THE INFLUENCE OF ORGANIC MULCHES ON WEEDS, DISEASES AND GROWTH OF MAIZE (Zea maysL.).

BY

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DECLARATION

I declare that this thesis is my original work and has not been submitted for a degree in any other University.

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DEDICATION

To my father,

the late Mzee Ogendo Olero

and my mother Caren Ogendo

in appreciation of the roles they have played,

both materially and morally,

in my life.

ABSTRACT

Effects of three organic mulches with two intra-row weeding, conventional tillage with two hand weeding and an unweeded check on maize (Zea maysL.) growth, weeds and diseases associated with the maize crop were evaluated for two seasons. The experiment was conducted during the long and short rains of 1989 at Kabete Farm, University of Nairobi, Kenya.

During the long rains, the organic mulches proved more effective in controlling annual weeds than the conventional tillage with hand-weeding. Better trends in weed control were registered during the short rains, although the conventional tillage with hand weeding showed superiority over the organic mulches. Maize stover mulch was found to be less effective in controlling *Bidens pilosa L.* and *Commelina benghalensis L.* compared to bean husks. However, stover was superior to bean husks in controlling *Oxalis latifolia* H.B.K. and *Oxalis corniculata L.*

Better crop growth was obtained during the short rainy season compared to that in the long rainy season. This corresponded well with the excellent weed control exhibited by the organic mulches except for the stover which had inferior plants during the long rains.

Crop stand, at harvest, during the short rains was superior to the long rains. All the treatments, except the unweeded check, had equally good stands during the short rains. During the long rains, conventional tillage with hand-weeding had the best stand, with bean husk and black polythene mulches at par. The unweeded check registered the least cob length, one thousand grain weight and grain yields during both seasons. The maize stover mulch resulted in very low grain yields during the long rains. However, its yield was comparable to that of black polythene during the short rains. The bean husk treatment gave consistently good yields during both seasons and even proved superior to the other two mulches during the short rains.

Maize stover mulch proved to have significant influence on incidence of northern leaf blight of maize. Plants in the maize stover plots attained 100% incidence level only six weeks after emergence compared to eight weeks after emergence in the other four treatments. However, the high incidence of this disease seems to have influenced grain yields in the stover mulched plots only.

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CHAPTER ONE

INTRODUCTION

Cereal grains dominate world agricultural production because they directly or indirectly provide a large portion of human subsistence. They are by far the most important source of concentrated carbohydrates and happen to be a cheap source in terms of effort and costs of production (Leonard and Martin, 1963).

Although maize (Zea maysL.) is not the first thing that springs to the mind whenever one thinks of Kenya, it is the staple food for 90% of the people and accounts for half of their land devoted to crops and nearly all small holders grow some maize variety to eat and market (Anon., 1980b).

Maize is the only important cereal thought to have evolved in the New world, reportedly in Mexico, and it is also the most highly domesticated of all field crops (Chapman and Carter, 1976). The crop was first introduced to Kenya along the Indian Ocean Coast in the sixteenth century by the Portuguese (Allan, 1971). Maize is now extensively grown in Kenya and occupies some 1.5 million hectares which is a large proportion of the country's limited arable land (Mwenda, 1985). More than 90% of the maize is currently produced by small-scale farmers. The output from the large scale farms has been declining over the years as many of them continue to be subdivided and revert to small scale operation.

Despite the long period of maize cultivation, total production has remained low compared to prevailing demand. Both local and hybrid varieties are available to the farmer with the hybrids out-yielding the locals. Despite the yield potential shown by these improved varieties, the realized yields in the farmers' fields still remain unbelievably low. Several researchers have given possible reason for low yields in the tropical zone and these include late weed control when weeds have already done the damage (Nieto et al, 1968; Allan, 1971; Oryokot, 1984). Late planting has been shown to reduce corn yields (Mock and Erbach, 1977).

Weed management is an important operation in maize production. The problems that have been associated with weed control are shortage and cost of labour. This is compounded by the fact that the climate is highly seasonal in the tropics and all crops have to be planted within a short interval of time. The small-scale farmer, whose source of labour is mainly his family, is frequently unable to carry out timely or proper weed control. Bearing in mind that the small scale farmers lack the capital needed for the acquisition of farm machinery, chemicals for weed control, labour and other costly inputs, the use of organic mulches (maize stover and bean husks) would greatly cut down on the man-hours needed for land preparation and conventional weed control and release part of the family labour for other activities. With these in mind, the objectives of this study were to find out:

1. The influence of organic mulches on growth and yield of furrow-tilled maize;

2. The effectiveness of the organic mulches in suppressing and hence controlling weed species growing in association with maize;

3. The relative benefits of organic mulches and the possibilities of replacing the effective but non-popular black polythene with maize stover and bean husks.

4. Also to establish the importance of maize stover mulch as a source of *Exerohilum turcicum* (syn. *Helminthosporium turcicum*) and thereafter its influence on northern leaf blight levels in maize crop.

CHAPTER TWO

LITERATURE REVIEW

Effect of Weeds on Crop Yield

A weed is defined as a plant out of place or a plant growing where it is not wanted (Klingman and Ashton, 1982). Competition is the restriction arising from association with other plants, and must result from a change in one or more factors of the local environment of the plant (Aspinall, 1960). Competition is also the mechanism by which one plant depletes some essential elements for plant growth to a level that is limiting to the growth of a second plant sharing that habitat (Bell and Koeppe, 1972).

Crop yield losses due to competition is usually proportional to the amount of light, nutrient and water used by weeds at the expense of the crop (Burnside and Wicks, 1967). Several experiments have been carried out in various countries to determine the effects of weeds on crop yields especially if they grew unchecked. In Peru, rice yields were reduced by 34-68% and in Latin America, maize yields by 53% simply by allowing weeds to grow unchecked (Fletcher, 1983).

Crop yield losses due to weeds are difficult to estimate, because it is almost impossible without creating an artificial environment to separate their effects from those caused by insects, disease, soil and atmospheric conditions. Worldwide, some 10% loss of agricultural production is due to the competitive effects of these plants; this represents a yearly loss of over 155.5 billion tonnes in cereals alone (Fletcher, 1983).

Documented research findings show that maize yield in Western Kenya is greatly reduced when weeds are present and that the yield reduction is highest in the first five weeks of maize growth (Allan, 1971). Some of the weed characters, recognized by weed scientists, which influence crop yields include: the nature or species of weeds, the density and relative time of crop and weed emergence. The weed's competitive ability depends upon its growth habit and extent and nature of top and root growth. Weeds shorter than the crop usually compete most severely during the early growing season while those that are taller than the crop generally reduce yields by competing late in the season (Staniforth and Weber, 1956; Smith, 1967; Simdahl and Staniford, 1967).

Scientific work on sorghum (*Sorghum vulgare*). cowpeas (*Vigna unguiculata*) and green grams (*Vigna aurens*) in Tanzania and Nigeria indicated that weed competition decreased grain yields of all the three crops. These low yields were due to reduction in leaf area index, dry weight of stems and number of mature pods at harvesting in the case of green grams and cowpeas, while in sorghum the reduction in the length of ears and grain weight per unit length of ear were implicated (Enyi, 1973); Remison, 1978).

Trials conducted in closely-spaced hybrid maize stand showed that yield reduction was correlated with dry matter, and was probably caused by lack of available nutrients by drying the plough layer (Marais, 1983). In other experiments, rainfed maize was extremely sensitive to established weeds during the second month. The results of the experiments were related to the level of weed infestation and availability of labour in Ciskei, and this indicated that peasant farmers may have lost 55% of their crop if weeding was left until the fortieth day (Marais, 1983).

Effects of Mulching on Crop Yield

Mulched cowpeas (*Vigna unguiculata*), under no-tillage, had significantly better yields than those from unmulched plots. Increase in seeds due to mulching was much larger than that obtained from non-mulched and fertilized plots (Anon, 1984; Daisley *et al*, 1988). In another related work at Ile-Ife, Nigeria, it was reported that cowpeas had significantly higher yields in the no-tillage plots while maize yields were not significantly different in both tillage systems (Fadayomi, 1990).

A long-term study by International Institute of Tropical (IITA) (1971-1983), on no-tillage with crop residue mulch, showed that this farming practice, which does not involve mechanical soil disturbance, can maintain economic yields of grain crops, such as maize, without causing a severe decline in soil productivity. Maize yields with the no-tillage system based on an average of twenty-four consecutive crops, have been higher than those obtained under conventionally ploughed system. Experiments on coffee by Kabaara and Kimeu (1973) showed that the practice of mulching is beneficial in Kenya East of the Rift, both as regards clean coffee yields and percent grade "A" coffee.

Mulching trials by Gregersen (1985) at Jyndervad, Tylsrup and Odum in Sudan on the effects of covering forage maize with plastic or forming small mounds as shelter resulted in 1919 and 2495 forage units/ha with plastic mulching at Jyndervad and Odum, respectively. Yield increases with mulching did not cover the cost of plastic. Shekour and co-workers (1987) using crop residue mulch and three anti-transpirants on dry season cropped maize found that mulch increased plant height, leaf area, fresh ear yield and total dry matter by 21.1% compared to the limited irrigated control.

Cassava (*Manihot esculenta*) had its yield reduced by only 1% when grown under no-tillage plus mulch, compared to 40% under no tillage without mulch (Aina, 1979). Other studies, in Fort Valley, USA, using different types of mulching materials and black plastic on egg plant (*Solanum melongena L.*) production showed that black plastic or pine needles significantly increased yields whereas newspaper was inferior. Hence, pine needles was seen as a potential inexpensive mulching material for home vegetable gardens (Carter and Clarence, 1988).

Irrigated maize research in india, over two seasons gave grain yields of 4.85 and 5.25 tonnes/ha with rice straw mulch between the rows, 5.16 and 5.35 tonnes/ha with black polythene between rows and 3.16t/ha and 4.93t/ha with full cover of polythene mulch. The mulch treatments increased grain weight per plant, and 1000-grain weight (Kalaghatagi et al, 1989). Several researchers in Samaru, Nigeria and Iowa, USA have reported that straw mulch and grass mulch increased dry matter yield of maize and beans and seed yield of beans. Grass mulching increased grain yield by between 15 and 22% in maize and by about 10% in millet. The same workers found that the final maize plant density and grain yields were lower in the conservation tillage system than in the conventional tillage system (Mock and Erbach, 1977; Adeoye, 1984; Barros, 1989). Maize may be grown under no-tillage for seven years or more with yields equal to those of the cultivated crops if weeds are controlled (Triplett and Lytle, 1972).

Natural Organic Mulches for Weed Control vs Other Control Measures

Holm (1969) in his discussion pointed out that more energy should be expended for the weeding of man's crops than for any other single human task. He talked of women and children working day after day in fields at the never-ending job of hoeing weeds, and he made a plea for modernisation of weed control so that women may have time to keep their home and that children may have the privilege of attending schools. Crafts (1975) states that because the principal virtue of cultivation of row crops is weed control, any method for handling weeds that minimizes or eliminates tillage is advantageous from the standpoint of soil structure.

Weed control problems are always named as one of the factors holding back the expansion of food production by small scale farmers in the humid and sub-humid tropics, where hand-weeding may account for 30% or more of the farm input. This could be substantially reduced with herbicides, but most small holders cannot afford them (Anon., 1984). While high rates of herbicides are more efficient in weed control, there is increased crop injury often manifested in yields, a situation that puts the farmer in a dilemma. Increasing organic matter along the planting furrows was found to significantly reduce herbicide (pendimethalin) injury to bean seedlings (Ariga and Michieka, 1985).

The IITA (1981/82) trials showed that cuttings from _Aciola barterri_. due to their slow rate of decomposition, have an excellent weed suppressing ability in both maize and cowpeas planted in an "alley cropping system". In a related work on tomatoes at Samaru, Nigeria, Quinn (1979) reported that in grass-mulched plots, weed emergence was much slower than in no mulch plots and that effective weed control depends on the correct choice and use of mulching material. Similar experiments in Peru and Nigeria showed that the use of grass-mulch and paraquat and dead crop residue decreased fresh weed weights and that weed growth was highly suppressed (Lal, 1974; Wade and Sanchez, 1983). In Michigan, USA, it was observed that a high cover crop seeding rate increased weed suppression in strawberries (Smeda and Putnam, 1988). Straw-mulched plots produced large plants, higher yields and had fewer weeds compared to herbicide treated plots (Creager, 1989).

Herbicides can increase agricultural productivity and rural welfare where agronomic considerations or labour shortages favour their utilization, but ecological, social and economic conditions in developing countries often favour alternative weed control methods. Traditional hoeing by peasant farmers, although labour and time intensive, is both effective and economical in comparison with other methods. On the other hand, chemical control is both labour and time saving but requires skill and accuracy for rightful application, a quality lacked by peasant farmers. A greater use of organic farming techniques would help reduce reliance on these often toxic (sometimes banned) chemicals. This is in line with a growing global awareness of the effect of chemical pollution such as residues in food and soil from herbicides and pesticides, river and water contamination from crop spraying (Young et al, 1978; Oryokot, 1984; Maratos, 1989).

The majority of small scale farmers in Kenya use traditional methods of seedbed preparation and weed control. These methods involve the use of simple hand tools making them labour demanding, a factor leading to delayed weeding due to labour pressure at the beginning of the rainy season when land preparation and planting are also competing for the farmers' available resources (Ngugi, 1987).

Field trials in high and low rainfall areas of Kenya showed that farmers could plant maize in stubble and achieve average yields comparable to those produced under conventional tillage. Early intra-row weeding was found to be fast in all reduced tillage systems (Michieka, 1985). A lot of research has been done to ascertain the potential of herbicides in controlling weeds in Kenya. But no efforts have been directed towards the mobilization of the locally available crop residues which, if carefully and fully exploited, can alleviate the poor farmers' weed control problems.

Influence of Mulching on Crop and the Environment

Mulch is a layer of material placed on the soil surface to conserve moisture, hold down weeds and if derived from organic material, to ultimately improve soil fertility (Engelken, 1985). No-tillage is defined as a system of soil management that eliminates all pre-planting mechanical seedbed preparation except for the opening of a narrow strip or hole in the ground for seed placement to ensure adequate soil-seed contact. The entire inter-row zone is covered by crop residue mulch or killed sod (Hullugale and Opara-Nadi, 1987). Ecofarming, on the other hand, is the system of controlling weeds and managing crop residues throughout a crop rotation, with minimum use of tillage in order to reduce soil erosion and production costs, while increasing weed control, water infiltration, moisture conservation and crop yields (Bloom et al., 1982). Soil fertility practice and plant residue management have an impact on the long-term effects of cropping on soil change in organic matter (Barber, 1979; Bloom et al 1982). Under continuous maize (Zea maysL.) removal of the stover plus grain has been shown to have deleterious effect on organic matter content of mollisols in Indiana, USA (Barber, 1979) and Iowa, USA (Larson et al, 1972).

Research done in various parts of the world indicate that reduced tillage of row crops with mulching have a positive influence on water conservation, control of soil surface, the elimination of the compaction and reduction of soil structural deterioration (Aina, 1979; Bloom et al., 1982; Constamagna et al., 1982). Experiments in Brazil showed that managing maize stalks immediately after harvest resulted in a decrease in the amount of larger aggregates but maize stalk left on the soil surface by rotary cutter contributed to formation of larger soil aggregates (Alvarenga et al., 1989). In Nigeria, soils in no-tillage plots, at the end of the experimentation, were found to have a higher cation exchange capacity, more nitrate-N and available phosphorus than ploughed treatments (Lal, 1974). The same author, while studying the non-tillage effects on soil properties under different crops in 1976, noted that the infiltration rates of no-tillage plots were higher than those of the ploughed plots, and thus, runoff and erosion losses were minimal. At Beltsville, USA, it was reported that tillage treatments affected the distribution of roots and extractable phosphorus in the soil top layer (Anderson et al., 1987).

The efficiency of various soil management practices, under ecofarming, for conserving moisture during the summer fallow period were 25% effective for plough and bare soil, 32% for stubble mulch and 44% for no-till at North Platte, Nebraska (Bloom et al., 1982). Protection of the soil surface by the residue mulch has been mentioned as the major contributory factor to the success of no-till farming in the humid tropics. In addition to protection, the mulch serves as a source of nutrients to the crop. But due to the high rate of decay of organic matter in the tropics, the residues do not remain for long on the soil surface. Hence, soil cover may be maintained by the application of an external mulch (Hullugale and Opara-Nadi, 1987).

Reported findings from Brazil, Nigeria, and Indiana and Fort Valley in USA, indicate that the use of crop residues (maize, wheat and soybeans) and grass mulch improve the soil cover, reduce the soil temperature, improve the soil moisture retention up to 60 cm deep, provide average crop stands and intermediate maize growth rate (Griffith et al., 1973; Mock and Erbach, 1977; Cruse, 1983; Wade and Sanchez, 1983; Adeoye, 1984; Sarpe, et al., 1989; Penescu and Lopes, 1987; Berry and Mallett, 1989).

In an experiment to monitor the anthracnose leaf blight, caused by *Colletotricum graminicola*, spread from maize residues on the soil surface under continuous maize-soyabean rotation, the number of infected leaves per plant was negatively correlated with distance from the residue area from 28 to 70 days after planting. The same experiment showed that leaf blight spread more rapidly within rows than across rows and that the percentage of plants with anthracnose stalk rot at the end of the season with negatively correlated with distance from the residue area (Lipps, 1988).

Rainfall, relative humidity and temperature have been reported, in the sub-tropical corn belt of South East USA, as the critical factors in the spread of *Helminthosporium maydis* and *H. turcicum*. The survival of *H. maydis* and *H. turcicum* in maize debris is instrumental in the development of epidemics of southern and northern corn leaf blight, respectively. Hence, surface maize residues are an important source of inoculum for anthracnose, and other leaf blights and the rate of disease spread may depend on the orientation of maize rows in relation to the inoculum source and cropping history of the field (Summer and Litterel, 1974; Lipps, 1988). In Saskatchewan, Canada and Washington, USA, the preservation of crop residues in wheat was found to increase common foot rot *(Cochliobolus sativus)* and *Cercosporella* foot rot. Also, infection at the seedling stage was confirmed to be substantially greater in stubble-mulched plots than conventional ploughing and seeding but the differences tended to lessen towards harvest because of cross-infection (Shipton, 1979).

Studies, in Germany, on the effect of maize stalk rot on maize revealed that, in heavily infected plants, the 1000-grain weight was reduced to a relative value of 83 and the yield to 80, compared with 100 in healthy plants (Kruger, 1984). Other related research findings from North Hertfordshire, North Carolina, USA and Bulgaria indicate that plant height, height of ear formation and basal diameter of the stalk are unaffected by disease severity but 23% of the active leaf area was destroyed by maximum infection. Also, the incidence of ***Exserohilum turcicum*** *(Syn. H.* ***turcicum)*** in maize leaves was 0-50% at the time of sampling and that the grain weight per ear and mean weight of single grains were negatively correlated with disease severity (King, 1976; Ivanova, 1984; Leonard et al, 1988).

CHAPTER THREE

MATERIALS AND METHODS

Experimental Site

The experiment was conducted at the University of Nairobi, Kabete Field Station, during the long (March to July, 1989) and short (October to December, 1989) rains. The farm is located at an altitude of 1800 m, a latitude 1^0 15' S and longitude 36^0 44' E. The site receives a mean annual rainfall of about 1000 mm with a mean maximum temperature of 23°C and a mean minimum temperature of 12°C. The soil consists of well-drained, deep, dark reddish brown to dark-red, friable clay with acid humic top soil (humic nitosols) developed from Limuru Trachyte (Michieka, 1977). The soil has humus content of 4%, base saturation of 16 to 70%, pH of 4.5-7 and a cation exchange capacity (CEC) of about 16 me/100g.

Experimental Design and Procedure

The experimental design used was a randomized complete block (RCBD) replicated four times in each of the two experiments and every plot measured 6 m x 8 m. The object of grouping was to have the units in a block as uniform as possible so that observed differences were largely due to treatment effects. Replication was aimed at providing an estimate error, improving the precision of the experiment and controlling the error variance (Steel and Torrie, 1980).

Of the total twenty plots, eight were manually (hand) tilled according to randomization performed in the respective blocks. The remaining plots were slashed (manually) to the ground; hoe-width furrows were opened in all the plots. Diamonium phosphate (DAP) fertilizer (18:46:0), at 200 kg product/ha, was applied in all the furrows and thoroughly mixed with the soil before seed placement. Maize hybrid H 511 was planted at a spacing of 0.75 m x 0.30 m; seeding rate was 2 seeds/hole which was later thinned to one plant/hill giving an expected population of 44,444 plants/ha.

Table 1 shows the five treatments and their respective descriptions.

Table 1: List of Treatment Descriptions

Treatment	Description
1.	Conventional tillage (hand digging & harrowing) no weeding, no mulch.
2.	Conventional tillage (hand digging & harrowing) with two hand weeding, no mulch.
3.	Furrow tillage (ground slashing, furrow opening) with maize stover mulch at 12t/ha, two intra-row weeding.
4.	Furrow tillage (ground slashing, furrow opening), with bean husks mulch at 5.7t/ha, two intra-row weeding
5.	Furrow tillage (ground slashing, furrow opening), with black polythene "gauge 500" mulch, two intra-row hand pulling of weeds

Measurements

The following parameters were measured during the two seasons when the experiment was conducted: % crop emergence, crop height (cm), weed counts and heights, incidence of northern corn leaf blight, grain yield and its components, plant stand at harvest and finally, a look at the cost of labour and mulching.

Crop Height

The maize plant heights (cm), in every plot were measured on a bi-weekly basis commencing the fourth week after crop emergence up to tasseling when no further change in height was observed. Ten plants were sampled at random in every row exclusive of the guard rows and the end hills of the harvest rows.

Weed Counts

The stand reduction, by species, in a unit area of sample was investigated. On a bi-weekly basis, weed counts were taken in the respective plots, commencing from the fourth week after emergence. This was done with the help of a 0.5 x 0.5 m quadrat. The quadrat was randomly placed four times in every plot and the number of shoots of each of the six weed species (see Table 4a) recorded.

Weed Heights

Heights of the six weed species, in every plot, were taken at the end of the experiment. These measurements were meant to give information on weed growth suppression by the various mulches.

Diseases

The northern corn leaf blight (NCLB) disease was identified through visual observation of its characteristic symptoms: long, elliptical greyish-green or tan lesions (Anon., 1980a). Also infected leaves were placed in a moist chamber for 24-48 hours and greyish-black spores appeared on the lesions. The following disease parameters were used to score for the occurrence on maize leaves:

Disease Incidence

a) The average number of infected plants per plot and the average of infected leaves per plant, in every plot, were taken on a weekly basis. This commenced on the fourth week after crop emergence and continued until the ninth week when the disease had stabilized in all the plots.

b) Visual observation of the average proportion of leaves per treatment affected by the disease was done on a weekly basis. The observations commenced the fourth week after crop emergence and continued until the eighth week when 100% incidence level had been reached in all plots. Scoring scale was as follows: zero (0) denoted completely disease-free leaves; one hundred (100) denoted that all sampled leaves were diseased.

Yield and Yield Components

The two outermost rows were treated as guard rows, while the remaining six rows were all harvested according to plots and the following parameters recorded:

i) Mean cob length - mean cob length (cm) per treatment was obtained by randomly sampling ten cobs per plot;
ii) Mean 1000-grain weight per treatment obtained by taking three random samples, using a telecounter and a balance, from every pot.
iii) The number of plants harvested as a percentage of emergence;
iv) The number of lodged plants as a percentage of harvested plants and,
v) Finally, the mean grain yield obtained from every treatment (kg/ha) by extrapolating from the actual grain yield per plot. This was calculated using a shelling % of 85 and grain moisture content adjusted to 13%.

The Economics of Organic Mulching

For the purpose of economic analysis, the following components were determined:

i) Labour requirements: this was determined for land preparation, seed and fertilizer placement, mulch placement, dipterex application and finally, weeding operations. Determination involved timing the operations, without the labourer(s) being aware, as they were performed in every plot. The times obtained were averaged across blocks and seasons and then extrapolated to Man-days/ha. The cost of hiring labour was @ Kshs. 41.70.

ii) Cost of mulching material - the maize stover and bean husks were obtained at no cost. However, the black polythene "gauge 500" was procured at @ Kshs. 16.10 per square metre.

iii) Returns (Revenue) - both gross and net revenue were calculated using the grain yields (bags/ha), the price of maize grain @ Kshs. 297/= and the total costs of production.

CHAPTER FOUR

RESULTS

I. Agronomic Parameters

1.1. Percent Emergence

Data given in Table 2 represent the percent crop emergence. There were significant differences (p = 0.05) among treatments during the long rains only. The overall crop emergence was 88 and 98 percent for long and short rains, respectively.

Table 2: Percent Maize Germination as Affected by Organic Mulching

Treatment		PERCENT GERMINATION	
		Long Rains 1989	Short Rains 1989
T1	Conventional tillage, no weeding, no tillage	90.0c	97.8
T2	Conventional tillage, weeding, no mulch	93.4c	98.7
T3	Furrow till, maize stover, intra-row weeding	79.6a	97.1
T4	Furrow till, bean husks, intra-row weeding	91.9c	97.7
T5	Furrow till, black polythene intra-row weeding	84.0b	98.6
Mean		87.8	98.0
Fcalc		4.40*	1.07ns
SE Treatments		3.90	0.92
CV (%)		6.29	1.33
LSD (0.05)		8.32	

ns = not significant at p = 0.05;
* = significant at p = 0.05
Means = along a column with the same alphabetical letters are not significanly different at p = 0.05 by DMRT.

1.2 Weed Density

Weed density (weeds/m^2) are presented in Tables 3a and 3b. Results show that the differences among treatments were highly significant (p=0.05) during both seasons. Generally, there were more weeds/m^2 during long rains than the short rains. These included Black Jack, (Bidens pilosa), Gallant soldier (*Galinsoga parviflora*). Mexican merigold (*Tagetes minuta*). *Oxalis spp*, Wandering Jew (*Commelina benghalensis*) and *Conyza bonariensis*. The weedy check had the highest number of weeds per unit area during both seasons. The polythene mulch proved to be the most effective in keeping down the weed population by having the least during the long rainy season. During the short rains, the conventional tillage with hand weeding proved superior to all. The overall mean weed densities were 130 and 105 weeds/m^2 for the long and short rains, respectively.

Table 3a: **Effect of Organic Mulching on Weed Density (Weeds/m^2) - Long rains, 1989.**

Treatment	WEEKS AFTER EMERGENCE				
	4	6	8	10	MEAN
T1	293c	380d	291d	175	285
T2	102b	245c	60a	50a	114
T3	96b	132b	117c	55a	100
T4	62a	92a	117c	48a	80
T5	64a	72a	91b	69b	74
Mean	123	184	135	79	130
F calc	75.84*	47.86*	82.41*	51.26*	
SE Trment	15.68	26.23	14.05	10.68	
CV (%)	17.97	20.14	14.70	19.02	
LSD (0.05)	33.41	55.89	29.95	22.76	

* - Significant at p=0.05. Means in a column with the same letters are not significantly different at 5% level by DMRT.

Table 3b: Effect of Organic Mulching on Weed Density (Weeds/m^2 - short rains, 1989.

Treatment	WEEKS AFTER EMERGENCE				
	4	6	8	10	MEAN
T1	197c	301b	329c	111d	236
T2	77a	73a	61a	26a	59
T3	128b	93a	56a	52c	82
T4	109b	90a	82b	41b	81
T5	78a	81a	66ab	38b	67
Mean	117	128	119	54	105
Fcalc.	12.08*	46.01*	71.75*	21.80*	
SE Trt	20.00	20.20	19.69	10.12	
CV (%)	24.09	22.29	23.43	26.69	
LSD (0.05)	42.62	43.05	41.95	21.56	

* - Significant at p = 0.05. Means in a column with the same letters are not significantly different at 5% level by DMRT.

T1 — Conventional tillage, no weeding, no mulch
T2 — Conventional tillage, weeding, no mulch
T3 — Furrow tillage, maize stover, intra-row weeding
T4 — Furrow tillage, bean husks, intra-row weeding
T5 — Furrow tillage, black polythene, intra-row weeding.

1.3 Weed Heights

Presented in Tables 4a and 4b are weed heights (cm) taken during the maize grain filling period. The inter-treatment differences were highly significant (p = 0.05) for all the weed species during both seasons except for the *Oxalis spp.* whose heights were not significantly different during the short rains. Generally, the weeds were taller during the long rains than the short rains. The weedy check had the tallest weeds during both seasons except for the *Oxalis spp.* The conventional tillage with hand weeding was the most effective treatment in reducing the weed heights. The other three (stover, bean husks and polythene) ytreatments were equally good in reducing the weed heights. The overall mean weed heights were 50 and 44 cm for the long and short rains, respectively.

Table 1a: Effect of Organic Mulching on Weed Heights (cm) - Long Rains, 1989.

Treatment	Bp	Gp	Tm	Os	Com	Cb	Mean
	WEED SPECIES						
T1	107.1d	86.8c	118.3d	9.1a	105.4d	130.2	92.8
T2	31.9a	21.7a	20.8a	14.7c	30.6a	21.2a	23.5
T3	16.8c	26.4b	51.3c	9.8b	74.2c	83.3b	46.7
T4	38.6b	23.7b	50.0c	10.0b	54.3b	81.3b	43.5
T5	29.0a	26.3b	11.0b	9.7ab	61.1	79.0b	41.0
Mean	50.5	37.0	56.3	10.7	65.1	79.6	49.5
Fcalc.	166.13*	76.8*	41.61*	29.82*	20.07*	86.30*	
SE-Trtm	3.55	1.53	8.06	0.59	8.70	6.73	
SE Weeds spp.	3.18	1.05	7.21	0.53	7.78	6.02	
CV (%)	9.96	17.32	20.25	7.82	8.89	11.95	
LSD(0.05) Trt	7.57	9.65	17.17	1.26	18.53	14.33	
LSD (0.05) weed spp.	6.56	8.36	11.87	1.09	16.05	12.42	

KEY

Bp	-	*Bidens pilosa* (Black jack)
Gp	-	*Galinsoga parviflora* (Gallant soldier)
Tm	-	*Tagetes minuta* (Mexican marigold)
Os	-	*Oxalis spp* (*O. latifolia* and *O. corniculata*)
Comm.	-	*Commelina benghalensis* (Wandering Jew)
Cb	-	*Conyza bonariensis*
SE Treatments	-	Standard Error for treatment means
SE Weed Spp.	-	Standard Error for weed species means
LSD (0.05) Treatment	-	Least Significant Difference for treatment means at p = 0.05.
LSD (0.05) Weed species - weed species		Least Significant Difference for means at p = 0.05.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

Table 4b: Effect of Organic Mulching on Weed heights (cm) -Short Rains, 1989.

Trat	Bp	Gp	Tm	Os	Com	Cb	MEAN
			WEED SPECIES				
T1	85.6c	81.8c	112.1	9.6ab	89.2d	118.8c	84.4
T2	26.5a	17.1a	12.0a	10.1b	21.9a	12.6a	16.7
T3	39.1b	21.0a	17.7a	8.6a	65.8c	71.8b	42.8
T4	31.3a	19.8a	12.8b	8.9ab	40.5b	80.1b	37.2
T5	27.9a	27.5b	15.7b	9.7ab	60.3c	76.3b	41.2
Mean	42.1	34.0	[illegible]	9.4	55.5	72.5	44.3
Fcalc	22.57*	86.62*	10.77*	0.52ns	17.63*	55.47*	
SE (Trt)	7.39	4.35	15.82	1.18	8.61	7.23	
SE (Weed spp)	6.61	3.89	14.15	1.06	7.70	6.47	
CV (%)	24.80	18.08	42.99	17.85	21.92	14.11	
LSD(0.05) Trt	15.74	9.27	33.72	18.35	15.41		
LSD (0.05) Weed spp	15.63	8.03	21.21	15.89	13.35		

For weed abbreviations see Table 4a.
* Significant at p = 0.05; ns - not significant at p = 0.05;
Means with the same letters in column not significantly at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

1.4 Maize Heights (cm)

Tables 5a and 5b show the effects of organic mulching on the maize heights (cm) during the long and short rainy seasons of 1989. There were significant height differences, throughout the maize growth period, among treatments. This was true for the two rainy seasons. Maize plants were, generally, taller during the short rains than the long rains. The conventional tillage with hand-weeding had the tallest plants during the long rains while the weedy check had the shortest as at tasselling. During the short rains, both the bean husk and black polythene treatments equally had the tallest plants while the weedy check had the shortest plants as at tasselling. The overall mean height, at tasselling, for the two seasons was 128.3 cm.

Table 5a: Height (cm) of maize as affected by organic mulching-Long rains, 1989.

Trtment	WEEKS AFTER EMERGENCE					
	4	6	8	10	12	MEAN
T1	25.6c	45.8c	65.7C	104.9b	132.0a	74.8
T2	21.8bc	51.7d	86.6d	137.4d	178.6c	95.8
T3	20.4ab	31.7a	52.6A	93.4a	139.5a	67.5
T4	24.1bc	43.2c	75.0c	128.6c	165.5b	87.3
T5	19.6a	38.6b	74.3c	128.4c	176.1c	87.4
Mean	22.9	42.2	70.8	118.5	158.3	82.6
Fcalc	5.98'	8.62'	9.31'	9.09'	13.08'	
SE (trt)	1.59	3.61	5.84	8.68	8.35	
CV (%)	9.84	12.22	11.66	10.35	7.46	
LDS (0.05)	3.39	7.77	12.45	18.49	17.79	

' Significant at p - 0.05; Means with the same letters in column not significantly different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

Table 5b: Heights (cm) of maize as affected by organic Mulching-Short rains, 1989.

Treatment	WEEKS AFTER EMERGENCE					
	4	6	8	10	12	MEAN
T1	34.0a	69.7a	112.4	9.6ab	89.2d	118.8c
T2	37.2b	87.1d	12.0a	10.1b	21.9a	12.6a
T3	36.4b	77.5b	47.7a	8.6a	65.8c	74.8b
T4	38.7c	85.6cd	42.8b	8.9ab	40.5b	80.1b
T5	31.5a	83.5c	45.7b	9.7ab	30.3c	78.3b
Mean	36.2	80.7	187.2	263.8	301.9	174.0
Fcalc	3.63'	9.61'	13.23'	7.24'	15.55'	
SE (Trt)	1.44	3.26	5.20	8.58	6.75	
CV (%)	5.63	5.71	3.93	4.60	3.16	
LDS (0.05)	3.07	6.95	11.08	18.29	14.38	

' Significant at p - 0.05; Means with the same letters in column not significantly different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

1.5 Lodged Plants at Harvest

Results presented in Table 6 on lodging indicate that there were significant differences (p = 0.05) among treatments during the short rains. No data was collected on the parameter during the long rains. The weedy check had the highest number of plants lodged at harvest while the conventional tillage with hand-weeding treatment had the least. On average, 7.9% of the harvested plants had lodged.

Table 6: Plants lodged as Affected by Mulching - Short Rains, 1989.

Treatment	Plants Lodged as Percent of Harvested Plants
T1	19.1c
T2	3.1a
T3	6.1b
T4	6.1b
T5	5.0b
Mean	7.9
Fcalc	40.6
SE (Trt)	1.42
CV (%)	25.50
LSD(0.05)	3.02

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

1.6 Number of Plants Harvested

Table 7 shows the plants harvested as % of emergence. There were significant differences (p = 0.05) among treatments during both seasons. Plants harvested during the short rains were more than the long rains by 23.2%. The overall mean number of plants during both seasons was 81.2%.

Table 7: Effect of Organic Mulching on Percent Plants Harvested.

Treatment	Plant Harvested as % Germination		
	LONG RAINS 1989	SHORT RAINS 1989	MEAN
T1	54.8a	73.3a	64.1
T2	85.2c	98.4b	91.8
T3	60.0a	97.9b	79.0
T4	76.2b	97.9b	87.1
T5	71.6b	96.0b	83.8
MEAN	69.5	92.7	81.2
Fcalc	4.48*	8.45*	
SE Trts.	8.20	5.30	
CV (%)	16.67	8.08	
LSD (0.05)	17.47	11.29	

* Significant at p = 0.05; Means with the same letter in column not significantly different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

1.7 Cob Length

Table 8 shows the mean cob lengths (cm). The lengths were significantly different (p = 0.05) among treatments only during the short rains. Cobs were generally longer during the short rains compared to the long rains. The unweedy plots had the shortest cobs during both seasons while the conventional tillage with had weeding treatment had the longest cobs during both seasons and this difference was significantly different at p = 0.05. The overall mean cob length for the two experiments was 18.1 cm.

Table 8:

Cob Length (cm) as Affected by Organic Mulches.

Treatment	COB LENGTH (CM)		
	LONG RAINS 1989	SHORT RAINS 1989	MEAN
T1	16.6	16.8a	16.7
T2	18.2	19.7c	19.0
T3	17.3	19.4bc	18.4
T4	18.2	19.1b	18.7
T5	18.2	19.1b	18.7
MEAN	17.7	18.8	18.3
Fcalc	2.38ns	7.97[1]	
SE TrtS	0.67	0.58	
CV (%)	5.40	4.38	
LSD (0.05)		1.24	

ns - Not significant at p = 0.05; [1] - Significant at p - 0.05
Means followed by some letters in a column are not significantly different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

1.8 Seed Weight

The mean seed weight (1000 weight) grain weights (g) are presented in Table 9. The results indicate that there were significant differences (p = 0.05) among treatments during both seasons. The weedy check had the least weight during both seasons. The black polythene mulch proved superior during the long rains but was surpassed by the conventional hand weeded treatment during the short rains. Generally, the grain weights were superior during the long rains compared to the short rains. The overall mean one thousand grain weight during both seasons was 4[illegible]1.4 g.

Table 9:

One Thousand Grain Weight as Affected by Organic Mulching.

Treatment	WEIGHT LONG RAINS 1989	SHORT RAINS 1989	MEAN
T1	380a	371a	376
T2	438b	430b	434
T3	423b	427b	425
T4	437b	424b	431
T5	487c	426b	457
Mean	433.1	416	425
Fcalc.	9.89*	7.61*	
SE Trts.	17.20	12.73	
CV (%)	5.64	4.33	
LSD (0.05)	36.79	27.14	

* - Significant at p = 0.05;
Means in a column followed by same letters are not significantly different at 5% level by DMRT.

T1 - Conventional tillage, no weeding, no mulch;
T2 - Conventional tillage, weeding, no mulch
T3 - Furrow tillage, maize stover, intra-row weeding
T4 - Furrow tillage, bean husks, intra-row weeding
T5 - Furrow tillage, black polythene, intra-row weeding

1.9 Maize Grain Yield

Maize yields are shown in Table 10. The yields were highly significant (p = 0.05) among treatments during both seasons. There were significantly higher yields during the short rains than the long rains. The grain yield from the weedy check was the least during both seasons while that from the conventional tillage with hand weeding was the highest during both seasons. All the treatments, except the weedy check yielded over 3000 kg/ha and the overall mean during both seasons was 4283 kg/ha.

Table 10: Mulching Effects on Maize Yield (kg/ha).

Treatment	YIELDS (kg/ha) LONG RAINS 1989	SHORT RAINS 1989	MEAN
T1	1946a	2911a	2429
T2	5092d	5405d	5249
T3	3413b	4875b	4144
T4	4192c	5164c	4678
T5	4975d	4859b	4917
Mean	3924	4643	4283
Fcalc.	25.65*	37.82*	
SE Trts.	361.77	228.58	
CV (%)	13.04	6.96	
LSD (0.05)	770.92	487.11	

* - Significantly different at p = 0.05
Means in the same column followed by same letters in a column are not significantly different at 5% level by DMRT.

T1 - Conventional tillage, no weeding, no mulch
T2 - Conventional tillage, weeding, no mulch
T3 - Furrow tillage, maize stover, intra-row
T4 - Furrow tillage, bean husks, intra-row weeding;
T5 - Furrow tillage, black polythene, intra-row weeding.

II. Pathological Parameters.

The mean number of plants per plot and the mean number of maize leaves per plant infected by _Excerohilum turcicim_ are presented in Tables 11 and 12, respectively. For the number of plants infected per plot, significant differences (p = 0.05) were recorded during the fourth and sixth weeks after maize emergence, thereafter the differences were insignificant. The maize stover treatment had the highest number of plants per plot infected with _E. turcicum_ upto eight weeks after emergence while bean husk and black polythene treatments equally had the least. Plots with maize stover attained 100% northern leaf blight infection after only six weeks compared to eight weeks for the other four treatments. Considering the mean number of infected maize leaves per plant (Table 12), it was observed that there were significant differences (p = 0.05) among the treatments from the fourth week to the eighth week after emergence. Maize stover treatment had the highest number of infected maize leaves per plant throughout the data collection period. The other four treatments equally had low numbers of infected leaves per plant.

Table 11

The Exserohilum turcicum incidence as influenced by organic mulching (number of plants infected/plot) short rains, 1989.

Treatment	WEEKS AFTER EMERGENCE						
	4	5	6	7	8	9	MEAN
T1	26c	56a	153ab	195b	204b	211ab	141
T2	20bc	50a	166b	197b	203b	213b	142
T3	80d	210a	210c	210c	210b	210a	188
T4	16a	44a	138a	138a	170a	211a	129
T5	12a	45a	147ab	147ab	184b	213b	133
Mean	31	81	163	191	202	212	147
calc	18.69*	62.10*	3.45*	2.73ns	1.20ns	1.08ns	
SE (Trt)	9.13	12.95	21.53	12.81	7.44	1.99	
CV(%)	42.32	22.65	18.74	9.48	5.21	1.33	
LSD (0.05)	19.45	27.61	45.88				

* Significant at p - 0.05; ns - not significant at p = 0.05; Means with the same letters in column not significantly at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

Table 12: The Number of Infected leaves per plant as influenced by Mulching - short rains, 1989.

Treatment	WEEKS AFTER EMERGENCE					
	4	5	6	7	8	MEAN
T1	1a	4b	4a	5a	6a	4
T2	1a	4b	4a	5a	8c	4
T3	4b	5c	6c	6b	9d	6
T4	1a	3a	4a	5a	6a	4
T5	1a	4b	4a	5a	7b	4
Mean	2	4	4	5	7	5
Fcalc.	121*	7.50*	35.67*	7.67*	7.03*	
SE	0.16	0.37	0.19	0.39	0.76	
CV(%)	14.43	13.77	6.37	11.07	15.77	
LSD(0.05)	0.34	0.78	0.41	0.83	1.63	

* - Significant at p = 0.05

Means in the same column followed by the same letters in a column are not significantly different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

The disease incidence data, measured in terms of the proportion of sampled maize leaves infected by E. turcicum, are given in Table 13. Highly significant differences (p = 0.05) among treatments were recorded from the fourth to the sixth week after emergence. Thereafter, the inter treatment differences became insignificant. The sampled leaves from the maize stover plots showed 100% infection by the sixth week whereas the other four treatments attained the same by the end of the eighth week.

Table 13 Proportion of sampled maize leaves infected with *Exserohilum turcicum* as influenced by mulching - short rains, 1989.

Treatment	WEEKS AFTER EMERGENCE				
	4	5	6	7	MEAN
T1	27.5a	45a	65a	82.5a	55.0
T2	37.5b	50a	80b	87.5ab	63.8
T3	90d	97.5b	100c	100c	96.9
T4	47.5c	55a	75b	90b	66.9
T5	40bc	55a	72.5ab	85ab	63.1
Mean	48.5	60.5	78.5	89	69.1
Fcalc.	14.66*	7.85*	5.42*	2.64ns	
SE	8.97	10.65	8.01	5.88	
CV(%)	26.15	24.89	14.43	9.34	
LSD (0.05)	19.11	22.69	17.07		

* - Significant at p = 0.05
ns - not significant at p = 0.05
Means in the same letters in a column are not statistically different at 5% level by DMRT.

T1 = Conventional tillage, no weeding, no mulch
T2 = Conventional tillage, weeding, no mulch
T3 = Furrow tillage, maize stover, intra-row weeding
T4 = Furrow tillage, bean husks, intra-row weeding
T5 = Furrow tillage, black polythene, intra-row weeding

III ECONOMIC ASPECTS

The labour requirements, cost of labour and mulching and returns (revenue) data are presented in Table 14. Highly significant (p = 0.01) differences among treatments were recorded for labour requirements. Conventional tillage with handweeding required 76 MDs, furrow-tillage with maize stover 26 MDs, furrow-tillage with bean husks 24 MDs and furrow-tillage with block polythene 18 MDs/ha in excess of labour required by the unweeded plots respectively. Bean husk plots gave the highest net revenue per unit man-day followed by maize stover conventional tillage with handweeding, unweeded plots and the block polythene plots had the least returns.

Table 14: **Economics of Organic Mulching**

Treatment	Labour Used MD	Total Cost (KSH)	Gross Revenue (KSH)	Net Revenue (KSH)	Net Revenue/Unit MD (SHS/MD)
T1	78a	3,252.60	8,096.80	4,844.05	62.10
T2	154d	6,421.80	17,496.70	11,074.85	71.90
T3	104c	4,336.80	13,813.30	9,476.50	91.10
T4	102c	4,253.40	15,593.30	11,339.90	111.15
T5	96b	20,103.20	16,390.00	-3,713.20	38.70
Mean	107				
Fcalc 312**					
SE	2.27				
CV(%) 3.0					
LSD (0.01)	4.83				

** Highly significant differences at p = 0.01

Means followed by the same letters in a column are not statistically different at 1% by DMRT.

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CHAPTER FIVE

DISCUSSION

I. Agronomic Aspects

Results show that organic mulching influences maize emergence and that inter-treatment differences were significant only during the long rains. The conventional hand-weeded treatment had consistently higher percent emergence compared to the other treatments during both seasons. This observation is attributable to tillage effects on crop emergence. Similar results have been reported by a number of workers. Their results indicate that seedlings emerged sooner in the conventional tillage than in the no tillage systems (Mock and Erbach, 1977; Aina, 1979; Michieka, 1985). Higher percent emergence was recorded during the short rains than the long rains. This could have been due to lack of adequate soil moisture at germination during the long rains (see Rainfall Data, Appendix 1).

The weed density and weed height results underscore the importance of organic mulching in suppressing and hence controlling weeds. Statistically significant differences were obtained during both seasons for the weed density and height except for the *Oxalis spp.* whose height differences were insignificant during the short rains. The weedy check had the highest density and the tallest weeds except for the *Oxalis spp*. This particular species was tallest in the conventional tillage but shortest in the weedy check. This implies that *Oxalis spp*. thrives best under continually disturbed environments but tends to be outcompeted in the less disturbed environments. The conventional treatment was superior in keeping down both the weed density and height. The mulch treatments (stover, bean husk, and black polythene) equally had low weed densities and short weeds. This signifies the importance of these organic mulches in suppressing the weed growth of annual weeds.

Generally, there were more weeds/m^2 and taller during the long rains compared to the short rains. This is explained by the lush growth of weeds encouraged by the heavy rains during the long rains as opposed to the short rains which lasted for a shorter period. Also the faster maize growth during the short rains meant that the weeds were outcompeted at an earlier stage and thereby smothered by maize shading effect. The weed density increased with time reaching peak six and eight weeks after emergence during the long rains and short rains, respectively. Hence, it appears that weed suppression was more effective during the short rains. Reported findings, elsewhere, indicate that mulching with crop residues significantly suppresses weed emergence and weed growth in the no-tillage plots. Also, that the effectiveness of a mulching material in controlling weeds is a factor of its rate of disintegration (Lal, 1974; Carter and Clarance, 1988; Creager, 1989). The black polythene mulch proved to be the most stable, followed by stover and bean husk mulches, respectively.

The maize heights data showed statistically significant differences with conventional hand-weeded treatment producing the tallest plants during the long rains. During the short rains, bean husk and black polythene treatments had the tallest plants. The weedy check had the shortest during both seasons at tasselling. This observation shows that weeds left to compete with the crop, throughout the season, can adversely affect crop growth. Weeds that sprout later in the season when the crop is already established offer relatively less competition. Maize plants, at tasselling, were almost twice as tall during the short rains as during the long rains. Also, the maize plants in the stover mulched plots grew very poorly during the long rains. This observation is attributed to the flooding of rain water around the crop plants. Akonaay and Mazige (1982) reported that maize is fairly drought tolerant during the first four or five weeks of its life. However, during this period it is susceptible to excessive amounts of water around the growing point, which at this stage is still at or close to the ground level. As organic mulching had excess of soil moisture or flooding during this stage, it could kill the plants or markedly reduce the grain yields. Lal (1974) reported that owing to the large quantity of undecomposed crop residues on the surface, it is possible that plants in the no-tillage treatments had also competed with micro-organisms for available nutrients. On the other hand, the weedy check had tall plants during the first six weeks after emergence, a fact attributed to the competitive attempt by the crop plant to avoid shading from light by weeds. Balah (1981) had similar results in beans. He observed that, if the bean plants were left to compete with weeds, the beans failed to have a concentrated growth which had serious consequences at the later stages.

Data on lodging indicate that weed competition and organic mulching significantly influenced the ability of maize plants to stand as at harvest. The weedy check had six times more plants lodged compared to the conventional hand-weeded treatment which had the least. This was due to the unconcentrated maize growth during the early stages which led to maize plants with weaker stems. This confirms Balah's (1981) findings, in beans, that unconcentrated early vegetative growth leads to serious consequences at the later stages. All the three no-tillage treatments had three times less plants lodged compared to the weedy check. Hence, organic mulches seemed to have reduced the competitive effects of weeds. The above mentioned lodging were at variance with that of Lal (1974). He reported that plants on ploughed plots lodged more than those on the no-tillage plots.

The percent plants harvested results show that organic mulching had a significant influence on plant stand and that the conventional hand-weeded treatment had more plants harvested compared to the no-tillage treatments during both seasons. Higher percent plants harvested were recorded during the short rains, an observation which could be explained by the fact that heavy rains enhanced lush weed growth at the expense of the crop and hence, not all crop plants survived upto the reproductive phase. Also weed suppression by organic mulches was more effective and hence more crop plants reached maturity during the short rains compared to the long rains. A number of scientists have reported similar results. Their results indicate that the final plant density was lower in the no-tillage systems (Mock and Erbach, 1977; Aina, 1979, Michieka 1985). Such results reflect on the effect of seedbed preparation and tillage on the final plant density. The very low percent plants harvested in the weedy check give the extent to which weed competition can be detrimental to the maize crop.

Results on the maize cob lengths, one thousand grain weights and grain yields point out the importance of weed competition and organic mulching in maize production. Differences between treatments were highly significant during the short rains. This corresponded well with the good vegetative growth during the short rains. Considering the grain weights, the grains were heavier during the long rains than during the short rains. This could be due to sufficient availability of soil moisture (or rainfall) during the grain filling period during the long rains (see rainfall data, Appendix 1). The weedy check had the lightest grains during both seasons, an observation explained by weed competition for available nutrients and water. Weeds tend to aggravate water shortage, a fact reflected in the very low weights (weedy check) during the short rains. Balah (1981) reported that there was more yield reduction, in beans, when moisture was limiting as this resulted in greater competition among the crop plants and between the crop and the weeds.

Hence, weeds that germinate with the crop and persist throughout the season considerably reduce the grain weights. Generally, there were higher grain yields during the short rains than long rains, an observation attributed to the high percent germination, the relatively good vegetative growth experienced due to the well spread rainfall during the growing phase of the crop and the high percent plants harvested. The conventional hand-weeded treatment proved superior to all during both seasons with the weedy check giving least returns. The overall mean grain yields were 3924 and 4643 kg/ha for the long and short rains, respectively. The conventional hand-weeded and black polythene treatments were equally good during the long rains. Aina (1979) reported that mulching resulted in more significant increases in crop yields. The fairly low yields obtained from the stover treatment may partly be due to the high incidence of Northern Corn Leaf Blight. This agrees with what Kruger (1984) reported on the effect of maize stalk rot on the yield of maize. He observed that in heavily infected plants, the yield was reduced to a relative value of 80, compared with 100 in the healthy plants.

The NCLB disease incidence data showed that the maize debris (stover) and weed infestation play important roles in the development and spread of the disease in the growing maize crop. There were significant differences, for the mean number of infected plants per plot, from the fourth to sixth week after crop emergence; thereafter the differences were insignificant. The maize stover treatment had the highest number of infected plants per plot upto the eighth week while the bean husk and black polythene treatments had the least. The stover mulched plots attained 100% NCLB incidence after only six weeks compared to eight weeks for the other treatments. Thus, the stover seemed to have served as a source of inoculum for E. turcicum and hence the higher incidence levels during the early growth period. Later in the season, the disease stabilized in all the treatments. The weedy check had fairly low incidence levels implying that weeds impeded the rate of disease spread during the early growth stages. The mean number of infected maize leaves per plant showed significant differences upto eight weeks, with stover treatment having highest number throughout the data collection period. All the other four treatments had low numbers of infected maize leaves per plant which underscores the importance of maize stover on the development and spread of the disease. Hence, the use of stover as a mulching material in maize crop, can lead to serious disease problems.

The proportion of sampled maize leaves infected showed highly significant differences from the fourth - sixth week after crop emergence. Thereafter, the differences became insignificant. The sampled leaves from the stover plots showed 100% infection at the end of the sixth week while the other treatments attained the same level by the end of the eighth week. The observed results, on incidence of NCLB, do agree with those obtained elsewhere. Lipps (1988) reported that surface maize residues are an important source of inoculum for the anthracnose leaf blight and the rate of disease spread may depend on the orientation of maize rows in relation to inoculum source and cropping history of the field. Summer and Litterel (1974) observed that corn debris is instrumental in development of NCLB epidemics. Shipton (1979) in his work observed that the preservation of crop residues increases the pathogenic inoculum on the surface or in the surface layer of the soil.

Results show that organic mulching highly reduced (p = 0.01) the labour requirements in maize production. Total labour requirements was cutdown by 32.5, 33.8 and 37.7% for furrow-tillage with maize stover, furrow tillage with bean husks, and furrow-tillage with black polythene, respectively compared to conventional tillage with handweeding. This observation is attributable to the fact that furrow-tillage with organic mulching reduces tillage to a minimum and hence cuts down labour required for land preparation by about 50%.

In terms of revenue per unit man-day used, furrow-tillage with bean husks gave Kshs. 111.15, followed by furrow tillage with maize stover with Kshs. 91.10, conventional tillage with handweeding with Kshs. 71.90, unweeded check with Kshs. 62.10 and furrow-tillage with black polythene gave Kshs. -38.70. Hence, the revenue accruing from black polythene treatment did not cover its cost and cost of application, with the total cost surpassing the gross revenue by Kshs. 4,323.90. It, therefore pays to input an additional man-day in maize stover and bean husks mulched plots. Use of organic mulches (the maize stover and bean husks) would enable a farmer to reduce his labour requirements by about 30% and hence, release part of his available labour to other competing enterprises on the farm during peak labour demand.

CONCLUSIONS

It can be concluded from this study that furrow-tillage plus organic mulches had no significant effect on maize emergence and compares favourably well with conventional tillage. Although flooding occurred around crop plants in the mulched plots, the maize grew faster during the short rains compared to the long rains. Maize stover and black polythene mulches caused more flooding than the bean husks.

The three organic mulches were more effective in controlling weeds than conventional tillage with hand weeding during the long rains. However, the conventional tillage with hand-weeding proved superior to all during the short rains. Black polythene maintained a lower weed density than the maize stover and bean husk mulches during both seasons. The stover and bean husk mulches were equally effective and more efficient in controlling weeds during the short rains when there was less rainfall compared to the long rains. However, the bean husk had a better control than maize stover during the long rains. Hence, crop residues, which are available in plenty, play a significant role in suppressing emergence and growth of annual weed species.

Maize plants were taller during the short rains after attaining their genetic potential height compared to the long rains when they experienced growth retardation due to excessive soil moisture. The maize stover reduced maize height during both seasons. However, bean husks, black polythene and conventional tillage with hand weeding compared favourably well during both seasons. Organic mulching significantly improved crop height during the short rains, due to excellent weed suppression during this period. Crop stand was drastically reduced in the mulched plots during the long rains due to inadequate moisture at germination and excessive moisture during crop growth. Maize stover had a poorer stand than the other two mulches during the long rains. All the treatments, except the unweeded check, had no significant effects on crop stand during the short rains. Hence, tillage effects on crop stand were more pronounced during the long rains than the short rains.

There were more plants lodged in the furrow-tillage plots plus organic mulches than in the conventional tillage plots. The unweeded check had the highest number of plants lodged, an indication that lodging is a function of tillage and weed competition. Weeds, left to grow with the crop unchecked, cause unconcentrated crop growth resulting in plants with weak stems.

/ The cob length, grain weights and grain yields were lowest in the unweeded check during both seasons, indicating the sensitivity of these parameters to weed competition. Although maize cobs were longer during the short rains compared to the long rains, the treatments had no significant effects on the cob length during the long rains./ Furrow-tillage with organic mulches produced heavier grains and higher yields as compared to those in the conventional tillage during both seasons, indicating that organic mulching reduces crop-weed competition, maintains high levels of soil organic matter, total nitrogen and exchangeable bases (See Appendix 2) and conserves moisture during periods of drought stress. Bean husks proved superior to stover with an overall mean yield of 4678 and 4144 kg/ha, respectively. Hence, bean husks should be preferred as a mulching material to maize stover.

The northern corn leaf blight (NCLB) incidence was much lower in all the treatments, except stover, during the early stages of crop growth. The plants in the stover plots attained 100% infection level as early as six weeks after emergence for the other treatments, a confirmation that maize stover acted as a source of inoculum for the *Exserohilum turcicum* resulting in the higher incidence levels during early growth period. Also weeds appear to have impeded the rate of disease spread during the same growth period. Hence, maize stover and weed infestation seemed to play an important role in the development and spread of NCLB disease in a maize crop. However, yield parameters did not show sensitivity to disease incidence levels.

It can be concluded that maize stover and bean husks have the potential of replacing the effective but unpopular black polythene mulch. However, bean husks prove superior and have no "carry-over" disease effect. Use of stover and bean husk mulches would enable a farmer to reduce his labour constraint by about 30% and hence release part of his available labour to other competing enterprises on the farm during peak labour demand.

SUMMARY

Minimum tillage trials and the use of mulches are now recognized crop production systems in parts of the country. The current research has strengthened the belief that farmers can indeed grow crops under less disturbed soils, and utilize their farm mulches for soil erosion control, weed control and as soil stabilizers.

FUTURE SCOPE OF RESEARCH

1. Future investigations are needed to establish the right time, amount and method of mulch application that offers the farmer efficient and economical weed control in maize.

2. More research efforts are required to develop any possible pathological measures to reduce the "pathogen carry-over effect" of maize stover on the succeeding maize crop.

3. Investigations should be made to come up with the organic mulching-tillage mix that minimises flooding but maximises crop yields.

4. The disease severity & yield + components correlation in maize should be investigated.

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APPENDIX 1: CLIMATIC DATA

	LONG RAINS - 1989						SHORT RAINS - 1989-90.						
	Mid-Apr	May	Jun	Jul	Aug	Sep	20 Oct	28 Oct	Nov.	Dec.	Jan	Feb	MAR
Rainfall (mm)	98.9	496.8	27.5	44.2	25.2	91.1	8.6	69.7	102.9	186.0	51.6	47.8	199
Mean Max Temp (^{o}C)	22.0	22.0	20.8	20.0	19.9	22.6	22.7	22.7	21.8	22.7	23.0	24.9	23.
Mean Min. Temp (^{o}C)	13.8	13.6	12.3	11.2	11.2	12.0	13.1	13.1	13.6	13.8	12.0	14.0	14

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APPENDIX 2: SOIL ANALYSIS (0 - 30 CM) DATA,

TREATMENT	pH	Na me%	K me%	Ca me%
1. Conventional tillage, no weeding,no mulch	5.80	0.53	0.96	7.95
2. Conventional tillage, weeding, no mulch.	5.73	0.54	0.97	8.40
3. Furrow till,maize stover, intra-row weeding.	5.75	0.54	0.99	8.15
4. Furrow till, bean husks, intra-row weeding.	5.93	0.62	1.08	8.30
5. Furrow till, black polythene, intra-row weeding.	5.83	0.55	1.11	7.80

SHORT RAINS, 1989.

Mg me%	Mn me%	P ppm	N %
2.50	0.50	20.25	0.18
2.33	0.55	14.00	0.21
2.50	0.48	11.75	0.18
2.78	0.56	13.75	0.18
2.68	0.55	14.00	0.17