*. There was no significant difference between the *L.leucocephala* and *C.siamea* mulches in terms of C:N ratio and %P in the first season.

In the second season, *C.siamea* C:N ratio was significantly higher compared to that of *L.leucocephala* while %P showed the reverse (Table 1). However absolute differences remained small. In both seasons *T. brownii* had significantly higher C:N ratio compared to other leaf mulches which suggest a slower decomposition of this leaf mulch and hence a lower turnover of nutrients in the soil.

4.2 INFLUENCE OF MULCHES ON THE SOIL.

Soil samples were taken at 0-15cm, 15-30cm and 30-60cm depths and analysed as described in 3.7 - 3.8.5 for their soil chemical status.

In total there were three samplings :- before the 987 first trial, at the end of the first trial and at the end of second trial. Tables 2-4 and appendices 2-4 summarize the results of soil analysis.

The tables show a progressive increase in soil nutrients with time in all the mulched plots and decrease in the unmulched ones. The increase in nutrients in the mulched plots can be attributed to decomposition of the leaf mulches and a net release of nutrients to the soil while the decrease in nutrients in the unmulched plots appeared to be due to nutrient uptake (removal) by the maize crop from soil without any immediate replacement.

Results indicate that in the plots where *T.brownii* was applied, there were generally lower nutrient levels than where other mulches were applied. The low %N content of *T.brownii* and its wide C:N ratio (Table 1) could have contributed to slower mulch decomposition and hence slower release of nutrients to the soil for plant uptake when compared to the other two mulches.

Table 2: Soil Nutrient status determined before planting 1987 first trial maize

TRT	DEPTH (cm)	%N	P (ppm)	K (m.e/100g of soil)	%O.C	C:N
LL_1	0-15	0.44±0.01	19.0±0.7	0.60±0.2	1.25±0.04	2.84
"	15-30	0.39±0.03	7.0±0.9	0.82±0.3	1.05±0.04	2.69
"	30-60	0.33±0.01	5.0±1.0	0.90±0.4	0.74±0.02	2.24
LL_2	0-15	0.54±0.01	35.1±3.7	0.85±0.3	1.52±0.04	2.81
"	15-30	0.56±0.01	20.0±1.5	1.05±0.6	1.35±0.04	2.71
"	30-60	0.46±0.02	13.6±0.6	1.28±0.4	0.98±0.03	2.13
CS_1	0-15	0.43±0.02	15.3±0.3	0.53±0.4	1.30±0.07	3.02
"	15-30	0.37±0.01	5.0±1.0	0.07±0.3	1.10±0.09	2.97
"	30-60	0.32±0.01	3.0±0.8	8.77±0.4	0.60±0.03	1.88
CS_2	0-15	0.53±0.01	34.3±3.2	0.60±0.4	1.45±0.04	2.74
"	15-30	0.48±0.02	10.0±1.1	1.01±0.3	1.30±0.04	2.71
"	30-60	0.42±0.03	9.7±0.7	1.05±0.6	0.64±0.04	1.52
TB_1	0-15	0.33±0.03	14.0±1.4	0.50±0.3	1.10±0.08	3.33
"	15-30	0.28±0.02	4.0±0.5	0.65±0.4	0.75±0.02	2.67
"	30-60	0.23±0.03	2.0±0.3	0.75±0.4	0.32±0.02	1.39
TB_2	0-15	0.39±0.01	28.0±1.2	0.87±0.5	1.20±0.02	3.08
"	15-30	0.34±0.02	8.0±0.5	0.89±0.5	0.83±0.03	2.44
"	30-60	0.27±0.02	7.0±0.9	0.95±0.7	0.52±0.02	1.92
CON.	0.15	0.28±0.01	12.5±1.9	0.60±0.4	0.95±0.03	3.39
"	15-30	0.26±0.01	3.0±0.4	0.85±0.4	0.75±0.02	2.88
"	30-60	0.21±0.02	2.0±0.3	1.03±0.5	0.28±0.01	1.33

TRT means treatment

The Organic Carbon figures are corrected Walkley Black values

Table 3: Soil Nutrient status determined after harvesting 1987 first trial maize

TRT	DEPTH (cm)	%N	P (ppm)	K (m.e/100g of soil)	%O.C	C/N?
LL_1	0-15	0.65±0.03	24.00±4.4	0.75±0.07	1.28±0.03	1.97
"	15-30	0.58±0.02	15.75±1.7	0.82±0.04	1.10±0.40	1.90
"	30-60	0.49±0.04	11.38±4.1	1.40±0.07	0.90±0.30	1.84
LL_2	0-15	0.77±0.03	37.00±3.2	1.02±0.05	1.53±0.05	1.98
"	15-30	0.71±0.04	25.50±5.8	1.20±0.07	1.38±0.09	1.94
"	30-60	0.65±0.05	19.00±2.4	1.58±0.07	1.20±0.20	1.84
CS_1	0-15	0.66±0.04	20.00±1.7	0.80±0.09	1.30±0.04	1.96
"	15-30	0.63±0.05	10.30±1.0	1.00±0.20	1.20±0.09	1.90
"	30-60	0.47±0.03	7.25±2.4	1.23±0.05	0.85±0.10	1.80
CS_2	0-15	0.76±0.05	35.00±4.8	1.00±0.10	1.48±0.08	1.95
"	15-30	0.70±0.04	23.40±2.6	1.30±0.05	1.35±0.06	1.93
"	30-60	0.66±0.06	15.50±1.6	1.43±0.06	1.22±0.06	1.85
TB_1	0-15	0.51±0.04	14.70±0.9	0.85±0.04	1.15±0.10	2.25
"	15-30	0.44±0.04	10.88±0.9	0.95±0.05	0.88±0.09	2.00
"	30-60	0.33±0.04	7.25±1.9	1.02±0.07	0.65±0.07	1.97
TB_2	0-15	0.62±0.03	30.20±3.7	0.95±0.05	1.25±0.21	2.02
"	15-30	0.57±0.05	20.00±2.9	1.25±0.06	1.12±0.04	1.96
"	30-60	0.34±0.04	12.00±2.6	1.28±0.03	0.65±0.08	1.91
CON.	0-15	0.24±0.05	10.00±2.9	0.28±0.07	0.78±0.06	3.25
"	15-30	0.20±0.04	2.00±0.3	0.74±0.06	0.60±0.07	3.00
"	30-60	0.13±0.04	1.70±0.5	0.97±0.09	0.23±0.04	1.76

TRT means treatment

Organic Carbon figures are corrected Walkley Black values

Table 4: Soil Nutrient status determined after harvesting 1988 second trial.

TRT	DEPTH (cm)	%N	P (ppm)	K (m.e/100g of soil)	%O.C	C/N
LL_1	0-15	0.95±0.05	32.50±3.5	1.08±0.05	1.46±0.04	1.52
"	15-30	0.92±0.05	28.00±2.6	1.13±0.03	1.34±0.05	1.46
"	30-60	0.75±0.09	24.00±3.1	1.22±0.04	1.04±0.09	1.39
LL_2	0-15	1.25±0.57	42.75±2.2	1.37±0.03	1.67±0.06	1.34
"	15-30	1.22±0.05	31.50±2.0	1.53±0.04	1.60±0.05	1.31
"	30-60	0.79±0.11	23.75±2.7	1.85±0.05	1.25±0.06	1.29
CS_1	0-15	0.94±0.05	31.50±3.2	1.13±0.03	1.52±0.05	1.62
"	15-30	0.89±0.05	26.50±2.0	1.15±0.02	1.37±0.05	1.54
"	30-60	0.84±0.04	23.50±3.2	1.30±0.05	1.14±0.12	1.36
CS_2	0-15	1.03±0.07	38.50±3.8	1.28±0.02	1.56±0.04	1.51
"	15-30	0.98±0.06	34.25±3.5	1.38±0.02	1.45±0.06	1.48
"	30-60	0.91±0.04	25.75±2.9	1.45±0.05	1.24±0.06	1.36
TB_1	0-15	0.66±0.04	29.00±2.0	1.05±0.04	1.20±0.05	1.82
"	15-30	0.60±0.05	15.00±2.9	1.07±0.03	1.00±0.05	1.67
"	30-60	0.53±0.05	14.00±2.9	1.15±0.04	0.85±0.07	1.60
TB_2	0-15	0.84±0.05	32.75±2.9	1.23±0.03	1.40±0.05	1.67
"	15-30	0.73±0.05	21.76±3.0	1.26±0.04	1.15±0.06	1.59
"	30-60	0.71±0.06	19.25±2.8	1.40±0.04	1.00±0.09	1.55
CON.	0-15	0.20±0.05	8.80±1.2	1.16±0.03	0.69±0.06	3.45
"	15-30	0.16±0.05	1.60±0.3	0.65±0.04	0.48±0.07	3.00
"	30-60	0.80±0.05	1.00±0.3	0.84±0.05	0.18±0.04	2.25

TRT means treatment

Organic Carbon figures are Walkley Black values

From the results %N and O.C were highest in plots under *L.leucocephala* and *C.siamea* applied at the rate of $2kg/m^2$ and lowest in the unmulched plots. The plots with mu!ches applied at $2kg/m^2$ showed higher O.C, %P and exchangeable bases than those with muches at $1kg/m^2$. The diifference between these nutrients within plots under same mulch type at different application rates must be due to unequal amounts of mulching materials added, while the difference between plots under different mulch types must be as a result of varying degree of decomposition and the chemical set up of the mulches.

The results show an expected pattern of distribution of organic matter and total N with depth. In all treatments the concentration of the two was decreasing with depth. This was largely due to the addition of organic matter at the top soil surface as mulch and crop residue. Farther down the profile could have been from root residues. The C:N ratio was higher in upper soil strata compared to the lower ones for all treatments involving the *T.brownii* which exhibited highest values.

The slow decomposition fo *T.brownii* (suggested by the wide C:N ratio) could probably have led to low rate of N mineralization resulting in lower N soil content and therefore a wide C:N ratio in plots under this mulch type. The narrower C:N ratios of *L.leucocephala* and *C.siamea* indicate higher rapid mineralization. This could explain the more N and the narrower C:N ratios in the soils under these mulches.

There was a fall in P concentration in the soils from soil surface to sub-surface at all sampling times. This fall was greater in unmulched plots and in plots mulched with *T.brownii* applied at $1kg/m^2$. This larger gradient might have been due to P additions from the mulching materials, hence enriching the top surface soil rather than the sub-surface ones as well as P removal by the growing roots. Phosphorus unlike Nitrogen has very little mobility particularly in dry soils.

Soil pH (Appendices 2-4) values were in most cases higher in the mulched than in the unmulched plots with values ranging from 5.9 for *T.brownii* applied at $1kg/m^2$ (start of first trial 0-15cm depth) to 7.4 for *L. leucocephala* applied at $2kg/m^2$ (end of second trial 30-60cm depth), while those of the control plots varied in pH between 5.7 (end of second trial 0-15cm depth) and 6.4 (start of first trial 30- 60cm depth).

Generally the soil pH appeared to increase with depth in all the treatments. Although the soil pH in mulched plots tended to increase with time, that of unmulched plots tended to decrease. This probably was as a result of enrichment by the bases from the decomposing mulching materials thus releasing high Ca into the soil as evidenced in their nutrients composition (Table 1).

Exchangeable bases (Ca, Mg, K and Na) were higher in the mulched compared to the unmulched plots (Appendices 2-4). They were also higher in plots which received $2kg/m^2$ of mulch compared to those with $1kg/m^2$ and highest in plots under *L.leucocephala* mulch. The control, however, had the lowest amounts of the bases. The exchangeable bases were less in the top than in the lower soil strata.

Calcium was found to be the dominant basic cation in all the soil samples, which could be attributed to the inherent composition of the soil and the additions from the decomposing mulch materials (Table 1) where Ca was higher in concentration than other bases.

4.3 THE EFFECT OF MULCHES ON SELECTED MAIZE GROWTH PARAMETERS

4.3.1 PLANT HEIGHT

Mean plant was taken from the candidate plants in each plot 30, 60, and 90 days after emergence as described in section 3.6.3. Table 5 summarizes the results for the two seasons.

Data are for two contrasting seasons that is, an extremely dry first trial and a wet second trial.

Table 5: Mean plant height in cm

First trial

	Days after emergence					
	30		60		90	
TRT.	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	66.4	21.8	81.1	3.8	88.1	2.3
LL_2	74.2	36.1	93.9	20.2	102.1	18.6
CS_1	67.9	24.6	88.7	13.6	91.0	5.7
CS_2	73.2	34.3	90.6	16.0	96.4	12.0
TB_1	64.0	17.4	80.7	3.3	85.8	0.3
TB_2	67.1	23.1	87.2	11.7	96.0	11.5
CON.	54.5	-	78.1	-	86.1	-
$LSD_{0.005}$	9.1		11.6		14.5	
CV%	9.2		9.1		10.6	
S.E.M	±6.54		±5.87		±7.6	

Second trial

	Days after emergence					
	30		60		90	
TRT	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	117.5	20.1	219.3	8.7	221.8	6.5
LL_2	118.6	21.3	219.8	9.0	221.7	6.5
CS_1	110.1	12.6	218.2	8.2	220.1	5.9
CS_2	111.9	14.4	218.4	8.3	221.4	6.3
TB_1	102.5	4.8	202.7	0.5	208.2	0.8
TB_2	112.4	14.9	216.8	7.5	217.7	0.8
CON.	97.8	-	201.7	-	206.6	-
CV%	14.5		6.4		6.9	
S.E.M	±7.6		±7.95			

TRT is treatment and DFC is the % difference from the control.

Plant height appeared to have been much more a function of time of growth rather than type of mulch.

During the second trial, mean plant heights under all treatments were not significantly different although they were higher than in the first trial due to the higher rainfall during this season leading to more nutrient release,transport and uptake rates (Appendix 1).

Analysis of variance (Appendix

6),indicated that among the treatments there were no significant differences in plant height during the second trial ($p=0.005$). Significant differences in height were noted only in the first trial (30 days after emergence). This could have been probably due to disuniformity as affected by season of planting.

4.3.2 LEAF AREA INDEX (LAI)

At the same time plant heights were measured the LAI measurements were determined. These were indirectly derived according to the formula given by Sang *et al* (1985) that:-

$$\text{LAI} = \frac{\text{LA (cm}^2\text{) X Number of leaves}}{\text{Area occupied by one plant (90x30cm)}}$$

Where LA =Leaf area = Leaf length x Leaf breadth (of the third leaf) x 0.75.

The leaf area index measurements are summarized in Table 6.

The LAI was highest at the second sampling. It also appears from the data that plants with mulches at 2kg/m^2 had higher LAI than those with mulches at 1kg/m^2. This can be attributed to the much higher soil nutrients in plots with mulches at 2kg/m^2

(Tables 2, 3 4). Second trial values were all higher than respective ones in the first trial. This could be due the lower transport and uptake of nutrients in the drier soil and the fact that the first trial crop was affected by water stress which led some leaves to wilt and probably reduce leaf expansion.

This reduction in the number of leaves and leaf size, lowered the LAI. At the same application rates, *T.brownii* leaf mulch gave lower LAI measurements than the others. This may have been due to its slower decomposition and hence slower release of nutrients compared to the others. The slower decomposition is indicated by its high C:N ratio (Table 1).

Table 6: Mean plant LAI for the two trials.

FIRST TRIAL

	Days after emergence					
	30		60		90	
TRT	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	0.74	32.1	1.00	69.5	0.52	11.5
LL_2	1.01	80.4	1.28	116.9	0.93	102.2
CS_1	0.86	53.6	1.13	91.5	0.67	45.7
CS_2	0.72	64.3	1.23	108.5	0.70	52.2
TB_1	0.68	21.4	0.76	28.8	0.50	8.7
TB_2	0.81	44.6	1.05	78.0	0.67	45.7
CON.	0.59	-	0.46	-	0.77	-
$LSD_{0.05}$	0.28	-	0.38	-	0.27	-
CV%	24.4	-	25.3	-	28.8	-
S.E.M	±0.15	-	±0.25	-	±0.16	-

SECOND TRIAL

	Days after emergence					
	30		60		90	
TRT	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	1.01	31.2	1.96	25.6	1.23	41.4
LL_2	1.04	35.1	2.02	29.5	1.34	54.0
CS_1	0.89	15.6	1.86	19.2	1.24	42.5
CS_2	1.02	32.5	2.06	28.2	1.25	43.7
TB_1	0.86	11.7	1.61	3.2	1.00	14.9
TB_2	0.99	28.6	1.81	16.0	1.05	20.7
CON.	0.56	-	1.56	-	0.87	-
CV%	18.2	-	20.5	-	17.0	-
S.E.M	±0.19	-	±0.19	-	±0.17	-

TRT means treatment and DFC means %difference from control.

Analysis of variance (Appendix 7), indicated that there were significant differences among treatments in LAI in second measurement of the first trial only and none later or earlier than this.In the second trial the differences were not significant.

During the second measurement of the first trial,all the mulched plots except those under *T.brownii* applied at $1kg/m^2$ had higher LAI than the unmulched control plots.

4.3.3 PLANT BASE DIAMETER

Plant base diameter of the candidate plants were measured 30, 60, and 90 d ys after emergence.

Results on these measurements are summarized in Table 7.

Table 7 Mean plant base diameter in cm.

FIRST TRIAL

	Days from emergence					
	30		60		90	
TRT	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	1.69	11.2	1.74	13.0	2.43	4.3
LL_2	2.04	34.9	2.05	33.1	2.71	16.3
CS_1	1.79	17.8	1.88	22.1	2.51	7.7
CS_2	1.91	25.7	2.01	0.5	2.54	9.0
TB_1	1.63	7.2	1.67	8.4	2.43	4.3
TB_2	1.81	19.1	1.90	23.4	2.52	8.2
CON.	1.52	-	1.54	-	2.33	-
$LSD_{0.05}$	0.28	-	0.23	-	0.16	-
CV%	10.5	-	8.6	-	4.2	-
S.E.M	±0.17	-	±0.19	-	±0.12	

SECOND TRIAL

	Days from emergence					
	30		60		90	
TRT	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	2.08	11.8	2.50	11.6	2.58	9.3
LL_2	2.11	13.4	2.71	21.0	2.64	11.9
CS_1	2.04	9.6	2.54	13.4	2.57	8.9
CS_2	2.08	11.8	2.60	16.1	2.62	11.0
TB_1	1.88	1.1	2.32	3.6	2.40	1.7
TB_2	2.07	11.3	2.59	15.6	2.61	10.6
CON.	1.86	-	2.24	-	2.36	-
CV%	5.5	-	1.6	-	6.9	-
S.E.M	±0.40	-	±0.12	-	±o.11	-

TRT means treatment and DFC means % difference from the control.

The results in table 7 show that the plant base diameter was higher in the mulched plots than in the unmulched ones in both trials, and also that plots mulched at $2kg/m^2$ had plants with larger diameter than plots with mulches at $1kg/m^2$.

4.3.4 PERCENTAGE NITROGEN CONTENT

Percentage N content of the maize was determined at seedling stage, prior to tasselling, at cobbing, in the grains at harvesting and in the stover. Results on %N content of maize at these stages are shown in Table 8.

The results indicate that the %N content of maize was highest in the seedlings and lowest in the stover. At the vegetative stage (prior to tasselling) the %N was higher than at the reproductive stage (cobbing stage) which was higher than that of the grains.

Generally all treatments had higher %N content than the control. During both trials the %N content of maize at the various stages was higher in plots where the mulches were applied at $2kg/m^2$ compared to where the application rate was $1kg/m^2$. *C.siamea* applied at $2kg/m^2$ had the highest impact on %N content of maize while *T.brownii* applied at $1kg/m^2$ had the lowest impact.

Analysis of variance (Appendix 8), indicated that significant differences in %N content of maize were only at cobbing stage. There were no significant differences in %N content among the treatments at any other stage in either trial.

The probable reason for non significant difference at the seedling stage is that no mulches were at the top soil and therefore their effects on soil nitrogen hence plant N content could not be realized. Also the mulches probably had not decomposed at this time. Although the differences in

%N among treatments were not significant there were some differences in that maize under *C.siamea* applied at 2kg/m^2 had about 17% more than maize in the control and those under *L.leucocephala* applied at 2kg/m^2 having approximately 14% more than those in control in the first trial an 31% and 27% respectively in the second trial.

At the cobbing stage results indicated significant differences in %N content of maize among the treatments. Comparison of means using LSD (P=0.05) indicated a significantly higher %N in maize leaves in plots with mulches at 2kg/m^2 compared to the control in both trials (Table 8).

Table 8. Mean %N content of the maize at various growth stages

FIRST TRIAL

TRT	Seedling stage Mean	DFC	Prior to tasselling Mean	DFC	Cobbing stage Mean	DFC	Grains Mean	DFC	Stover (post harvest) Mean	DFC
LL_1	3.44	8.9	2.48	9.7	2.13	7.6	1.77	10.6	0.85	3.7
LL_2	3.60	13.9	2.63	16.7	2.30	16.2	1.8	12.5	1.06	29.3
CS_1	3.52	11.4	2.51	11.1	2.25	13.6	1.77	10.6	0.87	6.1
CS_2	3.70	17.1	2.63	16.7	2.23	17.2	1.86	16.3	1.11	35.4
TB_1	3.43	8.5	2.36	4.4	2.01	1.5	1.70	6.3	0.82	-
TB_2	3.55	12.3	2.57	13.7	2.25	13.6	1.79	11.9	1.02	24.4
CON.	3.18	-	2.26	-	1.98	-	1.66	-	0.82	-
$LSD_{0.05}$	0.56	-	0.26	-	0.24	-	0.16	-	0.45	-
CV%	10.9	-	7.0	-	5.2	-	6.0	-	22.7	-
S.E.M	±0.17	-	±0.14	-	±0.14	-	±0.7	-	±0.12	-

SECOND TRIAL

	Seedling stage		Prior to tasselling		Cobbing stage		Grains		Stover (post harvest)	
TRT	Mean	DFC	Mean	DFC	Mean	DFC	Mean	DFC	Mean	DFC
LL_1	3.36	5.7	2.76	13.1	2.62	6.9	1.36	4.6	0.43	10.3
LL_2	3.45	8.5	3.10	27.0	2.90	18.4	1.40	7.7	0.54	38.5
CS_1	3.40	6.9	2.92	19.7	2.78	13.5	1.39	6.9	0.50	28.2
CS_2	3.48	9.4	3.20	31.1	2.97	21.1	1.49	14.6	0.57	46.2
TB_1	3.33	4.7	2.47	1.2	1.30	1.2	1.30	-	0.43	10.3
TB_2	3.44	8.2	2.94	20.5	2.81	14.7	1.32	1.5	0.51	30.8
CON.	3.18	-	2.44	-	2.45	-	1.30	-	0.39	-
$LSD_{0.05}$	0.44	-	0.50	-	0.22	-	0.20	-	0.22	-
CV%	8.7	-	11.9	-	5.6	-	9.6	-	1.4	-
S.E.M	±0.10	-	±0.29	-	±0.2	-	±0.07	-	±0.07	-

TRT means treatment and DFC means % difference from the control.

4.3.5 STOVER WEIGHT

The dry stover after harvest was weighed from the harvest area. The results are summarized in Table 9.

Analysis of variance (Appendix 11) indicated no significant differences in stover weight among the treatments in both trials.

Table 9 Mean stover weight in kg/Ha.

	FIRST TRIAL	SECOND TRIAL
	Mean	Mean
Treatment	weight (kg/Ha)	weight (kg/Ha)
LL_1	2601.4	10476.2
LL_2	3174.6	13492.1
CS_1	2804.2	10582.0
CS_2	2998.2	12125.2
TB_1	2777.8	9065.3
TB_2	2980.6	11710.8
Con.	2448.5	8779.3
S.E.M	±248.6	±1684.3
%CV	17.7	19.9

4.3.6 GRAIN YIELD

Grain yield from the net plot ($11.34m^2$) was weighed in grams for each plot.The mean for each treatment was then converted into kg/ha. Table 10 summarizes the result on grain yield.

Table 10 Mean grain yield in kg/ha

Treatment	FIRST TRIAL mean grain yield (kg/ha)	SECOND TRIAL Mean grain yield (kg/ha)
LL_1	853.1	4177.10
LL_2	939.4	4851.85
CS_1	794.9	4273.86
CS_2	1081.1	4760.96
TB_1	770.2	3860.21
TB_2	872.0	4475.77
CON.	741.2	3580.18
CV%	18.4	17.1
S.E.M	±116.66	±460.65

Maize was harvested at average moisture content of 17% for both trials

From the results the mulched plots had higher yields than the unmulched control plots in both trials, however analysis of variance (Appendix 9) indicated that the differences were not significant.

Although the differences were not significant plots that received mulch at $2kg/m^2$

generally had higher grain yield than those that received mulches at $1kg/m^2$ which had more than the control.

The yields were lower in the first trial compared with those of the second trial. *L.leucocephala* applied at $2kg/m^2$ had the highest yields while the control had the least.

4.3.7 1000 GRAIN WEIGHT

From a composite sample of grains from each plot, 1000 grains were oven dried until a constant weight was attained and the 1000 grain weight was recorded. Table 11 summarizes the results.

Table 11 Mean 1000 grain weight in grammes

Treatment	FIRST TRIAL Mean weight	SECOND TRIAL Mean weight
LL_1	308.73	361.31
LL_2	350.00	395.47
CS_1	325.85	378.59
CS_2	343.33	384.41
TB_1	306.23	353.44
TB_2	316.00	362.90
CON.	272.95	351.57
$LSD_{0.05}$	34.79	
S.E.M	±25.77	±16.68
CV%	7.4	6.17

From Table 11, *L.leucocephala* applied at $2kg/m^2$ gave the heaviest grains while the control had the lightest.

Analysis of variance for the grain size data (Appendix 9) indicated that significant differences were during the first trial but not in the second. During the first trial the mulched plots had significantly heavier grains than the control except those mulched with *T.brownii* applied at

$1kg/m^2$. *L.leucocephala* applied at $2kg/m^2$ gave significantly heavier grains than when applied at $1kg/m^2$ and than *T.brownii* applied at $1kg/m^2$ during the first trial.

4.3.8 COB WEIGHT

The weight of cobs in grams was taken from the net plot. Table 12 below summarizes these results.

Table 12 Mean cob weight in grams.

Treatment	FIRST TRIAL Mean weight	SECOND TRIAL Mean weight
LL_1	41.59	134.08
LL_2	53.37	154.63
CS_1	44.41	135.35
CS_2	50.13	152.05
TB_1	37.94	122.15
TB_2	46.93	142.65
CON.	33.76	113.83
$LSD_{0.05}$	17.22	34.27
S.E.M	±7.08	±14.92
CV%	26.3	2.4

$1kg/m^2$. *L.leucocephala* applied at $2kg/m^2$ gave significantly heavier grains than when applied at $1kg/m^2$ and than *T.brownii* applied at $1kg/m^2$ during the first trial.

4.3.8 COB WEIGHT

The weight of cobs in grams was taken from the net plot. Table 12 below summarizes these results.

Table 12 Mean cob weight in grams.

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CS_2	50.13	152.05
TB_1	37.94	122.15
TB_2	46.93	142.65
CON.	33.76	113.83
$LSD_{0.05}$	17.22	34.27
S.E.M	±7.08	±14.92
CV%	26.3	2.4

$1kg/m^2$. *L.leucocephala* applied at $2kg/m^2$ gave significantly heavier grains than when applied at $1kg/m^2$ and than *T.brownii* applied at $1kg/m^2$ during the first trial.

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LL_2	53.37	154.63
CS_1	44.41	135.35
CS_2	50.13	152.05
TB_1	37.94	122.15
TB_2	46.93	142.65
CON.	33.76	113.83
$LSD_{0.05}$	17.22	34.27
S.E.M	±7.08	±14.92
CV%	26.3	2.4

From the data on cob weight *L.leucocephala* applied at $2kg/m^2$ had the highest impact on cob weight followed by *C.siamea* applied at $2kg/m^2$ while the control had the lowest cob weight. In both trials mulches applied at $2kg/m^2$ produced heavier cobs than those applied at $1kg/m^2$ but the differences were not significant (Appendix 9).

Mulches applied at $2kg/m^2$ increased the mean cob weight by at least 25% above the control with 61%, 48.5%, and 39.0% for *L.leucocephala*, *C.siamea* and *T.brownii* respectively for the first trial and 35.85%, 33.6% and 25.3% during the second trial (Table 12).

The differences between the treatments and the control were lower during the second trial as compared to the relatively drier first trial.

4.4 INTERCORRELATION BETWEEN MAIZE GROWTH PARAMETERS

Intercorrelations between some maize growth parameters were calculated as a measure of intensity of association. The correlation coefficients were calculated using the fo mula:

$$r = \frac{\Sigma(\bar{X}-X)(\bar{Y}-Y)}{\sqrt{\Sigma(\bar{X}-X)^2 \Sigma(\bar{Y}-Y)^2}}$$

Where:- r = correlation coefficient

X = mean measurement of a given parameter

$\bar{X}$ = mean of all the measurements of the parameter

Y = mean measurement of second parameter

$\bar{Y}$ = mean of all the measurements of the second parameter

An example of how the correlation coefficients were calculated is given for plant height of first trial 30 days after emergence.

TRT	Mean height	Mean yield	$(\bar{X}-X)$	$(\bar{Y}-Y)$	$(\bar{X}-X)(\bar{Y}-Y)$
LL_1	66.4	853.1	0.36	11.46	4.1256
LL_2	74.2	939.4	-7.50	-74.84	561.3
CS_1	67.9	794.9	-1.14	69.66	-79.4124
CS_2	73.2	1081.1	-6.44	-216.54	1394.5176
TB_1	64.0	770.2	2.76	94.36	260.4336
TB_2	67.1	872.0	-0.34	-7.44	2.5296
CON.	54.5	741.2	12.26	123.36	1512.3936
Total	467.5	6051.9			3655.8876
Mean	66.76	864.56			

$$\Sigma(\bar{X}-X)^2 = 257.1936$$

$$\Sigma(\bar{Y}-Y)^2 = 81651.297$$

$$\Sigma(\bar{X}-X)(\bar{Y}-Y) = 3655.8876$$

$$r = \frac{3655.8876}{\sqrt{257.1936 \times 81651.297}}$$

$$r = 0.7977 \simeq 0.80$$

Appendix 12 (A-F) summarizes the intercorrelations while Table 13 below shows the correlation between the growth parameters with grain yield.

Table 13. Correlation between maize growth parameters with grain yield

		Correlation coefficient	
Height(H)	30	0.80	0.72
	60	0.72	0.85
	90	0.74	0.85
LAI(L)	30	0.75	0.90
	60	0.77	0.89
	90	0.46	0.83
Base diameter(D)	30	0.77	0.47
	60	0.80	0.97
	90	0.63	0.93
Cob weight(C)	-	0.80	1.00
Stover weight(S)	-	0.68	0.97
Grain size (Z)	-	0.78	0.89

From table 13 plant height taken 30 days after emergence was more correlated to yield in the first trial than in the second.

In the second trial, plant height taken 60 and 90 days after emergence was significantly correlated to yield while 30 and 60 days after emergence the LAI was correlated to yield during the two trials but more strongly in the second.

The plant base diameter 60 days after emergence was correlated to yield for the two trials but more strongly in the second. For both trials the cob weight and grain weight were correlated to grain yield but again more strongly in the second trial. At the earliest stage LAI appears to be least correlated to yield in a good rainy season.

CHAPTER FIVE

FINAL DISCUSSION AND SUMMARY

All growth parameters were measured routinely with an aim of assesing the influence of the different treatments. During the first trial a virtually rain free period (Appendix 1) resulted in plant water stress with severe curling of leaves and complete drying of some plants in all plots before a favourable soil water content was restored.

Plant height

Plant height data (Table 5) show that growth rate was less in the unmulched plots. During the second trial there was more rain and this explains the much taller plants in the trial compared to the first.

In using plant height as a measure of the effect of mulch on vegetative growth it is easy to gain the impression that the effect of the mulch on plant height decreased towards maturity. Results on the influence of mulches on plant height and stover weight (Table 5 and Table 9),however shows that the small non-significant differences in plant height towards maturity could not be matched with the much bigger (though also not significant) differences in the dry weight of the stover.

Leaf area index

Leaf area is important in that it affects the amount of radiation intercepted for photosynthesis. Watson (1947), noted that when the LAI is less than one, plants have low efficiency in total light utilization and would result in low rates of photosynthesis hence less assimilation and so lower yields.

In the present work the leaf mulches except *T.brownii* applied at 1kg/m^2 signficantly increased the LAI in the second measurement of the first trial probably through increased soil nutrients for plant use. Differences in LAI may also have been due to differences in drought impact in this trial.

After the second measurement there was a decline in LAI in both trials. This was perhaps due to senescence and death of the leaves in succession from the base of the plant as the crop matured.

Variation between seasons in LAI can be attributed to changes in climatic conditions during the two seasons. During the first trial plants were affected by water stress that resulted in the drying of many leaves and a decrease in both leaf number and size. This decrease might have caused the lower LAI and part of LAI differences during the first trial relative to the second trial.

Percentage N content

Table 8 show that the %N content of the grains was higher in the first trial than in the second. This could be attributed to the dryness of the growing period of the first trial. Boyer and Mcpherson (1975), have pointed out that the percentage of the protein in cereal grains increases during drought.

This is because of a decline in activity of nitrate reductase enzyme which is involved in the reduction of nitrates (Morilla *et al.*,1973). Studies on the nitrate reductase synthesis show that in the vegetative maize, the enzyme is unstable and must be continually synthesized (Beavers and Hegeman, 1969; Morilla *et al.*,1973). In the first trial there was probably a drought induced decline in nitrate reductase activity causing an accumulation of nitrates in the grains and thus the higher %N in the grains during this trial.

Most nitrogen in maize occurs in the first half of the growth period (Boyer and Mcpherson, 1975). This suggests that the protein of the grains must be derived primarily from the nitrogen that has previously been part of vegetative plant proteins. thus as grain fills, considerable amount of grain protein N is derived from nitrogenous compounds released from the vegetative tissues as senescence takes place, which must have resulted in the observed decline in %N content of maize with age and the much lower %N content of the stover relative to grain and other growth stages.

The leaf mulches contain inorganic nutrients and hence would be expected to have an influence on the nutrient composition of the soil and thus of the maize crop. During decomposition the mulches will have released some nitrogen which subsequently became available to the maize and this contributed to the higher %N content beyond the seedling stage of maize in mulched compared to the unmulched plots.

Differences in the %N content of maize under different mulch types will have been due to differences in nutrient composition of the mulches (Table 1) and differences in decomposition and mineralization rates and hence the time when the released nutrients became available for uptake by maize. If the "cobbing stage" is anything to go by, higher rates of mulch application may have resulted in higher %N content of maize due to more soil nitrates taken up relative to the lower rates as suggested by the Least Signficant Difference.

Grain yield

Water deficits adversely affect seed germination and seedling establishment (Hill, 1972), vegetative growth (Gates, 1968), reproductive growth (Kaufmann,1972), photosynthesis (Boyer,1976) and other physiological processes of the plant (Crafts,1968).

Water stress during the stage of floral development and flowering in maize reduces seed set number (Salter and Goode,1967). Even if subsequent improvement in water availability occurs, yield remains depressed. Water stress can cause fewer seeds by retardation of the floral primordia development (Hussein and Aspinall,1970), abortion of the egg cell within the emryo sac (Moss and Downey, 1971), delay in pollen development or through retardation of the extension of the stamens and styles of the flower or of the pollen tube (Salter and Goode, 1967). Through the influence of water stress on the above processes, the much lower yields during the first trial could be attributed to the drought that the crop experienced.

During the second trial water supply was adequate which explains the much higher yields in the trial.

The lower grain yields in the control plots may be attributed, at least partly, to poor soil physical properties and partly to low nutrierts due to the continous removal through previ·us harvested plants. Root growth of maize has been reported to be restricted by removal of mulches in alley cropping (Yomoah *et al.*,1986). Mulch application is reported to improve soil "physical fertility" (Lawes, 1962; Chinwuba, 1965; Lal,1973; 1975; 1979; Wade and Sanchez, 1975;). Thus mulch application besides improving soil nutrient status may also have resulted in improved soil physical properties leading to greater root lateral spread and proliferation and this could be associated with the better performance of maize in the mulched plots.

Although photosynthesis is important for grain production, the translocatin of photosynthetic products is also essential for the formation of yield. In maize half of the dry matter accumulated by the shoot is ultimately moved unto the grain (Boyer and Mcpherson, 1975). Wardlaw (1967, 1969) has shown that the rate of translocation is reduced by drought. This coupled with the lower amounts of photosythates that resulted from decreased photosynthesis because of water stress will have led to lower amounts of the photosynthates reaching the grains which in turn resulted in lighter grains in the first trial as compared to the second.

The posit ve correlation observed of the mean cob weight and grain size with grain yield is not suprising given the fact that of all other parameters measured, these are the primary components of grain yield. Such high correlations have for example also been reported by other workers (Hatfield *et al.*,1965; Goldsworthy *et al.*, 1974) for maize and Clarke (1978) and Adelana and Afolabi (1976) for *Brassica napus* and groundnuts respectively.

Soil nutrients and Organic Carbon

Whether a mulch will increase soil nitrogen depends upon its ease of decomposition and its C:N ratio. According to Louis and Frederick (1978), more decomposition of organic matter occurs in the upper soil layers because this is where there is a high concentration of micro-organisms and aeration is more adequate than in the underlying layers. Since the mulches were applied in one layer at a depth above 15cm, there was more decomposition in this upper layer.

The organic matter content of any

soil horizon depend of course partly on how much organic matter is turned over to the soil every year and partly on what percentage of the organic matter decomposes during the year (Broadbent, 1953). This explains the much higher %O.C in the mulched plots and the low %O.C in the control plots. Continued cultivation without the return and decomposition of adequate crop residue ultimately leads to a decline in the organic matter and Carbon of the soil (Tisdale and Nelson, 1970). This may explain the progressive decline of %O.C in the unmulched plots with time.

The increase in %O.C in the mulched plots would then be explained by the continued addition of the mulching materials every growing season. This according to Sutherland *et al.*,(1961), does not only maintain the level of soil organic matter but may as well increase it.

The results indicate a decrease in soil C:N ratio with depth which suggests variability in the soil organic matter content downwards. In some other study, Russel (1961), partly attributed such an apparent fall to the inclusion of ammonium ions held by clay in a form which they can orly be displaced by treatment with a strong acid. The narrowing C:N ratio with depth was also observed by Steveson (1959) who attributed it to two factors, one such factor was also suggested by Russel (1961). According to Steveson (1959), the narrowing was due to :-

(a) an increase with depth in the relative amount of soil N as a result of fixed ammonium; and

(b) the presence of relatively higher amount of nitrogen rich constituents in the organic matter of the subsoil as compared with the surface soil.

The high soil pH of the mulched plots is due to reduction of soil acidity by mulching. During decomposition of the mulches, high bases, especially Calcium were released to the soil. This effect has also been observed elsewhere (Robinson and Hoosegood 1965). The lower pH values of the control plots could possibly be due to progressive removal of bases through leaching and plant uptake. The difference between pH/water and pH/KCl could be attributed to the fact that measurement of pH in a soil-water suspension is influenced by the presence of soluble salts. Use of a salt like KCl or $CaCl_2$ tends to mask the variability of pH caused by differences in the salt concentration in the soil. The increase of pH values with depth could be attributed to high concentration of bases in the lower depth as compared to the top. This may either be due to accumulation of bases leached from top surface and/or reduced uptake by crops. The higher soil pH values and bases in plots under *L.leucocephala* and *C.siamea* may have resulted from the decomposition and release of more bases by the two leaf mulches. The amount of bases released is dependent on the amount of mulch. This could have been the reason for the slightly lower pH values and bases in plots which were mulched at $1kg/m^2$ rather than at $2kg/m^2$.

CHAPTER SIX

FINAL CONCLUSIONS AND RECOMMENDATION FOR FURTHER RESEARCH

Since the treatments only modified factors which because of their dependence on weather conditions, are inherently variable in time, it was expected that crop responses to them would vary from one season to another depending on the obsolute values of (in the tropics) mainly soil water content. From the two trials, it is clear that when water is limiting as in the first trial, the yield benefits of mulch application are appreciably less obvious in terms of crop performance (Appendix 1).This means that for nutrients added to the soil through mulch decomposition to be most usefull to the plant, there has to be adequate water.

The significance of mulching should be viewed in the light of its improvement in both soil physical and chemical properties because the nutrients released from the mulches become much less effective if the soil physical properties do not favour proper root development. A study into the effects of these mulches on the soil physical properties is highly recommended.

Overall performance of the maize in the

mulched plots irrespective of the season, rate and mulch type was slightly better than in the control. However, in a study like this, where only two rates of application were used, of which non may be expected to be the near maximum responce level (De Wit, 1953), one cannot talk of the optimal rate. Thus a comparable study, but including at least an economically (labour) maximum rate of mulch application in the farming systems aimed at, is recommended. The study may also include other types of trees like *Sesbania*, *Glyricidia*, and *Erythrina*.

The relatively high maize performance and %N content due application of *L.lecocephala* and *C.siamea* leaf mulches could have been due to time and place in which they decomposed and released nutrients. If nutrient release is premature or delayed (like after harvest), the nutrients are of little value to the existing crop in terms of nutrient supply. Further study into the decomposition rates and optimum timing and placement of mulch is desireable.

It is apparent from the study that the grain yield was positevely correlated to the cob weight, grain size, plant height, LAI, and base diameter. Though the results complement, for example, those of Lal and Haque (1971), who noted that (in mulched plots irrespective of the season, rate and mulch type was slightly better than in the control. However, in a study like this, where only two rates of application were used, of which non may be expected to be the near maximum responce level (De Wit, 1953), one cannot talk of the optimal rate. Thus a comparable study, but including at least an economically (labour) maximum rate of mulch application in the farming systems aimed at, is recommended. The study may also include other types of trees like *Sesbania*, *Glyricidia*, and *Erythrina*.

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It is apparent from the study that the grain yield was positevely correlated to the cob weight, grain size, plant height, LAI, and base diameter. Though the results complement, for example, those of Lal and Haque (1971), who noted that (in soybeans) the total leaf area, plant height and pod number are directly related to yield and are reliable criteria for yield prediction, the correlations only measures the mutual association between the variables and can neither be used to predict yield nor as a measure of causal relationship between the variables.

Analysis of the leaf mulches for their nutrient composition coupled with soil analysis showed that mulches with a wide C:N ratio released less nutrients to the soil due to their slow decomposition rates. It also showed that addition of mulches helped to maitain higher soil nutrient and organic matter content.

In a nutshell, even if the benefits of mulch farming within the semi-arid areas are recognized, it is the limitation of procuring the mulching materials that could make mulching a difficult practice, even in the context of multipurpose trees.

However, this limitation may be partly overcome by growing some of these tree species as field boundaries or as shelter belts to reduce erosion whose prunings can be used as source of mulch. In this connection the social and economic aspects of mulching have to be studied in specific farming systems contexts to know whether the innovation can be adapted by a certain target group of the small scale farmers. It is also necessary to diversify such studies towards other regions and using other crops such as sorghum, beans etc.

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APPENDICES

Appendix 1: Rainfall data during the two trials.

MONTH	1987 (FIRST TRIAL) TOTAL RAINFALL (mm)	1988 (SECOND TRIAL) TOTAL RAINFALL (mm)
January	26.2	146.8
February	0.0	27.2
March	19.2	119.0
April	79.8	216.0
May	63.6	13.4
June	61.5	10.9
July	4.7	6.2
August	10.8	3.7
September	0.0	13.8
October	1.0	
November	78.2	
December	19.3	

Taken from ICRAF field station which is adjacent to experimental site.

Appendix 2: Soil pH and exchangeable bases determined before planting 1987 first trial maize

		pH		Ca	Mg	Na
TRT	DEPTH (cm)	1:2.5H_2O	1:2.5KCl	(in m.e/100g	of	soil)
LL_1	0-15	6.0±0.1	5.0±0.2	4.4±0.2	1.40±0.06	0.13±0.03
"	15-30	6.2±0.2	5.1±0.2	7.4±0.3	1.60±0.18	0.16±0.03
"	30-60	6.4±0.2	5.4±0.2	8.0±0.4	1.70±0.05	0.18±0.02
LL_2	0-15	6.6±0.2	5.5±0.2	6.9±0.3	2.08±0.08	0.15±0.04
"	15-30	6.7±0.1	5.7±0.2	8.2±0.6	2.10±0.05	0.19±0.03
"	30-60	6.8±0.2	5.8±0.2	8.8±0.4	2.20±0.05	0.24±0.04
CS_1	0-15	6.1±0.2	5.1±0.2	5.0±0.4	1.20±0.18	0.12±0.03
"	15-30	6.2±0.3	5.2±0.2	5.8±0.3	1.40±0.17	0.17±0.03
"	30-60	6.5±0.2	5.5±0.2	7.2±0.4	1.70±0.09	0.19±0.04
CS_2	0-15	6.5±0.2	5.5±0.2	6.6±0.4	1.70±0.11	0.15±0.04
"	15-30	6.6±0.2	5.6±0.2	7.8±0.3	1.73±0.04	0.18±0.03
"	30-60	6.7±0.1	5.7±0.2	8.2±0.6	1.80±0.03	0.23±0.03
TB_1	0-15	5.9±0.2	4.9±0.2	4.4±0.3	1.20±0.09	0.11±0.03
"	15-30	6.1±0.2	5.0±0.3	5.0±0.4	1.35±0.13	0.13±0.03
"	30-60	6.3±0.1	5.3±0.3	7.0±0.4	1.40±0.04	0.15±0.04
TB_2	0-15	6.3±0.2	5.2±0.3	5.6±0.5	1.60±0.13	0.15±0.02
"	15-30	6.4±0.2	5.3±0.3	6.6±0.5	1.70±0.10	0.18±0.02
"	30-60	6.6±0.2	5.6±0.3	7.8±0.7	1.76±0.05	0.20±0.04
CCN.	0-15	6.0±0.2	5.1±0.3	4.0±0.4	1.20±0.08	0.18±0.03
"	15-30	6.3±0.1	5.3±0.3	5.6±0.4	1.35±0.15	0.220.04
"	30-60	6.4±0.2	5.4±0.3	6.9±0.5	1.60±0.05	0.250.06

TRT means treatment

Appendix 3: Soil pH and exchangeable bases determined after harvesting 1987 first trial maize.

TRT	DEPTH (cm)	pH 1:2.5H_2O	pH 1:2.5KCl	Ca	Mg	Na
				(in	m.e/100g of	soil)
LL_1	0-15	6.2±0.2	5.2±0.3	5.4±0.7	1.60±0.09	0.20±0.02
"	15-30	6.4±0.2	5.5±0.3	7.6±0.8	1.68±0.07	0.23±0.03
"	30-60	6.5±0.2	5.6±0.2	8.4±0.6	2.00±0.18	0.25±0.03
LL_2	0-15	6.8±0.2	5.7±0.2	8.0±1.0	2.20±0.18	0.25±0.05
"	15-30	7.0±0.1	6.0±0.2	8.6±0.7	2.40±0.52	0.27±0.03
"	30-60	7.2±0.3	6.2±0.4	9.4±0.8	3.00±0.27	0.31±0.04
CS_1	0-15	6.3±0.3	5.2±0.4	5.4±0.7	1.40±0.17	0.20±0.03
"	15-30	6.4±0.1	5.4±0.4	7.3±0.7	1.68±0.17	0.25±0.03
"	30-60	6.6±0.2	5.6±0.3	7.9±0.9	1.80±0.13	0.27±0.05
CS_2	0-15	6.7±0.2	5.6±0.[illegible]	[illegible].0±0.7	1.90±0.08	0.24±0.05
"	15-30	6.8±0.2	5.8±0.4	8.2±0.7	2.00±0.41	0.25±0.03
"	30-60	7.0±0.1	5.9±0.2	8.8±0.5	2.40±0.42	0.28±0.03
TB_1	0-15	6.1±0.3	5.2±0.2	5.0±0.6	1.40±0.17	0.20±0.05
"	15-30	6.3±0.3	5.3±0.3	5.6±0.5	1.85±0.07	0.22±0.02
"	30-60	6.4±0.3	5.4±0.1	7.1±0.5	1.60±0.08	0.24±0.02
TB_2	0-15	6.5±0.4	5.6±0.3	6.0±0.5	1.56±0.07	0.21±0.02
"	15-30	7.7±0.4	5.7±0.3	7.4±0.5	1.80±0.08	0.22±0.06
"	30-60	6.8±0.2	5.8±0.4	8.6±0.8	2.00±0.19	0.25±0.02
CON.	0-15	5.9±0.3	5.0±0.2	3.0±0.6	1.07±0.09	0.13±0.03
"	15-30	6.1±0.4	5.2±0.3	5.2±0.9	1.24±0.05	0.16±0.03
"	30-60	6.2±0.3	5.3±0.4	6.0±0.5	1.46±0.09	0.19±0.04

TRT means treatment

Appendix 4: Soil pH and exchangeable bases determined after harvesting 1988 second trial maize.

		pH		Ca	Mg	Na
TRT	DEPTH (cm)	1:2.5 H_2O	1:2.5KCl	(in	m.e/100g of	soil)
LL_1	0-15	6.4±0.2	[illegible].3±0.3	6.4±0.4	1.64±0.08	0.22±0.04
"	15-30	6.6±0.2	5.6±0.4	7.8±0.4	2.00±0.18	0.27±0.03
"	30-60	6.7±0.1	5.7±0.3	8.6±0.2	3.45±0.06	0.28±0.03
LL_2	0-15	7.0±0.1	5.9±0.3	9.5±0.4	3.00±0.13	0.28±0.02
"	15-30	7.1±0.1	6.1±0.2	9.7±0.3	4.30±0.04	0.29±0.04
"	30-60	7.4±0.2	6.3±0.4	10.2±0.4	5.33±0.04	0.35±0.03
CS_1	0-15	6.4±0.2	5.4±0.3	6.4±0.4	1.64±0.04	0.23±0.05
"	15-30	6.5±0.2	5.5±0.2	8.2±0.4	1.98±0.02	0.26±0.03
"	30-60	6.7±0.2	5.7±0.3	8.4±0.5	3.40±0.04	0.29±0.03
CS_2	0-15	6.8±0.2	5.8±0.3	7.4±0.3	2.50±0.04	0.25±0.03
"	15-30	6.9±0.2	5.9±0.2	8.8±0.4	3.00±0.12	0.28±0.04
"	30-60	7.2±0.3	6.1±0.2	9.0±0.3	5.10±0.09	0.33±0.03
TB_1	0-15	6.3±0.2	5.3±0.3	5.4±0.3	1.48±0.07	0.23±0.03
"	15-30	6.5±0.2	5.4±0.4	6.9±0.2	1.80±0.05	0.25±0.05
"	30-60	6.6±0.3	5.6±0.4	7.4±0.3	3.30±0.03	0.27±0.04
TB_2	0-15	6.7±0.2	5.7±0.4	6.4±0.4	2.00±0.11	0.23±0.04
"	15-30	6.8±0.2	5.9±0.3	7.8±0.3	2.80±0.03	0.27±0.05
"	30-60	6.9±0.3	6.0±0.3	9.6±0.4	4.75±0.04	0.30±0.03
CON.	0-15	5.7±0.3	4.7±0.3	3.0±0.6	0.98±0.05	0.09±0.03
"	15-30	5.9±0.2	5.0±0.4	4.7±0.3	1.00±0.05	0.12±0.04
"	30-60	6.0±0.2	5.1±0.3	5.3±0.4	1.35±0.05	0.14±0.04

Appendix 5: ANOVA for nutrient content of leaf mulches

FIRST TRIAL

Source		Total	Treatment	Error
	df	5	2	3
N	ss	3.345	3.26	0.085
	mss		1.63**	0.028333
P	ss	0.00388	0.00333	0.00055
	mss		0.00665**	0.00016667
K	ss	0.003235	0.000271	0.002964
	mss		0.0001355ns	0.000988
C	ss	159.63910	159.23205	0.40705
	mss		79.616025**	0.1356833
Na	ss	2.066533	2.065833	0.0007
	mss		1.0329167**	0.000233
Ca	ss	4172.29	4144.84	27.45
	mss		2072.42**	9.15
Mg	ss	1085.42	1084.84	0.58
	mss		542.42**	9.15
C/N	ss	765.331	760.4548	4.877
	mss		380.2274**	1.6256667

SECOND TRIAL

Source		Total	Treatment	Error
	df	5	2	3
N	ss	2.24115	2.2197	0.21918
	mss		1.10985**	0.018265
P	ss	0.00588	0.00573	0.00015
	mss		0.002865**	0.000016833
K	ss	0.0000875	0.000037	0.0000505
	mss		0.0000185ns	0.000016833
C	ss	152.4188	151.8949	0.5239
	mss		25.94745**	0.1746333
Na	ss	2.129	2.1289	0.0001
	mss		1.06445**	0.0000333
Ca	ss	4513.17	4512.72	0.45
	mss		2256.36**	0.15
Mg	ss	1099.9	1099.24	0.66
	mss		549.62**	0.22
C/N	ss	537.7483	537.3333	0.415
	mss		268.66665**	0.1383333

ns=not significant **=signficant at p=0.05

Appendix 6: ANOVA for plant height data

First trial

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	1971.37		4206.76		3557.83	
Block	3	272.47	90.82ns	2273.81	757.94**	935.68	311.98**
Treatment	6	1027.22	171.20**	827.19	137.87ns	900.90	150.15ns
Error	18	671.68	37.32	1105.76	64.43	1721.26	95.63
		CV=9.2%		CV=9.1%		CV=10.6%	

Second trial

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	9809.33		14386.63		15817.61	
Block	3	3852.95	1284.32**	9835.21	3278.40**	10301.41	3433.81**
Treatment	6	1386.25	231.04ns	1169.64	194.94ns	1516.36	252.73ns
Error	18	4570.13	253.90	3381.79	187.88	3999.83	222.21
		CV=14.5%		CV=6.4%			

ns = not significant

** = significant at p = 0.05

Appendix 7: ANOVA for plant leaf area index data

First trial

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	1.696		2.688		2.272	
Block	3	0.522	0.174**	0.026	0.0087	1.042	0.347**
Treatment	6	0.546	0.091ns	1.502	0.250**	0.631	0.105ns
Error	18	0.629	0.035	1.161	0.0645	0.599	0.033
		CV =23.3%		CV =25.3%		CV =28.8%	

Second trial

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	1.035		6.746		2.33	
Block	3	0.259	0.086ns	3.377	1.126**	0.093	0.331**
Treatment	6	0.251	0.042ns	0.826	0.138ns	0.664	0.111ns
Error	18	0.525	0.029	2.542	0.141	0.673	0.037
		CV = 18.2%		CV = 20.5%		CV = 17.0%	

ns - not significant

** - significant at p= 0.05

Appendix 8: ANOVA for maize %N content data.

FIRST TRIAL

		MAIZE		GROWTH	STAGES						
		Seedling stage		Prior to tarsselling		Cobbing		Grains		Stover	
Source	df	ss	mss	ss	mss	ss	mss	ss	mss	ss	mss
Total	27	5.116		2.384		1.038		0.474		1.658	
Block	3	1.824	0.608**	1.372	0.457**	0.344	0.115**	0.172	0.057**	0.478	0.159**
Treatment	6	0.702	0.117ns	0.462	0.077ns	0.459	0.077**	0.103	0.017ns	0.368	0.061ns
Error	18	2.589	0.144	0.549	0.031	0.234	0.013	0.199	0.011	0.813	0.045
		CV = 10.3%		CV = 7.0%		CV = 5.2%		CV = 6%		CV = 22.7%	

SECOND TRIAL

		MAIZE		GROWTH	STAGES						
		Seedling stage		Prior to tarsselling		Cobbing		Grains		Stover	
Source	df	ss	mss	ss	mss	ss	mss	ss	mss	ss	mss
Total	27	2.667		5.714		2.632		0.518		0.582	
Block	3	0.850	0.284**	1.601	0.534**	1.255	0.418**	0.173	0.058	0.065	0.022ns
Treatment	6	0.250	0.042ns	2.060	0.343ns	0.967	0.161**	0.107	0.018ns	0.107	0.018ns
Error	18	1.567	0.087	2.053	0.114	0.410	0.023	0.311	0.017	0.410	0.023
		CV = 6.7%		CV = 11.3%		CV = 5.6%		CV = 9.6%		CV = 31.4%	

** - significant at p = 0.05

ns - not significant

Appendix 9: <u>ANOVA for Yield, Cob weight, and Grain size data.</u>

FIRST TRIAL

		Grain yield		Cob weight		Grain size	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	3311344.7		5850.174		26657.49	
Block	3	182523.2	608412.07**	2226.85	742.28**	853.19	284.40ns
Treatment	6	326616.28	54436.05ns	1204.27	200.71ns	15935.73	2655.95**
Error	18	1159492.2	64416.23	2419.05	134.39	9868.57	548.25
		CV = 18.4%		CV = 26.3%		CV = 7.4%	

SECOND TRIAL

		Grain yield		Cob weight		Grain size	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	24759000		24773.71		23206.48	
Block	3	9969000	3323000**	9843.47	3281.18**	7308.10	2436.03**
Treatment	6	5093000	848833.3ns	5345.29	890.88ns	6676.73	1112.79ns
Error	18	9667000	538722.22	9584.95	532.50	9221.64	512.31
		CV = 17.1%		CV = 2.4%		CV = 6.12%	

** - significant at p = 0.05

ns - not significant

Appendix 10: ANOVA for plant base diameter data

FIRST TRIAL

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	2.31		1.61		0.76	
Block	3	1.02	0.34**	0.26	0.09**	0.23	0.08**
Treatment	6	0.66	0.11**	0.91	0.15**	0.34	0.06**
Error	18	0.63	0.03	0.43	0.02	0.19	0.01
		CV = 10.5%		CV = 8.6%		CV = 4.2%	

SECOND TRIAL

		DAYS AFTER EMERGENCE					
		30		60		90	
Source	df	ss	mss	ss	mss	ss	mss
Total	27	1.34		2.04		1.64	
Block	3	0.68	0.23**	0.65	0.22**	0.79	0.26**
Treatment	6	0.25	0.04ns	0.66	0.11ns	0.30	0.05ns
Error	18	0.41	0.02	0.72	0.04	0.56	0.03
		CV = 5.5%		CV = 1.6%		CV = 6.9%	

** - significant at p=0.05

ns - not significant

dix 11: ANOVA for stover weight data.

		First trial		Second trial	
	df	ss	mss	ss	m: s
	27	8.84		273.43	
	3	1.39	0.46ns	77.52	25.8**
ent	6	1.60	0.27ns	87.73	14.62ns
	18	5.85	0.33	108.18	6.01

CV = 17.7%

** - significant at p=0.05

ns - not significant

x 12: Intercorrelations between maize growth parameters.

FIRST TRIAL

(A) Thirty days after emergence

	Grain yield(G)	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
G		0.80	0.77	0.75	0.80	0.65	0.78
H			0.94	0.75	0.89	0.83	0.99
D				0.84	0.98	0.90	0.96
L					0.81	0.71	0.78
C						0.86	0.91
S							0.86

(B) Sixty days after emergence

	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
Grain yield(G)						
G	0.75	0.80	0.77	0.80	0.68	0.78
H		0.93	0.68	0.87	0.94	0.95
D			0.82	0.98	0.91	0.96
L				0.74	0.63	0.83
C					0.86	0.91
S						0.86

(C) Ninety days after emergence

	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
Grain yield(G)						
G	0.74	0.63	0.46	0.80	0.68	0.78
H		0.93	0.70	0.96	0.90	0.84
D			0.59	0.93	0.90	0.92
L				0.56	0.48	0.35
C					0.86	0.91
S						0.86

SECOND TRIAL

(D) Thirty days after emergence

	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
G	0.72	0.47	0.90	1.00	0.97	0.89
H		0.96	0.65	0.86	0.88	0.68
D			0.56	0.91	0.88	0.75
L				0.62	0.57	0.45
C					0.97	0.89
S						0.88

(E) Sixty days after emergence

	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
G	0.85	0.97	0.89	1.00	0.97	0.89
H		0.92	0.36	0.85	0.81	0.71
D			0.84	0.97	0.96	0.86
L				0.85	0.75	0.69
C					0.97	0.89
S						0.88

(F) Ninety days after emergence

	Grain yield(G)	Height(H)	Base diameter(D)	LAI(L)	Cob weight(C)	Stover weight(S)	Grain size(Z)
G	------	0.85	0.93	0.83	1.00	0.97	0.89
H	------	------	0.96	0.89	0.86	0.80	0.76
D	------	------	------	0.85	0.93	0.90	0.77
L	------	------	------	------	0.83	0.75	0.77
C	------	------	------	------	------	0.97	0.83
S	------	------	------	------	------	------	0.88