"AGRONOMIC AND ECONOMIC ANALYSIS OF MINIMUM AND CONVECTIONAL TILLAGE IN MAIZE GROWING IN KENYA"

BY

JEDIDAH MUKAMI MUTUOTA

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DEDICATION

To my family

D E C L A R A T I O N

I, Jedidah Mukami Mutuota declare that this is my own work and has not been presented for a degree in any other university.

Jedidah Mukami Mutuota — Date: 9-6-1989

This thesis has been submitted for examination with my approval as University Supervisor

Prof. R. W. Michieka — Date: June 9, 1989.

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ABSTRACT

Farmers spend a lot of time every year in Kenya in seed-bed preparation and weeding for maize. Late planting and poor weed control are among the major causes leading to low grain yields in many small-scale farms This study was carried out to compare the economic and agronomic analyses of conventional tillage and minimum tillage systems. Glyphosate at a rate of 2.5 Kg a.i. per hectare and paraquat at a rate of 1.0 Kg a.i. per hectare were applied as post-emergence herbicides in the minimum tillage plots. In this tillage system furrows and spots were opened for seed and fertilizer placement. In conventional tillage a hoe was used to prepare the whole seed bed. Conventional tillage took more time than minimum tillage during seed-bed preparation. During the short rains, weeding in conventional tillage took less time than in minimum tillage. There was no significant difference (P=0.05) in yields between the minimum and conventional tillage treatments. Paraquat application was the most economical method of seed-bed preparation followed by conventional tillage. Paraquat application was the most economical method of seed-bed preparation followed by conventional tillage. The most expensive method was in minimum tillage where glyphosate was used. Although less time was used in minimum tillage in spraying the herbicides and digging furrows than in conventional tillage where the whole area was dug clean with a hoe to prepare the seed-bed, the cost of glyphosate herbicide was very high. Glyphosate was more expensive than paraquat.

This made minimum tillage treatments where glyphosate was used the most expensive. Conventional tillage method required significantly less labour (P=0.05) during weeding than minimum tillage, therefore cheaper than minimum tillage. The only advantage in minimum tillage was during the first weeding because labour was spread over a longer period i.e. by first having intra-row weeding which removed weeds from the plants,followed by inter-row weeding where the weeds were cut at ground level using a panga.

- CHAPTER ONE -

INTRODUCTION

Tropical farmers most time consuming single activity is hand weeding. A lot of time is spent every year in most developing countries in seed-bed preparation and weeding for the crop. This work may consume as much as 70% or more of the farmers' time and energy during the cropping season (Cook 1957, Wrigley 1969). Most of the small scale farmers and peasant farmers in most developing countries use simple hand tools such as the hoe and machete for seed-bed preparation and subsequent weeding during the growing period of the crop, with limited use of animal power and mechanical power.

The food deficit areas of the world are in the developing countries of Africa, Asia, Central and South America mainly between latitudes 15° and 20° north and south of the equator (Okigbo, 1978). In Kenya for example the farmers' yields are generally low mainly because of poor husbandly practice especially late planting and weed competition (Allan, 1971). In Kenya most of the seed bed preparation work is done during the dry period prior to the long rains when most soils are dry and hard to till. This often leads to late planting and consequent reduction in yields (Gurnah, 1975). Research done in Kenya shows that crop loss can be up to 40% because of inadequate weed control measures (Monsanto, Technical Report 1983). This is due to a chronic problem of both perennial and annual weeds in virtually all of the small holder crop fields.

The conventional method of weed control both pre-plant and post-plant using a hoe or machete is time consuming and tedious. The mere lifting of the blade to a height of one metre 10,000 times a day in order to cover as little an area as 500 m^2 at a rate of 0.05 m^2 per stroke takes a lot of time and energy (Druijff and Kerkhoven,1970). The other drawback is the chronic shortage of labour available on small farms. This is mainly due to rises in standard of living, free education for all children and rural - urban migration. This has resulted into farm labour becoming very scarce and expensive. Farm returns are low and this makes most of the small holder farmers unable to hire labour leaving only the family labour which in most cases is unable to cope with the work. On large scale farms mechanization using tractors for ploughing, harrowing, planting and weeding have been used to improve agricultural production.

It is difficult to imagine how the developing countries can achieve the increased agricultural productivity needed for economic and general development if 80 per cent of the population is engaged in the back-breaking labour of weed control (Muzik, 1970). It is therefore obvious that any system of crop production which will make early planting possible and easier to achieve and minimize the weed problem will go along way to improve crop yields. Such methods would be the use of herbicides for control of weeds in minimum tillage. This would offer an alternative method for our small scale farmers. This method requires less labour and may go a long way to improve the problem of chronic shortage of labour available on small farms.

Minimum or reduced tillage can be used to cover any system of cultivation involving less mechanical movement of the soil than is conventional or traditional. These vary from true or non-tillage systems where only a seeding slot is cut into uncultivated soil surface and where herbicides may be applied before or after seeding, to systems which employ over all cultivation but where the operation is speeded up and made easier by the use of herbicides before or between cultivations. The term can also refer to stubble and trash farming systems developed to counteract erosion in slopy areas (Wood and Dadd, 1981).

Depending upon the cropping situation, the advantages of reduced tillage are to minimize soil erosion, improve soil structure, speed the change from pasture to fallow or from one crop to another, reduce dependence on weather, reduce moisture loss caused by cultivation, cut crop establishment cost and increase yields (Wood and Dadd, 1981).

Cost-effectiveness is the main reason why certain tillage systems are used in preference to others. Herbicides may compare more favourably with mechanization in the tropics than temperate areas. The reason is that mechanization needs more capital, and to be economical must be used throughout the year, thus displacing more labour for whom no other work may be available in the tropics (Kasasian, 1971). Herbicides in minimum tillage should be seen as a means of increasing effectiveness of labour and increasing crop production, rather than saving labour entirely.

It has been reported that two hand weedings cost an average of 200 Naira per hectare in Nigeria (250 U.S. dollars) compared with 50 Naira per hectare for chemical weeding (I.I.T.A. 1980, Research highlights). If farmers could use post emergence herbicides to kill the weeds it will be possible to plant early and crops can germinate and establish in weed free conditions.

By using herbicides less labour will be required in seed bed preparation and therefore the area to be cropped is less severely limited. Subsequent weeding during the growing period can be done by practicing intra-row weeding using a hoe and inter-row slashing of weeds using a machete. This method will ensure that the weeds next to the plant are removed before competition sets in then this is followed by inter-row slashing of the weeds. This will help increase the crop yields. Herbicides in this respect should not be regarded as a routine measure to replace labour but rather as a supplement to human labour to increase its effectiveness and decrease drudgery so that agriculture becomes more attractive (Kasasian, 1971).

The objective of this study was to compare minimum tillage with traditional or conventional weed control methods in maize growing. The research was to establish whether minimum tillage using herbicides during seed bed preparation and two hand weeding was more economical and more efficient than conventional tillage (where seed bed preparation is carried out by digging the whole plot clean using a hoe and two hand weedings).

- CHAPTER TWO -

LITERATURE REVIEW

Most small holder farmers in Kenya today grow maize largely for home consumption and only the surplus is sold (Allan, 1971; McCarthy and Mwangi, 1982). The demand for food is very high due to increased population. Higher acreages, greater yields and improved technology are expected to increase domestic production levels to meet this demand.

The production target for maize in the FAO study for the year 2,000 is 4559 thousand tonnes, this estimate arises from the postulate that 1857 thousand hectares of land will have an average yield of 2.46 MT/ha. The farmers' yields vary significantly from less than 0.5 MT/ha for local varieties using no modern inputs to levels close to 4 MT/ha for most advanced small holder using hybrid seeds and fertilizer (McCarthy and Mwangi, 1982). The area under hybrid maize in Kenya has increased at a rate of about 600,000 to 700,000 hectares per year since 1970 (McCarthy and Mwangi, 1982).

Many tropical soils are difficult to plough during the dry season thus making it necessary to wait for the first showers of rain before planting. This often leads to late planting and consequent reduction in yields (Gurnah,1975).

Yield reductions due to late planting have been well documented. Moberly, (1962) cited by Allan 1971 working in Kitale showed yield reductions in maize due to late planting.

He reported that maize planted early in March yielded 1450 kg per hectare whereas maize planted in May yielded 1390 kg per hectare. Dowker (1964) working in Machakos showed that everyday delay in planting resulted in 5-6 percent loss in yields. Allan (1972) showed that it is important to plant maize at the beginning of the rains since delays could reduce yields linearly by as much as 100 kg per hectare for each day's delay.

Poor weed control leads to considerable yield losses. Weeds may be defined as plants growing where man does not want them (Kasasian, 1971). Weeds are commonly most injurious in using moisture, nutrients or light that crops require to give higher yields; they may also provide cover or act as hosts for pests and diseases. Weeds may also contaminate produce thus reducing the quality of crops. Weeds increase labour costs and cause difficulties in harvesting; weeds also reduce land values. Some weeds exude toxins which adversely affect crop growth (Kasasian, 1971). Ashby and Pfeiffer (1956) estimated that increase of crop yields obtained by proper weed control is in the order of 100 percent or more in the tropics as compared to 25 percent yield increases in the temperate countries. Prentice, (1957) quoted a loss of 50 percent in yield in cotton due to Digitaria scalarum with greater loss in a bean crop in Mexico.

Nieto et. al. (1968) reported that when weeding was carried out one month after planting, yield reductions of 25 percent in maize and 53 percent in bean resulted. Moody (1975) reported that in Nigeria crop losses due to weeds range from 20 percent for maize to 100 percent for upland rice. Nieto et. al. (1968) working in Mexico reported that season long infestation of weeds reduced maize yields from a potential of 4770 kg/hectare to 382 kg per hectare. Makatiani (1974) reported that uncontrolled weeds caused 76 percent yield reductions in maize and 64 percent in beans. Wimer and Harland (1925) working in U.S.A. found that average yield reductions in unweeded maize plots was 81 percent. Denham (1964) in a review of American weeding trials quoted yield reductions ranging from 41 to 86 percent. Five maize trials carried out in Western Kenya by Allan, (1968) showed that unweeded plots yielded 3400 kg per hectare less than plots which were clean weeded by hand three times. Kasasian and Seeyave (1969) working in Trinidad reported 18 to 37 percent yield reductions in beans. Doll (1975) reported 58 percent yield reductions in sorghum due to weeds. Mohammed (1985) working in the Sudan reported yield reductions ranging from 23 percent to 60 percent caused by weed competition in irrigated onions. In India losses caused by weeds are sometimes 70 percent to 80 percent and where no control is attempted losses go up to 93 percent (Joshi, 1977).

In Kenya and Nigeria farm labour is becoming increasingly hard to get and expensive (Laycock, 1974; Ngugi and Kinyanjui, 1978; Ogborn 1977). The hoe is the most widely used cultivation tool for seed bed preparation and post-emergence weed control but it is slow and tedious. For example in Samaru Nigeria a single weeding requires 300 to 500 man hours per hectare (Ogborn, 1977 a). In Kenya the labour cost and scarcity has made some farmers to limit the farm sizes they can cultivate (Ngugi, 1978). This has resulted in decreased crop yields due to decrease in size of area cultivated. Research done in Kenya has shown crop losses of up to 40 percent due to weed competition (Monsanto Tech. report, 1983). Chemical control of weeds under minimum tillage offers an alternative for the small farmer (Monsanto, Tech. report 1983).

Tillage refers to any physical soil manipulation which changes the structure of the soil, kills weeds or rearranges dead plant material (Raney and Zingg, 1957) cited by (Gurnah, 1975). It increases the porosity of the soil, and also creates the proper condition for proper root development, fertilizer application and easier harvesting of root crops (Blake, 1965, Larson, 1962).

Minimum tillage usually implies use of herbicides to control weeds (Monsanto Tech. Report 1983). Arnon (1975) defines minimum tillage as a method aimed at reducing tillage to the minimum necessary for ensuring a good seed bed, rapid germination, satisfactory stand and favourable growing condition. Macqueen (1976) further defines it as any system of cultivation whereby there is less mechanical movement of the soil than is conventionally practiced. Minimum tillage also covers systems which employ overall cultivation but where operations are speeded up by use of herbicides before and after cultivation; it can also refer to trash farming (Wood and Dadd, 1981). Minimum tillage gained emphasis in 1960's when paraquat herbicide was introduced to the market for farm inputs (Brown, 1979). Tillage practices have shown that frequent tillage operations are rarely beneficial in addition to being costly (Arnon 1975). Macqueen (1976) reports that less cultivation on many soils particularly volcanic ones would lead to greatly reduced erosion, better moisture conservation and increased yields.

The advantages of using herbicide are:- crops can germinate and establish weed-free thus ensuring maximum production, area which may be cropped is less severely limited, soil disturbance, erosion, loss of nutrients and soil moisture are reduced.

The acceptance of any innovation in crop production will be influenced largely by its effect on cost and profit. Herbicides are potentially one of the most labour saving innovations in modern agriculture. The use of herbicides closely resembles mechanization in its effects on factor intensities (Young and Miller 1977). The transition from the hoe to herbicides applied with a back pack sprayer can reduce labour requirements twenty fold in short cycle crops from 25 man days per hectare to 1.2 man days per hectare (Scolai and Young, 1976). Krochmal (1966) reported a 35 fold reduction in labour requirements in cassava a long cycle crop for a similar translation (i.e. Transition from hoe to herbicide). Matsunga (1967) observed that labour required to grow one hectare of rice in California was reduced to 18.5 man hours per hectare as a result of the use of herbicide as compared to 1000 to 2250 man hours per hectare without herbicides. Results obtained at

Samaru in Nigeria indicated that pre-plant herbicide application supplemented with hoe weeding can reduce the effort required for weed control from 670 to 440 man hours per hectare (Ogborn, 1978). The use of low rates of pendimethalin with one supplementary weeding gave net benefits that were of the same magnitude as two hand weedings (Oryokot 1984, Versteeg and Maldonado, 1978). Dowler and Parker (1981) reported the advantage of combining an effective herbicide weed control programme with the use of timely cultivations. They also reported that weed control was better when herbicides were combined with cultivations than when cultivations were used alone. McWhorter and Barnetine (1975) reported that the use of cultivation in combination with herbicides in control of Cocklobur (*Xanthium pensylvanicum* Wallr.) produced significantly greater soy bean yields than did herbicide alone. Gebhardt, (1971) found that hand weeding in combination with low rate pre-emergence herbicide resulted in increased weed control.

Chang (1968), Brown (1969) and Renaut (1975) have expressed concern that herbicides are too costly to be used by majority of the farmers in the tropics. Druijff and Kerkhoven (1970) have expressed the same view. The ability of the peasant farmers to apply herbicides correctly and at the right time and dosage has been debated upon (Young, *et al* 1970). This is because most of the peasant and small scale farmers are illiterate or semi-illiterate and lack the know-how on herbicide use. This is changing as we are having more and more literate small scale-farmers, also the number of trained agricultural extension workers has increased and these people are educating the farmers on better farming methods.

In many parts of the world increasing labour costs, and unavailability at critical times of the cropping season are rapidly making the use of herbicide to become more economical. Acute labour shortages during critical periods of crop production have been reported in Kenya and Nigeria (Heyer, 1971; Laycock, 1974; Akobundu 1978). This problem is due to mass exodus of young people to urban areas to look for white collar jobs (Monsanto Tech. Report, 1983, Kasasian, 1971).

Herbicides, unlike other innovations in Agriculture e.g. tractor cultivation and many other mechanical innovations, are not characterized by large economics of size or indivisibilities. For example, a small scale farmer can buy a simple back pack sprayer useful for application of both insecticides and herbicides for KShs. 1,200 - 1,500 (Kenya Grain Growers Cooperative Union Prices 1986). Herbicides can be bought by the kilogramme or litre according to the farmer's need. These factors make herbicides easier to acquire than machinery.

Low income farmers are more likely to use herbicides more than fertilizers. This is because by using herbicides they reduce labour requirement and produce more whereas using fertilizers means using more labour but will only produce more if conditions are optimum for fertilizer response (Haswell, 1973). Use of minimum tillage with herbicides combined with timely cultivation makes work easier and reduces labour requirements.

The above review shows that little work has been accomplished in this subject. Although minimum tillage is being seen as an alternative for the small scale-farmer,not much has been done to the actual comparison between minimum tillage and convectional tillage. The aim of this research is to establish whether minimum tillage using herbicides during seed bed preparation followed by intra-row weeding, inter-row slashing of weeds during first weeding and slashing weeds with a panga over whole plot is more economical and easier to achieve than conventional tillage.

Herbicides Used:-

Glyphosate:- ROUNDUP$^{(R)}$. Glyphosate is a broad spectrum herbicide, non selective and is very effective on deep rooted perennial weeds and on annual and biannual species of grasses, sedges and broad leaved weeds. It is applied as post emergence spray to vegetation. The herbicide is absorbed through the foliage and translocated throughout the plant. Visible effects normally occur on annual species in two to four days and perennial species is seven to ten days. Glyphosate is non persistent in the soil and has no soil activity.

Toxicity:- Acute oral LD_{50} (rat) 4320 Mg/Kg

Acute oral LD_{50} (rabbit) 7940 Mg/Kg

Glyphosate is mainly used in coffee and tea plantations in Kenya for controlling perennial grasses such as couch grass (Digitaria scorlarum) and Kikuyu grass (Pennisetum clandestinum).

Paraquat:- (GRAMOXONE (R))

Paraquat is a post-emergence herbicide. It causes rapid desiccation of the foliage to which it is applied. Wilting is an early symptom of this desiccation which is followed by necrosis and ultimate death of the leaves and the other parts of the plant. Paraquat is very rapidly absorbed by the foliage and is very resistant to removal by rain.

Toxicity:- Acute oral LD_{50} (rat) 150 Mg/Kg

Paraquat is also widely used in coffee plantations, large farms and also by small scale farmers in Kenya, particularly for the control of annual weeds (Handbook of the Weed Science Society of America)

- CHAPTER THREE -

MATERIALS AND METHODS

Two field experiments were conducted at the Faculty of Agriculture field station of the University of Nairobi and one at Katumani dryland research station in Machakos district 1985 in and 1986. The field station is at an altitude of 1815 m above sea level and lies within latitude 1° 35' South and 37° 17' East. The first experiment was conducted during the short rains of 1985 at Kabete field station and the other two during the long rains of 1986 at Kabete and at Katumani research station in Machakos district.

Field treatments involved two tillage systems; minimum and conventional tillage. Minimum tillage involved cutting of furrows and opening of spots for seed and fertilizer placements. After planting, two different post-emergence herbicides were applied to kill the weeds, these were glyphosate (N-(Phosphonomethyl) glycine) and paraquat (1,1' - dimethlyl - 4,4' - bipyridinium ion) at their recommended rates. At first weeding, intra-row weeding using a hoe was done followed by inter-row slashing of weeds using a panga During the second weeding all the plots were weeded clean by slashing the weeds at soil surface level using a panga.

In the conventional tillage system the seed bed was prepared by digging all the plot using a hoe to kill the weeds and loosen the soil. The first and second weeding were accomplished by weeding all plots using a hoe.

A complete list and explanation of each treatment is shown below:

1. Furrow tillage - Glyphosate at 2.5 kg a.i/ha plus two hand weedings (i.e. intra-row weeding using a hoe and inter-row slashing of weeds using a panga at first weeding, and slashing of weeds all over the plot at ground level using a panga during second weeding)

2. Furrow tillage - Paraquat at 1.0 kg a.i/ha plus two hand weedings (i.e. intra-row weeding using a hoe and inter-row slashing of weeds using a panga at first weeding, and slashing of weeds all over the plot at ground level using a panga during second weeding).

3. Spot Tillage - Glyphosate at 2.5 kg a.i/ha plus two hand weedings (i.e. intra-row weeding using a hoe and inter-row slashing of weeds using a panga at first weeding and slashing of weeds all over the plot at ground level using a panga during second weeding).

4. Spot Tillage - Paraquat at 1.0 kg a.i/ha plus two hand weedings (i.e intra-row weeding using a hoe and inter-row slashing of weeds using a panga at first weeding and slashing of weeds all over the plot at ground level using a panga during second weeding).

5. Conventional Tillage - Seed bed preparation using a hoe to dig clean the plot plus two hand weedings using a hoe.

A randomized complete block design was used with four replicates. Each block had five treatments, and each plot measured 5 x 10 metres. The furrows were dug 75 cm apart and 4-5 cm deep. The sports were opened in rows which were 75 cm apart and intra-row spacing of 50 cm, the holes were 4-5 cm deep. Katumani maize variety (composite B) was planted at the recommended spacing of 75 cm x 50 cm placing two seeds per hole. This spacing gave a plant population of 56,000 plants per hectare.

A Cooper-Peglar (CP3) knapsack sprayer with water delivery of 250 L/ha was used for herbicide application. Hoes of almost similar sizes were used for hand weeding. Slashing of weeds was done using pangas of almost similar sizes. Workers were assigned to individual plots at random to account for individual work variation. Time taken to cut furrows, open hills, weed and slash the weeds in each plot was taken and recorded in minutes. The time was later converted into man-days per hectare. One-man day was estimated to be equivalent to eight man-hours (Norman, 1972). Time taken in herbicide application was determined by repeatedly spraying water over a specified area at a uniform speed. The average length of time was converted to man-days per hectare. In addition, 20 percent of the spraying time was added to the spraying time to give total spraying time, this was to account for time taken in filling the tank and resting.

The total spraying time was taken as constant for all the herbicide treated plots. In the minimum tillage plots total spraying time was added to the weeding time to obtain weed control time per hectare.

Diammonium phosphate (N, P_2O_5, 18.46) was applied at 80 kg per hectare at planting time. This was placed evenly along the base of the furrow or hole and mixed thoroughly with soil before seed placement. Herbicide application was done a day after planting in the minimum tillage plots. Hand weeding was done two times in the season. First weeding was done two weeks after crop emergence and the second weeding four weeks after the first weeding.

Observations and Records:-

Visual weed rating was done a week after the treatments to determine how effective the treatments were. A scale of 0-100 was used, where 0 meant no control at all and 100 meant complete control of weeds. A quadrant measuring 0.5 m by 0.5 m was placed randomly at three sites within each plot and the weed rating was done for each site. An average was taken to give the percentage weed control. Immediately after crop germination, physical counts of the maize seedlings was done. This was to determine whether the type of seed- bed preparation had any effect on seed germination.

Labour Input Requirements:-

These included:

(i) The length of time taken for herbicide application per plot in the minimum tillage plots.

(ii) Time required for opening furrows and spots, digging the plots, weeding and slashing was obtained by timing each worker per plot from start to finish. Female and male workers of 20-28 years of age were employed as labourers. Time in minutes obtained was converted to man days per hectare. The cost of the two herbicides required at their recommended rates per hectare were calculated.

Cost of the herbicides and labour in 1985/86 was:

(1) Glyphosate KShs. 1948 for 5 Litres.

(2) Paraquat KShs. 447.00 for 5 Litres.

(Agricultural Costs and Prices, book 1985)

The cost of labour in the three experiments was valued at KShs. 17.55 per man-day in 1985 and 1986 according to University of Nairobi rates.

The maize was harvested when the grain was at 15% moisture content. After harvesting the maize was dried in the sun to constant weight. The maize yield was calculated in Kg/ha for each treatment, this was then converted into tonnes per hectare. The yield was calculated when the maize was at 13% moisture content.

Net Income:-

A partial budget was prepared for the two tillage systems to obtain the net income. Variable costs were deducted from gross income to give the net income.

The variable costs included:

- The cost of the herbicides and labour required to apply it.
- Labour required for hand weeding. All other cost were regarded as fixed costs as they applied to all the treatments.

(I) Variable Costs

(a) Herbicides

(i) Quantity required (L/ha)

(ii) Cost per Litre (Cost (L x KShs.))

(b) Wage rate per day

(i) amount (man days per hectare)

(ii) value (Rate per day)

(iii) total cost (man days x rate/day)

(II) Income

(a) Crop yield (Kg/ha)

(b) Gross Income (Kg/ha x price per kg)

Statistical Method Used:-

The analysis of variance was done and the T-test method to separate the means according to Steel and Torrie (1960) was used.

Percentages were calculated to make it easier to compare the differences between the two types of tillage systems, i.e. for all the results dealing with seed bed preparations, the following sets of means were compared:

1. - furrow tillage vs. conventional tillage
2. - spot tillage vs. conventional tillage
3. - spot tillage vs. furrow tillage

For all other results, four sets of means were compared as follows:

1. - minimum tillage vs. conventional tillage
2. - glyphosate treatment vs. paraquat treatment
3. - glyphosate furrow tillage vs. glyphosate spot tillage
4. - paraquat furrow tillage vs. paraquat spot tillage

- CHAPTER FOUR -

RESULTS

The effect of Type of Seed-bed Preparation on Labour requirement

The effect of the type of seed bed preparation method on labour requirement was significant (P=0.05) in both the 1985 short rains season and long rains season in 1986, in all the three experiments (Table 1).

During the short rains of 1985 at Kabete field station furrow tillage required 59.3 percent less man- days per hectare than conventional tillage whereas spot tillage took 71.6 per cent less man days per hectare than conventional tillage. There was no significant difference (P=0.05) in the time taken to open up furrows or spots. The high coefficient of variation could have been contributed by the management of the area as compared to other sites.

Similar results were obtained during the long rains of 1986 (Table 1). Furrow tillage took 70.2 percent less man days per hectare than conventional tillage and spot tillage took 71.1 percent less man day per hectare than conventional tillage respectively. There was no significant difference (P=0.05) in the time taken between the two minimum tillage systems (furrow and spot tillage).

During the 1986 long rains at Katumani dryland research station, furrow tillage took 69.0 percent less man days per hectare than conventional tillage and spot tillage took 91.2 percent less man days per hectare than conventional tillage. No Significant difference was found in the time taken to open furrows or spots (Table 1). (Formulation for calculation of the percentages is shown in appendix D.)

Table 1

<u>Mean time taken in seed bed preparation in man-days per hectare 1985-1986</u>.

	Treatment means in Man-days per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	15.25	10.98	11.71
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	18.90	13.90	14.33
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	11.19	11.61	11.30
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	12.53	12.51	13.07
5. Conventional Tillage	42.00	42.78	42.33
C.V.	40.84%	29.56%	17.98%
S.E. (TREATMENTS):	4.08	2.68	1.67
L.S.D. (TREATMENTS):5%	12.56	8.28	5.14

The most common weeds which occurred in the experimental sites both at Kabete field station and at Katumani dryland research station were mainly broad leaved weeds and a few grass weeds. The broad-leaved weeds were pigweed (Amaranthus hybridus L.), common purslane (Portulaca oleracea L.), wild mustard (Brassica arvensis L.), Clover (Oxalis latifolia H.B.K.), thorn apple (Datura stramonium L), Mexican marigold (Tagetes minuta L.), Gallant soldier (Galinsoga parviflova Cav.), devils thorn (Emex australis Steinh.) and Common chick weed (Stelleria media L). The grass weeds were fox tail (Setaria verticillata Beauv.), wild finger millet (Eleusine indica L. Gaertn.), danel (Lolium telementor), and couch grass (Digitaria Scalarum)

Visual weed rating

Visual weed rating was done in all the plots one week after spraying of the herbicides. This was done to determine how effective the different treatments were in killing the weeds. The visual weed rating was based on a scale of 0-100 where 100 meant complete control while 0 meant no control at all. The results are summarised in appendices 1a, 1b and 1c.

The type of Tillage System and it's effects on Crop Emergence

The effect of the type of seed bed on crop emergence was not significant (P=0.05) during the 1985 short rains season at Kabete and also at Katumani during the long rains 1986. The difference was significant (P=0.05) at Kabete field station during the 1986 long rains season (Table 2).

During the 1986 long rains season at Kabete, conventional tillage had the highest crop emergence count. Furrow tillage had significantly (P=0.05) higher crop emergence count than spot tillage (Table 2). There was better crop emergence during the long rains of 1986 at Kabete than during the 1985 short rains. The reason was because it was wetter at Kabete during the long rains 1986 than during the short rains of 1985 (Appendix D).

At Katumani crop emergence was very low and inconsistent due to very little rain when the maize was planted (Appendix C). This contributed to the poor germination (Table 2).

Table 2

Mean percentage plant emergence count 1985-1986.

	Treatment means in percentage		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	72.25	87.15	29.90
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	74.50	89.15	32.20
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	72.75	78.90	36.15
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	71.88	76.85	37.20
5. Conventional Tillage	83.38	89.45	35.50
C.V.	8.22%	6.55%	14.62%
S.E. (TREATMENTS):	3.08	2.76	2.50
L.S.D. (TREATMENTS): 5%	NS	8.51	NS

Labour requirement at first weeding as influenced by the type of tillage system.

The effect of type of tillage system on labour requirement at first weeding was significantly different (P=0.05) during the 1985 short rains and 1986 long rains season at Kabete field station. However, there was no significant difference (P=0.05) at Katumani dryland research station during long rains season 1986 (Table 3).

During the short rains season 1985, conventional tillage required less labour than minimum tillage. Minimum tillage plots required 101.0 percent more man days per hectare than conventional tillage. In minimum tillage there was significant difference (P=0.05) between the time taken to weed glyphosate treated plots and paraquat treated plots. Glyphosate treated plots required 31.3 percent less man days per hectare than paraquat treated plots. No significant difference (P=0.05) was found between time taken to weed glyphosate furrow and glyphosate spot tillage plots. Spot tillage plus additions of paraquat required 28.8 percent more man-days per hectare than furrow tillage plots plus paraquat.

The same trend of results were obtained during long rains 1986. Results in Table 3 show conventional tillage required less labour than minimum tillage. Minimum tillage required 73.5 percent more man-days per hectare than conventional tillage. Within the minimum tillage treatment, glyphosate treated plots required 38.0 percent less man days per hectare than paraquat treated plots. There was no significant difference (P=0.05) between glyphosate spot tillage plots and glyphosate furrow tillage plots and the same case applied to the paraquat spot tillage and paraquat furrow tillage plots.

At Katumani dryland research station long rains 1986 (Table 3) there was no significant difference (P=0.05) between the time taken to weed conventional tillage plots and minimum tillage plots. Conventional tillage plots took relatively shorter time to weed than the minimum tillage plots but the difference was not significant (P=0.05). (For the calculation of percentages see appendix E. This general formular will apply for percentage calculations in the results up to table 12).

Table 3

Mean time taken in first weeding in man-days per hectare 1985 - 1986.

	Treatment means in man-days per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	24.27	15.00	24.56
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	31.46	24.89	21.98
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	25.21	17.09	28.13
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	40.52	26.87	21.56
5. Conventional Tillage	15.10	12.08	18.63
C.V.	8.49%	15.93%	21.86%
S.E. (TREATMENTS):	1.16	1.53	2.51
L.S.D. (TREATMENTS): 5 %	3.573	4.71	NS

The Labour requirement during second weeding as influenced by the type of tillage system.

The effect of type of tillage system on labour requirement during second weeding was not significantly different (P=0.05) in the 1985 short rains season (Table 4), but the difference was significant (P=0.05) during the 1986 long season rains both at Kabete and at Katumani. It took relatively shorter time to weed conventional tillage plots than the minimum tillage plots.

During the long rains season 1986 in Kabete (Table 4), minimum tillage took 44.1 percent more man days per hectare than conventional tillage. The plots treated with glyphosate required 16.6 percent more man days per hectare than paraquat treated plots. There was no significant difference (P=0.05) in the time taken to weed glyphosate furrow and glyphosate spot tillage plots. This was also true for the paraquat furrow and paraquat spot tillage plots.

Results from Katumani dryland research station during long rains of 1986 are shown in Table 4. Minimum tillage took 62.0 percent more man days per hectare than conventional tillage. There was no significant difference (P=0.05) in the time taken to weed minimum tillage plots i.e. glyphosate treated plots and paraquat treated plots. Also within the treatments there was no significant difference (P=0.05) in the time taken to weed glyphosate furrow and glyphosate spot tillage plots. Similarly, paraquat furrow and paraquat spot tillage plots did not differ significantly (P=0.05).

Table 4

Mean time taken in second weeding in man-days per hectare 1985 - 1986.

	Treatment means in man-days per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	11.15	23.13	24.90
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	16.56	19.38	27.50
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	13.44	21.46	24.17
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	13.64	18.86	24.05
5. Conventional Tillage	11.87	14.37	15.52
C.V.	21.86%	12.45%	18.22%
S.E. (TREATMENTS):	2.51	1.21	2.07
L.S.D. (TREATMENTS): 5%	NS	1.08	6.518

The effect of type of tillage system on the total weeding time

The effect of type of tillage system on total weeding time was significantly different (P=0.05) in both the short rains 1985 and long rains 1986 seasons at Kabete field station and also at Katumani Dryland research station. In all the three experiments minimum tillage system required more time than conventional tillage (Table 5).

During the 1985 short rains at Kabete, (Table 5), minimum tillage required 77.2 percent more man days per hectare than conventional tillage. Glyphosate treated plots required 25.6 percent less man days per hectare than paraquat treated plots. No significant difference (P=0.05) was found in total weeding time between glyphosate furrow and glyphosate spot tillage plots. There was significant difference (P=0.05) in the total time taken to weed paraquat furrow and paraquat spot tillage plots. Furrow tillage plus additions of paraquat required 12.75 percent less man days per hectare than paraquat spot tillage.

During the long rains 1986 at Kabete field station minimum tillage required 72.8 percent more man days per hectare than conventional tillage. No significant difference (P=0.05) was found in total weeding time between glyphosate treated plots and paraquat treated plots. There was no significant difference (P=0.05) in total time taken to weed glyphosate furrow tillage plots and glyphosate spot tillage plots and the same case applied to paraquat furrow tillage and paraquat spot tillage plots (Table 5).

At Katumani dryland research station, minimum tillage required 34.9 percent more man days per hectare than conventional tillage. Glyphosate treated plots required 7.03 percent more man days per hectare than paraquat treated plots but the difference was not significant at (P=0.05). There was no significant difference (P=0.05) in total weeding time taken between glyphosate furrow and glyphosate spot tillage plots, similarly for the paraquat furrow and paraquat spot tillage plots (Table 5).

Table 5

Mean total weeding time taken in man-days per hectare 1985 - 1986.

Tillage system	Treatment means in man-days per hectare		
	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	39.83	42.55	49.48
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	51.12	45.80	49.48
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	41.70	45.77	52.29
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	58.59	48.83	45.61
5. Conventional Tillage	26.98	26.48	36.48
C.V.	9.49%	10.45%	13.34%
S.E. (TREATMENTS):	2.07	2.19	9.77
L.S.D. (TREATMENTS): 5%	6.38	6.74	9.52

The effect of type of tillage system on total labour per hectare

The effect of type of tillage system on total labour per hectare was significantly different (P=0.05) during the short rains 1985, at Kabete field station and during the long rains 1986 at Katumani dryland research station. However the difference was not significant (P=0.05) during the long rains of 1986 at Kabete field station (Table 6).

During the 1985 short rains at Kabete, minimum tillage required 15.49 percent less man days per hectare than conventional tillage. There was significant difference (P=0.05) in the total labour required between glyphosate and paraquat treated plots. Glyphosate treated plots required 28.0 percent less man days per hectare than paraquat treated plots. There was no significant difference (P=0.05) in the total labour required for glyphosate furrow tillage and glyphosate spot tillage plots and also for the paraquat furrow tillage and paraquat spot tillage plots.

Results from Kabete field station long rains 1986 showed that there was no significant difference (P=0.05) in total labour between conventional and minimum tillage treatments. Table 6 shows that conventional tillage required more labour than minimum tillage but this difference was not significant at (P=0.05).

Results from Katumani dryland research station during the long rains of 1986 (Table 6), showed that minimum tillage required 19.9 percent less man days per hectare than conventional tillage. No significant difference at (P=0.05) was found between total labour needed for glyphosate treated plots and paraquat treated plots. There was no significant difference (P=0.05) in total labour required for glyphosate furrow and glyphosate spot tillage plots, also between paraquat furrow and paraquat spot tillage plots.

Table 6

Mean total labour in man days per hectare 1985 - 1986.

	Treatment means in man-days per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	48.17	49.04	63.22
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	66.92	55.28	64.01
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	49.83	52.96	63.57
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	68.21	58.79	58.68
5. Conventional Tillage	68.96	62.00	77.85
C.V.	18.754%	17.844%	9.85%
S.E. (TREATMENTS):	5.67	4.96	3.22
L.S.D. (TREATMENTS): 5%	17.458	NS	9.937

The influence of type of tillage system on yield

The effect of type of tillage system on yield was not significantly different at (P=0.05) during the two seasons in Kabete field station, but there was significant difference (P=0.05) at Katumani Dryland Research Station (Table 7).

At Kabete field station yields were higher during the 1985 short rains than during the long rains of 1986. The Coefficient of Variation for Kabete during the 1985 short rains was high. This could have been contributed by the management of the area as compared to other sites.

There was no significant difference (P=0.05) in yields between conventional tillage and minimum tillage plots at Katumani during the 1986 long rains (Table 7). There was significant difference (P=0.05) between the yields in glyphosate treated plots and paraquat treated plots. Glyphosate treated plots yielded 33.0 percent more than paraquat treated plots. There was significant difference (P=0.05) in the yields between glyphosate furrow and glyphosate spot tillage plots. Glyphosate furrow tillage plots yielded 30.0 percent less than glyphosate spot tillage plots.

Table 7

<u>Mean grain yields in tonnes per hectare 1985 - 1986</u>.

Tillage system	Treatment means in tonnes per hectare		
	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	4.06	3.54	2.03
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	4.16	3.46	1.63
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	2.95	3.83	2.90
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	5.06	3.86	2.07
5. Conventional Tillage	4.89	3.53	2.15
C.V.	39.60%	0.20%	20.42%
S.E. (TREATMENTS):	0.84	11.03	0.22
L.S.D. (TREATMENTS): 5%	NS	NS	0.667

The requirements of type of tillage system and type of herbicide applied on cost at seed bed preparation

The requirement of type of tillage system and type of herbicide applied on cost at seed bed preparation was significantly different at (P=0.05) in all the three experiments during the two seasons. Glyphosate treated plots were the most expensive followed by conventional tillage and lastly the paraquat treated plots were the cheapest (Table 8).

During the 1985 short rains at Kabete field station, minimum tillage using glyphosate required 206.5 percent more money per hectare than conventional tillage (Table 8). Glyphosate treated plots required 326.9 percent more money per hectare than paraquat treated plots. Using paraquat for seed bed preparation was cheaper than conventional tillage. It required 28.3 percent less money per hectare than conventional. There was no significant difference (P=0.05) in cost between either glyphosate furrow and glyphosate spot tillage or paraquat furrow and paraquat spot tillage.

During the 1986 long rains at Kabete field station glyphosate treated plots required 201.8 percent more money per hectare than conventional tillage. Glyphosate treated plots required 348.7 percent more money per hectare than paraquat treated plots. Paraquat treated plots required 32.7 percent less money per hectare than conventional tillage. There was no significant difference (P=0.05) in cost between glyphosate furrow and glyphosate spot tillage plots or between paraquat furrow and paraquat spot tillage plots (Table 8).

During the 1986 long rains at Katumani dryland research station, minimum tillage using glyphosate for seed bed preparation required 189.4 percent more money per hectare than conventional tillage. Glyphosate treated plots required 411.0 percent more money per hectare than paraquat treated plots. Minimum tillage using paraquat required 43.3 percent less money per hectare than conventional tillage. There was no significant difference in cost between glyphosate furrow and glyphosate spot tillage or between paraquat furrow and paraquat spot tillage.

Table 8

Mean labour cost for seed bed preparation plus herbicide cost per hectare in KShs. 1985 - 1986.

	Treatment means in KShs. per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	2293.30	2218.40	2153.50
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	580.70	500.40	433.70
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	2222.00	2206.20	2146.25
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	476.50	485.70	407.60
5. Conventional Tillage	736.70	733.10	743.00
C.V.	11.48%	7.41%	4.99%
S.E. (TREATMENTS):	72.40	45.50	29.34
L.S.D. (TREATMENTS): 5%	223.11	140.21	90.418

Requirements of type of tillage system on cost at first weeding.

The requirements of type of tillage system on the cost of first weeding was significant (P=0.05) in both seasons at Kabete but not at Katumani during the 1986 long rains. Conventional tillage method was cheaper than minimum tillage method (Table 9).

During the 1985 short rains at Kabete field station (Table 9), minimum tillage required 101.0 percent more money per hectare than conventional tillage. In minimum tillage glyphosate treated plots required 31.3 less money per hectare than paraquat treated plots. It was significantly (P=0.05) cheaper to weed paraquat furrow tillage plots than paraquat spot tillage plots. Paraquat furrow tillage plots required 22.4 percent less money per hectare than paraquat spot tillage plots. There was no significant difference (P=0.05) in the cost of weeding glyphosate furrow and glyphosate spot tillage plots.

During the 1986 long rains at Kabete field station, minimum tillage required 73.65 percent more money per hectare than conventional tillage. In minimum tillage, glyphosate treated plots required 38.0 percent less than paraquat treated plots. There was no significant difference (P=0.05) in the cost of weeding glyphosate furrow and spot tillage plots similarly for paraquat furrow and paraquat spot tillage.

There was no significant difference (P=0.05) in the cost at first weeding in all the treatments at Katumani dryland research station during the 1986 long rains (Table 9).

Table 9

Mean labour cost per hectare in KShs. during first weeding 1985 - 1986.

Tillage system	Treatment means in KShs. per hectare		
	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	425.95	263.40	431.40
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	552.10	436.90	385.80
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	442.40	299.90	493.60
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	711.10	472.40	378.40
5. Conventional Tillage	265.10	212.00	327.25
C.V.	8.49%	15.95%	21.86%
S.E. (TREATMENTS):	20.35	26.87	44.08
L.S.D. (TREATMENTS): 5%	62.71	82.19	10.50

Requirements of type of tillage system on cost in second weeding.

The requirements of type of tillage system on the cost of second weeding was not significantly different (P=0.05) during the 1985 short rains at Kabete field station. However, there was a significant difference (P=0.05) during the 1986 long rains at Kabete field station and Katumani dryland research station (Table 10).

During the 1986 long rains at Kabete field station, minimum tillage required 44.1 percent more money per hectare than conventional tillage. Glyphosate treated plots were more expensive to weed than paraquat treated ones and they required 16.6 percent more money per hectare than paraquat treated plots. There was no difference in the cost of weeding the glyphosate or paraquat furrow and spot tillage plots.

At Katumani dryland research station, minimum tillage required 61.8 percent more money per hectare than conventional tillage during the 1986 long rains (Table 10). There was no significant difference (P=0.05) in the cost for second weeding between glyphosate treated plots and paraquat treated plots. There was no significant difference (P=0.05) in the cost of weeding the glyphosate or paraquat furrow and spot tillage (Table 10).

Table 10

<u>Mean labour cost per hectare in KShs. during second weeding 1985 - 1986</u>.

Tillage system	Treatment means in KShs. per hectare		
	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	192.60	405.95	436.90
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	290.70	340.10	482.60
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	235.80	376.60	424.10
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	239.50	330.90	419.50
5. Conventional Tillage	208.40	252.20	272.40
C.V.	22.09%	12.45%	18.30%
S.E. (TREATMENTS):	25.85	21.23	37.26
L.S.D. (TREATMENTS): 5%	NS	65.425	114.822

The effect of the type of tillage system on total weeding cost.

The effect of type of tillage system on total weeding cost was significantly different (P=0.05) during the 1985 short rains and the long rains of 1986 at Kabete field station but the difference was not significant at Katumani dryland research station. Minimum tillage was more expensive than conventional tillage (Table 11).

During the 1985 short rains at Kabete, minimum tillage required 63.3 percent more money per hectare than conventional tillage. There was significant difference (P=0.05) in the total weeding cost between glyphosate treated plots and paraquat treated plots. Glyphosate treated plots required 27.5 percent less money per hectare than paraquat treated plots. There was no difference in the total weeding cost between the glyphosate furrow and spot tillage plots.

During the 1986 long rains at Kabete field station, minimum tillage required 59.9 percent more money per hectare than conventional tillage. Glyphosate treated plots required 8.6 percent less money per hectare than paraquat treated plots but the difference was not significant (P=0.05).

There was no significant difference in the mean labour cost for weeding in all the treatments at Katumani dryland research station during 1986 long rains (Table 11).

Table 11

Mean labour cost for total weeding per hectare in KShs. 1985 - 1986.

Tillage system	Treatment means in KShs. per hectare		
	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	621.45	692.30	870.80
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	842.80	749.40	868.40
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	678.20	725.80	906.80
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	950.60	802.50	850.40
5. Conventional Tillage	473.50	464.30	640.20
C.V.	10.746%	13.610%	14.41%
S.E. (TREATMENTS):	38.325	47.050	59.625
L.S.D. (TREATMENTS): 5%	118.102	144.989	NS

Effect of type of tillage system on Gross income per hectare in KShs from sale of Grain.

The effect of type of tillage system on the Gross income per hectare was not significant (P=0.05) at Kabete field station in the two seasons but was significantly different (P=0.05) at Katumani dryland research station (Table 12).

There was no significant difference (P=0.05) in the Gross income between conventional and minimum tillage at Katumani during the 1986 long rains, but the difference was significant (P=0.05) between glyphosate treated plots and paraquat treated plots. Glyphosate treated plots gave 32.5 percent more money per hectare than paraquat treated plots. There was no significant difference (P=0.05) in the Gross income from glyphosate furrow tillage plots and glyphosate spot tillage plots, the same case applied to the paraquat furrow and paraquat spot tillage plots.

Table 12

Mean gross income per hectare from grain sale in KShs. 1985 - 1986.

	Treatment means in KShs. per hectare		
Tillage system	Kabete field station short rains 1985	Kabete field station long rains 1986	Katumani dryland research station long rains 1986
1. Furrow Tillage plus Glyphosate 2.5 Kg a.i./ha	7891.50	6881.20	3944.30
2. Furrow Tillage plus Paraquat 1.0 Kg a.i/ha	8097.15	6733.00	3173.30
3. Spot Tillage plus Glyphosate 2.5 Kg a.i./ha	5741.50	7430.20	5628.20
4. Spot Tillage plus Paraquat 1.0 Kg a.i./ha	9845.20	7665.90	4050.80
5. Conventional Tillage	9500.55	6871.90	4171.80
C.V.	39.603%	10.775%	20.36%
S.E. (TREATMENTS):	1626.720	383.381	426.848
L.S.D. (TREATMENTS): 5%	NS	NS	1315.36

Production cost.

The total production cost included the cost of labour plus cost of herbicide for the minimum tillage treatment. In conventional tillage only the cost of labour was considered (Table 13).

Net Income

The net income was obtained by subtracting the total cost of production from the total income (Tables 13a-c). In all the three experiments in both seasons paraquat spot tillage treatment had the highest Net Income followed by conventional tillage. The minimum tillage treatments where glyphosate was used to kill weeds had the lowest Net income at Kabete field station during the two seasons.

During the 1986 long rains at Katumani dryland research station, glyphosate spot tillage gave higher Net income than paraquat furrow tillage. Glyphosate furrow had the lowest Net income (Table 13 c). The results from Katumani on grain yield were not very consistent because of the poor germination which was due to low rains and this resulted in very low yields.

Table 13 a

Total production cost and Net Income per hectare

Short rains 1985 Kabete.

Tillage system	Total labour man days	Cost of total labour KShs.	Total herbicide KShs.	Total production KShs.	Total yield in (Metric tonnes)	Total income	Total Net Income	Net income per Ha.
Furrow Tillage Glyphosate 2.5 Kg a.i./Ha	192.664	3381.25	7792.00	11173.25	16.234	31566.10	20392.85	5098.20
Furrow Tillage Paraquat 1.0 Kg a.i./Ha	267.66	4697.45	715.20	5412.65	16.57	32388.60	26975.95	6744.00
Spot Tillage Glyphosate 2.5 Kg a.i./Ha	199.399	3498.40	7792.00	11290.40	11.811	22965.80	11675.40	2918.85
Spot Tillage Paraquat 1.0 Kg a.i./Ha	272.835	4788.25	715.20	5503.45	20.253	39380.80	33877.35	8489.40
Convent-ional Tillage	275.835	4826.25	0.0	4826.25	19.544	38002.20	33175.95	8294.00

Table 13 b

Total production cost and Net Income per hectare

Long rains 1986 Kabete

Tillage system	Total labour man days	Cost of total labour KShs.	Cost of herbicide KShs.	Total production KShs.	Total yield in (Metric tonnes)	Total income	Total Net income	Net income per ha
Furrow Tillage Glyphosate 2.5 Kg a.i./Ha	196.15	3442.40	7792.00	1123.40	14.156	27525.55	16291.15	4072.80
Furrow Tillage Paraquat 1.0 Kg a.i./Ha	221.103	3880.40	715.20	4595.60	13.851	26932.50	22336.90	5584.30
Spot Tillage Glyphosate 2.5 Kg a.i./Ha	211.87	3718.40	7792.00	11510.40	15.32	29788.90	18278.50	4569.60
Spot Tillage Paraquat 1.0 Kg a.i./Ha	235.150	4124.25	715.20	4839.45	15.769	30661.90	25822.45	6455.60
Conventional Tillage	248.00	434.90	0.0	4354.90	14.137	27480.60	23125.70	5781.40

Table 13 c

Total production cost and Net Income per hectare

Long rains 1986 Katumani

Tillage system	Total labour man days	Cost of total labour KShs.	Cost of herbicide KShs.	Total production KShs.	Total yield in (Metric tonnes)	Total income	Total Net income	Net income per ha
Furrow Tillage Glyphosate 2.5 Kg a.i./Ha	252.89	4438.20	7792.00	12230.20	8.114	15777.20	3547.00	866.75
Furrow Tillage Paraquat 1.0 Kg a.i./Ha	256.03	4493.30	715.20	5208.50	6.528	12693.30	7484.80	1817.20
Spot Tillage Glyphosate 2.5 Kg a.i./Ha	254.26	4462.30	7792.00	12254.30	11.578	22152.80	10258.50	2564.60
Spot Tillage Paraquat 1.0 Kg a.i./Ha	234.7	4119.00	715.20	4834.20	8.333	16203.05	11368.85	2842.20
Convent-ional Tillage	311.4	5465.10	0.0	5465.10	8.582	16687.20	11222.10	2805.50

- CHAPTER FIVE -

DISCUSSION

Conventional method of seed bed preparation using a hoe to dig the whole area to be planted takes more time than minimum tillage. During the 1985 short rains season at Kabete furrow and spot tillage systems took 59.3 percent and 71.6 percent less man days per hectare than conventional tillage in that order. Similar results were obtained during the 1986 long rains season at Kabete and Katumani. During this period at Kabete, furrow and spot tillage systems required 70.2 percent and 71.1 percent less man days per hectare than conventional tillage respectively. This is so because digging with a hoe is tedious and requires a lot of energy. According to Druiff and Kerkhoven (1970), the mere lifting of the blade to a height of about one metre 10,000 times in a day in order to cover an area as little as 0.05 m^2 per stroke takes a good deal of energy. The other reason is because most tropical soils are hard and difficult to till during the dry season and this forces some of the farmers to wait until the first showers of rain before tilling the land and this results in late planting and leads to crop yield reductions (Gurnah, 1978).

In minimum tillage, furrow and spots were opened for seed and fertilizer placement, then two post emergence herbicides were applied to kill the weeds using a knapsack sprayer. These operations took less time and energy than digging the conventional tillage plots where the whole plots were dug clean using a hoe. It took 0.876 man days to spray one hectare.

Opening spots took less time than opening furrows but the time taken was not significantly different (P=0.05) in both the 1985 short rains and the 1986 long rains seasons in Kabete and Katumani (Table 1). Using minimum tillage for seed bed preparation is faster and less tedious than conventional tillage. Labour has become very scarce and expensive (Laycock, 1974; Ngugi, 1983). This in most cases has forced farmers to limit their farm sizes and to plant late resulting in low crops yields. Use of minimum tillage and herbicides to control the weeds will ease the labour bottlenecks at the critical period of the cropping season. Since less labour is required with minimum tillage, larger areas can be farmed where land is not limiting and early planting can be done thus increasing crop production.

Crop emergence was generally better in the conventional tillage plots than in the minimum tillage ones but this difference was not significant (P = 0.05) during the 1985 short rains at Kabete or during the 1986 long rains season at Katumani (Table 2). However, the difference was significant (P=0.05) during the 1986 long rains at Kabete. This was attributed to better soil moisture at planting time during the 1986 long rains at Kabete than was the case during the short rains of 1985 (Appendix B).

At first weeding, conventional tillage took less time than minimum tillage at Kabete but at Katumani, the tillage method did not influence weeding labour requirements (Table 3). In the conventional tillage plots the whole area was clean weeded using a hoe, while in minimum tillage intra-row weeding was done using a hoe and immediately followed by inter-row slashing of the weeds with a panga at ground level. The intra-row weeding in the minimum tillage is a very important operation because it ensures that the weeds growing around the crop are cleared and thus reduces weed competition. The intra-row weeding operation takes less time than conventional tillage which involves both inter-row and intra-row weeding. It therefore requires less labour. With the present labour constraints, during weeding, intra-row weeding can be very useful because the farmer can utilize the little labour available to clear the weeds next to the crop plants and then follow it up by inter-row slashing of the weeds at ground level using a panga. This inevitably spreads the labour over the entire weeding period. As a result, minimum tillage will appear to use more labour than conventional tillage. However, since the labour is spread over along period it is ultimately effective and less tiring.

According to Nieto et al. (1968), when weeding was carried out one month after planting yield reductions of 25 percent in maize and 53 percent in beans resulted. Other losses due to weed competition have been reported by many workers, Ashby and Pfeiffer (1956), Prentice (1957), Makatiani (1974), Harland (1925), Denham (1964), Allan (1968). In order to obtain maximum yields with tropical maize, the crop must be kept free from weeds during the first thirty days of growth and weeds growing after that period have no depressive effect on yields (Nieto, 1960).

The type of herbicide applied during seed bed preparation had significant (P=0.05) effect on the time taken during first weeding. This was noted in the trials conducted at Kabete during the two seasons. However, no significant difference (P=0.05) was noted at Katumani (Table 3). Glyphosate treated plots had few weeds during first weeding and therefore less time was spent during weeding as compared to the paraquat treated plots.

During second weeding, conventional tillage took shorter time than minimum tillage. This was noted at Kabete and Katumani during the long rains 1986 but the difference was not significant (P = 0.05) during the 1985 short rains at Kabete (Table 4). Using a panga to slash the weeds between the rows of maize is more difficult than weeding using a hoe. Therefore, it requires more time. Since no advantage was gained by using a panga for slashing weeds during second weeding in the minimum tillage plots then a hoe should be used since it is easier to use and faster.

Conventional tillage requires less total weeding time than minimum tillage (Table 5). This is so because in first and second weeding, conventional tillage was taking less time than minimum tillage. Although minimum tillage is taking more total weeding time than conventional tillage, the advantage of minimum tillage is seen in first weeding where intra-row weeding followed by inter-row weeding helps in spreading the labour over a long time making it more effective.

Hand weeding consumes a lot of the farmers time. A survey carried out in Machakos and Kitui districts showed that about 50 percent of the total labour available for crop production is used up in weeding (Muita et al, 1981). From the results, it shows clearly that the part of hand weeding which consumes the most time is in seed bed preparation (Table 1). This is because the soils are hard and difficult to till when dry (Gurnah, 1975). Also, the heaviness of the hoe makes this very tedious. Minimum tillage with use of herbicide to kill the weeds markedly reduced the labour requirement for seed bed preparation as compared to conventional tillage. Conventional tillage took less total weeding time than minimum tillage (Table 5).

Minimum tillage with use of herbicides to kill the weeds during seed bed preparation followed by two hand weedings required less total labour than conventional tillage (Table 6). This was noted at Kabete during the 1985 short rains and Katumani during the long rains of 1986. This was because very little time was spent in seed bed preparation as compared to conventional tillage where a lot of time was spent (Table 1). This led to the total labour required for minimum tillage being lower than conventional tillage.

There was no significant difference in yields at Kabete during the two seasons but the difference was significant (P=0.05) at Katumani (Table 7). Looking at the results from Kabete which were more consistent, it is clear that the type of tillage system had no effect on the output of the maize crop. The yields were higher during the 1985 short rains than during the 1986 long rains season at Kabete. The reason was that during the 1986 long rain season the maize was affected by a fungal disease (Helminthusporium turcicum) during the grain filling stage. This disease caused the leaves to die in patches then gradually the whole leaf would dry up. This reduced the yields.

Minimum tillage using Glyphosate to kill the weeds was the most expensive method of seed bed preparation followed by conventional tillage and the cheapest was minimum tillage using paraquat (Table 8). The difference in cost between the treatments occurred because of the difference in prices of the two herbicides. Glyphosate killed weeds very well (Appendix 1a - c) but it was very expensive. Five litres which is enough to spray only one hectare costs KShs 1,948.00 (Agricultural Costs and Prices, 1985). On the other hand, paraquat which killed the weeds satisfactorily was cheaper in terms of cost and amount required per hectare. It costs KShs 447.00 for five litres (Agricultural Costs and Prices, 1985) and the rate required is only 2 Litres/Ha. (Chang, 1968; Brown, 1967; Renaut, 1972) cited by Moody (1975) expressed concern that herbicides were too costly to be used by majority of farmers in the tropics. This would depend on the choice of herbicides.

With the right guidance, herbicides can be chosen according to the farmers needs with the present scarcity of labour especially during seed bed preparation and weeding use of minimum tillage with the right herbicide can enable the farmers to prepare enough land for planting, and at the same time plant on time. They will also be saving on labour.

The cost of weeding during first weeding was lowest for the conventional tillage system. This was noticed at Kabete during the 1985 short rains and the long rains season but not at Katumani (Table 9). In minimum tillage, intra-row weeding using a hoe was done followed by inter-row weeding, these two operations resulted in more labour being spent thus costing more than conventional tillage. Glyphosate treated plots were cheaper to weed than the paraquat treated plots. This was because the glyphosate treated plots had fewer weeds than the paraquat treated ones. Therefore glyphosate was a better weed killer than paraquat (Appendix 1a-c). The paraquat furrow tillage plots required less money to weed than the paraquat spot tillage plots during the 1985 short rains. The reason was because the weeds had been sprayed at an advanced stage of their growth, some were already flowering and had a thick canopy. This resulted in poor weed kill by Paraquat which is a contact herbicide. The weeds died on top but there was a lot of re-growth at the time of the first weeding. This resulted in more time being spent in the paraquat spot tillage plots as compared to the paraquat furrow tillage where more area had been cleaned when digging the furrows.

In areas where labour is not a constraint during weeding, then conventional tillage is more economical than minimum tillage. With the present labour shortage in Kenya during the critical periods of crop production (Laycock, 1974; Ngugi,1983). Minimum tillage though more expensive than conventional tillage would be more effective and favourable.

The two operations (intra-row followed by inter-row weeding) help to spread the little labour over a longer period. Having removed the weed competition from the crop during intra-row weeding, the farmer is assured of higher yields. Intra-row weeding was taking a shorter time than conventional tillage.

The cost of weeding was lowest for conventional tillage system during second weeding. This was noticed at Kabete and Katumani during the 1986 long rains season (Table 10). It was noted that slashing of weeds with a panga between the rows of maize which were 75 cm apart was more tedious than using a hoe, thus it required more labour and therefore more money. Although the pangas were lighter than the hoes, swinging them between the rows to slash the weeds was difficult. It would be more economical to weed using a hoe than slashing the weeds using a panga during second weeding. Whether furrows or spots had been dug in minimum tillage had no effect on the cost of weeding during second weeding.

The total weeding cost was lowest for the conventional tillage system. This was noted at Kabete during the two seasons but not at Katumani (Table 11). This was because in first and second weeding, conventional tillage was cheaper than minimum tillage. Although minimum tillage cost less in terms of total cost, the advantage was seen earlier during first weeding where the labour was spread over a longer period making it more effective in terms of reducing weed competition next to the plants and less tiring. In the minimum tillage system, glyphosate treated plots required less money in terms of total weeding than paraquat treated plots. This is carried over from the first weeding, where as stated earlier glyphosate treated plots had fewer weeds therefore requiring less labour.

The gross income from the sale of grain was not significantly different (P = 0.05) during the two seasons at Kabete but was significant at Katumani (Table 12). The results from Katumani were not very consistent in yields due to the poor germination (Tables 7 and 12). Looking at the results from Kabete the gross income was not different whether in minimum or conventional tillage.

Paraquat spot tillage treatment had the highest net income followed by conventional tillage. This was consistent over the two seasons at Kabete and also at Katumani during the 1986 long rains season. Glyphosate treatment was the most expensive and thus had the lowest net income. This was because of the high cost of glyphosate (Tables 13a-c).

- CHAPTER SIX -

CONCLUSIONS AND FUTURE WORK

Minimum tillage with the use of herbicides to kill weeds combined with timely cultivations is a very good alternative for small scale farmers. Digging furrows and spots for fertilizer and seed placement then spraying with herbicides to kill the weeds during seed bed preparation took a shorter time therefore required less labour than conventional tillage. In this way the farmers can avoid the labour bottlenecks, which occur at the peak periods of the planting season making them limit their land size where land is not limiting and also plant late resulting in reduced crop yields.

For herbicides use to be economical, the right choice of herbicide as far as weed control is concerned is very important. Some herbicides are very good weed killers but are very expensive thus increasing the production costs while others will kill the weeds satisfactorily but are cheaper as seen from the report. With proper guidance, farmers can use herbicides effectively. In areas where labour is limiting, intra-row weeding followed by inter-row weeding should be practiced during first weeding. This will help increase crop yields because the intra-row weeding helps remove weed competition from the crop plants. This should be followed by inter-row weeding. This will make the little labour available to the farmers more effective and less tiring. During second weeding, the whole area should be weeded clean using a hoe as this was taking less time and was therefore cheaper than slashing the weeds to ground level using a panga.

FUTURE WORK

Future work can be done to look into the possibility of zero tillage systems being used by the small scale and peasant farmers. This work would involve use of post emergence herbicide for seed-bed preparation then cutting furrows or opening holes, for seed and fertilizer placement. Pre-emergence or early post-emergence herbicides can be applied during the growing season of the crop to control the weeds. This way hand weeding which is tedious and time consuming can be done away with where labour is scarce and expensive.

This method of zero tillage can be compared with conventional and minimum tillage systems to determine which is most economical and thus which is the most suitable for the small scale and peasant farmers.

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Appendix 1a

Mean % weed rating figures .

Short Rains 1985 Kabete field station

COMMON NAME OF WEEDS	FURROW TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	FURROW TILLAGE PARAQUAT 1 Kg a.i./Ha	SPOT TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	SPOT TILLAGE PARAQUAT 1.0 Kg a.i./Ha	CONVENTIONAL TILLAGE
Gallant Soldier	100	100	100	99	100
Mexican Marigold	100	99	100	99	100
Fox Tail	100	99	100	98	100
Wild Finger Millet	100	100	100	97	100
Damel	100	96	100	97	100
Clover	100	100	100	99	100
Pig Weed	100	100	100	100	100
Common Purslane	100	100	100	100	100
Wild Mustard	100	100	100	100	100
Thorn Apple	100	100	100	100	100
Devil's Thorn	100	99	100	100	100
Couch Grass	100	100	100	100	100
Common Chick Weed	100	99	100	100	100

Appendix 1b.

Mean % weed rating figures.

Long Rains 1986 Kabete Field Station

COMMON NAME OF WEEDS	FURROW TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	FURROW TILLAGE PARAQUAT 1 Kg a.i./Ha	SPOT TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	SPOT TILLAGE PARAQUAT 1.0 Kg a.i./Ha	CONVENTIONAL TILLAGE
Gallant Soldier	100	100	100	100	100
Mexican Marigold	100	99	100	96	100
Fox Tail	100	93	100	95	100
Wild Finger Millet	98	100	100	91	100
Damel	100	100	100	93	100
Clover	100	100	100	100	100
Pig Weed	100	99	100	100	100
Common Purslane	100	100	100	100	100
Wild Mustard	100	100	100	95	100
Thorn Apple	100	100	100	100	100
Devil's Thorn	100	100	100	100	100
Couch Grass	100	100	100	100	100
Common Chick Weed	100	100	100	96	100

Appendix 1c.

Mean % weed rating figures.

Long Rains 1986 Katumani Dryland Research Station

COMMON NAME OF WEEDS	FURROW TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	FURROW TILLAGE PARAQUAT 1 Kg a.i./Ha	SPOT TILLAGE GLYPHOSATE 2.5 Kg a.i./Ha	SPOT TILLAGE PARAQUAT 1.0 Kg a.i./Ha	CONVENTIONAL TILLAGE
Gallant Soldier	100	100	100	100	100
Mexican Marigold	100	98	100	97	100
Fox Tail	100	94	100	96	100
Wild Finger Millet	100	96	100	90	100
Damel	100	100	100	98	100
Clover	100	100	100	100	100
Pig Weed	100	100	100	100	100
Common Purslane	100	99	100	100	100
Wild Mustard	100	100	100	100	100
Thorn Apple	100	100	100	95	100
Devil's Thorn	100	100	100	100	100
Couch Grass	100	99	100	100	100
Common Chick Weed	100	100	100	100	100

Appendix B

Monthly Rainfall totals in millimetres for Kabete field station during 1985 and 1986

MONTH	YEAR 1985	1986
January	0.0	6.4
February	94.1	0.2
March	171.4	62.8
April	200.1	237.8
May	80.4	315.4
June	16.2	29.5
July	30.1	6.2
August	8.7	2.3
September	37.3	4.3
October	42.1	40.4
November	137.9	274.3
December	72.8	91.5

Appendix C

Monthly Rainfall totals in millimetres for Katumani Dryland Research Station during 1986

MONTH	YEAR 1986
January	59.0
February	0.0
March	59.4
April	192.4
May	72.7
June	5.7
July	0.4
August	0.3
September	0.0
October	2.6
November	180.0
December	127.2

Appendix D

Formulation for calculation of the percentage difference in labour requirement for seed bed preparation.

1) $\frac{FT - CT}{CT} * 100$

2) $\frac{ST - CT}{CT} * 100$

FT = Furrow tillage.
ST = Spot tillage.
CT = convectional tillage.

Appendix E

Formulation for calculation of percentages for tables 3 to 12.

1) $\frac{MT - CT}{CT} * 100$

2) $\frac{GT - PT}{PT} * 100$

3) $\frac{GF - GS}{GS} * 100$

4) $\frac{PF - PS}{PS} * 100$

MT = Minimum tillage.
CT = Convectional tillage.
GT = Glyphosate treated plots.
GS = Glyphosate furrow tillage.
GF = Glyphosate spot tillage.
PT = Paraquat treated plots.
PF = Paraquat furrow tillage.
PS = Paraquat spot tillage.