THE EFFECT OF TILLAGE METHODS AND SUBSEQUENT WEED CONTROL ON MAIZE (*Zea mays* L.)

By

MICHAEL NJOROGE NGUGI

Thesis submitted in part fulfilment for the degree of
MASTER OF SCIENCE IN AGRONOMY
in the
UNIVERSITY OF NAIROBI

Nairobi

1987.

DECLARATION

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

Date 11/6/87 Name MICHAEL N. NGUGI

Signature [signature]

This thesis has been submitted for examination with my approval as the University supervisor.

Date 12·6·87 Name RATEMO W. MICHIEKA

Signature [signature]

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Two minimum tillage methods (strip and spot) each with three weed control methods were evaluated and compared with a conventional tillage method for maize (Zea mays L.) production. During a relatively dry season (short rains of 1984), grain yield differences were not significant between tillage treatments although minimum tillage had slightly higher yields than conventional tillage. Percent seed germination was slightly less under minimum tillage than under conventional tillage. However, there was more rodent damage on the seed under conventional tillage resulting in no plant population differences between the tillage methods.

During a relatively wet season (long rains of 1985), plant vigour was significantly different between the two tillage methods. Conventional tillage maize was significantly taller and gave higher yields than minimum tillage although the differences were small. There was a higher incidence of stem rots under minimum tillage especially where paraquat was applied. More plants lodged under minimum tillage.

Soil organic carbon and phosphorus increased during both seasons, but slightly more under minimum tillage. Nitrogen level did not change. All the exchangeable cations Ca^{2+}, Mg^{2+}, and Mn^{2+} increased.

Intra-row weeding had little effect on maize growth, but intra-row weeding had a significant effect on all growth and yield components.

providing literature materials. Sincere appreciation goes to Mr. D.T. Kirubi for his moral support and encouragement.

Finally I owe special thanks to my dear Eunice Wanjiru and our children for their tender love and patience during the "difficult" period and Mrs Jane Njeri Mbugua for typing the thesis.

INTRODUCTION

Maize (Zea mays L.) is one of the most important food crops in Kenya. Over 80% of the human population depends on this grain as the staple food. It is grown widely throughout the country both in small holdings and large scale farms. Seed bed preparation and subsequent weed control are some of the major limitations in the growing of all annual crops. This is more pronounced in small scale agriculture where inadequate capital and hence inadequate mechanization prevail. Unfortunately this group of farmers constitute the bulk of the farming community all over Kenya.

The majority of small scale farmers use traditional methods of seed bed preparation and weed control. Traditional methods involve the use of simple hand tools making them labour demanding. A major reason for the inefficiency of traditional farming is that early weeding is often delayed due to labour pressure at the beginning of the rainy season when land preparation and planting are also competing for the farmers available labour.

It is often undesirable to take a full course of tillage operations especially on steep slopes, highly erodable soils and in areas with low rainfall. Reduced tillage, sometimes referred to as minimum tillage techniques combined with effective herbicides can save time and use less labour than existing techniques.

Minimum tillage methods would enable fertility restoration while also reducing soil erosion by surface runoff and rain drop detachment. Other benefits of minimum tillage include conservation and better utilization of soil moisture. Reduced soil disturbance and presence of mulch improves infiltration rate and reduce surface loss through evaporation.

Perhaps an even greater attribute of minimum tillage techniques is the ability of obtaining comparable or even higher yields than conventional methods. Thus minimum tillage has great potentials considering all the foregoing benefits and hence growing of maize of possibly lower costs. These techniques would enable maize production in dry areas at reduced risks of crop failure.

The increase in population pressure is forcing farmers to move into even drier and steeply sloped land. The Kenya Government in one of its strategies of increasing food production has emphasized on the need for more research in the area of minimum tillage. This would enable the farmers to avoid the effect of late planting on maize yield and thus evade the vicious cycle of food uncertainty and poverty.

The major objective of this study was to investigate the feasibility of minimum tillage and subsequent weed control methods in maize production in a medium potential area of Kenya. The feasibility will be judged on the ability of these techniques to sustain high yields of maize at reduced costs and reduced risks. This is in consideration of the current lack of progress in the development of better weed management systems. There has often been a gross under-estimation of the fragile nature of the labour force in tropical regions.

The other important objective was to determine the effectiveness of minimum tillage on maize yields without the need for extra investment on specialized tools. This is in view of the fact that minimum tillage techniques often dictate the use of specialized tools.

Another objective was to investigate the potential for soil moisture retention and availability during a crop cycle. This is important in regard to shortage of rain that is often experienced in medium and low potential areas of Kenya.

Along with these objectives, the trials were aimed at establishing the best weed control method under minimum tillage. Weed control should be an integral part of any good crop management system.

Lastly, the experiments were designed to establish the problems likely to be associated with minimum tillage in this region. These include new or increased perennial weeds problem, pest and disease incidence.

LITERATURE REVIEW

Moisture Conservation. There is good potential for moisture conservation and increased yields due to reduced evaporation and surface run-off resulting from minimum tillage techniques. Long term studies done in Western Iowa, USA by Miller and Shrader (1976) indicate that average maize yields are increased by any practice that increases available soil moisture. Soil moisture conserved by the dead mulch in the later part of the growing season contributed to higher grain yields in Virginia, USA. Jones *et. al*. (1968). Work done in Tanzania by Ley and Semoka (unpublished) indicate that roots were more vigorous under minimum tillage. The results were attributed to higher soil moisture content resulting in greater concentration and uptake of nutrients. This supports earlier work done in Kentucky, USA by Blevins et. al. (1971). They recorded higher volumetric moisture contents to a depth of 60 cm during most of the growing season compared to conventional ploughing methods.

Experiments conducted at the International Institute for Tropical Agriculture, Nigeria (IITA) have shown the superiority of minimum tillage methods in conditions of drought compared to conventional methods, (Maurya and Lal, 1980). The authors found that maize produced slightly less grain in a good rainy season, but more in a season with prolonged drought under minimum tillage compared to yields under conventional ploughing. This agrees with earlier work done by Legg et. al. (1979), in Western Virginia, USA. Maize yields were higher under reduced tillage during a two year study when rainfall was low, but not different in two years of heavy rainfall. During the two dry years 1974 and 1976 available water was consistently higher in the upper 30 cm of soil under reduced tillage than under conventional tillage.

Minimum tillage can also reduce irrigation water requirement. Reddy and Hukkeri (1983), working in Andhra Pradesh, India noted that irrigation water requirement decreased from 2295 mm under ordinary ploughing to 1350 mm under reduced tillage. This agreed with previous work of this kind by Wilson et. al. (1982), in Nigeria which laid emphasis on the more favourable water regimes under reduced tillage.

The major attribute of favourable moisture regimes under reduced tillage is the presence of soil cover from both crop and weed residues. This favours infiltration Lal et. al. (1978), reduces evaporation Blevins et. al. (1971), and increases soil moisture retention, (Batchelder and Jones (1976). Lal et. al. (1978) in IITA Nigeria recorded higher mean saturated hydraulic conductivity under minimum tillage (7.1 cm Min^{-1}) compared to conventional tillage (6.1 cm Min^{-1}). The improved hydraulic conductivity can be attributed to improved soil structure, better pore continuity and increased earthworm activity, Blevins et al. (1983). Triplett, et. al. (1968) working in Ohio, USA noted increased infiltration rate and total infiltration and consequently higher yields in maize grown under mulch.

Earlier work in the Great Plains, USA has shown that maintaining surface residues with stubble mulch tillage or chemical weed control significantly improves moisture conditions in the soil and markedly reduces surface crusting, Army et. al. (1961). Estes (1972) working in the

North East USA, argued that acceptance of the minimum tillage system by farmers is increasing due to reduced labour costs, improved soil and water conservation and frequently higher yields than conventional tillage. Michieka (1985) working in low, medium and high potential areas of Kenya noted crop failures in farmers fields due to drought while his adjacent maize crop under minimum tillage gave optimum yields. He concluded that available moisture was better utilized under minimum tillage than under conventional tillage. Earlier work by Unger (1977) in Texas, USA showed similar results.

From the foregoing literature review on moisture retention, it is evident that minimum tillage techniques are more suitable in dry areas or during dry seasons than conventional tillage. Lal (1976) in his conclusion noted that during periods of drought stress, minimum tillage maize may yield higher than that grown with conventional tillage.

Soil Temperature: The other attribute of minimum tillage is reduced soil temperature (Allmaras *et. al*., 1964, Lal, 1974). Lal (1974), working at

IITA, Nigeria recorded significantly lower soil temperatures to a depth of 20 cm under minimum tillage than under conventional tillage. On sunny days the differences in maximum soil temperatures were as high as 9.8°C and 4.2°C at depths of 5 and 20 cm respectively.

Lower soil temperatures are undoubtedly beneficial to crop growth in dry areas or in a dry season. This temperature drop, however, may have a negative attribute to crop growth in cold regions as noted by Allmaras, et. al (1964) and Moody et. al. (1963) working in Iowa and Virginia, USA respectively. Soils under minimum tillage had more available water which reduced soil temperatures and consequently reduced early crop growth. Working in USA, Parker and Larson (1962) observed lower soil temperatures where plant residues were left on the surface. The lower temperatures favoured nitrification. Later work in Punjab, India (Choudhary and Prihar, 1974), showed temperature drops of 2.6°C to 6.3°C under plant residues. They noted that this led to greater root growth and lateral spread. Similar results were obtained in Georgia, USA by Adams et al.(1970). As early as 1963, Kohnke and Werkhoven working in Indiana, USA, had noted significant drops of temperature by 2.2^{o}C under plant residues. Extensive research done at IITA, Nigeria indicate that the insulating effect of crop residues causes an increase in soil moisture and a drop in soil temperature under drought conditions, Anon (1983).

The foregoing review reveals that soils under minimum tillage systems have lower maximum and higher minimum temperatures with a pronounced shift compared with tilled soils. The magnitude of the differences in soil temperatures due to tillage depend on the quantity of crop residue, Lal (1983).

Conventional tillage however, plays an important role in soil temperature and aeration. Thus both conventional and minimum tillage systems are suitable options depending on the existing soil and weather conditions. Regions characterized by heavy rainfall and/or heavy expanding clays are more suited to the conventional tillage systems. These may require frequent soil turning to improve on aeration and temperature for faster initial growth.

Soil Physical and Chemical Characteristics: At IITA, Nigeria Lal *et al*. (1978) found increased soil organic matter, higher total nitrogen and a higher cation exchange capacity under reduced tillage. Soil physical properties were also favourably influenced. Similar findings have been recorded elsewhere (Moschler *et*. *al*., 1972, Wilson *et*. *al*., 1982, Blevins *et*. *al*., 1983). Reduced tillage in Kentucky, USA had no effect on soil bulk density, Blevins *et*. *al*. (1983). There was better continuity and increased earthworm activity in addition to significantly higher total Nitrogen and organic carbon compared to conventionally tilled plots. In the same year, Anon, (1983) identical results were obtained under tropical conditions in Nigeria.

Research done in the USA (Estes, 1972, Moschler *et*. *al*. (1972) has shown that higher yields are attributed to greater nutrient availability. Leaf tissue analysis showed more Nitrogen, Phosphorus, Potassium and Calcium under reduced tillage while soil analysis also showed more nutrients under reduced tillage. This indicates that reduced tillage systems are more efficient in nutrient uptake and also aids nutrients accumulation. Estes (1972) noted reduced nutrient utilization by maize under minimum tillage although yields were comparable to conventional tillage. He concluded that this is of particular importance if the tillage system is used over an extended period of time without ploughing.

Baeumer and Bakermans (1977), reviewing tillage research in USA, reported that one of the major causes of decreased land productivity is the continuous removal of the fertile top soil by erosion. It has been realized that there is need to restore soil fertility through suitable cultivation methods (La, 1976, Wilson et. al. 1982). Fertility restoration through fallow is no longer feasible due to increased population pressure. In Kenya, Anon. (1981) the expansion of production has been achieved at the expense of widespread soil erosion, depletion of the nutrient content of the soil and the destruction of indigenous forests. Documented evidence, Wilson et. al. (1982) show that farmers can grow crops while partly leaving the land fallow. Using strip tillage, there was

Akobundu (1979).

Under certain conditions, minimum tillage systems may not give optimum results thus making it necessary to use conventional tillage systems. These conditions may include presence of hard pans and or some rhizomatous perennial weeds.

Crop Performance. Many researchers (Lal, 1974, Miller and Shrader, 1974; Estes, 1972) have shown that comparable and even greater yields are obtained under minimum tillage compared to conventional tillage. Lal (1974) found that tillage method did not influence plant height and did not significantly affect grain yield. Surface residues from the previous crop left under minimum tillage methods led to increased growth rate of maize and sorghum and also affected morphological development, Bond and Willis (1971).

Work done in Virginia, USA, Jones *et. al*. (1968) indicates that plant growth and yield of maize generally increased with decreasing degrees of tillage in a two year study. Yields from minimum tillage were comparable and even higher by 18 - 39% above those from conventional tillage. Work done in West Virginia, USA, Legg et. al. (1979) has shown that minimum tillage had higher yields during a two year study period when rainfall was scarce but no difference in two years of heavy rainfall. This supports similar results obtained in Iowa, USA, Amemiya (1968). He noted that in dry years, minimum tillage maize outyielded conventionally planted maize. Maize produced higher grain yields under a minimum tillage system in three different soil types in Virginia USA, Moschler et. al. (1972).

Michieka (1985) working in Central and Eastern Kenya recorded comparable maize yields across three agro-ecological zones under conventional, furrows and spot tillage. Njogu (1981) had also observed similar results in Western Kenya. Work in Ibadan, Nigeria showed that in a good rainy season, maize produced slightly less grain but more in a season with prolonged dry spells under minimum tillage compared to yields under conventional ploughing, Maurya and Lal (1980).

During a six-year study period in Virginia, USA, Jones et. al. (1968) found greater or comparable grain yields under minimum tillage in five years. Plant heights in the six-year period indicated that zero tillage systems provided a rooting media which contributed to greater plant growth. Soil moisture conserved by the dead mulch in the later part of the growing season contributed to higher grain yield. In dry years, grain yield was higher by as much as 1374 kg per hectare under minimum tillage.

In Western Illinois, USA, Fink and Wesley (1974) working on reduced tillage systems concluded that with proper cultural practices it is possible to obtain satisfactory maize yields using reduced tillage systems. Research in the USA corn belt, Stougaard et. al. (1984) indicates that reduced tillage systems, since inception, have frequently produced results comparable to those achieved with conventional tillage with the added advantage of reduced soil erosion and operating costs.

Long term studies indicate that average maize yields are increased by any practice that increases available soil moisture, Miller and Shrader (1974). Moody et. al. (1963) in Virginia noted significant increase in growth over mulched maize due to greater soil moisture. Later in Ohio, USA, Triplett (1966) found that moisture stress and hence yield was related to the type of tillage. Minimum tillage systems led to low moisture stress and higher maize yields. Treatments with higher mulch cover had more vigorous plants and gave higher yields possibly due to increasing moisture conservation, Triplett et. al. (1968).

Choudhary and Prihar (1974) in India noted reduced moisture loss which led to greater root growth, better plant growth and higher yields. Ley and Semoka (unpublished), while working on the effect of tillage on maize in Tanzania noted more vigorous shoot and root development under minimum tillage during the first weeks of growth than under conventional tillage. This was attributed to greater moisture content resulting in greater concentration and uptake of nutrients.

Moschler et. al. (1972) working in Virginia USA, found higher yields of maize under minimum tillage than under conventional tillage. Tissue analysis showed more nutrients in minimum tillage plants, but soil analysis still showed more nutrients in minimum tillage plots than under conventional tillage. In the same year, Estes (1972) recorded reduced utilization of nutrients although yields were comparable to conventional tillage. Lime application in zero tillage plots resulted in significantly higher grain yields than in conventional tillage, Blevins _et. al_. (1978).

M'Arimi (1977) working in Machakos, Kenya, found that minimum tillage gave significantly higher dry matter yields than under ploughing. Later, Wood and Dadd (1981) working in Narok, Kenya concluded that one of the advantages of reduced tillage over conventional tillage is the frequently higher yields achieved and reduced costs. Agboola (1981) working in Nigeria drew similar conclusions.

Weed Control. An effective weed control method is an integral part of a good crop management. Godfrey-Sam-Aggrey (1978) working in Sierra-Leone found highly significant differences between various weeding intervals and non-weeding. Reduced weeding and reduced frequency of weeding with resultant increase in the amount of weed growth decreases all yield components. Guleria and Singh (1980) reported similar results while working on weed and fertility management in rainfed maize at Palampur, India. Control of weeds by either hand or chemical resulted in significantly higher yields compared to the non-weeded controls. Chemical control (alachlor) gave the highest economic returns while fertility level had no significant effect on weed population or dry matter.

Reviewing weed control in Nigeria, Akobundu (1979) concluded that hoe weeding is the most popular method of weed control. Hoe weeding however, relies on the abundance and availability of cheap labour. Due to rural-urban migration, labour for hand weeding is often scarce and when available it is too expensive for the average farmer.

Ndahi (1982) while evaluating glyphosate and paraquat as tillage substitutes in Nigeria concluded that application of effective herbicides that could kill established weeds at planting time would be more labour effective for farmers forced to adopt minimum tillage practices than seedbed preparation using a hoe.

Vernon and Parker (1983) working in Chilanga, Zambia, estimated that 42% of the total cost of crop protection is due to weeds in tropical regions. Weed control is thus the most important and perhaps the most expensive post-emergence operation.

The foregoing review indicates the major advantages associated with minimum tillage. The frequently higher yields over conventional tillage and reduced risks of crop failure under water stress strengthens the great potential for this system in the medium to low potential areas of Kenya and other tropical regions. These regions are characterized by low and often unreliable rainfall which is the major cause of crop failures.

Farmers in these regions often lack adequate capital which would otherwise help them to mechanize their farms. This has led to poorly and untimely prepared seed-beds. As a result, low yields are frequently obtained forcing the farmers into the vicious circle of poverty and despair.

Farmers in these regions thus require an agronomic package that would enable them to produce higher yields. The package should however not involve expensive investments as most of these farmers are subsistence. The minimum tillage system, if well investigated, can be one of the major steps to increase yields. Thus more research is needed in these tropical regions which would give a complete and cheap package to peasant farmers. Research work done in these regions has not developed a complete package directed to this group of farmers. Most of the research work lays extra emphasis on the use of expensive herbicides and specialized tools.

MATERIALS AND METHODS

The experiments were conducted at the Embu Agricultural Research station, Eastern Kenya located 0^{o} 30'S and 37^{o} 27' E at an altitude of 1460M above sea level.

The trials were laid down on a gently sloping ground (3%) that had maize (Zea mays L.) previously. The field was under an established pasture of Rhodes grass (Chloris gayana) upto 1982.

The soils which are predominantly clay are described as well drained very deep, dark reddish brown derived from Mt. Kenya phonolytes (Kenytes). These are classified as eutric Nitosols (FAO/UNESCO), Shitakha (1984).

Soil analysis indicate that prior to trial initiation, soil reaction was moderately to strongly acidic (pH 4.8 - 5.5). Available phosphorus was very low (5-11 parts per million). Perhaps due to the low pH. Nitrogen level was low (0.28%), but organic carbon was ranging from 0.97 - 2.28%.

The mean annual rainfall is about 1080 mm. There are two rainy seasons and two dry seasons. The long rains occur between March and May while the short rains occur from October to December. The dry periods occur during January to February and June to September. A summary of the weather conditions during the trials are shown in Appendix 1.

For both seasons, maize hybrid 512 was used at the rate of 25 kg seed per hectare. Both Nitrogen and P_2O_5 were supplied at the recommended rate of 50 kg per hectare using a compound fertilizer N.P.K. (20:20:0) at the rate of 250 kg per hectare. Table 1 shows the field trial treatments during the two seasons of experimentation

Conventional Tillage. Conventional tillage is used here to designate the traditional tillage system which typically begins with a primary tillage operation which is often followed by some secondary tillage for seedbed preparation. The basic objectives of this tillage are to provide a suitable seedbed capable of rapid seed germination and weed free for optimum crop growth. Conventional tillage involves moving and turning the soil in the whole area to be planted.

In this experiment, conventional tillage was

Table 1: Field Trial Treatments

A.	Conventional tillage, hand weeding
B.	Conventional tillage, Primagram (Pre-emergence)
C.	Strip tillage, Paraquat + intra-row weeding
D.	Strip tillage, slashing + intra-row weeding
E.	Strip tillage, intra-row weeding
F.	Spot tillage, Paraquat + intra-row weeding
G.	Spot tillage, slashing + intra-row weeding
H.	Spot tillage, intra-row weeding
I.	Conventional tillage, no weeding (check)
J.	Strip tillage, no weeding (check)
K.	Spot tillage, no weeding (check)

used to denote the commonest form of land preparation in Central Kenya.

The seedbed was prepared using simple hand tools, the hoe This was made easier by first slashing the previous seasons' weeds. A typical seedbed with small clods and a rough surface was produced. Plant residues were also removed from the plots to facilitate digging and planting.

Strip Tillage. This was one of the minimum tillage methods used in the experiment. Narrow strips of approximately 20 cm wide were cut along the planting rows. The hand hoe was used as the basic tool. The spaces between the rows were not disturbed thus leaving plant residues from the previous season on the surface.

Spot Tillage. This was the other form of minimum tillage. The only primary tillage was digging planting holes for seed placement. The holes were measuring about 10 by 10 cm and were made by using small hand tools namely, hoof weeders. The spaces between the rows were left undisturbed as in strip tillage.

Weed Control. The three tillage methods were subjected to several weed control techniques. Under conventional tillage, some plots were hand weeded using the hand hoe. The first weeding was done twenty days after crop emergence. This is the recommended time for maize since the competitive effect of weeds is greatest during the third week of growth. The second hand weeding was done just before maize flowering.

Under conventional, some plots were sprayed with an Atrazine/Metolachlor mixture (Primagram), (Atrazine: 2-chloro-4-ethylamino-6-isopropyl amino -1, 3 s-triazine), (Metolachlor: 2-ethyl-6-Methyl-N-2-Methoxy-1-Methyl-α-chloro acetanilide). This is a selective herbicide in maize capable of controlling both grasses and broad leaf weed species. It was sprayed at the rate of 2.5 kg active ingradient per hectare in the relevant plots. In both seasons, the herbicide was sprayed before crop emergence.

Under both minimum tillage methods (strip and spot), some plots were hand weeded along the rows (intra-row). Hand hoes were used and the weedings were done two times at the same time as in the conventional tillage.

Paraquat (Gramoxone) (1,1'dimethyl-4,4'-bipyridinium ion) was sprayed to the relevant plots under spot and strip tillage at the rate of 0.5 kg active ingredient per hectare. This contact non-selective herbicide was sprayed four weeks after crop emergence. It was applied along the inter-row spaces. A protective shield was attached to the sprayer boom to direct the spray and thus avoid injury to the maize plants.

Slashing of weeds in the relevant plots was done using a Machette (panga). Slashing was done between the maize rows five weeks after emergence. Each of the three tillage treatments had non-weeded controls as checks.

Each plot was measuring 6 by 3.75 metres with six maize rows spaced at 75 by 30 cm. The harvest plot measured 5.5 m by 3.0 m with four rows of maize.

The design was a completely randomized block with four replications per treatment.

Data Collected. Soil samples were taken from each treatment at the beginning and at the end of each experiment. All the soil samples were analysed for organic Carbon, Nitrogen, Phosphorus, pH and all exchangeable cations. This was to help in determining whether there was a change over time in the level of nutrients due to tillage treatments.

Other parameters measured included germination percentage, disease and pest incidence, lodged plants, usable ears, harvest weight and grain weight per plot. Plant height after physiological maturity, stem rots and diseased ears (cob rots), were recorded for long rains of 1985 only. Stalk borer incidence (*Buseola fusca*) was recorded for short rains of 1984 only, since there was no incidence in 1985.

All the data collected were subjected to the analysis of variance and other statistical tests in accordance with procedures proposed by Snedecor and Cochran (1967) and Steel and Torrie (1980).

RESULTS

Stand Count. The number of maize plants per plot computed as a percentage of the expected number of plants are shown on Table 2. Tillage method and weed control method had no significant effect on plant population during the short rains of 1984. Under all the three tillage methods the non-weeded controls had the lowest maize plant population.

During the long rains of 1985, tillage and weed control had significant (P = 0.05) effect on maize population. Conventional tillage had the highest percent plant stand (90.1%) followed by strip tillage (86.9%) and spot tillage (84.4%). Although the differences were small, intra-row weeding had higher maize population than the non-weeded controls. Inter-row weeding had little effect on maize population. Under conventional tillage, hand weeding gave a higher population than chemical weed control.

Lodged Plants. Table 3 shows the percent number of lodged plants as affected by tillage method

Table 2: Stand Count as a Percentage of the Expected Number of Plants per Plot

	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	76.1	91.0
B. Conventional tillage, Primagram	66.8	89.2
C. Strip tillage, Paraquat + intra-row weeding	58.5	80.2
D. Strip tillage, slashing + intra-row weeding	71.6	96.4
E. Strip tillage, intra-row weeding	70.0	84.1
F. Spot tillage, Paraquat + intra-row weeding	69.3	85.6
G. Spot tillage, slashing + intra-row weeding	70.7	84.7
H. Spot tillage, intra-row weeding	67.6	82.9
I. Conventional tillage, no weeding (check)	57.1	82.3
J. Strip tillage, no weeding (check)	57.4	81.5
K. Spot tillage, no weeding (check)	50.3	61.3
CV %	13.09	5.52
SE (Treats)	0.49	0.27
LSD (0.05)	- NS	0.77 **

NS = Not significant ** = Significant at 1%

Table 3: Percent Lodged Plants as Affected by Tillage and Weed Control

	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	14.9	7.7
B. Conventional tillage, Primagram	17.0	7.1
C. Strip tillage, Paraquat + intra-row weeding	30.6	24.0
D. Strip tillage, slashing + intra-row weeding	25.8	20.6
E. Strip tillage, intra-row weeding	30.1	14.2
F. Spot tillage, Paraquat + intra-row weeding	18.9	19.5
G. Spot tillage, slashing + intra-row weeding	18.5	18.9
H. Spot tillage, intra-row weeding	18.1	17.8
I. Conventional tillage, no weeding (check)	24.4	26.0
J. Strip tillage, no weeding (check)	15.8	24.6
K. Spot tillage, no weeding (check)	7.9	24.3
CV %	33.39	25.92
SE (Treats)	0.53	0.50
LSD (0.05)	-	1.46
	NS	*

NS = Not significant * = Significant at 5%

and subsequent weed control method. During the short rains of 1984, both tillage and weed control method did not significantly affect maize plant lodging. Minimum tillage however, had slightly more lodged plants than conventional tillage. Under both minimum tillage methods, the non-weeded controls had fewer number of lodged plants.

During the long rains of 1985, there were significantly (P = 0.05) more lodged plants under strip tillage followed by spot tillage and lastly conventional tillage. Under all the three tillage methods, the non-weeded controls had the highest number of lodged plants. Under both minimum tillage methods, plots weeded using paraquat had slightly more lodged plants than slashing.

Stalk Borer Damage. The percent number of maize plants seriously damaged by stalk borer (*Buseola fusca*) are shown on Table 4. The results shown are for short rains of 1984 only since there was no stalk borer incidence during the long rains of 1985. Tillage and weed control method significantly (P = 0.05) affected the attack of maize plants by

Table 4. Percent Number of Plants Attacked by Stalk Borer (<u>Buseola</u> <u>fusca</u>)

	Short Rains 1984
A. Conventional tillage, hand weeding	31.3
B. Conventional tillage, Primagram	34.0
C. Strip tillage, Paraquat + intra-row weeding	24.3
D. Strip tillage, slashing + intra-row weeding	18.7
E. Strip tillage, intra-row weeding	24.0
F. Spot tillage, Paraquat + intra-row weeding	12.3
G. Spot tillage, slashing + intra-row	8.8
H. Spot tillage, intra-row weeding	16.8
I. Conventional tillage, no weeding (check)	15.4
J. Strip tillage, no weeding (check)	7.4
K. Spot tillage, no weeding (check)	6.2
CV %	31.35
SE (Treats)	0.47
LSD (0.05)	1.36 *

* = Significant at 5%

the stalk borers. Conventional tillage had the highest incidence (32.7%) compared to minimum tillage strip (22.3%) and spot (12.6%).

All the non-weeded controls under the three tillage methods had lower stalk borer incidences compared to weeded plots. Under conventional tillage, the non-weeded check had an incidence of 15.4% compared to the weeded plots (32.7%). Under both minimum tillage methods (strip and spot), Paraquat spraying resulted in slightly higher incidence than slashing.

Stem Rots. The effect of tillage and weed control method on the percent number of plants attacked by stem rots are shown on Table 5. There were no stem rots during the long rains of 1985. Tillage and weed control method significantly ($P = 0.05$) affected the incidence of stem rots. Under both minimum tillage methods paraquat spraying resulted in the highest incidence of stem rots compared to slashing. All the plots with no inter-row weeding gave the lowest incidence of stem rots.

Table 5. Percent Number of Plants Affected by Stem Rots.

		Long Rains 1985
A.	Conventional tillage, hand weeding	3.7
B.	Conventional tillage, Primagram	4.5
C.	Strip tillage, Paraquat + intra-row weeding	6.0
D.	Strip tillage, slashing + intra-row weeding	3.5
E.	Strip tillage, intra-row weeding	1.9
F.	Spot tillage, Paraquat + intra-row weeding	6.1
G.	Spot tillage, slashing + intra-row weeding	3.7
H.	Spot tillage, intra-row weeding	2.7
I.	Conventional tillage, no weeding (check)	1.9
J.	Strip tillage, no weeding (check)	1.1
K.	Spot tillage, no weeding (check)	1.5
CV %		25.04
SE (Treats)		0.23
LSD (0.05)		0.66 **

** = Significant at 1%.

Soil Fertility. Table 6 shows the status of soil fertility at the beginning of the experiments. Prior to trial initiation, soil reaction was moderately to strongly acidic (pH 4.8 - 5.5) and had very low available phosphorus (6.6 parts per million). Organic carbon was fairly low (1.66%) while Nitrogen level ranged from 0.25 - 0.34%. The average level in milliequivalents for the other nutrients were; Sodium 0.22, Potassium 1.06, Calcium 4.5; Magnesium 4.8 and Manganese 0.6. This soil analysis indicates that soil fertility was fairly low at the beginning of the trials.

Table 7 shows the soil analysis report at the end of the first experiment. All the treatments show a soil reaction that is moderately acidic (pH 4.9 - 5.6). The lowest pH was recorded under conventional tillage after primagram spraying. The average level of sodium dropped compared to soil analysis before trial initiation. Minimum tillage (strips) had the lowest level. A similar

Table 6. Soil Analysis Report Prior to Trial Initiation, October, 1984*

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
pH	5.3	5.5	4.8	5.4	5.1
Na me%	0.15	0.33	0.17	0.15	0.31
K me%	0.97	2.35	0.63	0.79	0.57
Ca me%	4.5	4.8	3.3	5.5	4.5
Mg me%	5.7	5.7	3.4	4.9	4.5
Mn me%	1.33	0.41	0.72	0.15	0.41
P ppm	11	7	5	5	5
N%	0.27	0.34	0.26	0.27	0.25
C%	0.97	0.97	1.89	2.22	2.28

*Courtesy of National Agricultural Laboratories, Nairobi, Kenya.

Table 7. Soil Analysis Report at the end of the First Experiment. January,1985.

Treat-ment	pH	Na	K	Ca	Mg	Mn	Pppm	N%	C%
A	5.3	0.14	1.24	0.4	2.9	0.98	66	0.09	2.0
B	4.9	0.06	0.72	0.2	2.1	0.96	128	0.26	2.65
C	5.2	0.1	1.02	0.8	2.9	1.0	38	0.26	2.29
D	5.4	0.06	1.87	0.6	2.3	0.66	48	0.23	2.38
E	5.4	0.05	1.18	0.8	2.9	0.86	60	0.28	2.29
F	5.1	0.06	0.76	0.4	2.1	0.78	125	0.24	2.15
G	5.2	0.12	1.00	0.6	2.6	0.78	68	0.30	2.35
H	5.3	0.14	0.82	0.8	2.8	0.76	57	0.26	2.27
I	5.6	0.12	1.5	0.6	2.3	0.76	66	0.23	2.27
J	5.3	0.14	1.24	0.4	2.3	0.58	57	0.26	2.03
K	5.4	0.1	0.86	1.0	2.8	0.64	38	0.27	2.23

Na, K, Ca, Mg and Mn are in milli-equivalents

*Treatments are shown on page 5.

trend was observed for the level of potassiu. The level of calcium was deficicient in all treatments. The drop in calcium level was highest under conventional tillage. Both minimum tillage methods had a slightly higher average of calcium.

The level of magnesium dropped for all treatments Tillage method showed no influence on the level of magnesium. The average level of manganese increased in all treatments although conventional tillage had a slightly higher level. Available phosphorus was very high in all the treatments. During this season there was little rain to dissolve the applied fertilizer and so some of it might have remained in the soil. This residual fertilizer could have contributed to the high phosphorus figures shown on Table 7. The level of nitrogen did not change appreciably but both minimum tillage methods had slightly higher average levels. Organic carbon for all treatments increased. After the first season (1984) tillage method did not greately influence nutrient levels.

Table 8 shows the soil analysis report after the end of the second experiment. Plots spraying with primagram gave strongly acidic reaction. There was a significant (P = 0.05) drop in the pH for all the treatments. There was a significant (P = 0.05) increase in the level of sodium. The highest level of sodium was recorded under minimum tillage (strips). There was no

Table 8. Soil Analysis Report at the end of the Second Experiment. August, 1985.

Treatments	pH*	Na*	K	Ca*	Mg	Mn*	Pppm*	N%	C%
[illegible]	5.0	0.18	1.19	2.3	2.9	1.26	15	0.20	2.0
[illegible]	4.6	0.16	0.86	1.1	2.3	1.37	17	0.20	1.67
[illegible]	4.7	0.2	0.78	1.1	1.6	1.18	11	0.19	1.53
[illegible]	5.2	0.2	1.41	2.5	2.7	1.22	13	0.21	2.0
[illegible]	4.9	0.2	0.86	2.7	2.8	2.0	17	0.21	1.97
[illegible]	5.3	0.24	0.73	4.7	3.5	1.69	13	0.23	2.29
[illegible]	5.4	0.18	1.31	4.7	2.8	0.86	15	0.23	1.46
[illegible]	5.2	0.16	0.93	5.0	3.2	2.0	13	0.22	2.18
[illegible]	5.4	0.2	1.27	5.6	3.3	1.26	13	0.23	2.26
[illegible]	5.1	0.23	0.97	4.5	3.7	2.0	11	0.23	2.18
[illegible]	5.0	0.2	0.56	5.6	3.3	1.85	13	0.24	2.18

Na, K, Ca, Mg, and Mn are in Milli-equivalents

*Significantly different from 1984 results.

significant change in the level of potassium compared to the previous season. The level of calcium increased significantly (P = 0.05) for all the treatments. Both minimum tillage methods had higher levels of calcium compared to conventional tillage. Magnesium level did not change significantly but minimum tillage (spots) had the highest level. The level of manganese increased significantly (P = 0.05) over the previous season. Under both minimum tillage methods plots with no inter-row weeding had toxic levels.

The level of available phosphorus dropped sharply (P = 0.05) for all treatments. These are the expected levels of phosphorus in nitosols. This strengthens the possibility of fertilizer effect during the first experiment. The level of nitrogen did not change significantly compared to the previous season. Minimum tillage (spots) had slightly higher average levels (0.23%) of nitrogen compared to minimum tillage (strips) (0.020%) and conventional tillage (0.20%). Organic carbon did not change significantly over the previous season. Minimum tillage spots had slightly higher levels of organic carbon (1.98%) compared to conventional tillage (1.84%) and minimum tillage strips (1.83%). Weed control methods within tillage treatments had no consistent effect on nutrient levels.

Plant Height. The mean plant height in metres as affected by tillage and weed control method are shown on

Table 9. Plant Height (M) as Affected by Tillage and Weed Control.

Treatments		Short Rains 1984	Long Rains 1985
A.	Conventional tillage, hand weeding	2.53	3.04
B.	Conventional tillage, Primagram	2.60	2.86
C.	Strip tillage, Paraquat + intra-row weeding	2.56	2.85
D.	Strip tillage, slashing + intra-row weeding	2.60	2.55
E.	Strip tillage, intra-row weeding	2.60	2.69
F.	Spot tillage, Paraquat + intra-row weeding	2.50	2.71
G.	Spot tillage, slashing + intra-row weeding	2.60	2.49
H.	Spot tillage, intra-row weeding	2.63	2.54
I.	Conventional tillage, no weeding (check)	2.48	2.90
J.	Strip tillage, no weeding (check)	2.56	2.20
K.	Spot tillage, no weeding (check)	2.61	2.05
CV%		4.9	8.27
SE (Treats)		0.04	0.108
LSD (0.05)		- NS	0.314 **

NS = Not significant ** = Significant at 1%

table 9. During the short rains of 1984, there were no plant height differences. However the differences were highly significant during the long rains of 1985. Conventional tillage had the tallest plants (average 2.95 m, compared to strip tillage (2.70 m) and spot tillage (2.60 m). Weed control affected plant height since the non-weeded controls had very short plants. This was more pronounced under minimum tillage where the non-weeded checks gave 2.20 metres and 2.05 metres under strip and spot tillage respectively. Plots sprayed with paraquat gave taller plants than slashing under minimum tillage.

Bare Tips on Cobs. The results shown on Table 10 indicate that tillage and weed control method had no significant effect on percent number of bare tips on maize cobs during the short rains of 1984. There were however, significant (P = 0.05) differences between treatments during the long rains of 1985. There were more bare tips under conventional tillage (17.65%) and strip tillage (17.73%) compared to spot tillage (13.5%). Weed control method did not affect the number of bare tips during both seasons.

Diseased Ears. The percentage of harvested ears affected by ear rots are shown on Table 11.

Table 10. Percent Number of Ears with Bare Tips

Treatments	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	11.3	20.7
B. Conventional tillage, Primagram	15.3	14.6
C. Strip tillage, Paraquat + intra-row weeding	16.9	21.1
D. Strip till, slashing + intra-row weeding	16.7	15.2
E. Strip till, intra-row weeding	18.1	16.9
F. Spot tillage, Paraquat + intra-row weeding	14.9	13.3
G. Spot tillage, slashing + intra-row weeding	11.7	13.7
H. Spot tillage, intra-row weeding	6.6	13.5
I. Conventional tillage no weeding (check)	10.1	14.2
J. Strip tillage, no weeding (check)	12.5	10.1
K. Spot tillage, no weeding (check)	9.9	14.0
CV%	11.52	18.20
SE(Treats)	0.09	0.28
LSD (0.05)	- NS	0.80 *

NS = Not significant * = Significant at 5%.

Table 11. Percent Number of Diseased ears as affected by Tillage and Weed Control

Treatments	Long Rains 1985
A. Conventional tillage, hand weeding	10.9
B. Conventional tillage, Primagram	15.6
C. Strip tillage, Paraquat + intra-row weeding	7.5
D. Strip tillage, slashing + intra row weeding	15.6
E. Strip tillage, intra-row weeding	10.2
F. Spot tillage, Paraquat + intra-row weeding	11.5
G. Spot tillage, slashing + intra-row weeding	4.6
H. Spot tillage, intra-row weeding	10.8
I. Conventional tillage, no weeding (check)	12.2
J. Strip tillage, no weeding (check)	7.9
K. Spot tillage, no weeding (check)	4.8
CV%	26.33
SE (Treats)	0.34
LSD (0.05)	0.98

*Significant at 5%.

The results shown are for the long rains of 1985 only since there were no ear rots during the short rains of 1984. The number of diseased ears were significantly different but the differences were small. The results also show that more diseased ears were recorded in the treatments that had less weeds. Minimum tillage plots had very low incidences of diseased ears. The highest number of diseased ears were obtained in the herbicide treated plots under both conventional and minimum tillage treatments.

Usable Ears. The number of usable ears as affected by tillage and weed control method are shown on Table 12. Neither tillage nor weed control method significantly affected the number of usable ears during the short rains of 1984. However both minimum tillage methods had more usable ears than conventional tillage. During the long rain season, tillage and weed control significantly (P = 0.05) affected the number of usable ears. Strip tillage had more usable ears (69.75) than both conventional tillage (68.63) and spot tillage (66.67). The non-weeded checks under all tillage

Table 12. Number of Usable Ears as Affected by Tillage and Weed Control.

Treatments	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	39.75	68.75
B. Conventional tillage, Primagram	39.25	68.5
C. Strip tillage, Paraquat + intra-row weeding	41.5	64.0
D. Strip tillage, slashing + intra-row weeding	37.5	75.75
E. Strip tillage, intra-row weeding	38.75	69.5
F. Spot tillage, Paraquat + intra-row weeding	53.75	695.
G. Spot tillage, slashing + intra-row weeding	40.75	63.75
H. Spot tillage, intra-row weeding	45.5	66.75
I. Conventional tillage, no weeding (check)	32.5	60.0
J. Strip tillage, no weeding (check)	30.0	59.5
K. Spot tillage, no weeding (check)	27.75	41.25
CV%	14.57	7.25
SE (Treats)	0.45	0.29
LSD (0.05)	-	0.84
	NS	**

NS = Not significant
** = Significant at 1%.

methods had lower number of usable ears than weeded plots.

Weight of Harvested Cobs. The weight of unshelled maize cobs are shown on Table 13. During both seasons, tillage method and subsequent weed control had significant effect on the weight of harvested cobs. During the short rains of 1984, strip tillage had a higher weight of harvested cobs (4.68 Tons/ha) than both spot tillage (4.39 T/ha) and conventional tillage (4.36 T/ha). During the long rains of 1985, conventional tillage had significantly (P = 0.05) more weight of harvested cobs (7.76 T/ha) than both strip (6.97 T/ha) and spot tillage (6.51 T/ha).

During both seasons, hand weeding gave higher harvest weight than where primagram was used under conventional tillage. Also in both seasons, under both minimum tillage methods, paraquat and slashing gave comparable harvest weights although the long rains had overall higher yields. The non-weeded checks had the lowest cob weights under all tillage methods in both

Table 13. Weight of Harvested Cobs, Tons/ha

Treatments	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	4.64	8.47
B. Conventional tillage, Primagram	4.08	7.05
C. Strip tillage, slashing + intra-row weeding	4.89	6.74
D. Strip tillage, slashing + intra-row weeding	4.44	7.56
E. Strip tillage, intra-row weeding	4.71	6.61
F. Spot tillage, Paraquat + intra-row weeding	5.00	7.14
G. Spot tillage, slashing + intra-row weeding	4.33	6.67
H. Spot tillage, intra-row weeding	3.85	5.73
I. Conventional tillage, no weeding (check)	3.17	6.58
J. Strip tillage, no weeding (check)	3.35	4.58
K. Spot tillage, no weeding (check)	2.76	4.35
CV%	24.57	21.59
SE (Treats)	0.30	0.42
LSD (0.05)	1.46 *	2.03 *

* = Significant at 5%.

seasons.

Grain Yield. Grain yield in tons per hectare for both seasons are shown on Table 14. The results show that there were no significant grain yield differences during the short rains of 1984. However, strip tillage gave higher average grain yields (3.46 T/ha) than spot tillage (3.31 T/ha) and conventional tillage (3.18 T/ha). During the same season, weed control had no significant effect on grain yield. However, observed differences show that where paraquat was used under minimum tillage there was higher yield than slashing. Under conventional tillage, hand weeding gave higher grain yield than where primagram was used. The non-weeded checks under all tillage methods gave extremely low yields.

During the long rains of 1985, tillage and weed control methods caused significant grain yield differences. Conventional tillage gave the highest grain yields (5.64 T/ha) compared to strip tillage (5.14 T/ha) and spot tillage (4.73 T/ha). Under minimum tillage, both paraquat and slashing gave comparable grain yields.

Table 14. Grain Yield (Tons/ha) as affected by Tillage and Weed Control.

Treatments	Short Rains 1984	Long Rains 1985
A. Conventional tillage, hand weeding	3.38	6.06
B. Conventional tillage, Primagram	2.97	5.21
C. Strip tillage, Paraquat + intra-row weeding	3.57	5.17
D. Strip tillage, Slashing + intra-row weeding	3.33	5.79
E. Strip tillage, intra-row weeding	3.48	4.45
F. Spot tillage, Paraquat + intra-row weeding	3.71	5.25
G. Spot tillage, slashing + intra-row weeding	3.34	4.65
H. Spot tillage, intra-row weeding	2.88	4.29
I. Conventional tillage, no weeding (check)	2.35	4.44
J. Strip tillage, no weeding (check)	2.40	3.27
K. Spot tillage, no weeding (check)	2.07	1.88
CV%	25.75	16.35
SE (Treats)	0.12	0.11
LSD (0.05)	-	1.09

NS = Not significant
* = Significant at 5%.

Plots with no inter-row weeding gave slightly lower grain yield than those with inter-row weeding. Under conventional tillage, hand weeding gave higher grain yield than where primagram was used. Weed control affected grain yield since the non-weeded controls under all the tillage methods had lower grain yield than the weeded plots. Although grain yields were higher during the long rains, the treatments caused similar effects during both seasons.

DISCUSSION

Plant population was fairly uniform during the short rains of 1984, but was affected by tillage and weed control during the long rains of 1985. Seed emergence was better under conventional tillage in both seasons, but there was more rodent damage on the seedlings under this system. This may have led to similar plant stands under all treatments. Plant population therefore did not greately affect the resultant grain yields. That plant population may not be seriously affected by tillage method had been observed earlier (Fink and Wisley 1974, William _et_. _al_. 1970). Weed control had little effect on plant population but weeds may have affected plant growth as observed from the yields obtained. Under all the three tillage systems, the seeds had suitable environments for emergence and establishment. Weeds on the other hand, came during the later part of seedling growth. Thus weeds may have affected plant vigour due to their competitive effect and not seed germination.

Both minimum tillage systems(strip and

grasses and therefore less were laid on the maize plants. Conventional tillage maize on the other hand may have been more exposed leading to higher attack. This attack may have caused the small yield drop under conventional tillage during the short rains (1984). The occurrence of stalk borer is sporadic and hence it was not related to the prevailing weather conditions.

Two stem rots Diplodia maydis and Fusarium graminearum were recorded during the long rains only. It is possible that the prolonged wet conditions may have favoured fungal spore growth and hence disease development. Contrary to the common belief, the non-weeded controls had the lowest incidence of stem rots in all tillage treatments. Perhaps the weeds played as alternate hosts or just physical barriers. Plots sprayed with paraquat had the highest incidence of stem rots in both minimum tillage methods. It is possible that paraquat droplet injury may have predisposed the maize plants to fungal attack. Tillage method had little effect on stem rots. Under all tillage methods, stem rot incidence decreased with increasing weed density. This strengthens the possibility of weeds playing the role of alternate hosts or physical barriers to stem rot spread.

Although the trials were carried out for two seasons, there was a marked change in the general soil fertility. There was a greater nutrient building under both minimum tillage methods (strip and spot) than under conventional tillage. Research done elsewhere (Lal 1983, Moschler *et*. *al*., 1972; Blevins *et*. *al*., 1983) has shown that soils managed under minimum tillage systems have a higher concentration of organic carbon, total nitrogen, available phosphorus, exchangeable calcium, magnesium, potassium, sodium and manganese. Dead plant residues left on the surface under minimum tillage may have contributed to the nutrient build up. Since there was no significant yield drop under minimum tillage, it is likely that available nutrients were used more efficiently than under conventional tillage. Similar results have been evidenced (Estes, 1972; Moschler *et*. *al*., 1972).

Plant height was uniform in the whole

experiment during the short dry season of 1984. The slightly taller plants under conventional tillage during the wetter season of 1985 may have been as a result of better growth. This may have been as a result of better soil moisture conditions and reduced competition by weeds. Plants under minimum tillage systems grew less vigorously than under conventional tillage at the beginning of the season. Soils disturbed during primary tillage may have created a better rooting media for maize plants under conventional tillage during the prolonged wet season.

During the later part of the season, weed intensity may have affected plant gowth. This is evidenced from the shorter plants in the non-weeded checks under all tillage methods. Possibly the weeds out-competed the maize plants for soil moisture and nutrients. This may have in turn reduced grain yields as recorded in all non-weeded controls.

The number of ears (cobs) which were not completely covered by grain was related to tillage method during the long rains of 1985, but not related during the short rains of 1984. In 1985, both conventional and minimum tillage (strip) had similar number of bare tips but spot tillage had less. During both seasons, inter-row weed control method had little effect on the number of bare tips although paraquat treated plots had slightly more bare tips. Intra-row weeding greatly influenced the number of bare tips since the non-weeded controls gave very few bare tips in both seasons. The checks had smaller cobs which were however better filled by grain. Currently no documented evidence exists describing the relationship between tillage and the number of bare tips.

Absence of diseased ears (cob rots) during the drier season (short rains of 1984) indicates that pathogens thrive better under wet conditions (Ullstrup, 1979). The short rains were characterized by long dry spells which could not favour fungal growth. The wetter and prolonged season of 1985 may have provided better conditions for fungal development. The non-weeded controls had very low incidences, of diseased ears. Weeds, like in the stem rots may have played a role of alternate hosts or physical barriers. Observations under minimum tillage clearly suggest that some maize pathogens do remain viable in the surface debris from the preview crop. This may provide the initial inoculum for causing diseases. Presence of susceptible plants like grass weeds may absorb much of the initial inoculum reducing the attack to the maize crop (Ullstrup, 1979).

The number of usable ears were related to treatments in both seasons. Although conventional tillage gave a less number of usable ears, which were larger in size than those under minimum tillage systems during the long rains of 1985. Weed control methods did not affect the number of usable ears appreciably during both seasons. Weed control however, was important since the non-weeded controls gave fewer usable ears. Guleria and Singh (1980) had reported similar results in India.

The weight of maize on the cob before shelling is a good indicator of final maize yield. Both minimum tillage methods gave slightly more harvest weight than conventional tillage during the short rains of 1984. This suggests the possibility of better moisture conservation and utilization under minimum tillage. Similar findings have been recorded elsewhere (Legg et. al., 1979, Michieka, 1982).

Inter-row spraying with paraquat gave slightly more harvest weights in both seasons. This perhaps resulted from the absence of crop/weed competition because paraquat killed all the weeds giving weed free plots. Weed thus killed provided dead mulch which in turn helped to reduce soil temperatures and water loss through evaporation. This supports the absence of water stress (wilting) under both minimum tillage systems during the drier season of 1984. This again strengthens conclusions drawn from similar work done in Tanzania by Ley and Semoka (unpublished) and in the USA corn belt by Hallauer and Colvin (1985).

In a relatively dry season of 1984, grain yields for both minimum tillage methods (strip and spot) were slightly higher than the yields under conventional tillage. During a relatively wetter season of 1985, grain yields under conventional tillage were higher than the yields under both minimum tillage methods (strip and spot). This confirms similar observations recorded elsewhere (Legg, et. al., 1979 in USA and Maurya and Lal, 1980 in Nigeria) that minimum tillage methods are better under dry situations. Blevins, et. al. (1971) and Jones, et. al. (1968) working in USA attributed higher yields under minimum tillage to moisture conservation during dry periods.

Both minimum tillage methods had a lot of plant residues especially from weeds that were killed and left on the surface. Perhaps these surface residues reduced soil moisture loss through evaporation and thus made water available during critical growth stages. Several workers (Wilson, et. al., 1982, Unger and McCalla, 1980) have argued that soils under minimum tillage have more favourable water regimes which benefit the crop during growth. The more favourable water regimes may in turn increase nutrient availability and uptake. During the drier season of 1984, water stress (wilting) was evident in maize under conventional tillage plots.

Lower soil temperatures under minimum tillage (strip and spot) may also have favoured maize growth during the dry period. Similar arguments have been raised by several researchers working in the USA (Allmaras, et. al., 1970, William et. al., 1970). Weed or crop residues left on the surface, reduces solar radiation hitting the soil surface and hence help in reducing soil temperatures.

Increase in nutrient density under minimum tillage as reported by other researchers (Moschler et. al., 1972 in USA and Wilson, et. al., 1982 in Nigeria), may have contributed to comparable and even higher yields during the two experiments. The results of soil analysis indicate increase in both organic carbon and phosphorus but no change in nitrogen level. The small increase in pH especially under minimum tillage may have led to increased availability of phosphorus.

Improvement of soil physical properties such as structure and improved pore continuity may have stimulated better root growth. Some of the major reasons for tillage are provision of suitable tilth, kill weeds and bury trash to provide a clean rootbed for seed germination and establishment. Contrary to these reasons, minimum tillage systems may provide suitable root beds and actually provide high yields. The major advantages of minimum tillage systems are attributed to the presence of plant residues on the surface. These residues as observed by other researchers, (Miller and Shrader 1974, Moody, et. al., 1963, Triplett, 1966) reduce evaporation and thus increase available water for crop growth. Conventional tillage on the other hand completely exposes the soil leading to great soil water losses.

Plant residues left on the surface would also modify soil temperatures and stimulate earthworm activity and bacterial action leading to increased organic matter. All these provide a suitable rooting media and may lead to high yields. Similar conclusions were drawn from a six year study in Virginia, USA by Jones et. al. (1968).

Perhaps the greatest advantage of minimum tillage systems is the possibility of obtaining high yields at reduced costs. Seedbed preparation and weed control under conventional tillage constitute a large proportion of the total costs of crop growing. According to Anon. (1985), any system that reduces the cost of seed bed preparation and weed control would be a great step towards increasing farming profits. This aspect was not considered due to the nature of the experiment. Further work is hence recommended in economics.

There is a possibility of reduced soil erosion due to the presence of dead plant residues on the surface. This may help in increasing the cultivation of marginal areas.

CONCLUSION

From this study, a general conclusion can be drawn that minimum tillage techniques are advantageous over conventional tillage under certain farming conditions. The favourable yields obtained under minimum tillage during the dry weather strengthens the above statement. Fertility build up under minimum tillage ensures that even if the system is used for a prolonged period, the soil conditions will not deteriorate as fast as under conventional tillage.

Presence of plant residues on the surface reduces rain drop impact and surface run-off and hence reduces the risk of soil erosion. Plant residues also reduces the amount of solar radiation hitting the surface. This reduces soil moisture loss through evaporation and consequently reduces soil temperatures. This makes the minimum tillage system suited to dry areas or dry seasons. This is a beneficial attribute especially in Kenya which has more than 75% arid or semi arid areas. Also in situations of erratic rainfall, this system will ensure successful crop growth.

Most important of all is that farmers adopting the minimum tillage system would grow maize at greatly reduced costs. Minimum tillage would require far less labour to prepare a seed bed. This cuts the cost of seed bed preparation while enabling timely planting. Consequently there is a choice between cheaper methods of weed control.

Minimum tillage using strips provides the best opportunity to areas where the ox-plough is a common tool. Narrow strips cut at the beginning of the season will enable planting and provide the germinating seedling with a suitable environment. The inter-row spaces can be sprayed with a contact non-selective herbicide like paraquat giving dead weeds as mulch. The weeds may also be slashed. This mulch from the previous season will help to check erosion while providing favourable soil temperatures and moisture for crop growth. Where mulch is not used, the weeds can be checked two times by slashing during a crop cycle.

In regions where the hand hoe is the commonest tool, minimum tillage using spots is the best alternative to conventional seed-bed preparation. Weeds can be checked by a contact herbicide or by slashing like under strip tillage.

Digitaria scalarum L. (Couch grass) is however likely to accumulate and spread under minimum tillage systems. Using a translocated herbicide like glyphosate would go a long way in reducing the problem.

The majority of soils in this region are high in clay content. This often leads to cementing of soil particles forming hard semi-permeable layers at the surface. This may reduce initial water infiltration and root development. Thus it may be necessary to carry out a conventional ploughing after several seasons of minimum tillage.

Some Short-comings during the Trials.

The short rains of 1984 were low and erratic leading to prolonged drought which caused low average maize yields. Stalk borer (*Buseola fusca*) incidence was higher than normal in the whole of Embu district. Just before flowering, there was an outbreak of armyworm (*Spodoptera exempta*) in the area and indeed the whole country. These were however controlled before causing serious damage.

The long rains of 1985 were more prolonged than usual and average temperatures dropped towards maize flowering. The increase in humidity favoured the establishment of stem rots such as Diplodia stalk rot (*Diplodia maydis*) and *Fusarium* stalk rot (*Fusarium graminearum*) and ear rots such as Gray ear rot (*Physalospora zeae*) and Gibberella ear rot (*Gibberella zeae*). The pests and diseases can cause significant yield reductions on maize when the attack is high.

REFERENCES

1. Adams, W.E., J.E. Pallas and R.N. Dawnson. 1970. Tillage methods for corn-sod systems in the Southern Piedmont. Agron. J; 62: 646-649.

2. Agboola, A.A. 1981. The effects of different soil tillage and management practices on the physical and chemical properties of soil and maize yield in a rain forest zone of Western Nigeria. Agron. J.; 73: 247-251.

3. Akobundu, O.I. 1979. Weed control in Nigeria. Tropic Pest Management PANS; 25: 287-298.

4. Allmaras, R.S., W.E. Burrows and W.E. Larson. 1964. Early growth of corn as affected by soil temperature. Soil Sci. Soc. Amer. Proc.; 26: 271-275.

5. Allmaras, R.R. and W.W. Nelson. 1971. Corn root configuration as influenced by some row inter-row variant of tillage and straw mulch management. Soil

Sci. Soc. Amer. Proc.; 35: 974-980.

6. Amemiya, M. 1968. Effectiveness of tillage methods in association with weather and consequent soil water conditions. Agron. J; 60: 534-536.

7. Anonymous, 1981. Sessional paper number four on National Food Policy (Kenya). Government Printer. Nairobi, Kenya.

8. Anonymous, 1983. Effects of tillage on soil physical properties and maize production. International Institute of Tropical Agriculture. Annual Report. 157-158.

9. Anonymous, 1985. Conservation tillage. Helping you to reap the profits. MONSANTO. Newsletter Number two.

10. Army, T.J., A.F. Wiese and R.J. Hanks, 1961. Effects of tillage and chemical weed control practices on soil moisture losses during the fallow period. Soil Sci. Soc. Amer. Proc., 23: 410-413.

11. Baeumer, K. and W.A.P. Bakermans, 1977. Zero tillage. Adv. Agron.; Volume 25: 77-120.

12. Batchelder, A.R. and J.N. Jones, 1972. Soil management factors and growth of corn (Zea mays L.) on top soil and exposed sub-soil Agron. J.; 64: 648-652.

13. Blevins, R.L., D. Cook, S.N. Phillips and R.E. Phillips, 1971. Influence of no-tillage on soil moisture. Agron. J.; 63: 593-596.

14. Blevins, R.L., G.W. Thomas, M.S. Smith, W.W. Frye and P.L. Cornelius, 1983. Changes in soil properties after ten years of continuous non-tilled and conventionally tilled corn. Soil tillage Res.; 3: 135-146.

15. Blevins, R.L., L.W. Murdock and G.W. Thomas. 1978. Effect of lime application on no-tillage and conventionally tilled corn. Agron. J.; 70: 322-326.

16. Bond, J.J. and W.O. Willis. 1971. Soil and water evaporation: Long term drying as

influenced by surface residue and evaporation-potential. Soil Sci. Soc. Amer. Proc.; 34: 924-928.

17. Box, J.E., S.R. Wilkinson, R.N. Dawnson and J. Kozachyn 1980. Soil water effects on no-till corn production in strip and completely killed mulches. Agron., 72: 797-802.

18. Choudhary, M.R. and S.S. Prihar 1974. Root development and growth response on corn following mulching, cultivation or inter-row compaction. Agron. J.; 66: 350-355.

19. Estes, G.O. 1972. Elemental composition of maize grown under no-till and conventional tillage. Agron. J.; 64: 733-735.

20. Fink, R.J., and D. Wesley, 1974. Corn yields as affected by fertilization and tillage system. Agron. J.; 66: 70-71.

21. Godfrey-Sam-Aggrey, 1978. Effects of plant population on sole crop cassava in Sierra Leone. Expl. Agric.; 14:

239-244.

22. Guleria, W.S. and C.M. Singh, 1980. Weed and fertility management in rainfed maize in Palampur, India. Expl. Agric.; 16: 195-199.

23. Hallauer, A.R. and T.S. Colvin, 1985. Corn hybrids response to four methods of tillage. Agron. J.; 77: 547-550.

24. Jones, J.N., J.E. Moody, G.M. Shear, W.S. Moschler and J.N. Lillard, 1968. The no-tillage system for corn (Zea mays L.). Agron. J. 60: 17-20.

25. Kohnke, H. and C.H. Werkhoven, 1963. Soil temperature and soil freezing as affected by organic mulch. Soil Sic. Soc. Amer. Proc.; 27: 13-17.

26. Lal, R. 1974. No tillage effects on soil properties and maize (Zea mays L.) production in W. Nigeria. Plant and soil.; 40: 321-331.

27. Lal, R. 1976. No tillage effects on soil properties under different crops in W.

Nigeria. Soil Sci. Soc. Amer. Proc.; 40: 762-768.

28. Lal, R. 1976. No till farming: Soil and water conservation and management in the humid and sub-humid tropics. Monograph number two. IITA, Nigeria.

29. Lal, R., G.F. Wilson and B.N. Okigbo, 1978. No-till farming after various grasses and leguminous cover crops in a tropical Alfisol.
1: Crop Performance. Field Crops Res.; 1: 71-84.

30. Lal, R., P.R. Maurya and S. Osei-Yeboah, 1978. Effects of no-tillage and ploughing on efficiency of water use in maize and cowpeas. Expl. Agric.; 14: 113-120.

31. Legg, J.O., G. Stanford and O.L. Bennet, 1979. .Utilization of labelled N-fertilizer by silage corn under conventional and no-till culture. Agron. J.; 71: 1009-1015.

32. Ley, G.J. and J.M.R. Semoka (unpublished). Effects of tillage on soil properties, growth, nutrient uptake and yield of maize at Uyole, Mbeya, Tanzania. Proc. ann. gen. meeting for the Soil Sci. Soc. E. Afric.

33. M'Arimi, A.M. 1977. The effects of some tillage methods and cropping sequence on rainfall conservation in a semi-arid area of Eastern Kenya. M.Sc. Thesis, University of Nairobi.

34. Maurya, P.R. and R. Lal, 1980. Effects of no-tillage and ploughing on roots of maize and leguminous crops. Expl. Agric.; 16: 185-193.

35. Meyer, L.D., W.H. Wischmeier and G.R. Foster, 1970. Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Amer. Proc., 34: 928-930.

36. Michieka, R.W. 1982. Effects of plant residues on water holding capacity of the soil in no-tillage system. Proc. 2nd Nat. Workshop on soil and water

41. Ndahi, W.B. 1982. Evaluation of glyphosate and paraquat as substitutes for seedbed preparation by tillage in a hoe farming system. Tropic. Pest Management; 28: 10-13.

42. Njogu, N. 1981. Experiences with zero-tillage for small scale farms in Kitale. Proc. 8th, E. Afric. Weed Sci. Soc. Conf. Nairobi, Kenya; 145-155.

43. Parker, D.T. and W.E. Larson 1962. Nitrification as affected by temperature and moisture content of mulched soils. Soil Sci. Soc. Proceedings 26: 238-242.

44. Reddy, S.R. and S.B. Hukkeri 1983. Effects of tillage practices on irrigation requirements, weed control and yield of lowland rice. Soil and Tillage Res.; 3: 147-158.

45. Richey, C.B., D.R. Griffith and S.D. Parsons, 1979. Yields and cultural energy requirements for corn and soyabeans with various tillage-planting systems. Adv. Agron., 29: 141-180.

46. Shitakha, F.M. 1984. Detailed soil survey of Embu Research Station. Kenya Soil Survey: National Agricultural Laboratories.

47. Snedecor, G.W. and W.G. Cochran, 1976. Statistical methods (6th Edition), Iowa State University Press. AMES, IOWA, USA.

48. Steel, G.D.R. and J.H. Torrie, 1980. Principles and Procedures of Statistics. Mc Graw-Hill Book and Co. New York. USA.

49. Stougaard, R.N., G. Kapusta and G. Roskamp, 1984. Early pre-plant herbicide applications for no-till soybean (_Glycine_ _max_) weed control. Weed Science; 32: 293-298.

50. Triplett, G.B. 1966. Herbicide systems for no-tillage corn (_Zea_ _mays_ L.) following sod. Agron. J.; 58: 157-159.

51. Triplett, G.B., D.M. van Doren and B.L. Schimidt, 1968. Effect of corn (_Zea_ _mays_ L.) stover mulch on no-tillage corn yield and water infiltration. Agron. J.; 60: 236-239.

52. Ullstrup, A.J., 1979. Diseases of corn. Corn and corn improvement. Editor, D.G. Sprague. American Society of Agronomy, Inc., Publisher, Madison, Wisconsin, USA. 392-482.

53. Unger, P.W., 1977. Tillage effects on winter wheat production where irrigated and dryland crops are alternated. Agron. J.; 69: 944-950.

54. Unger, P.W. and T.M. McCalla, 1980. Conservation tillage systems. Adv. Agron.; 33: 2-53.

55. Vernon, R. and J.M.H. Parker, 1983. Maize/ weed competition experiments: implications for tropical small farm weed control research. Expl. Agric.; 19: 341-347.

56. William, E.A., J.E. Pallas and R.N. Dawson (1970). Tillage methods for corn sod systems in Southern Piedmont. Agron. J. 62: 646-649.

57. Wilson, G.F., R. Lal and B.N. Okigbo, 1982. Effect of cover crops on soil structure and on yield of sub-

sequent arable crops grown under strip tillage on an eroded Alfisol. Tillage Res.; 2: 233-250.

58. Wood, H.C. and M.L. Dadd, 1981. A reduced tillage/Herbicide system for cereal growing in Kenya. Proc. 8th E. Afric. Weed Sci. Soc. Conf. Nairobi. Kenya.

Appendix 1. Weather Conditions During the Study

Month	Total rainfall (mm)	Rainy days	Mean Temp.
October, 1984	373.9	20	19.3
November, 1984	164.6	11	18.7
December, 1984	33.3	4	18.3
January, 1985	0.5	-	19.0
February, 1985	53.3	5	20.4
March, 1985	204.6	10	19.9
April, 1985	302.6	20	20.3
May, 1985	195.0	15	16.8
June, 1985	24.6	6	17.2
July, 1985	21.4	5	18.7
August, 1985	45.1	9	16.3

Period

% Relative Humidity 9.00 A.M.	3.00 P.M.	Mean Evaporation (mm)
87	57	4.6
84	65	4.4
74	61	4.6
61	48	5.7
67	52	4.8
79	49	4.4
87	65	4.5
82	65	3.7
89	67	2.3
90	64	2.4
86	61	2.5