EFFECTS OF DIFFERENT TILLAGE SYSTEMS ON GROWTH AND YIELD OF TOMATO (*Lycopersicon lycopersicum* L.)

BY

CHIPO ZISHIRI

A DESSERTATION SUBMITTED TO THE UNIVERSITY OF ZAMBIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN AGRONOMY (CROP SCIENCE)

SCHOOL OF AGRICULTURAL SCIENCES

CROP SCIENCE DEPARTMENT

2001

DECLARATION

I, Chipo Zishiri, hereby declare that this thesis represents my own work and that it has not been submitted for a degree at this University or any other University.

Signature..CZishiri..........................

Date:....4-09-01..................................

APPROVAL

This dessertation of Miss Chipo Zishiri is approved as fulfililling part of the requirements for the ward of the degree of Master of Science in Agronomy (Crop Science) of the University of Zambia.

Examiner' s signature:	Date:
1..	7/9/01
2..	7/9/2001
3..	7/9/2001

DEDICATION

To my mother Veronica and father Crispen.

ABSTRACT

Tomato (*Lycopersicon lycopersicum L*) production among the subsistance farmers in Zambia virtually stops during the rainy season and in low during the dry season. Field trials were carried out during the rainy and dry seasons at Zamseed farm, Lusaka, Zambia to detrmine the effects of different tillage systems on growth and yield of tomato. The rainy season trial was conducted from January to May, 1999 while the irrigated trial was done from June to October, 1999. The tillage systems used were: furrow, ridge planted on the side, ridge planted on top, raised bed and flat seedbed (control). For each season treatments were arranged in a randomized complete block design with four replications. Parameters measured were seedling mortality, plant height, lateral branches, days to 50 % flowering and fruiting , fruit size (mm), diseased fruits, soil moisture content and yield of tomato.

Plant height at 14 weeks after transplanting was significantly ($P \leq 0.01$) higher in raised bed and ridge planted on top treatments i.e., 81.4 cm and 73.8 cm, respectively across seasons. The shortest plants were in the flat seedbed, ridge planted on side and the furrow tillage systems. The raised bed and the ridge planted on top treatments delayed maturity at 50 days and 49 days, respectively, compared to the furrow, ridge on side and flat seedbed at 42 days, 45 and 38 days respectively. The raised bed and the ridge planted on top also increased lateral branches to 17 and 15, respectively, compared to the furrow, ridge planted on side and flat seedbed which averaged 13.The largest fruit size (60mm) was obtained from the ridge plated on side while the smallest sizes (28mm) were obtained from the furrow and the flat seedbed. Seedling mortality was reduced from 13 388 in furrow to 6250, 1388 and 4 166 on flat seedbed, raised bed and ridge planted on side, respectively. Similary, diseased fruits per ha reduced from 65 972 in

furrow to 55 902, 24 305 and 17 361 on the flat seedbed, raised bed and ridge planted on top, respectively.

Tomato yield was significantly ($P \leq 0.01$) higher in raised bed (50.6 t/ha), followed by the ridge planted on top (41 t/ha), furrow (37.6 t/ha), ridge planted on the side (36.9 t/ha) and flat seedbed (control) (35.8 t/ha). In addition, the rainy season recorded lower average yield (14.3 t/ha) compared to (66.6 t/ha) under irrigation.Total yield for combined analysis was positively and significantly correlated ($r=0.74^*$) with plant height and also between total yiel and number of lateral branches ($r=0.8^*$).

The study showed that different tillage systems have profound effects on the tomato plant performance, with the ridge planted on top and raised bed giving the highest yields; while the largest tomato fruits were obtained in all treatments except the furrow. Differential responses observed for some of the measured characteristics between rainy and irrigated season did not have significant effect on final yield. The best yields were during the irrigated season regardless of the tillage system used.

Economic returns were highest during the rainy season as supply decreased and prices increased. During the same season, gross margins were highest on raised bed and ridge planted on top tillage systems, with K11 498 796 and K7 693 187 returns respectively; however, the raised bed tillage system used the highest labour cost. In addition, the ridge planted on the side obtained (K2 085 078). Lower gross margins (K-292 486 and K922 952) were observed on the flat and the furrow treatments, respectively. On the other hand, the furrow and the flat seedbed tillage

systems recorded the highest gross margins (K2 625 849 and K2 405 639), respectively, under irrigated conditions. There was no significant difference in gross margins (K1 732 431 and K1 723 891) for the ridge planted on side and the ridge planted on top, respectively. The raised bed tillage system had the lowest gross margin (K1 223 681) and highest variable costs (K7 790 681). The conclusion is that the tillage systems with highest and lowest yields during the rainy season were the raised bed and the flat seedbed, respectively while the raised bed and the ridge planted on top obtained the highest and lowest yields under the irrigated season, respectively.

ACKNOWLEDGEMENT

I express my sincere appreciation to Dr. D.N. Mbewe and Dr.M. Mwala, both who generously gave effective assistance towards the research work and subsequent thesis write up. In addition, I thank my sponsors (SACCAR/GTZ) for paying for all my expenses that were associated with my course and research work.

Other acknowledgments are duly extended to the Zamseed Farm Management and the Principal of Gwebi College of Agriculture, Mr. W. Matizha for their contribution to my success.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
C.V (%)	Coefficient of variation (percentage)
DF	Degrees of freedom
MSS	Mean sum of squares
P	Probability
RB	Raised bed
RPS	Ridge planted on the side
RPT	Ridge planted on top
SE	Standard Error
ZMK	Zambian Kwacha
SE	Standard error
WAT	Weeks after transplanting
SS	Sum of squares

CHAPTER 1

INTRODUCTION

Tomato (*Lycopersicon lycopersicum* L.) is a fruit vegetable which belongs to the family Solanaceae, and has its origin in the Andean region of Chile, Colombia, Equador and Peru (Rick,1978). In Zambia, it is the most widely cultivated horticultural crop and ranks first among more than 8 species of exotic vegetables grown in the three agro-eclogical regions (Appendix 1). Tomatoes in Zambia are sold as fresh fruits or dried and cooked as vegetables, eaten raw in salads; while about 10 % is processed as chutney, pastes, jams, sauces, purees, juices and canned fruits (Ministry of Agriculture, Food and Fisheries, 1995). In fact, almost every pot of relish cooked in Zambia has tomato as an ingredient (Zulu ,1996).

Consumption of tomato in Zambia is high, although no actual consumption data is available. However, information from other countries indicates that consumption is increasing. For example, the per capita annual consumption in the preserved form in the United States of America increased from about 8.2 kilograms in 1920 to 25.5 kilograms in 1978, a rise of 300% (FAO,1997).

One of the major positive attributes of tomato is its relatively high concentration of water soluble vitamins and minerals, where it ranks first (Stevens,1978). In terms of its specific nutrition, the fruit has 0.06mg iron, 0.6 mg riboflavin, 26 mg vitamin C, 450 μg vitamin A, 0.06 mg thianine, 0.6 mg niacin, 24 mg phosphorus, 10 mg calcium, 4 mg carbohydrate, 1mg protein and 24% edible oil (Rice *et al* ., 1995). From the human nutrition point of view, defiencies of vitamin A and C are most tragic. Vitamin A is the major cause of irrivessible blindness or xerophthalmia in children and miscarriages in pregnant women (FAO,1997). In the Sahelian and other semi-arid parts of Africa, the deficiency of vitamin A in the diet is a major cause of death in children (Okigbo, 1976). In the Luapula valley of Zambia for example, studies have shown that 16% of children under the age of five years had inadquate vitamin A in their blood stream and about 2% had eye problems related to vitamin A defiency which leads to blindness (Musulwe *et al.*, 1996). On the other hand, deficiency of vitamin C causes scurvy, tooth decay, bleeding gums, anemia and premature aging. Studies also indicate that absorption of iron is increased by consumption of vitamin C (Zulu, 1996). This suggests that the consumption of tomato can go a long way in minimising the risks involved with low intake of some of the vitamins, especially vitamins A and C. Another advantage of tomato is that its production is labour intensive, thereby increasing employment.

In terms of production, India produces about 730, Brazil 1 500, Mexico 1 500 and Agentina 570 million tonnes per season (Okigbo,1976). In Africa, during the 1989 season, a total production of 41.6 million tonnes of fruit vegetables including tomatoes was recorded (FAO,1989). In the SADC region, the total production area for the 1998 season, was recorded as 114 000 hactares, while the total yield for the same countries was reported as 113 000 metric tonnes (Mnzava,1990). In addition, commercial farmers in Zimbabwe, Zambia, Tanzania and Angola produce about 72t/ha, 11t/ha, 75t/ha and 9t/ha respectively compared to small-scale farmers who produce about 7t/ha for Zimbabwe, 7.5 t/ha forTanzania and 1.5 t/ha for Angola (FAO,1988).

Large and medium scale commercial farmers of Zambia grow tomatoes thoughout the year because their technology is advanced in terms of machinery, irrigation and capital to purchase inputs. These farmers grow tomatoes on top of ridges during the rainy season to facilitate drainage. During the dry season, they grow tomatoes on flat land and use irrigation to boost their production. Such farmers harvest about 9 t/ha during the rainy season and about 90 t/ha during the dry season under irrigation. Tomato production is profitable during the rainy season as prices are attractive compared to the dry season. For example, urban market prices in Zambia range from US$9.6 per 25 kg box during the rainy season to US$0.96 per 25 kg box during the dry season (Zulu,1998, pers communication).

In all Zambian provinces, production of tomatoes by subsistance farmers is lower than that of commercial farmers (Muliokela, 1995), and there are no statistical records for these farmers because there is no organised horticultural marketing system in Zambia (MAFF,1995). Production by the subsistence farmers is for home consumption and for sale within rural communities and to a lesser extent to urban markets (Mubita,1996). During the dry season, subsistance farmers grow tomatoes in home gardens, along river/dam banks and lowlands (dambos). They obtain water for irrigation from rivers, dams and streams. During the rainy season, tomato production stops completely because of excessive rains which cause water logging and increase root rot diseases (Daka,1996).

Tomato production constraints among subsistance farmers include lack of capital to purchase certified seeds of improved cultivars, insecticides, fungicides, high incidence of pests and diseases, lack of technical knowhow, poor distribution of hybrid seeds to communal areas, shortage of water during the dry season and excessive rains during the rainy season (Muliokela, 1995).

Low yields obtined by subsistance farmers could also in part be as a result of excessive water during the rainy season and limited water supply during the dry season. Heavy rains damage tomato seedlings (Rice *et al.*,1995) and they tend to be water logged and poorly drained resulting in seedling rot (MAFF, 1995), while sandy soils are quickly saturated resulting in leaching of nutrients (Marshner,1993) and if they are exposed to high temperatures, results in rapid evaporation of water from the soil surface, wilting of crops, flower and fruit drop (Rice *et al.*, 1995).

Knowledge of the different tillage systems could be a solution to low yields obtained by subsistance farmers during the rainy season and dry season in sandy soils and heavy soils respectively. Tillage systems facilitate drainage and aeration in all soil types. This reduces seedling rot, promotes rapid root development and facilitate earlier crop maturity (Marshner,1993). Water harvesting techniques achieved through different tillage systems would help in moisture conservation, thus improving growth and yield of tomatoes.

Different tillage systems have been reported to improve growth and yield of fruit vegetables , tomatoes included. This has been achieved by commercial farmers during the rainy and dry season (MAFF, 1995). However, Mingochi *et al.,* (1998), has reported a slow adoption of tillage systems by subsistance farmers in Zambia.The tillage systems: ridges (planted on top and on side), flat seedbed, raised bed and furrows would improve growth and yield of tomatoes by subsistance farmers in Zambia.This will improve output for economic returns and livelihood.

The broad objective of this study was therefore to improve production of tomatoes by subsistance farmers through use of different tillage systems. The specific objectives were:

i) To determine the effect of different tillage systems : ridges (planted on top and on side), flat seedbed, raised bed and furrow on growth and yield of tomatoes.

ii) To analyse the economic returns as influenced by the tillage system.

The hypothesis of this study was that different tillage systems will improve the production of tomatoes among subsistance farmers.

CHAPTER 2

LITERATURE REVIEW

2.1 EFFECTS OF TILLAGE SYSTEMS ON GROWTH AND YIELD OF TOMATO

2.2 TILLAGE

Tillage is a manual or mechanical soil stirring action (Vogel,1991) and it embraces all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and growth of the crop (Chuma *et al.*,1993). It is a generic term that caters for adequate soil temperature, seed- soil contact, moisture conservation, aeration and weed control (Hagman *et al.*,1994). Tillage facilitates incorporation and mixing of fertilzers, lime and pesticides in the soil (Vogel,1993).Tillage systems examples include mounds, ridges, raised beds, flat seedbeds, furrows, clean ripping, mulch ripping and tied ridges (Chuma *et al.*,1993). Mounds are used in the tropical traditional agriculture. In Nigeria, large mounds of 3 - 4 metres wide and 1 metre high are constructed on poorly drained soils (Bradfield,1970). A slightly modified version of the mound system in which the crop residues and weeds are put in the centre of the mound is called "mofuka" in Zaire (Kawal *et al.*,1973), "ufipa" in Tanzania (Shetto,1998) and "fundikila" in Zambia (MAFF,1995). Most farmers in Zambia use ridges, raised beds and small basins to plant vegetable crops, and this conservation tillage system is adapted for ease of irrigation (Mingochi *et al.*,1998).

2.2.1 RIDGES

Ridges increase yields by facilitating drainage and aeration, increasing rooting volume and depth. Ridges also improve the uptake of nutrients that promote plant groth and development They also reduce seedling rot and nematode attack (Muliokela,1995).Tomatoes can be produced successifully on top of ridges during the rainy season as they facilitate drainage and aeration. Improved plant growth has been reported by using rigdes. For example, Ngamila (1987) recorded potato plant height of 32.2 cm and 5 stems per plant at 43 days after planting on top of ridges compared to 27.6 cm and 3 stems on the furrow tillage system. The improved plant growth on ridges was due to improved drainage and aeration and poor drainage contributed to shorter plants and fewer stems in the furrow. The drainage and aeration advantages provided by ridges are in agreement with Vogel (1993), who observed that natural regions with highest rainfall are associated with water logging and growing crops on ridges results in increased growth because ridges facilitate drainage and aeration. The risk of seedling rot is also reduced because the roots are not deprived of oxygen which is needed for adequate respiration. A report by Messien (1992) indicated that ridging reduces the risk of seedling rot in high rainfall areas and on ferrallitic soil due to improved drainage and aeration. Planting on the ridge is also recommended in sandy soils, especially under exessive rainfall conditions. Sandy soils tend to quickly get saturated, resulting in reduced aeration and water movement. In such conditions, ridge planting is recommended (Nyagumbo, 1994). The method of ridge preparation, i.e., heaping the soil, increases the soil volume, from which roots can easily absorb water and nutrients from deeper soil levels. This enhences seedling establishment, growth and yield of crops.

Ridges also reduce fruit rot and improve harvesting turnover. They add extra height to crops from the groung level so that flowers and fruits are formed well above the ground level. This reduces the risk of fruits being contaminated by disease pathogens, thus reducing losses due to fruit rot (Messian,1992). The added height also facilitates easy and fast harvesting of fruits before they are subjected to pest and disease attack (John,1978). This is in agreement with Dufalt *et al.* (1994) who reported that fruit vegetables planted on ridges are easy and fast to harvest. Ridges are also known to reduce nematode attack. They facilitate easy fumigation and distribution of the fumigant in the heaped soil. Agrios (1985) concluded that solanaceous crops planted on ridges are less attacked by nematodes as it is easy to fumigate the soil. However, ridges can decrease yields by losing moisture from the top of the ridge during the dry spells, excessive leaching of nutrients from the ridge and due to exposure to high temperatures on the elevated sides of the ridge. During dry spells or drought periods, there is limited moisture to saturate the increased soil volume of the ridge. Therefore, reduced growth and subsiquent wilting can be experienced if transpiration exceeds water uptake (Chuma *et al.*, 1993), resulting in reduced yield. This is also in agreement with Mharapara *et al.* (1994), who reported lowest yield of cotton of 1408 kg/ha from the top of the ridge and this was attributed to increased loss of moisture during drought, particulary in sandy soils. As rainfall increases, more nutrients, fertilizers and clay particles are leached from the ridges reducing growth and yield of crops. Reports by Vogel (1991) show that under high rainfall conditions, nutrients, fertilizers and clay particles are leached from the to of the ridge resulting in reduced growth.

2.2.2 FLAT SEEDBED

The flat seedbed tillage system is one of the most commonly practiced by small-scale subsistance farmers (Vogel,1993) because it is easy, quick and effectively implemented. It increases growth and yield through its ability to conserve early rainfall, and decreases yields through poor water infiltration, increased soil erosion, nutrient leaching, high water logging and poor drainage, exposure to temperature and poor root deveopment. Flat seedbed takes advantage of early rainfall. Water concentrates inside the planting hole, thus increasing its micro- catchment effect. This gives insuarance against early drought and the crop does not grow in the dry root environment. Hagman *et al.*,(1994) reported that flat seedbed promotes excellent crop establishment through water catchment before major capping occurs. Limited moisture conservation and soil capping have been reported as reasons for slow establishment and growth of tomatoes and paprika (Chuma *et al.*,1993). Reduced yields by flat seedbed are due to poor water infiltration. Flat seedbed is prepared by hand and may promote rough and compacted surface that reduces water infiltration. Water is essential for metabolic activities in the plant such as respiration and photosynthesis. Water is also required for dissolving fertilizers and lime. Therefore, poor water infiltration reduces growth and yield. This has been supported by Vogel (1993) which states that the rough and compacted seedbed normaly associated with flat seedbed limits water infiltration and cause incomplete dissolving of fertilizers resulting in stunted growth. The soil under flat seedbed tillage system is often exposed to rain drop action and soil erosion. With the onset of torential rains, soil erosion increases resulting in washing away of fertile top soil and nutrients, resulting in limited plant growth. Limited soil due to erosion may also lead to root and stem lodging due to poor soil support. Soil erosion may expose roots to pest, disease attack and dessication. This is supported by Hagman *et al.*,(1994) who reported accelerated soil erosion in flat seedbed, leading to reduced seedling establishment and growth. Anaerobic conditions created by poor drainage and water logging reduce oxygen levels, resulting in reduced root respiration and increased root rot. The translocation of water and nutrients to other parts of the plant is reduced, hence stunted growth and wilting may occur. Caldwell (1981) reported that water logging in flat seedbed resulted in reduced water and nitrate absorption and this increased root and stem rot, stunted growth and physiological disoders in tomatoes. Flat seedbed crops are sometimes disadvataged in that they are often exposed to very high temperatures during the hot, dry periods and to very low temperatures during the low temperature periods compared to crops grown on ridges and raised beds. Very high temperatures increase transpiration rates and evaporation from the soil, resulting in moisture stress and wilting of plants. On the other hand, exposure of crops to very low temperatures causes slow growth and short unproductive plants (Quinin,1974).

2.2.3 RAISED BEDS

Raised bed is prepared by hoes and shavels. The system has been found to increase yields of vegetable crops. For example, growth and yield of crops have been found to increse through improvement in soil structure and soil stability, provision of a better environment for organic matter decomposition, root development and water infiltration. It acts as a resevoir for storage of nutrients, increases the activity of micro organisms, provides surface drainage, reduces disease incidences and improves soil temperature. Raised beds have also been known to improve water use efficiency. Soil structure and soil stability are achieved when the soil is heaped together and this creats a physical environment which greatly modifies the pattern of growth. The improved soil aggregate size achieved by heaping the soil, has been found to influence root and shoot growth of dicotyledonous plants such as paprika and egg plants (Dufault *et al.,* 1994). Soil structure also promotes soil conditions and characteristics such as water infiltration, heat transfer and aeration (Brady,1990), as and seedling establishment of most dicotyledonous crops can be impeded in weakly structured soils.When raised beds are constructed, plant residues are put in the middle of the bed before heaping the soil. This increases decomposition of the organic matter, resulting in increased mineralization, nutrient concentration and availability within the root zone. These nutrients improve root development, stem elongation, flower and fruit formation and total yield. . Shetto (1998) reported that raised beds are constructed for fertility improvement in Tanzania. Plant residues are incoperated underneath before heaping the soil. Raised beds provide resevoir and storage for nutrients such as phosphorus. Since phosphorus is immobile, it is transfered to greater depth of the raised bed through improved root development and root activity. The concentration of phosphorus coincides with high root densities and Marshner (1993) states that phosphorus promotes rapid root development and hastens maturity. It also regulates the starch:sucrose ratio in leaves and reproductive organs. Rapid root development increases uptake of more nutrients leading to improved growth and yield. Micro-organisms such as earth worms increase their activities in mounded soil such as that achieved in raised bed. The biological activities increase organic matter decomposition, resulting in slow release of nutrients and stimulate increase in soil temperature within the bed. The nutrients promote vegetative and reproductive growth and the high soil temperature improves root development and uptake of nutrients. Raised beds are also known to improve surface drainage and reduce water logging. A poorly drained soil may lead to poor seedling establishment due to lack of oxygen because of poor diffusion rates. Seedling establishment, growth and yield can be affected because of loss of nutrients under excessive conditions of moisture. Nitrogen for example, is lost through microbial denitrification. Reports by AVRDC (1988) state that during excessive rains, wide raised beds increased early tomato yield to 1.1 t/ha due to improved drainage compared to 0.6 t/ha in flat seedbed. In another trial by AVRDC (1988), raised beds recorded significantly greater yields (5.8 t/ha) compared to low beds (3.8 t/ha) due to surface drainage. Surface drainage also improved tomato yield by 4 6 kg/plant from raised bed and this was four times more than 1.2 kg/plant from low bed which experienced water logging (Caldwell, 1986). Disease pathogens such as *fusarum, pythium, rhizoctonia and blight* are normally associated with water logging conditions. Raised beds are well drained and aerated to improve root and shoot growth. Rapid root and shoot growth escape severe attack from diseases. This is because of rapid formation of meristamatic tissue that gives rise to secondary growth that is resistant to pathogen penetration (Bidwell, 1987). Disease pathogens attack crops at specific stage of growth and once that stage is passed, the crop withstands damage. Therefore, fast growth due to rapid root and shoot development can escape the stage of growth favourable for pathogen infestation. Raised beds also reduce favourable environment for growth and development of disease pathogens. Report by Linneman (1980) states that a 70 cm high raised bed minimized southern blight (*Sclerotium rolfsii*) on tomato and (AVDRC, 1988) also recorded less disease counts of 3 for *fusarium* and 3.5 for *pythium* and concluded that this was due to improved drainage, aeration and rapid growth. Raised beds have also been known to increase yield through improved water use efficiency. For example, improved water use efficiency and yield were demonstrated by (Mharapara, 1987), when a one 1 m wide raised bed was compared to a 3 m wide raised bed. Results showed that a 1 m bed, with a total rainfall of 255.4mm, yielded 474 kg/ha maize grain, giving a water use efficiency of 1.5 kg of grain/mm rain. On the other hand, a 3 m wide bed with 210 mm rainfall, yielded 1 139 kg/ha maize grain, with a water use efficiency of 5.4 kg of grain/mm rain.

2.2.4 FURROWS

Furrows are known to harvest and store soil moisture. However, they are susceptable to nutrient washing as the water moves through the soil surface and cause soil erosion, thereby reducing plant height and number of stems per plant. Nyamudeza *et al.* (1983) showed that soil water content in furrows improved by 33% more than the flat seedbed and concluded that furrows constructed on heavier soils of vertisols have the ability to hold more water. Yields of 80% pepper was observed when alternate furrows were left open to harvest water (Messian, 1992) while furrows improve irrigation efficiency, save water and improve storage water in the root zone (Elwell,1988). Ngamila obtained a ssignificant decrease in plant height of Irish potato(27.6)when planted in furrows. In addition, Mingochi *et al.*, (1998) reported that fertilizer placed in furrows is washed away by run off water.

CHAPTER 3

MATERIALS AND METHODS

3.1 Site selection

The experiment was conducted at ZAMSEED farm, which is situated about 18 km north of Lusaka. It was carried out during the 1998/99 rainy season and the 1999 dry season under irrigation. The site is located at 1 186 meters above sea level. It receives a mean annual rainfall of 800 mm with daily temperatures ranging from 23°C to 25°C, mean maximum temperature of 32°C and a mean minimum temperature below 10°C. This is representative of agro-ecological region II. The soil type is slightly leached clay soil, red to reddish in colour, and its heavy textured top soil sometimes makes it difficult to work (Muliokela,1995).The rainy season experiment was conducted on a field which was under maize (*Zea mays* L.) during 1997/98 season, while the irrigated experiment was carried out on a field which was fallow during the 1998 rainy season.

3.2 Soil analysis and land preparation

3.2.1 Soil analysis

Two soil samples were taken at a depth of 20 cm and the pH ($Cacl_2$) values were 7.3 and 7.4 for the two fields, respectively (Tables1 and 2). These values were ideal for tomato growth (John, 1983). Nitrogen levels varied from 0.11% to 0.10 % for rainy and irrigated season respectively. In addition, phosphorus levels for the rainy and irrigated seasons ranged from 36.7 mg/kg and 35.6 mg/kg respectively. Potassium is one of the major nutrients in tomato production but however it was not determined in this trial. Land for the rainy season crop was ploughed by the end of November, 1998; while preparation for the irrigated crop was completed by the end of April, 1999, using a tractor mounted disc plough and later levelled by a rotary cultivator.

Table 1: Soil Analysis results for the rainy season experimental area at Zamseed Farm, 1999.

Parameter	Value
pH	7.3
Nitrogen (%)	0.11
Phosphorus (mg/kg)	36.7

Note:

1. pH determined in M calcium chloride.

2. Analysis done at the University of Zambia, School of Agricultural Sciences Laboratory.

3. Soil samples taken at 20 cm depth.

Table 2: Soil analysis results for the irrigated season experimental area at Zamseed Farm, 1999.

Parameter	Value
pH	7.2
Nitrogen (%)	0.10
Phosphorus (mg/kg)	35.6

Note:

1. pH determined in 0.01 M calcium chloride

2. Analysis done at the University of Zambia, School of Agriculcural Sciences Laboratory.

3. Soil samples were taken at 20 cm depth.

3.2.2 Seed sowing and nursery management

Tomato seeds (cultivar Money Maker) for the rainy season were sown on 5th December 1998, while the seeds for the irrigated experiment were sown on the 2nd May, 1999. The seeds were sown in sixteen plastic trays measuring 30 cm wide and 50 cm long and10 mm deep. The trays were then placed in the greenhouse for four weeks. The soil used was 1:4 soil/compost mix to which 135g/m^2 compound D (10N, $20P_2O_5$,$10K_20$) was added. The seedlings were watered regularly for 30 days.

3.2.3 Treatments and experimental design

Treatments consisted of :

i) raised bed measuring 2 m wide, 6 m length and 30 cm height

ii) ridge planted on top- 30 cm x 6 m x 30 cm

iii) ridge planted on side - 30 cm x 6 m x 30 cm height and was planted at 15 cm from the top of the ridge

iv) furrows - 30 cm x 6 m x 15 cm depth

The treatments were prepared by hand hoes and shavels and they were arranged in a Randomised Complete Block Design with four replications. A plot was made up of 6 rows which were 6 m long and seperated by a 1 m path. Spacing was 90 x 50 cm, inter -and intra-row, respectively.

3.2.4 Basal fertilizer application and transplanting

Basal fertilizer (compound D) was broadcast uniformly before tillage systems preparation at the rate of 500kg/ha. This supplied 50, 100, 50 kg nitrogen, phosphorus and potassium, respectively. Transplanting of the two season crops took one day for each and transplanting of rainy season crop commenced on 13th January 1999, while the irrigated crop was transplanted on 3rd June 1999. Regular watering of the seedlings was stopped for 5 days to harden the seedlings before transplanting. At the time of transplanting, the seedlings were between 5-8 cm tall.

3.2.5 Weeding and top dressing

Plots were kept weed free as much as possible by use of hand hoes. Weeding for the two trials was done three times. Top dressing was done three times as recommended by the National Irrigation Research Station of Zambia, using urea (46 %N) at the rate of 30 kg/ha per each application. The fertilizer for the rainy season was side dressed on 5th February (23DAT), 6th March (53 DAT) and 21st April 1999 (78 DAT); while the irrigated crop was top dressed on 25th June (23 DAT), 26th July (53 DAT) and 20th August 1999 (78 DAT).

3.2.6 Insect pest and disease control

Dimethoate 40% E.C (*rogor*) and metasystox, (a synthetic pyrethroid) were both applied at the rate of 400 ml/ha for the control of aphids (*Aphis gossypii)*, whiteflies (*Bemisa tabaci)* and bollworms *(Heliothis armigera).* Copper oxychloride and Dithane M-45 at 200g/100 litres of water were used as full cover to control damping-off complex diseases *(Phytopthora parasitica, Rhizoctonia spp* and *Pythium* spp*),* early blight (*Alternaria solani*), late blight (*Phytopthora infestans)* and bacterial wilt (*Pseudomonas solanacearum).* Insect pests and disease sprays for the rainy season crop were done every week as routine operations while emergency sprays were done after every rain. The irrigated crop received fungicides and insecticides as routine sprays once every two weeks. The chemica types and rates are to those used for the rainy season.The spraying was achieved by using a 15- litre capacity hand operated knapsack sprayer.

3.2.7 Staking

The rainy season crop was staked three times, i.e., 14th February (32 DAT), 16th March (63 DAT) and 14th April 1999 (92 DAT); while the irrigated crop was staked on 16th July (43 DAT), 17th August (75 DAT) and 22nd September 1999 (111DAT). The branches were tied to 1.5m tall stakes to avoid branches and fruits coming into contact with bare wet soil.

3.2.8 Irrigation

The rainy season crop was given three supplimentary irrigations after dry spells and 35mm water was applied per each irrigation. A sprinkler irrigation system was used for both the rainy and irrigated crops. The irrigated crop received 450 -550mm of water throughout the growing period, with 30.5 mm per 4 hours of application. The crop received 18 irrigations. For the first four weeks after transplanting (4WAT), irrigation was done twice a week. Between five to seven weeks after transplanting (5 to 7 WAT), water was applied once a week for four hours. During peak flowering and early fruiting periods (8-10 WAT), irrigation was applied twice a week. From eleven to forteen weeks after transplanting (11-14WAT), watering was done once a week. *This irrigation schedule was as per recommendation from the National Irrigation Research* Station in Mazabuka, Zambia, where research on horticultural crops is carried out.

3.3 Harvesting

Harvesting for the rainfed crop was done at 92, 113 and 128 days after transplanting, while for the irrigated, it was done at 117, 126 and 133 days after transplanting (DAT). This was done at mature green and pink blossom end stage of ripening to avoid rapid deterioration if harvested later than this stage (Muliokela,1995).

3.4 Fruit grading

Tomatoes were graded according to three diameter sizes, large (45-100mm), medium (35-44mm) and small (0-34mm). The diseased, cracked and bruised fruits were also removed. A verneer caliper was used to measure the diameter sizes.

3.5 Yield

The fruits were harvested from a net plot area of 3.6 m^2 and weighed using a movable scale in the field. Only the markatable fruits were considered as yield.

3.6 Data collection.

3.6.1 Soil moisture determination

This was done for the dry season (irrigated crop). Soil moisture determination was done using the gravimetric procedure. The samples were taken from six depths, i.e., 20, 40, 60, 80,100 and 120 cm. These were collected at 2 weekly intervals from 2 weeks after transplanting (2 WAT) to12 (WAT) i.e., 3rd and 17th June 1999, 1st , 15th, 29th July and 12th , August, 1999. An auger was used to take soil samples at different depths at the same point. The soil samples were put in plastics and later transffered to the metal cans. The weight of wet soil for each sample were recorded before putting the soil in the oven for 24 hours at 105^{0}C.The weight of dry soil was also recorded. The difference in soil moisture between the wet and dry soil was considered for analysis.

3.6.2 Seedling mortality

This was achieved by monitoring sixteen plants from the two middle rows of each plot and two plants were left on either end of each row as border plants. Data was therefore collected from an area of 3.6 m^2 and records of seedling deaths were done at two weeks after transplanting.

3.6.3 Plant height

Sixteen plants from two middle rows of each plot (3.6 m^2) were measured between 4 and 14 WAT.The measurements were taken from the soil surface to the growing tip.The mean height was taken as the plant height of the plot.

3.6.4 Number of auxillary shoots/suckers/lateral branches

These are described as lateral growths from the main stem other than the main apical shoot (John,1978). Data for this parameter was collected at the same time as that for plant height , on the same plants and area. Branch numbers were physically counted and taken as the sum of secondary branch from the main stem and the average of the 16 plants was recorded as the branch number for the plot.

3.6.5 Days to 50 % flowering

For the same number of plants from each plot (3.6 m^2), the dates of flowering were recorded and then counted from the date of transplanting. This was done until the period when 50% of plants had flowered. The average days for eight (8) plants were recorded as the 50% days to flowering.

3.6.6 Days to 50 % fruiting

The plants from the same plot as above were monitered and dates of fruiting were noted so that a total count of the number of days from transplanting to first fruiting were recorded when 50 % of the plants had fruited. The average days of 8 plants were taken as the 50% days to first fruiting.

3.7 Economic analysis

Gross margin budgets were prepared to compare the rainy and irrigated seasons. This was achieved by calculating the gross revenue and then subtracting the variable costs from the gross revenue. Break even yield and return to labour were also determined.

3.8 Statistical analysis

The data was analysed using the Analysis of Variance to determine the effects of the different tillage systems on growth and yield of tomato. The experimental design used was the Randomised Complete Block Design and the statistical package used was MSTAT. The means seperation was done using Duncan's Multiple Range Test. Correlation was also done to determine the relationships among growth parameters. A combined season analysis was carried out according to the ANOVA model in Table 3.

Table 3. Model for the combined season analysis of variance.

Source		Degrees of freedom
Season (1)		1
Rep/Season	Season (r-1)	6
Tillage system	(t-1)	4
Tillage x Season	(t-1) (s-1)	4
Error	s (r-1) (t-1)	24

Note:

s= seasons

r= replication

t= tillage system

CHAPTER 4

RESULTS

4.1 Effects of tillage system on soil moisture content

Table 4 shows the results of soil moisture taken at different depths under different tillage systems during the irrigated season. Tillage system did not affect the soil moisture content (Appendix 5).

4.2 Seedling mortality

Table 5 shows the results of seedling mortality under different tillage systems, during the rainy and irrigated season. The rainy season crop recorded the highest seedling mortalities compared to the irrigated crop with no seedling deaths.The mortality was significantly ($P \leq 0.05$) higher under the furrow tillage system, while there were no differences amoung the other tillage systems, i.e., flat, ridge planted on the side, ridge planted on top and raised bed, respectively (Table 5, Appendix 6). In contrast, no seedling mortality was observed for the crop grown under irrigation.

4.3 Plant height

Table 6 shows that seasons were significantly ($P \leq 0.05$) different with regard to height of tomato plants. Tomato plants were significantly ($P \leq 0.01$) different in height across the tillage systems. A significant ($P \leq 0.01$) interaction between seasons and tillage systems was evident. The differences among tomato plants in the different systems was observed during the rainy season (Appendices 7,8.1 and 8.2). The tallest plants (75.1 cm) were under irrigation compared to the rainy season (60.2 cm). Overally, the tallest plants (81.4cm) were observed in the raised bed, followed by those in the ridge planted on top tillage system (73.8 cm). No differences were observed for the plants in the other systems and no differences were observed among plants in all the systems under irrigation. In general, plant height was higher during the irrigated season

Table 4 Effects of tillage system on soil moisture content (mm) at 14 weeks after transplanting for the irrigated season crop

Tillage system	**Moisture content (mm)**
Furrow	19.2a[1/]
Ridge planted on side	19.3a
Ridge planted on top	20.2a
Raised bed	19.7a
Flat seedbed	20.7a
Mean	**19.8**
C.V (%)	**12.1**

[1/] Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at $P \leq 0.05$

(75.1 cm) than rainy season (60.1 cm). The plants in the furrow, ridge planted on side and flat seedbed averaged 28.5 cm high. No significant change was observed for plants in raised beds.

4. 4 Lateral branches

The irrigated season crop had more lateral branches compared to the rainy season crop. Tomato plants were significantly ($P \leq 0.01$) different in the number of lateral branches among tillage systems and seasons (Table 7). Interaction between seasons and tillage systems was significant. The highest number of lateral branches (15) was under rainy season compared to irrigated season (13).

Overall, the highest number of lateral branches (17) was observed in the raised bed tillage system, followed by those in the ridge planted on top system (14.5) However, the later was not significantly ($P \leq 0.01$) different from the furrow, ridge planted on side and flat seed bed which recorded an average of (13). The ranking observed in the combined analysis is similar to that of rainy season ranking. Differences were observed in all the systems under irrigation. In general, lateral branches decreased in rainy season (15) as opposed to in irrigated season (13). The lowest change was in furrow and flat tillage systems, followed by ridge planted on side (3) and the ridge planted on top (5). The highest number of lateral branches was observed from plants on raised beds.

4. 5 Days to 50% flowering

Table 8 shows that days to 50% flowering were not different between the two seasons. The tomato plants were significantly ($P \leq 0.01$) different in days to 50% flowering among the tillage systems. Overall, the latest flowering (49 days) were observed in raised bed and ridge planted on top tillage systems. Early flowering was in furrow, ridge planted on side and flat seedbed

Table 5 Effects of tillage system on seedling mortality at 2 weeks after transplanting

Tillage system	**Rainy season (ha^{-1})**	**Irrigated season (ha^{-1})**
Furrow	13 388 a[1/]	0
Ridge planted on side	6 944 b	0
Ridge planted on top	4 166 b	0
Raised bed	1 388 b	0
Flat seedbed (control)	6 250 b	0
Mean	**6 427**	**0**
C.V (%)	**62.6**	**0**

[1/].Means in a colunm followed by the same letter are not significantly different, according to Duncan's Multiple Range Test at $P \leq 0.05$

systems. However, the ridge planted on side was not different from the other treatments except the flat seedbed, which was not different from the furrow tillage system. A significant ($P \leq 0.01$) interaction between seasons and tillage systems was observed. The days to 50% flowering (45.5 days) under irrigation was not different from rainy season days (44).

The ranking observed in the combined analysis is different from that of rainy and irrigated season. However, the latest days to 50% flowering for rainy season averaging 53 days, observed in raised bed, followed by 51 days in ridge planted on top, while the earliest flowering of 39 days were observed in furrow, ridge on side and flat seedbed. Under irrigation, days to 50% flowering were also significantly ($P \leq 0.05$) different among tillage systems. The longest duration (49 days) was observed under ridge planted on side, followed by an average 46 days on furrow, ridge planted on top and raised bed systems. Generally, the number of days to 50% flowering was less in rainy season (44 days) than under irrigation (46).

4. 6 Days to 50% fruiting

Table 9 shows that 50% fruiting of tomato plants among the five tillage systems differed between seasons.Tomato plants were not significantly different ($P \leq 0.01$) in days to 50% fruiting among tillage systems. No significant interaction between seasons and tillage systems was observed. The ranking observed in combined analysis was similar to the rainy and irrigated seasons (Appendices 13, 14.1 and 14.2). However, the number of days to 50% fruiting was higher under irrigation than rainy season. The biggest change for days to 50 % fruiting was on flat seedbed (19 days), followed by furrow, ridge on side and raised bed (14 days). No significant change was observed for days to 50% fruiting in ridge on top system.

Table 6. Effects of tillage system on plant height of tomatoes at 14 weeks after transplanting

Tillage system	**Rainy season (cm)**	**Irrigated season (cm)**	**Combined analysis (cm)**
Furrow	45.8b[1/]	75.9a	60.9b
Ridge planted on side	48.2b	76.2a	62.2b
Ridge planted on top	76.8a	70.8a	73.8a
Raised bed	83.9a	78.8a	81.4a
Flat seedbed (control)	46.2b	73.6a	59.9b
Mean	**60.2**	**75.1**	**67.6**
C.V (%)	**5.8**	**7.3**	**6.8**

[1/] .Means in the colunm followed by the same letter are not significantly different, according to Duncan's Multiple Range Test at $P \leq 0.01$

4. 7 Fruit size (mm)

4.7. 1. Small fruit size

Tables 10 shows small fruit sizes among tillage systems that were significantly different between rainfed and irrigated crop. Generally, the irrigated season had slightly greater proportion of small fruit sizes than the rainy fruits. No significant interaction between seasons and tillage systems was observed. The ranking observed in the combined analysis was similar to the rainfed and irrigated crops (Appendices 15, 16.1 and 16.2).

4.7. 2. Medium fruit size

Table 11 shows medium fruit sizes that were not significantly different with respect to seasons among different tillage systems. No significant interaction between season and tillage systems was observed. The ranking observed in combined season analysis was similar to that of rainy and irrigated season.

4.7. 3. Large fruit size

Table 12 shows that seasons were significantly ($P \leq 0.01$) different with regard to large fruit sizes. Tomato sizes were highly significantly ($P \leq 0.01$) different in the large fruits among tillage systems. Overall, the largest fruit sizes (60 mm) were observed in the ridge planted on the side, followed by an average of (55 mm) in the ridge planted on top, raised bed and the flat systems. These last three treatments were not significantly different from the furrow and ridge planted on the side. However, the smallest medium fruit size (50 mm) was recorded on the furrow tillage system. A significant ($P \leq 0.01$) interaction between season and tillage systems was evident. The observed differences among large fruit sizes in different systems were mainly due to those differences observed during the rainy and irrigated season (Appendices 19, 20.1 and 20.2). The largest fruit size (62 mm) was observed under irrigation compared to (48 mm) in the rainy

Table 7. Effect of tillage system on number of lateral branches at 14 weeks after transplanting

Tillage systems	Rainy season	Irrigated season	Combined analysis
Furrow	13.0b[1/]	13.0a	13.0b
Ridge on side	11.2b	14.0a	13.0b
Ridge on top	17.0ab	12.0a	14.5ab
Raised bed	20.0a	13.0a	17.0a
Flat seedbed	13.0b	13.0a	13.0b
Mean	**15.0**	**13.0**	**14.0**
C.V (%)	**15.5**	**7.7**	**12.7**

[1/] Means in the same colunm followed by the same letter are not significantly different, according to Duncan' Multiple Range Test at $P \leq 0.01$

season. The largest fruit size (50 mm) was obtained from raised bed while the smallest (47.1 mm) was from the ridge planted on side and flat system for rainy season. For irrigated crop, the largest fruit size (73 mm) was from the ridge planted on side and the smallest (52 mm) from the furrow tillage system. In general, fruit sizes from rainy season crop (48 mm) were lower than from the irrigated (62 mm). The largest change was for fruits in ridge planted on side (26mm), followed by a change of (19 mm) in the flat seedbed tillage system.

4. 8 Number of diseased fruits

Table 13 shows diseased fruits that were significantly ($P \leq 0.01$) different between seasons per ha. Diseased fruits were significantly ($P \leq 0.01$) different among the tillage systems. The highest number of diseased fruits (59 490 fruits) were observed in furrow, ridge on side and flat seedbed followed by lower average number (20 833 fruits) in ridge on top and raised bed. A significant ($P \leq 0.01$) interaction between seasons and tillage system was obtained. The highest diseased fruits (55 694 fruits) per ha were under the rainy season as compared to 32 361 fruits under irrigation.The ranking observed in combined analysis was similar to the rainy and irrigated seasons. Generally, diseased fruits were more in rainy season (55 694) than in irrigated season (32 361 fruits). The largest increase of diseased fruits was from the furrow, flat seed bed and ridge on side tillage systems which averaged (33 332 fruits), followed by 8 333 fruits in the ridge on top and raised bed.

4. 9 Tomato yield t/ha

Table 14 shows that tomato yield was different between seasons and tillage systems. Overall, the highest yield (50.6 t/ha) was observed in the raised bed, followed by ridge on top (41 t/ha) and furrow (37.6 t/ha). The lowest average yield of (36 t/ha) was obtained from ridge planted on side and flat tillage systems. The ranking observed in the combined analysis was similar to

Table 8. Effects of tillage system on days to 50 % flowering of tomatoes.

Tillage system	Rainy season	Irrigated season	Combined analysis
Furrow	37.7b[1/]	46.5ab	42.1bc
Ridge on side	41.5b	49.3a	45.4ab
Ridge on top	50.7a	46.5ab	48.6a
Raised bed	53.4a	45.8ab	49.6a
Flat seedbed (cont)	37.5b	39.3b	38.4c
Mean	**44.2a**	**45.5a**	**45.0**
C.V (%)	**5.0**	**7.6**	**6.5**

[1/] Means in a colunm followed by the same letter are not significantly different, according to Duncan's Multiple Range Test at $P \leq 0.01$

the rainy season while no differences were observed among yields in all the systems under irrigation. There was no significant interaction between seasons and tillage systems. The highest yield under irrigation was (66.6 t/ha) compared to (14.3 t/ha) in the rainy season.

The biggest change was for furrow (58.9 t/ha), ridge on side (52.7 t/ha), flat seedbed (59 t/ha) and laslty (44.3 t/ha) and (46.2 t/ha) for ridge on top and raised bed, respectively.

4.10 Relationships among growth parameters.

Tables 15 shows positive and significant correlation (r=0.74*) between the plant height and yield (t/ha) of tomato and lateral branches (r=0.8*) and yield of tomato.

4.11 Gross margins

Table 16 shows the results of the gross margins under different tillage systems during the rainy season. The raised bed tillage system had the highest gross margin (K11 498 796) and variable costs (K6 821 610), followed by the ridge planted on top and ridge planted on side (K7 693 187) and (K2 085 078) gross margins, respectively. These two treatments used the same variable costs (K5 019 110). The lowest gross margins (K-292 486) and (K922 952) were recorded on the flat and furrow treatments respectively. The same tillage systems inccured the same variable costs (K4 591 610).

On the other hand, Table 17 shows the gross margins for tomatoes under irrigation. The furrow tillage system had the highest gross margin (K2 625 849), followed by the flat system (K2 405 639). These two treatments used the same variable costs (K5 558 277). Similar results were obtained for ridge planted on top and ridge planted on side with gross margins of K1 732 431 and K1 723 891, respectively. The same treatments used K5 985 777 as variable cost. However, the raised bed tillage system recorded the lowest gross margin (K1 223 681) and highest variable cost.

Table 9: Effect of tillage system on days to 50% fruiting of tomato plants.

Tillage systems	Rainy season	Irrigated season	Combined analysis
Furrow	48.8a[1/]	61.5a	55.2a
Ridge on side	45.4a	60.5a	52.9a
Ridge on top	54.7a	61.8a	58.5a
Raised bed	48.8a	62.8a	56.8
Flat seedbed	41.8a	60.8a	51.3a
Mean	**47.9**	**61.5**	**54.7**
C.V (%)	**16.8**	**4.0**	**10.9**

[1/] Means in a colunm followed by the same letter are not significantly different according to Duncan' Multiple Range Test at $P \leq 0.05$

Table 10: Effect of tillage system on small fruit size

Tillage system	Rainy season (mm)	Irrigated season (mm)	Combined analysis (mm)
Furrow	28.9a[1/]	26.9a	27.9a
Ridge on side	31.6a	30.7a	31.2a
Ridge on top	31.4a	27.6a	29.5a
Raised bed	31.3a	28.2a	29.7a
Flat seedbed	30.4a	27.5a	28.0a
Mean	**30.7**	**28.2**	**29.8**
C.V (%)	**7.4**	**8.1**	**7.7**

[1/] Means in a colunm followed by the same letter are not significantly different, according to Duncan' s Multiple Range Test at $P \leq 0.05$

Table 11: Effect of tillage system on medium fruit size

Tillage system	**Rainy season (mm)**	**Irrigated season (mm)**	**Combined analysis (mm)**
Furrow	39.1a[1/]	39.5a	39.3a
Ridge on side	40.1a	41.0a	40.5a
Ridge on top	39.2a	38.9a	39.0a
Raised bed	39.6a	38.8a	39.2a
Flat seedbed	38.6a	39.3a	38.9a
Mean	**39.3**	**39.5**	**39.3**
C.V (%)	**2**	**4**	**3**

[1/] Means in a colunm followed by the same letter are not significantly different according to Duncan' s Multiple Range Test at $P \leq 0.01$

Table 12: Effect of tillage system on large fruit size

Tillage system	Rainy season (mm)	Irrigated season (mm)	Combined analysis (mm)
Furrow	47.6ab[1/]	51.5c	49.6a
Ridge on side	47.1b	72.7a	59.9b
Ridge on top	48.5ab	60.4abc	54.4ab
Raised bed	49.9a	58.4bc	54.1ab
Flat seedbed	47.1a	66.1ab	56.6ab
Mean	**48.0**	**61.8**	**54.9**
C.V (%)	**2.3**	**9.6**	**7.8**
Standard error	**0.5**	**3.0**	**2.1**

[1/] Means in a column followed by the same letter are not significantly different according to Duncan's Multiple Range Test at $P \leq 0.01$

Table 13: Effects of tillage system on number of diseased tomato fruits

Tillage system	Rainy season	Irrigated season	Combined analysis
Furrow	84 722a[1/]	47 222a	65 972a
Ridge on side	72 222a	40 973a	56 597a
Ridge on top	20 833b	13 889b	17 361b
Raised bed	29 166b	19 444b	24 305b
Flat seedbed	71 527a	40 278b	55 902a
Mean	**55 694**	**32 361**	**44 027**
C.V (%)	**27.5**	**18.0**	**18.1**

[1/] Means in a colunm followed by the same letter are not significantly different according to Duncan's Multiple Range Test at $P \leq 0.01$

Table 14: Effects of tillage system on tomato yield in t/ha.

Tillage system	**Rainy season** **Mean yield (t/ha)**	**Irrigated season** **Mean yield (t/ha)**	**Combined analysis** **Mean yield(t/ha)**
Furrow	8.21b[1/]	67.1a	37.6ab
Ridge on side	10.6b	63.3a	36.9b
Ridge on top	18.9ab	63.2a	41ab
Raised bed	27.2a	73.4a	50.6a
Flat sedbed	6.4b	65.3a	35.8b
Mean	**14.3**	**66.6**	**40.4**
C.V (%)	**40.7**	**10.4**	**15.8**

[1/] Means in a colunm followed by the same letter are not significantly different according to Duncan's Multiple Range Test $P \leq 0.05$

Table 15: Correlation coefficient (r) of tomato growth parameters for combined seasons

	DFR	DFL	PH	LB
DFR				
DFL	-0.11			
PH	0.21	0.40		
LB	0.03	0.50	0.67	
YIELD	0.29	0.11	0.74*	0.8*

Note:

DFR= Days to 50% fruiting
DFL= Days to 50% flowering
PH= Plant height
LB= Lateral branches
* = significant ($P \leq 0.05$)

Table 16 : Gross margins for the rainy season tomatoes

Item (zmk)	Furrow	RPS	RPT	RB	Flat
Yield kg/ha	8 194	10 556	18 889	27 222	6 388
Price/kg	673	673	673	673	673
Gross revenue	**5 514 562**	**7 104 188**	**12 712 297**	**18 320 406**	**4 299 124**
Labour input	3 725	5 093	5 093	10 865	3 725
Man days/ha	466	637	637	1 358	466
Labour cost	1 165 000	1 592 500	1 592 500	3 395 000	1 165 000
Ploughing Discing	179 738 57 189	179 738 57 189	179 738 57 189	179 738 57 189	179 738 57 189
Seedlings	1 635 000	1 635 000	1 635 000	1 635 000	1 635 000
Fertilizer basal top dressing	136 000 363 000	136 000 363 000	136 000 363 000	136 000 363 000	136 000 363 000
Fungicides	84 600	84 600	84 600	84 600	84 600
Insecticides	289 000	289 000	289 000	289 000	289 000
Twine/ tying	260 000	260 000	260 000	260 000	260 000
Transport and packing	330 000	330 000	330 000	330 000	330 000
Irrigation	92 083	92 083	92 083	92 083	92 083
Variable Cost (zmk)	**4 591 610**	**5 019 110**	**5 019 110**	**6 821 610**	**4 591 610**
Gross margin	**922 952**	**2 085 078**	**7 693 187**	**11 498 796**	**-292 486**
Break even yield (kg)	**6 823**	**7 458**	**7 458**	**10 136**	**6 823**
Return to labour (zmk)	**4 481**	**5 773**	**14 577**	**10 967**	**1 872**

Note: All items are valued in (ZMK). Man day =8 hours. Labour rate/ man day= ZMK 2 500/ man day.

N.B.

Labour units per 36 m^2, the plot for 6 rows = Appendix 25
Labour units per hactare = Appendix 26
Input costs per ha for both seasons = Appendix 27

Table 17: Gross margins for irrigated season tomatoes.

Item (zmk)	Furrow	RPS	RPT	RB	Flat
Yield kg/ha	67 083	63 264	63 194	73 889	65 278
Price/kg (zmk)	122	122	122	122	122
Gross revenue	**8 184 126**	**7 718 208**	**7 709 668**	**9 014 458**	**7 963 916**
Labour input	4465	5833	5833	11605	4465
Man days/ha	558	729	729	1451	558
Labour cost	**1 395 000**	**1 822 500**	**1 822 500**	**3 627 500**	**1 395 000**
Ploughing	179 738	179 738	179 738	179 738	178 738
Discing	57 189	57 189	57 189	57 189	57 189
Seedlings	1 635 000	1 635 000	1 635 000	1 635 000	1 635 000
Fert basal Top dressing	136 000 363000	136 000 363000	136 000 363000	136 000 363000	136 000 363000
Insecticides	289 000	289 000	289 000	289 000	289 000
Fungicides	84 600	84 600	84 600	84 600	84 600
Twine/tying	260 000	260 000	260 000	260 000	260 000
Transport and packing	330 000	330 000	330 000	330 000	330 000
Irrigation	828 750	828 750	828 750	828 750	828 750
Variable costs	**5 558 277**	**5 985 777**	**5 985 777**	**7 790 777**	**5 558 277**
Gross margin	**2 625 849**	**1 732 431**	**1 723 891**	**1 223 681**	**2 405 639**
Break even yield (kg)	**45 560**	**49 064**	**49 064**	**63 859**	**45 560**
Return to labour (ZMK)	**7 206**	**4 876**	**4 865**	**3 343**	**6 811**

Note: All items valued in Zambian Kwacha. Man days= 8 hours labour rate/manday.ZMK 2 500/man day

N.B. Labour units per 36 m^2 , the plot for 6 rows = Appendix 25

Labour units per hactare =Appendix 26

Input costs per ha for both seasons = Appendix 27

CHAPTER 5

DISCUSSION

5.1 EFFECTS OF TILLAGE SYSTEMS ON VEGETATIVE GROWTH

5.1.1 Seedling mortality after translpanting

Differences observed among the tillage systems maybe due to water logging and poor surface drainage, damping off disease complex, root damage, transplanting shock. More seedlings died during the rainy season in the furrow, ridge planted on side and flat seedbed tillage systems possibly due to water logging and poor surface drainage which deprived root of adquate oxygen resulting in limited root respiration. Plants growing under such conditions experience root rot and roots fail to translocate water and nutrients to support vegetative growth (Bibwell,1987). The furrow, ridge planted on side and flat seedbed were constructed in a manner that would allow water to accumilate. The plant roots therefore grew inside the water logged conditions causing high seedling mortalities.

The above explaination is supported by findings from the Vegetable Research Development Centre (ARVDC) 1988, which indicated that tomato plants are highly sensetive to flooded conditions and die extensively during heavy rains reducing seedling establishment. (Mingochi *et al.*) 1998, also supported that water accumilates in furrows results in poor seedling establishment during the rainy season due to water logging conditions. The other contributing factor for high seedling mortalities in furrow, ridge planted on side and flat seed could have been due to diseases. Damping-off complex is a seedling disease caused by the fungi, Pythium *ssp* and the disease pathogens multiply rapidly under excessive rains, water logged conditions and poor drainage. The disease causes seedling root and stem rot by producing proteolytic, cellulolytic and pectinolytic enzymes that destroy the cell wall (John,1978). However, once the seedlings develop secondary thickening, the fungi concentrate in the cortex there by escaping disease attack. The furrow, ridge planted on side and flat seedbed treatments had soil compacted at transplanting as workers moved up and down the plot during the transplanting process. This reduced soil volume required for rapid root establishment and seedlings could have been subjected to transplanting stress leading to death of seedlings. Some studies by Vogel (1993) have shown that limited top soil depth in furrows caused by subsoil compaction cause poor root distribution and root density. Nyamudeza *et al.* (1983) indicated that shallow rooting depth in furrows caused by removing the top soil when constructing furrows results in seedlings being transplanted into compacted subsoil , restricting root establishment. Seedlings may also have experienced transplanting shock. The seedlings were raised in a green house and later hardened under a shade cloth. The protected environment in the nursery and unprotected in the field caused transplanting shock. Dafault *et al.* (1994) reported that *Casicum annum* L. seedlings experienced a long transplanting shock in the field under flat seedbed conditions and that transplants took long periods to recover from the shock. Another contributory factor for high seedling mortality in the furrow,flat seedbed and ridge planted on side were due possibly soil erosion and nutrient washing. i ridge planted on top. Shetto (1998) reported that under tropical heavy rains, the flat seedbed soils may cap or crust , increasing erosion,soil degradation and nutrient washing This results in soil compaction, reduced soil volume, reduced root growth and development.

Few seedlings died after translpanting on the ridge planted on top and the raised bed treatments. The two tillage systems were prepared by heaping the soil to a height of 30 cm. This could have provided good surface drainage and encouraged rapid root development. Positive attributes of ridges planted on top and raised bed on root development have been reported by Nyagumbo et al.,(1983) who stated that ridges increase the effective rooting depth. Caldwell (1981) also reported that problems of water logging during the rainy season can be solved by growing tomatoes on raised beds as they promote surface drainage. Similary, Linneman (1980) concluded that under heavy rains, raised beds of 30 - 40 cm high lost soil moisture in 15 cm top soil quicker than the top soil in low beds of 15 cm high. This could have resulted in improved surface drainage which contributed to high tomato survival rate in this study. However, Vogel (1993) reported that applied fertilizers, nutrients and clay particles are lost through leaching on ridges under high rainfall conditions and the lower top soil moisture caused by drainage can be a problem for crop emergence and seedling establishment in drought seasons and semi- arid regions. In another trial, Vogel (1993) suggested high soil temperatures in the elevated sides of ridges caused rapid drying of crops during dry weather. This caused delayed emergence, poor seedling establishment and un even crop stands. The seedling establishment under irrigation was 100% and this could have been atributed to stable environmental conditions such as uniform irrigation and low humidity.

5.1.2 Plant height

Differences observed among the tillage systems for plant height could be explaied by seedling mortality.Very few seedlings died in the raised bed and ridge planted on top tillage systems after two weeks of transplanting. Plants that establish well and grow fast have high chances of survival as they are able to establish an efficient canopy that allows uniform distribution of incident sunlight energy over the total leaf area. The result of this is increased efficient interception of photosynthetically active radiation leading to increased dry matter build up and subsiquent tomato yield. Reduced seedling mortality could have promoted a head start advantage to the seedlings in terms of nutrient uptake, rapid root development, larger canopy and vigour.

Generally, an indeterminate tomato cultivar reaches a plant height of 90-120 cm up to the end of maturity and roots can go down to 3 metres in deep alluvial soils (Rice *et al.*,1995). From this botanical description, tomato is a perrenial crop that requires a long growing season of about 180 days to maturity (Muliokela, 1995) and therefore early seedling establishment ensures early vegetative growth that provides enough photosynthates invested in plant growth and development.

The raised bed and the ridge planted on top were constructed by heaping the soil together. This provided a stable structure that would not crust easily during intense rainfall. Soils with good structure have fine soil aggregates and a lot of large pore spaces that promote root and stem growth (Brady, 1990) These advantages of soil heaping and improving soil structure are in agreement with Jose (1998) who suppoted soil heaping to improve exploitation of soil profile by roots resulting in rapid soil cover.

Improved soil fertility is achieved by heaping soil together so that top soil is put at the bottom and seedlings are transplanted into bottom fertile top soil. This ensures early seedling establishment that gives early and sufficient leaf area for photosynthesis, resulting in enough carbohydrates to support the plant height (Dufault *et al.,* 1994).

The organic matter put at the bottom of the mound during construction of ridges and raised improved plant height. During construction, organic matter is placed at the bottom before heaping the soil.This increases organic matter decomposition resulting in increased mineralization, nutrient concentration and availability within the root zone. This could have promoted rapid and extensive vegetative growth. The faster the expansion of leaf area, the greater the increase in light interception and photosynthesis. In Tanzania, ridges and raised beds are used in fertility improvements as they incorperate plant residues and vegetation underneath during their construction (Shetto, 1998).

Adquate drainage on ridges and raised beds during the rainy season could have influenced improved growth. Ngamila(1987) recorded mean plant height of 32.2 on Irish potato *(Solanum tuberosum* L.) grown on top of the ridge during the rainy season. This was due to reduced soil water content in the soil profile and surface drainage promoted earlier establishment and vigourous plant growth on ridges.

Shorter plants on furrow and flat seed bed and ridge planted on the side tillage systems could have been subjected to unfavourable conditions of water logging, poor drainage, poor aeration and possibly damping-off disease infection. These conditions increased seedling root and stem rot there by reducing uptake of nutrients and minerals resulting in stunted growth and shorter plants (Messian, 1992). Ngamila (1897) obtained a significant decrease in plant height of Irish potato (27.6cm) when planted in furrows. He concluded that major nutrients were washed away as water moved through furrows. In addition, fertilizer placed in furrows and flat seed bed was washed away by run off water.

Taller plants were generally produced under irrgation compared to the rainy season. Climatic and environmental conditions such as temperature, excessive rains, light intensity, relative humidity and abiotic factors such as pests and diseases may have influenced the differences in plant height between the two seasons.The rainy season crop was transplanted on 13 th January,1999 during high temperature (Appendix 2), high rainfall (Appendix 4) and high relative humidity which increased the incidence of insect pests and diseases that destroyed the stems and leaves reducing the photosynthetic area for photosythesis. This resulted in reduced carbohydrates production and their translocation to increase vegetative growth. During the rainy season , light intensity is low and this reduces photosynthetic efficiency reducing plant growth.

Light penetration during the rainy season is difficult as light intensity is limiting (Linneman, 1980). Light penetration is reduced for unprunned tomato plants (John,1978). The tomato plants in this trial were unprunned and penetration of light intensity and net assimilation may have been reduced. This is in agreement with Zucker (1972) who states that light intensity is important in net assimulation, movement and translocation of assimulates.The irrigated crop was transplanted on 3rd June 1999 and a very slow vegetative growth in terms of plant height was observed. The temperatures were low (Appendix 3) and this could have caused very short and thick stems. Short and thick stems under low temperature are caused by increased carbohydrate accumulation (Zucker,1972). In August, temperatures suddenly rose causing a sudden increase in stem elongation hence taller plants.

4.4. Number of lateral branches

The number of suckers increased on raised beds and ridges in rainy season. This could have been due to improved surface drainage and aeration that enabled the plant to take up more nutrients from the soil and reduced root and stem rot. Ngamila (1987) recorded positive increase of (5) suckers on Irish potato grown on top of the ridge due to improved drainage and aeration. In the same experiment, Ngamila (1987) recorded a decrease of (3) suckers on potatoes grown in flat seedbed and furrows due to water logging and poor surface drainage. The other reason for more suckers in plants grown in the raised bed and ridge on top tillage systems could be earlier seedling establishment. These seedlings established earlier and had improved root development that extracted more nutrients from the soil to promote growth of taller plants. The improved plant vigour stimulated more suckers to grow. Generally, the rainy season crop recorded the highest number of suckers than the irrigated crop High temperature during rainy season at vegetative period (January and February) may have stimulated prolific development of suckers while low temperature for the irrigated crop (June and July) may have reduced the number of suckers.

5.2 EFFECT OF TILLAGE SYSTEM ON REPRODUCTIVE GROWTH

5.2.1 Days to 50% flowering

Differences observed among tillage systems with respect to days to 50% flowering could be explained similary to those for lateral branches. Some of these factors are improved soil fertility, early seedling establishment and plant height observed in raised bed and ridge planted on top. Generally, tomato plants take 45 to 65 days to flower after transplanting (Rice *et al.*,1995). In this trial, it took longer for plants from the above two tillage systems to flowering. These tillage systems recorded earlier seedling establishment, taller plants and vigorous vegetative growth. Taller plants could have probably delayed maturity due to promotion of vegetative growth at the expense of the production of reproductive structures.

The improved vegetative growth could have been promoted by good environment provided by heaped soil. Raised bed and ridge planted on top for both seasons could have provided better environment such as improved nutrients uptake compared to flat seedbed, furrow and ridge planted on side.

The plants from the furrow, ridge planted on side and flat seedbed flowered earlier. This could have been attributed to seedlings which were stressed by excessive rains causing stunted stunted growth. This may have due limited nutrients availability from the soil resulting from soil erosion and leaching. The plants therefore responded to stress by taking shorter days to flower. When total growth is reduced, plants take fewer days to flower and this may reduce yield (Rice *et al.*,1995). As plants grow taller, there is delay in crop maturity and this may have a positive effect on yield as more resources are invested over a longer period.

5.2.2 Days to 50 % fruiting

Fruiting of indeterminate tomato cultivars normaly takes 45- 55 days between opening of flowers and ripening of the corresponding fruit (John,1978) while they take 40-60 days from full flowering to full ripeness (Rice *et al.*,1995).The longer days to 50 % fruiting under irrigation may have delayed maturity due to an increased duration of vegetative growth. The sudden increase in temperature (Appendix 2) in August for the irrigated season may have increased the vegetative growth causing longer reproductive period to days to 50 % flowering. The rainy season crop matured earlier maybe due to stress caused by excessive rainfall and high incidence of diseases.

5.2.3 Fruit size

There was no significant difference ($P \leq 0.01$) in small and medium fruit size among the tillage systems for both seasons. However, differences observed among the tillage systems for large fruit sizes could be explained by lateral branches and atmosheric temperature. Larger fruit sizes in the ridge planted on side tillage system could have been due to lower number (13) of lateral branches for both seasons. Lateral branches are secondary growth which act as stronger sinks and compete for nutrients, light and water. They deprive nutrient and water distribution to reproductive structures such as flowers and fruits. The nutrients and water are required for cell division and cell expansion which are components of fruit formation (Bidwell, 1987). The rainy season tillage systems generally produced plants with more lateral branches compared to irrigated season crop. The negative effects of the suckers may have contributed to smaller fruit sizes of the rainy season. On the other hand, irrigated fruits were generally larger than the rainy season fruits. This could have been attributed to longer days to 50% fruiting. The fruits were exposed to longer period of fruit filling resulting in bigger fruits. Higher temperatures experienced in August/Septemper, a period of fruit maturation under irrigation, promoted rapid stem elongation, more lateral branches and more fruiting points. The warm temperatures (Appendix 2) provided maximum heat units for tomato plants and in turn increased the photosynthetic capacity and sink strength. This may have resulted in larger sink sizes and hence resulting in bigger fruits. Improved soil temperatures during the same period increased carbohydrate accumulation and translocation to the sink through improved photosynthetic efficient (Rylski,1979). The improved translocation of nutrients and photoassimulation for fruit production resulted in larger fruit sizes (Went, 1949).

However, high temperatures during flowering of rainy season crop may have resulted in higher proportion of small fruit sizes in the furrow tillage systems. In this trial, the rainy season flowered in average of 44 days after transplanting (mid February) when mean maximum daily temperature was 29.1^{0}C (Appendix 2). Although the fruits in these tillage systems are within the large sized fruit range (John, 1978) they are on the lower side of the range. High temperatures during flowering result in smaller fruit sizes and translocation efficiency of indeterminate tomato cultivars is poor under high temperature and about less than 20 % of fixed carbon is exported from the leaf (Zucker,1972)

5.2.4 Diseased fruits

Differences obseved among the tillage systems for diseased fruits could be explained by surface drainage and water logging, atmospheric temperature, rainfall and humidity.High number of diseased fruits on furrow, ridge on side and flat seedbed tillage systems could be due to unfavourable conditions of poor drainage and water logging. The stressed plants may have produced fruits which were not firm enough to withstand disease attack. On the other hand, fewer numbers of diseased fruits were recorded in raised bed and ridge planted on top because of favourable conditions that reduced disease attack such as improved drainage. (AVDRC, 1978) recorded higher scores of *fusarum spp* (3.5), *pythium* (3), and *rhizoctonia* (14%) in soil taken from narrow width beds of 28 cm compared to beds with 56 cm width beds. This indicates that more disease pathogens that attack fruits may hibenate in narrower beds than in wider beds. In these trials, wider raised beds of 2 m wide were used and this may explain the lowest diseased fruits. The rainy season crop recorded higher number of diseased fruits compared to the irrigated season. This could be attributed to high rainfall and humidity that are favourable for rapid multiplication and develpment of disease pathogens.

5.3 EFFECT OF TILLAGE SYSTEM ON YIELD

Differences observed among the tillage systems for yield could be explained by the initial seedling mortality, plant height, number of lateral branches, days to 50% flowering and fruiting and environmental conditions such as atmospheric temperature, rainfall, light intensity and humidity. In addition, pests and diseases are other contributing factors.

For the rainy season, raised bed and ridge planted on top showed better yields than the flat seedbed, the ridge planted on side and the furrow. The less seedling mortality observed on raised bed and the ridge planted on top could explain earlier seedling establishment. This promoted rapid root development for extraction of nutrients and minerals and gave rise to taller plants that improved photosynthetic efficiency. This resulted in production of adquate carbohydrates to support growth of leaves, lateral branches, flowers and fruit development. On the other hand, higher seedling mortality observed on the flat, ridge planted on side and furrow tillage systems could have contributed to lower yields. Seedling mortality influences the optimum plant population, which is a function of yield. Lower the plant population reduces the ultimate yield. This may also explains why better yields were obtained under irrigation where no seedling mortalities were recorded.

The highest yields were obtained from the ridge planted on top and raised bed which had tallest plants than lower yields from ridge planted on side, flat seedbed and furrow treatments. Improved surface drainage could have contributed to better yields from the former tillage systems compared to poor drainage and water logging conditions associated with the later systems.The advantage of surface drainage was reported by AVRDC (1988) which recorded lower yield of 1.9 t/ha of tomato on lower bed of 15 cm high while 13.2 t/ha on raised bed were height of 45 cm. The lower yields were due to poor surface drainage that caused fewer fruit number per plant. In this trial, raised beds and ridges were constructed at 30 cm height. In another trial, tomato yield of 4.6 kg per plant were harvested from raised bed were four times more than 1.2 kg per plant from low beds. (Linneman, 1980) observed that wide raised beds increased early tomato yields to 1.1t/ha while late tomato yields at AVDRC (1988)were significanltly ($P \leq 0.01$) greater on raised beds at 5.8 t/ha compared to 3.8 t/ha on low beds during the rainy season.

Lower yields from the rainy season in furrows, ridge planted on side and flat seedbed could have been due to poor drainage and water logging, high seedling deaths, shorter plant height, reduced number of lateral branches, shorter days to flowering and fruiting. Water logging caused leaching of nutrients and plant lodging resulting in flower and fruit drop. Root rot, stem rot and leaf blight were also observed. Root and stem rot reduce translocation of nutrients and minerals to support growth and survival of the plant. The leaf blight reduced photosynthetic area, photosynthesis and carbohydrates to support growth of leaf, flowers and fruits.lant height was positive and significantly correlated ($r=0.74^*$) with yield for combined analysis. The positive correlation of plant height with yield found in this study could have been a result of bigger canopy which developed as the plants were growing taller. The bigger canopy might have enhanced more light capture and production of more photosynthates which could have been used for total soluble solutes accumulation. Bidwell (1987) asserted that increase in height of plant gives the plant an advantage in competing with other plants for light and that the formation of new more efficient and better positioned leaves at the top enhences photosynthesis. The photosynthates produced are used in dry matter accumulation. Plant height is a function of fast growth rate and yield. Fast growth observed from the ridge planted on top and the raised bed could have enhanced higher yield from these treatments.This could have enabled the plant to quickly develop the photosynthetic machinery which in turn produces more photosynthates for dry matter accumulation before the plant is subjected to unfavourable harsh conditions. The number of tomatoes harvested on a plant are dependent upon the plant height. The taller the plant, the more flowers are produced and more leaves are formed to photosynthesize and provide assimulates to the flowers and fruits. Plant height could also affect yield through the prevention of fungal diseases which attack fruits when they touch the ground. If tomato fruits hang low and touch the ground, fungal problems such as fruit rot are enhanced thereby reducing yield.

The raised bed and the ridge planted on top tillage systems recorded the highest number of lateral branches, hence yield, compared to the flat seedbed, flat seedbed and the ridge planted on the side. Lateral branches in solanacous plants such as tomatoes is important as flowers are set at each node branch. It is these flowers which ultimately produce fruits. Therefore, more branching gives rise to more flowers, better fruit set and culminate in higher yields. The economic yield of tomato is from fruits. These fruits develop from flowers which are produced at each branch node (Rice *et al.*,1995). Therefore, tomato plants having more branch nodes, could result in higher yield than those with less branch nodes.

Fruit size affects yield positively by increasing the mass of tomatoes. Fruit size is a function of cell expasion. Cell expansion is mostly a result of turgor pressure created by availability of water and solutes (Bidwell,1987). Genarally, rainy season yields were lower than irrigated season because of climatic conditions such as excessive rains, temperature, light intensity and humidity.Exessive rains cause flower and fruit drop, resulting in reduced yields. This is in agreement with AVRDC (1988) that reported high flower and fruit drop in pepper resulting in serious yield losses.

5.4Gross Margin Analysis

Positve returns were recorded on raised bed and ridge planted on top tillage systems. Poor returns were recorded on furrow, ridge plant on side and negative returns on flat tillage system. The results show that even if the labour units for raised bed and break even yield are high, it is still profitable to produce tomatoes under this tillage system because the yields are high. However, since preparation of this system requires a lot of labour, it may be difficult to practice it. The more reliable tillage system would be the ridge planted on top since yields are second from raised bed. The gross margins for the furrow and ridge planted on side are marginal. The flat seedbed is not profitable to practice as yields are low and gross margins are negative. On the other hand, the irrigated season negative returns were recorded on the raised bed while almost uniform yields were obtained under furrow, ridge planted on top ridge planted on side and flat. The raised bed had highest yields, labour units and break even yield. However, gross margin was lowest. This could have been due to high labour units for bed construction. The furrow and flat tillage system recorded the highest gross margins, this could have been due to low labour units incurred during preparation. Generally, the rainy season tomatoes recorded highest gross margins compared to the irrigated season crop. This could be due to shortage of tomatoes on the market resulting in high demand and high prices. The other reason could be very low irrigation costs.

On the other hand, the irrigated season had lowest gross margins due to excess supply of tomatoes resulting in lower prices. In addition, irrigation costs were very high reducing the gross margins.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The objectives of this research were achieved because different tillage systems have been found to improve the production of tomatoes by subsistance farmers. Some tillage systems had positive effects and others negative effects on the growth and yield of tomatoes between the rainy and irrigated seasons. The results study showed that improved production of tomatoes could be achieved by growing tomatoes on raised bed and the ridge planted on top. Tomato growth and yields improved for all treatments and for both seasons. The hypothesis tested in this study was answered.The ridge planted on top and raised bed have the potential of improving growth and yield as plant height, lateral branches, days to maturity and yield were better than those from the flat seedbed, furrow and ridge planted on side systems. The later tillage systems had shorter plants, fewer branches, earliest maturity and lower yields. In addition, seedling mortality and diseased fruits were lower in the ridge planted on top and raised bed.The highest economical returns during the rainy seasons were obtained on raised bed tillage system compared to the ridge planted on top, furrow, ridge planted on side and flatseedbed. The irrigated season showed that the furrow and the flat tillage systems had the highest gross margins compared to the other three systems. The rainy season showed better gross margins because of attractive prices and very low irrigation costs while the irrigated crop returns were low because of very low prices and high irrigation costs.

6.2 RECOMMENDATIONS

The most economical tillage system would be the ridge planted on top as labour units are lower than those for the raised bed. Subsistance farmers are charactereized by lack of labour and capital to pay for the construction of raised beds. This may be the biggest constrain against the raised bed technology. However, it is more profitable to grow tomatoes on ridge planted on top and raised bed. Further research should be done on the effect of higher ridges and raised beds over 3 seasons or more to detrmine the effects on changing seasons. In addition, the tillage systems should be done on different soil types and on different tomato cultivars and other horticultural crops. Another research could be done to determine the effects of tillage systems on plant rooting depths, nitrogen, phosphorus and potassium levels.

REFERENCES

Agrios, G.T. M.E. Walker and D.N. Ferro, 1985. Effect of cucumber mosaic virus on inoculation at successful weekly intervals on growth and yield of pepper plants (*Capsicum annuum*) .Plant Disease, 69:52-55.

AVRDC, 1988. Vegetable Research and Development in Zambia. Proceedings of the First National Vegetable Research Planning Workshop held in Lusaka, Zambia, 1-4 May.

AVRDC, 1978. Tomato and pepper production in the tropics. Proceedings of the International Symposium on Integrated Management Practices, Taiwan, 21-26 March, 1978. Publication no. 81-317. pp. 70-573.

Bidwell, R.G. 1987. Plant physiology. Second edition. Macmillan Publishing, New Zealand. pp. 89-557

Bradfield, E. 1970. Tillage systems for soil and water conservation. Conservation tillage for sustainable Agriculture. FAO-ARC-ZFU-FARMESA-GTZ Project. pp. 21-32.

Brady, N. C. 1990. The Nature and Properties of Soils. Tenth edition. Macmillian Publishing Company, New York.

Caldwell, J. S. 1986. Assessing rainy season vegetable production alternatives: a case study in "upstream" farming systems research 1986. Asian Vegetable Research and Development Centre.

Caldwell, J.S. 1981. In seach of a new 'Lunes in Kodas' : An intergrated Approach to Vegetable Production in two municipalities in Ilocos Norte, Phippines, Asian Vegetable Research and Development Centre.

Chuma, E. and J.Hagman, 1993. Summary of results and experiments from on- station and on-farm testing and development of conservation tillage . Farming Systems in the Semi- Arid Masvingo, Zimbabwe. Proc. of a Technical Workshop: Belmont Press. pp. 41-60.

Daka, A. 1996. Vegetable Research and Development in Zambia. Proceedings of the First National Vegetable Research Planning Workshop held in Lusaka, Zambia, 1-4 May1996. pp. 29-32.

Dufault, R. J. and J. R. Schultheis. 1994. Bell pepper seedling growth and yield following pre-transplant nutritional conditioning. Hortscience 29 (9): 999-1001.

Elwell, H.A. 1988. Development and adoption of conservation tillage practices in Zimbabwe. Institute of Agricultural Engineering, Harare. pp. 129-165 in Soil Tillage in Africa: Needs and Challenges, F.A.O Soil Bulletin No. 69, Rome.

F.A.O. 1997. Year-book of Production, Rome.

F.A.O. 1989. Year-book of Production, Rome.

F.A.O. 1988. Year- book of Production, Rome

Hagman, J . and O. Gunduni, 1994. Mechanical soil conservation with contour ridges: Care for , or cause of rill erosion? In: Land Degradation and Development, Vol. 7, No.2, pp. 145-160.

John, G. 1978. Zimbabwe Horticultural handbook, Ministry of Lands and Agriculture, Agricultural Technical and Extension services, Harare, Zimbabwe. pp. 314-339.

Jose, B. 1998. Overcoming constraints in the adoption of conservation tillage practices. Conservation tillage for sustainable Agriculture. FAO-ARC-ZFU-FARMESA-GTZ Project: pp. 219-225.

Kawal, S.1973. Tillage systems in the tropics: Management options and sustainability implications. Conservation Tillage for Sustainable Agriculture. FAO-ARC-ZFC-FARMESA-GTZ Project. pp. 72-73.

Linneman, A. R. 1980. Effect of bed height and mulching on yield of summer chinese cabbage and tomato. Shanhua, Taiwan: Asian Vegetable Research and Development Centre

Research Scholars Report.

Marshner, H. 1993. Mineral Nutrition of Higher Plants. Institute of Plant Nutrition. University of Hohenheim, Federal Republic of Germany Academic Press. pp. 226-235.

Messian, C.M. 1992. The tropical vegetable garden. Principles for improvement and increased production with application to the main vegetable types. Macmillian Press.

Mingochi, D.S., S.W.S. Luchen and Kembo. 1998. Small - holder Agricultural practices and their implications on fertilizer use in Zambia. IFA Regional Conference for Africa, Maputo, Mozambique, 8-12 June , 1998. pp. 1-6.

Ministry of Agriculture and Water Development, 1995. Vegetable Research Team Annual Report 1981-82 of the National Irrigation Research Station, Lusaka, Zambia.

Mharapara, I.M. 1987. Cropping of rice and maize in vleis. "Cropping in semi-arid areas of Zimbabwe." Proceedings of a workshop held in Harare, 24th to 28th August, 1987. pp. 543-561.

Muliokela, W.S. 1995. Zambia Seed Technology Handbook, Ministry of Agriculture, Food and Fisheries. pp. 19-26.

Mnzava, N.A. 1990. The Vegetable Industry: A SADC Regional Perspective, Proceedings of a workshop held in Tanzania, Arusha, 9-13 July, 1990. pp. 63-69.

Mubita, T.S. 1996. Vegetable Consumption - A step towards a healthy nation. Vegetable Research and Development in Zambia. Proceedings of the First National Vegetable Research held in Lusaka, Zambia. pp 44-47.

Musulwe, N. and K. Chongo. 1996. Vegetable production status in the Southern Province, Vegetable Research and Development in Zambia. Proceedings of the First National Vegetable Research, held in Lusaka, Zambia. pp. 35-40.

Ngamila, J. 1997. Effect of two cultural practices ' ridge and furrow', on yield of potato cultivar 'up-to-date'. Research project, B. Agric. Sci. Thesis, University of Zambia, Lusaka, Zambia. pp. 7-11.

Nyagumbo, I. 1994. On-farm trials, for the 1991/92 season Chinamhora/ Chiweshe Report. Unpublished Annual Report, Agritex/GTZ Conservation Tillage Project, Harare/Masvingo.

Nyamudeza, P. and E.Z. Nyakatawa, 1983. The effect of sowing crops in furrows of tied ridges on soil water and crop yield in Natural Region V of Zimbabwe. Conservation tillage in Natural Region V. ADRITEX/GTZ Conservation Tillage Project. Haraer/ Masvingo. pp. 32-40.

Okigbo, B.N. 1976.Vegetables in the tropics.A SADC Regional Perspective: Proceedings of a workshop held in Arusha, Tanzania, 9-13 July,1990. pp. 29-54.

Quinin J.G. 1974. Environment and establishment of an industrial tomato crop in Northern Nigeria. International Centre for Advanced Mediterranean Agronomic Studies. Bari, Italy.

Rice, R.P. W. Rice and H.D.Tindall, 1995. Fruit and vegetable production in warm climates. Macmillian Press Ltd. pp. 273-276.

Rick, C.M. 1978. The Tomato. Scientific American Journal: 239 (2) 66-75.

Rylski, I. 1979. Fruit set and development of seeded and seedless tomato fruits under diverse regimes of temperature and pollination. J. Am. Soc. Hort.Sci. 104:835- 838.

Shetto, R.M. 1998. Tillage practices and conservation measures in Tanzania. Conservation tillage for sustainable Agriculture. FAO-ARC-ZFU-FARMESA-GTZ Project. pp. 187-195.

Stevens, M.A. and J. Rudich,1978. Genetic potential for overcoming physilogical limitations on adaptability and quality in the tomato. Hort. Science 13:673-678.

Vogel, H. 1993. Tillage effects on maize yield, rooting depth and soil water content on sandy soils in Zimbabwe: Field Crop Research, Vol, 23, pp. 367.

Vogel, H. 1991. Conservation tillage fo small-scale farming in Zimbabwe. Soil tillage and agricultural sustainability, 12th ISTRO conference, 8-19 July, 1991. Ibadan/Nigeria, pp. 417-426.

Went, F.W. 1949. Plant growth under controlled conditions. II. Thermoperiodicity in growth and fruiting of tomato. Amer. J. Bot., 31:135-150.

Zucker, M. 1972. Light and enzymes. Ann. Rev. Plant Physiol. 23:133-156.

Zulu, R.M. 1996. Nutritional aspects of vegetables in Zambia.Vegetable Research and Development in Zambia. Proceedings of the First National Vegetable Research Planning Workshop held in Lusaka, Zambia. pp. 41-44.

APPENDICES

Appendix 1. Exotic vegetables grown in Agro-ecological Region 2 of Zambia

Vegetable crop	Mean scores[1/]	Rank [2/]
Tomato	0.25	1
Irish potato	0.24	2
Cabbage	0.23	3
Rape	0.21	4
Onion	0.19	5
Beans	0.18	6
Okra	0.18	6
Peas	0.17	7
Pumpkin	0.17	7
Bell pepper	0.14	8

Source: Proceedings of the First National Vegetable Research Planning Workshop, Lusaka, Zambia.

Note:

1/ Mean scores = Weighted mean criteria for individual importance of vegetables according to its contribution to consumption, nutritional value and income.

2/ Ranking of prioritized vegetable species in descending order of importance.

Appendix 4: Raingal and irrigation data at Zamseed Farm for 1998-1999 season

Rainfall (mm)		Irrigation (mm) 18 times	
November 1998	38.5	May	30.5
December1998	304.9	June	213.5
January 1999	375.9	July	61.0
February 1999	181.9	August	120.0
March 1999	23.7	September	183.0
Total Rainfall	924.9	Total:	608.0

Note: Rainfall figures obtained from Lusaka International Airport, Lusaka, Zambia.

Appendix 5: Analysis of Variance for soil moisture for the irrigated crop

Source of variation	DF	SS	MS	F value	P
Replication	3	27.96	9.319	1.60	0.195
Tillage system	4	14.27	3.568	0.61	
Moisture content	5	47.16	9.432	1.62 ns	0.164
Tillage system x Moisture content	20	10.26	5.213	0.89ns	
Error	87	507.73	5.836		
Total	119	607.38			

C.V=12.1 %

ns = not significant

Appendix 6: Analysis of variance for seedling mortality for the rainy season crop

Source of variation	DF	SS	MS	F Value	P
Replication	3	5.750	1.917		
Tillage system	4	44.800	11.200	5.1692*	
Error	12	26.000	2.167		
Total	19	76.550			

C.V= 62.64 %

* **= significant at P≤ 0.05**

Appendix 7: Combined analysis of Variance for plant height

Source of variance	DF	SS	MS	F value	P
Season	3	2214.14	2214.144	7.69	0.032
Rep/season	6	1727.28	287.880		
Tillage system	4	2891.18	697.796	34.28 **	0.000
Tillage x season	4	2791.19	697.796	33.10**	0.000
Error	24	506.01	21.084		

C.V=6.79 %

** = **significant at $P \leq 0.01$**

Appendix 8. 1: Analysis of variance for plant height for the rainy season crop

Source of variation	DF	SS	MS	F value	P
Replication	3	32.79	10.930	0.89	
Tillage system	4	5535.96	1383.991	112.82**	0.000
Error	12	147.21	12.268		
C.V=5.82 %					

** = significant at $P \leq 0.01$

Appendix 8. 2: Analysis of variance for plant height for the irrigated season crop

Source of variance	DF	SS	MS	F value	P
Replication	3	1694.490	564.830	18.89	
Tillage system	4	146.403	36.601	1.2241^{ns}	0.351
Error	12	358.793	29.899		
C.V= 7.28 %					

ns = not significant

Appendix 9: Combined analysis of Variance for lateral branches

Source of variation	DF	SS	MS	F value	P
Season	1	28.90	28.90	8.26	0.028
Rep/season	6	21.00	3.500		
Tillage system	4	91.25	22.813	7.45**	0.000
Tillage x season	4	118.85	29.713	9.70**	0.000
Error	24	73.50	3.063		

C.V=12.73 %

** = **significant at $P \leq 0.01$**

Appendix 10. 1: Analysis of Variance for lateral branches for the rainy season crop

Source	DF	SS	MS	F-value	P
Rep	3	4.40	1.467	0.29	
Tillage system	4	204.80	51.200	9.97**	0.000
Error	12	61.60	5.133		

C.V=15.52 %

** = **significant at $P \leq 0.01$**

Appendix 10. 2: Analysis of Variance for lateral branches for the irrigated season crop

Source	DF	SS	MS	F-value	P
Rep	3	16.60	5.533	5.58	0.012
Tillage system	4	5.30	1.325	1.34^{ns}	0.312
Error	12	11.90	0.992		

C.V=7.72 %

ns = not significant

Appendix 11: Combined analysis of Variance for days to 50% flowering

Source of variation	DF	SS	MS	F value	P
Season	1	16.41	16.410	0.15	
Rep/season	6	636.08	106.013		
Tillage system	4	687.23	171.808	20.41**	0.000
Tillage system x Season	4	416.64	104.161	12.37**	0.000
Error	24	202.07	8.420		

C.V=6.48 %

** =significant at P≤0.01

Appendix 12. 1: Analysis of Variance for days to 50 % flowering for the rainy season crop

Source of variance	DF	SS	MS	F value	P
Replication	3	14.33	4.777	1.000	
Tillage system	4	883.18	220.794	46.02**	0.000
Error	12	57.57	4.798		
C.V=4.96 %					

** = significant at P≤ 0.01

Appendix 12. 2: Analysis of Variance for days to 50 % flowering for the irrigated season crop

Source of variation	DF	SS	MS	F value	P
Replication	3	621.75	207.250	17.21	0.000
Tillage system	4	220.70	55.175	4.58 *	0.017
Error	12	144.50	12.042		
C.V=7.64 %					

* = significant at P≤0.05

Appendix 13: Combined analysis of Variance for days to 50% fruiting

Source of variation	DF	SS	MS	F value	P
Season	1	1843.08	1843.078	21.38	0.003
Rep/season	6	517.22	86.203		
Tillage system	4	230.16	57.541	1.61^{ns}	0.204
Tillage system x Season	4	150.82	37.706	1.06^{ns}	0.400
Error	24	857.68	35.737		

C.V=10.94 %

ns = not significant

Appendix 14. 1: Analysis of Variance for days to 50 % fruiting for the rainy season crop

Source of variance	DF	SS	MS	F value	P
Replication	3	380.67	126.889	1.94	0.176
Tillage system	4	368.29	92.072	1.41^{ns}	0.289
Error	12	783.98	65.332		

C.V=16.88 %

ns = not significant

Appendix 14. 2: Analysis of Variance for days to 50 % fruiting for the irrigated season crop

Source of variance	DF	SS	MS	F value	P
Replication	3	136.55	45.517	7.41	0.004
Tillage system	4	12.70	3.175	0.52^{ns}	
Error	12	12	73.70	6.142	

C.V= 4.03 %

ns = not significant

Appendix 15: Combined analysis for small fruit sizes

Source	DF	SS	MS	F-value	P
Season	1	65.54	65.536	10.39	0.018
Rep/season	6	37.84	6.306		
Tillage system	4	45.97	11.493	2.22^{ns}	0.97
Tillage system x					
Season	4	9.98	2.494	0.48^{ns}	
Error	24	124.47	5.186		

C.V=7.74 %

ns = not significant

Appendix 16. 1: Analysis of variance for small fruit sizes for the rainy season crop

Source	DF	SS	MS	F-value
Rep	3	12.31	4.104	0.79
Tillage system	4	19.90	4.974	0.95^{ns}
Error	12	62.68	5.224	

C.V=7.44%

ns = not significant

Appendix 16. 2: Analysis of variance for small fruit sizes for the irrigated season crop

Source	DF	SS	MS	F-value	P
Replication	3	25.52	8.508	1.65	0.229
Tillage system	4	36.05	9.013	1.75^{ns}	0.203
Error	12	61.79	5.149		

C.V=8.06 %

ns = not significant

Appendix 17. Combined analysis of variance for medium fruit sizes

Source	DF	SS	MS	F-value	P
Season	1	0.29	0.289	0.08	
Rep/season	6	20.61	3.436		
Tillage system	4	13.59	3.397	2.50	0.069
Tillage system x Season	4	4.34	1.086	0.80	
Error	24	32.56	1.357		

C.V= 2.96 %

ns = not significant

Appendix 18. 1: Analysis of variance for medium fruit sizes for the rainy season crop

Source	DF	SS	MS	F-value	P
Replication	3	4.33	1.443	2.35	0.123
Tillage system	4	5.11	1.277	2.08^{ns}	0.146
Error	12	7.36	0.613		

C.V=1.99 %

ns =not significant

Appendix 18. 2: Analysis of variance for medium fruit sizes for the irrigated season crop

Source	DF	SS	MS	F-value	P
Replication	3	16.28	5.428	2.58	0.101
Tillage systems	4	12.82	3.206	1.53^{ns}	0.256
Error	12	15.20	2.100		

C.V=3.67 %

ns = not significant

Appendix 19: Combined analysis of variance for large fruit sizes

Source	DF	SS	MS	F-value	P
Season	1	1898.88	1898.884	31.85	0.001
Rep/season	6	357.76	59.627		
Tillage system	4	455.63	113.908	6.22**	0.001
Tillage system x Season	4	594.85	148.713	812**	0.000
Error	24	439.77	18.324		

C.V= 7.79 %

**** = significant at $P \leq 0.01$**

Appendix 20. 1: Analysis of variance for large fruit sizes for the rainy season crop

Source	DF	SS	MS	F-value	P
Replication	3	1.86	0.620	0.51	
Tillage system	4	21.47	5.367	4.40**	0.02
Error	12	14.64	1.220		

C.V=2.30 %

* **= significant at P ≤ 0.05**

Appendix 20. 2: Analysis of variance for large fruit size for the irrigated season crop

Source	DF	SS	MS	F -value	P
Replication	3	355.90	118.633	3.35	0.055
Tillage system	4	1029.02	257.254	7.26**	0.003
Error	12	425.13	35.428		

C.V=9.63 %

** **= significant at P ≤ 0.01**

Appendix 21: Combined analysis of Variance for diseased fruits

Source of variation	DF	SS	MS	F value	P
Season	1	5444475555	5444475555	22.34	0.003
Rep/season	6	1462219754	243703292.33		
Tillage systems	4	15045166945	3761291736	59.09**	0.000
Tillage system x Season	4	1559811173	389952793	6.13**	0.001
Error	24	1527806946	63658622.8		

C.V=18.12 %

** = **significant at P≤0.01**

Appendix 22. 1: Analysis of Variance for diseased fruits for the rainy season crop

Source of variation	DF	SS	MS	F value	P
Replication	3	1238829938.6	412943312.867	4.42	0.025
Tillage system	4	13142020525	3285505131.25	35.19**	0.000
Error	12	1120411575.40	93367631.283		

C.V=17.35 %

** = **significant at P≤0.01**

Appendix 22. 2: Analysis of Variance for diseased fruits for the irrigated season crop

Source of variation	DF	SS	MS	F value	P
Replication	3	223389815.4	74463271.8	2.19	0.141
Tillage system	4	3462957593.3	865739398.325	25.50**	0.000
Error	12	407395371.10	33949614.258		

C.V=18.01 %

** = **significant at P≤0.01**

Appendix 23: Combined analysis of variance for tomato yield

Source of variance	DF	SS	MS	F value	P
Season	1	27344428056	27344428056	59.77	0.00
Rep/season	6	2745123155	457520525.883		
Tillage system	4	1153690120.85	28842250.213	7.09**	0.000
Tillage system x Season	4	365276805.65	91319201.412	2.24^{ns}	0.09
Error	24	976498977.50	40687457.396		

C.V=15.79 %

ns = not significant

*** = significant at P ≤ 0.05**

Appendix 24. 1: Analysis of Variance for tomato yield for the rainy season crop

Source of variance	DF	SS	MS	F value	P
Replication	3	179690765.80	59896921	1.78	0.203
Tillage system	4	1207671845.80	301917961.45	8.99**	0.001
Error	12	402781612.2	33565134.35		

C.V=40.66 %

**** =significant at $P \leq 0.01$**

Appendix 24. 2: Analysis of Variance for tomato yield for the irrigated crop

Source of variance	DF	SS	MS	F value	P
Replication	3	2565432389.2	855144129.733	17.89	0.000
Tillage system	4	311295080.70	77823770.175	1.63^{ns}	0.230
Error	12	573717365.30	47809780.442		

C.V=10.31 %

ns = not significant

Appendix 25 Labour units per 36 m^2, the plot for 6 rows

Operatio	No.of time	Furrow	RPS	RPT	RB	Flat
Tillage making	1 per treat	1.4	1.4	1.4	5.2	1.4
Weeding	1 per treat	1.4	1.4	1.4	5.2	1.4
Total weeding	3 times	4.2	4.2	4.2	15.6	4.2
Re ridging	1 treat	0	0.7	0.7	2.6	0
Re-ridging	3 times	0	2.1	2.1	7.8	0
Nursery	12 man	3.8	3.8	3.8	3.8	3.8
Spraying	per treat	0.1	0.1	0.1	0.1	0.1
Spraying	13 times	1.3	1.3	1.3	1.3	1.3
Transplant	1x12 man	3.8	3.8	3.8	3.8	3.8
Fertilizer	per treat	0.1	0.1	0.1	0.1	0.1
Fertilizer	4 times	0.4	0.4	0.4	0.4	0.4
Staking	per treat	0.9	0.9	0.9	0.9	0.9
Staking	3 times	2.7	2.7	2.7	2.7	2.7
Rainy	2 times	4	4	472	472	472
Irrigateted	18 times	72	72			
Harvest	per treat	0.7	0.7	0.7	0.7	0.7
Harvest	3 times	2.1	2.1	2.1	2.1	2.1
Total units		**20.1**	**22.2**	**22.2**	**43.1**	**20.1**

Appendix 26 Labour units per ha (10 000 m2)

Operation	Furrow	RPS	RPT	RB	Flat
Bed preparation	389	389	389	1 444	389
Weeding	389	389	389	1 444	389
Total weeding	1 167	1 167	1 167	4 333	1 167
Re- ridging	0	195	195	722	0
Total- ridging	0	617	617	2 167	0
Nursery	1 056	1 056	1 056	1 056	1 056
Spraying	28.3	28.3	28.3	28.3	28.3
Total spraying	368.2	368.2	368.2	368.2	368.2
Fertilizer	28.3	28.3	28.3	28.3	28.3
Total fertilizer	113	113	113	113	113
Staking	250.5	250.5	250.5	250.5	250.5
Total staking	751.6	751.6	751.6	751.6	751.6
Rainy season	44	44	44	44	44
Irrigated season	**784**	**784**	**784**	**784**	**784**
Harvesting	195	195	195	195	195
Total harvesting	588	588	588	588	588
Total units(Rainy)	**3 725**	**5 093**	**5 093**	**10865**	**3725**
8 hours/man day	**466**	**637**	**637**	**1358**	**466**
(Irrigated)	**4 465**	**5 833**	**5833**	**11605**	**4465**
8 hours/man day	**558**	**729**	**729**	**1451**	**558**

Appendix 27 Input costs/ ha for both seasons

Input	Quantity	Price/unit (K)	Total cost (K)
Seedlings	327 trays	5000	1 635 000
Compond D	11 bags	33 000	363 000
Urea	4 bags	34 000	136 000
Tying string	65 balls	4 000	260 000
Dimethoate	2 litres	6 500	130 000
Metasystox	2 litres	25 000	100 000
Red spider mite	1 litre	11500	23000
Dithane-M-45	3 kg	15200	45 600
Copper oxychloride	3 kg	6 500	39 000
Total			**2 731 600**