EFFECT OF TIMING AND METHOD OF TRELLISING ON GROWTH, YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum*).

BY

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A research project submitted in partial fulfillment of the requirements of Bachelor of Science honors degree in Agronomy.

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DECLARATION

I hereby declare that this submission is my own work towards the BSc (Agronomy) degree and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the awarded of any other degree of the University, except where due acknowledgement has been made in the text.

Muza Donater Chitanda	…………………………	………………………
Student No. R102363B	Signature	Date

CERTIFICATION OF THESIS WORK

I, the undersigned, certify that **Muza Donater Chitanda,** a candidate for the Bachelor of Science Agronomy Honours Degree has presented this thesis with the title:

EFFECTS OF TIMING AND METHOD OF TRELLISING ON TOMATO (*Solanum lycopersicum*) YIELD AND QUALITY.

That the thesis is acceptable in form and content, that satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through oral examination held on **09/05/2014**.

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(SUPERVISOR)	Signature	Date
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ABSTRACT

Tomato production is being limited especially during the rainy season due to the incidence of fruit rotting due to pest and disease attack. Due to the aforementioned limitation, modification of microclimate by trellising can assist improve crop yield. A 5*2 plus control factorial experiment in a randomized complete block design with three replications was carried out at Chiredzi Research Station in the 2013/14 rainy season in an open field environment to study the effects of timing and method of trellising on tomato yield and quality. Timing consisted of five levels: at transplanting, 2WAT, 4WAT, 6WAT and 8WAT while method of trellising has two levels which are trellis posts and Stake and weave. The control treatment for the experiment was no trellising. The study indicated that the highest number of days to 50% flowering was from timing at transplanting and 2WAT in both trellis posts and stake and weave methods while the lowest days were from no trellising but was not statistically different from 4WAT in stake and weave, 6 and 8WAT from both trellis post and stake and weave methods. Plant height at 50% flowering was highest for timing at transplanting and 2WAT in both trellis posts and stake and weave method and the least was from no trellising but was not significantly different from 8WAT in the other two methods. On number of fruits per plant, no trellising gave the highest number and trellis post the least. Trellis posts at transplanting and 2WAT gave the highest marketable yield and no trellising gave the least (t/ha) and on total yield, again trellising at transplanting and 2WAT in trellis post gave the highest total yield whereas the least was from no trellising, and timing at 8WAT in both trellis posts and stake and weave methods. The highest fruit sunscalds were observed from no trellising and stake and weave method gave the least affected fruits. Again, highest number of fruit rots were obtained from no trellising, trellising at 8WAT in both trellis post and stake and weave methods. Based on these results, trellising at transplanting and 2WAT in trellis post is recommended as the treatments resulted in the highest marketable yield.

DEDICATION

To my beloved wife **MUTANDE CHIPO** for her encouragement, moral and financial support.

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ACRONYMS ANDABBREVIATIONS

A1-A7	Appendices 1 to 7
ANOVA	Analysis of variances
CRS	Chiredzi Research Station
LSD	Least square difference
^{o}C	degrees of Celsius
P<0.05	Probability less then 5%
WAT	Weeks after transplanting tomato crop
NS	Not significant at P<0.05
Sed	Standard error of the difference between means

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Tomato is the leading grown vegetable in Africa and the second most produced in Zimbabwe after potato (Zitsanza, 2000). Tomato fruits are of great value in nutritional composition of human beings because they comprise a red pigment called lycopene which has high antioxidant power against oxygen radials which induce cancer and aging (Karen Collens, 2007). Besides lycopene, tomatoes are a beneficial source of vitamin A, B and C. Vitamin A is responsible for the healthy vision, cell replication and growth. Inadequacy of vitamin A in children causes blindness and even fatality while Vitamin B helps in digestion of carbohydrates, braces appetite, and also boosts growth and is a necessity in the normal functioning of the nervous system (Kanyomeka and Shivute, 2005). Vitamin C is for the growth and care of salubrious bones, teeth, gums, ligaments and blood vessels and its deficiency causes scurvy, a disease in which the immune system is weakened (FAO, 2007). Besides importance of tomato in human health, the production of the crop provides income to farmers and also creates employment in both production and processing industries (Karen Collins, 2007).

Despite the economic importance of tomato, its production under smallholder agriculture face the following constraints, lack of capital to purchase certified seeds , insecticides, fungicides; high incidence of pest and disease; lack of technical knowhow; poor distribution of hybrid seeds; shortage of water especially during the dry periods and excessive rains in the rainy season (Saunyama and Knapp, 2003). FAO, (2006) concurred with Saunyama and Knapp, (2003) in that seasonality is another barrier in tomato production especially during the rainy season in tropical countries. This is due to excessive rains which promote weeds, pest and disease incidence. Excess rains also promote fruit rots thereby reducing the quality of fruits. Lushi, (2012) also revealed that rain promote lodging of the crop leading to great losses. In Zimbabwe, these losses make farmers fail to meet the ever increasing demand of quality tomatoes throughout the year which ranges between 6000 to 7000 tonnes per year with a lower limit value of US$0.5/kg (FAVCO, 2010).

Due to the problems of excessive rains during the rainy season which reduce crop yield and quality, modification of microclimate by trellising can assist improve crop yield and quality.Karen Collins, (2007) reported that countries like South Africa produce tomatoes with supports in order to obtain earlier, clean and large fruits using trellis posts, cages or stake and weave to support their crops. Trellised plants do not snap easily during moderate winds and the system produce healthy plants which in turn produce a bumper and earlier harvest (Zitsanza, 2000). Trellising also keeps branches and leaves off the ground where most fungal diseases develop from. Also, Wszelaki and Miller, (2005) noted that trellising facilitates pest scouting, crop management like weed control, pest and disease control and also easy harvesting of fruit. In a research work conducted in Mutoko and Muzarabani in 2001 on the effect of pruning and trellising of tomatoes on Red spider mite incidence and crop yield, pruned and trellised plants resulted in better mite management, less disease incidence, less fruit rot and a reduced damage in fruits hence more marketable yield which gave an extra gain of US$18,780 ha^{-1} (Saunyama and Knapp, 2003).

There is also gap in knowledge about the critical period of trellising and its effect on yield and quality of tomatoes. Ariyarathne (1999), revealed that trellising should be done at the initial stages of plant growth especially soon after transplanting to minimize root damage which tend to stress the plant reducing its maximum genetic yield. Delay in trellising cause breaking of stems or fruit trusses and even dropping of berries (Cadwell, 2005). Leaving fruits being in contact with the soil promotes fungal infection and also insect pests like rodents. Little research has been conducted on the influence of time of trellising on the yield and quality of tomatoes.

However, trellising is a pricy exercise in terms of both materials and to some extent labour but these costs are usually off-set against easier harvesting, higher marketable yields, less disease, insect and sunburn problems, and reduced injury to both plants and fruits during harvesting and other operations in the field Wszelaki and miller, (2005).

1.1 Main Objective

1.1.1 To evaluate the effect of timing and method of trellising on yield and quality of tomato.

1.2 Specific objectives

1.2.1 To investigate the effect of timing and method of trellising on days to 50% flowering, plant height at 50% flowering, number of fruits per plant, marketable yield and total yield.

1.1.2 To determine on the effect of timing and method of trellising on; sunscald and fruit rot.

1.3 Hypotheses

1.3.1 Timing and method of trellising has a significant effect on days to 50% flowering, plant height at 50% flowering, number of fruits per plant, marketable yield and total yield.

1.3.2 Timing and method of trellising has a significant effect on; fruit sunscald and fruit rot of tomatoes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Economic Importance of tomato in Zimbabwe

Tomato is one of the important horticultural crops grown in Zimbabwe and it ranks second after Irish potato (FAO, 2006). In Zimbabwe, tomatoes are sold as fresh fruits or dried and cooked as vegetables, eaten raw in salads; while some are used in soups, sauces, and various dishes. Almost every pot of relish cooked in Zimbabwe has tomato as an ingredient. Information from other nation's shows that consumption is increasing for example, the South African Statistics and Economic Services, (2011) highlighted that in 2010, South Africa's annual fresh tomato consumption increased from approximately 234 450 to 321 260 tons per annum.

Tomato has relatively high concentration of water soluble vitamins and minerals. Deficiencies of vitamin A and C are most tragic. Lack of vitamin A causes irreversible blindness in children and miscarriages in pregnant women (FAO, 2006). This is supported by studies carried in the Luapula valley of Zambia which showed that 16% of children under the age of five had inadequate vitamin A in their blood stream 2% had eye problems related to vitamin A deficiency which lead to blindness (Musulwe, 2003). Vitamin C is important for growth and maintenance of healthy bones, gums, ligaments and blood vessels (Kanyomeka and Shivute, 2005).

Economically, tomato production creates opportunities for employment and family income generation. Tomato production is labour intensive and can generate 3 - 10 times the employment and income per hectare of land compared to that of cereals like maize. Tomato production also creates a number of job opportunities in complementary businesses that arises such as marketing, processing and transportation.

2.2 Challenges associated with tomato production in Zimbabwe

Despite the economic importance of tomato, following are the challenges faced by smallholder farmers, exorbitant seed prices, poor agronomic practices, adverse climatic conditions, pests and diseases (Zitsanza, 2000). Ahmad and Singh, (2005) revealed that production of most horticultural crops is affected by seasonality. Seasonality is mainly due to climatic factors like rainfall, frost, temperature and radiation which limit production of some vegetables at specific times of the year (Acquaah, 2005). In open field conditions, tomato production is limited during winter period due to frost and in summer due to rains which promote proliferation of pests and diseases.

2.3 Trellising of tomatoes

Mahungu and Otiende, (2004) defines trellising as the supplying of an artificial support to a growing, trailing or climbing plant or plants with vines of rambling habit of growth, to get sunlight, which is essential for photosynthesis.

2.3.1 Benefits of trellising

Trellising or supporting of fruiting vegetables has been proven to be effective in reducing the incidence of pest and disease problems, thereby increasing yields (Saunyama and Knapp, 2003). According to Ahmad and Singh (2005) trellising tomatoes allowed better coverage of chemical sprays and prevented fruit clusters from touching the soil, resulting in a reduction of rots and soil-borne diseases. This was also supported byNzanza (2006) who mentioned that an erect growth allows the whole plant to be completely soaked in chemicals during spraying operations giving higher chances of effective pest and disease control. Also, trellising tomatoes improves fruit quality by keeping fruit off the ground and increasing air flow through the plant (MAFES, 2010).

Caldwell (2005) also testified that tomato plant has a weak stem hence need to be supported for it to have an erect growth stature. Trellising is of importance as it helps keeping leaves and developing fruits off the ground that may be a source of infection of most troublesome fungal diseases. In addition, Wahundeniya*et al.*, (2006) illustrated that trellising tomato plants has a benefit of increased fruit size, facilitate quick pest identification for control measure and also facilitate easy harvesting of fruits. Trellising also reduces the proportion of unmarketable fruits hence the farmer realizes high returns per unit area (Chadha, 2001).

According to Muhammad and Singh (2007b), trellising is of great importance in tomato production since it facilitates easy management and also protects the plants from animals, diseases and also provides good quality fruits free from physiological disorders like sunburn. Rice *et al*., (1990) and (FAO 2007) revealed that trellising facilitates exposure of leaves for effective light reception for better photosynthesis and also easy harvesting of fruits. Trellising tomato helps in acceleration of fruit ripening due to more light penetration from training and this will result in lengthening the harvest season which will benefit the farmer (Saunyama and Knapp, 2003). Trellised plants do not snap easily during moderate winds and they produce healthier plants which in turn produce a bumper and earlier harvest (Sibanda, 2006).

2.4 Methods of trellising

2.4.1 Stake and weave system

In stake and weave method, wooden or metal stakes are driven between plants then lines of strings between the stakes on both sides of the plants are used to support the plant. Wurster and Nganga (1991) suggested that nylon twine is best in terms of supporting the plants as it resists stretching and weather, also have a sufficient grip to wrap tightly around the stake. Wooden stakes method has a disadvantage of rotting due to fungi and they require peeling to avoid termites attack therefore should be treated before use.

Some commercial farmers use metal stake are stronger, easy to drive into the soil and helps prevent failure of post by providing a greater soil contact (Franco *et al.*, 2009). Kemble (2000) also revealed that metal stakes have an advantage of being reused for more than one season. The stakes are driven 25-30 cm deep into the soil between every 2 plants leaving about 35cm space between the stake and the main plant stem. Muhammad and Singh, (2007a) further explained that the first line of the string should be 10-20cm above the ground. The twine should be secured to an end stake for it to offer maximum support to the plant. The strings should be 15-20cm apart and the following row of string is run before the plants begin to fall over. The number of lines to be run and length of stakes is a dependent of the variety cultivated, but Kelley (2006) suggested that 3-5 and 5-6 lines are ideal for determinate and indeterminate varieties respectively. For stakes to be effectively driven into the soil, a heavy copped, metal cylinder that is 7-10cm in diameter and 45-60cm long can be used to hit the head of the stake (EARO, 2004). According to Saunyama and Knapp (2003) and Evans, (2004) stake and weave method is easy to maintain and supports a large number of tomatoes in a small space, inexpensive and requires little storage space.

2.4.2 Trellis posts

The system consist of heavy gauge wire string constructed horizontally across the top of widely spaced, sturdy 7-15cm support posts (Franco *et al.*, 2009). Lengths of baler twine are dropped from this top wire and secured to the base of each tomato plant. Plants can be trained to either a single or two main stems. Each stem is wounded around a length of twine as the plant grows. The support posts should stand 150-180cm the soil and be placed 366-610cm down the row. Fruits of trellised plants are more susceptible to sunburn because of reduced canopy and greater exposure to terrestrial radiation. According to Ahmad and Singh (2005), plants from trellis posts produce fewer fruits which are larger and ripen earlier than the plants trellised in other ways. This was supported by Chen and Lal, (2009) who hypothesized that plants trellised with posts produce larger fruits and typically ripen earlier. The fruits are larger and ripen faster due to more radiation captured by leaves which is important for the production of ATP and NADPH which are produced at adequate amounts of light. These two products are crucial products used in the Calvin Cycle for photosynthesis (Acquaah, 2005).

On the other hand, the fruits are more susceptible to cracking due to high light intensity and this reduces the quality of the fruits. Also, trellis posts have a negative effect of damaging plant roots if pressed into the soil at a closer distant to the crop unlike in caging and stake and weave methods which does not interfere with the plant roots (Kelley, 2006).

2.5 Timing of trellising in tomato production

Timing of trellising is a critical factor required in tomato production. Late trellising leads to damage of roots during driving stakes into the soil and also breaking of stems or fruit trusses and even breaking of stems and even dropping of followers and berries. This will affect the growth of the plant and also predispose damaged plants to pathogens attack. Ariyarathne (1999), advocated that trellising should be done at the initial stages of plant growth especially soon after transplanting to minimize root damage which tend to stress the plant reducing its maximum genetic yield According to Norman, (2003), early trellising lead to early seedling establishment and increased plant height which may delay flowering and fruit set of the crop hence lateness to harvest. In contrary to the above, Rice *at al,* (2003) suggested that as plants grow taller, there is a delay in maturity and this may have a positive effect on yield as more of the resources are invested over a longer period of time. Norman (2005) advocated that untrellised plants especially during the rainy season tend to flower earlier due to the effect of stress. If a plant is stressed, it responds by taking shorter days to flower. This was supported by Rice *et al.*, (2003) who supported that when total growth of a plant is reduced, the plant will take fewer days to flower but yield may not be reduced.

2.6 Problems of trellising

According to Norman (2003) problems of trellising are attributed to lower total yield per plant, higher susceptibility to blossom end rot, high cracking and sunburn and spread of viral diseases during operations especially when done at a late. Fayaz*et al.*, (2004) emphasised that trellising is a very laborious aspect of crop production. It is estimated that an average crop farmer spends about 60 man–days per hectare in producing stakes and staking his crop (Gore *et al.*, 1992). Added to that, conventional stakes are becoming scarcer and more costly as the forest is depleted (Nwosu, 2005). In addition, the stake must be sturdy enough to withstand breakage or dislodging especially when foliage becomes heavy on it. Norman, (2003) concluded that staked plants therefore produced higher yield than untrellised ones.

CHAPTER THREE

METHOD AND MATERIALS

3.1 Research site characteristics

The study was carried at Chiredzi Research Station located in the South-east Lowveld of Zimbabwe. The station is located at 21° 01' south and 31° 33' East at an altitude of 429m above sea level. The region lies under agro ecological natural region v of Zimbabwe that is semi-arid, with mean rainfall average of 550mm per annum (Vincent and Thomas, 1960). The minimum and maximum temperatures are 12^0C and 29^0C respectively, but maximum absolute temperature can go up to 42ºC especially in summer. The soils at Chiredzi Research Station are dark-brown clays derived from basic gneiss and are classified as the Triangle B2 series.

3.2 Experimental design and treatment

The experiment was laid out in a 5x2 plus control factorial experiment in randomized complete block design (RCBD) with 3 replications. Factor 1 was timing of trellising with the following levels; trellising at transplanting, 2W.A.T, 4W.A.T, 6W.A.T and 8WA.T.The second factor was method of trellising with the levels of trellis posts; stake and weave. The total treatment combinations are outlined in Table 3.1

Table 3 1: Treatment combinations of timing and method of trellising

Trellising time	Method	
	Trellis posts	Stake and weave
At Transplanting	T_1	T_6
2WAT	T_2	T_7
4WAT	T_3	T_8
6WAT	T_4	T_9
8WAT	T_5	T_{10}
No trellising	T_{11}	

3.3 Trial management

3.3.1 Sowing and nursery management

Tomato seedlings of Money maker were used for the trial at a seed rate of 250g ha^{-1}. Money maker is an indeterminate hybrid suited to open-field production. It is a medium maturing variety with an approximate of 80 days to the first pick though it varies with planting time. The variety produces high quality fruits with an average fruit mass of 110-120g when pruned to single stem and is highly tolerance to verticilium 1 (V), Fusarium wilt and nematodes. (Nirit Seeds, Breeders' Manual, 2010). The seedlings were raised in floating trays in the nursery shade. Planting media was made of 1:4 soil/compost mixed with 135g/m^2 compound D and the seedlings were watered regularly for 30 days. Regular watering of seedlings was stopped at 3 weeks after sowing for 7 days by reducing amount of water supplied to the seedlings before transplanting.

3.3.2 Land preparation

The land was ploughed using a tractor mounted disc plough to a depth of 38cm. Heavy soil clumps were broken using a hand hoe in order to achieve a fine soil texture. Ridges of 1 m apart were constructed using tractor mounted ridger. The total experimental area was 442m^2 with a cropping area of 198 m^2. Each plot size measured 2m x 3m giving an area of 6 m^2.

3.3.3 Fertilization and transplanting

Compound D (N_7:P_{14}:K_7) was spot applied at rate of 500kg ha^{-1} before transplanting seedlings. The spacing was 1.0 m x 0.3 m, inter-and-intra row respectively to give a plant population of 33 333 plants ha^{-1} hence each plot was having 18 plants. Top dressing was done with Ammonium Nitrate (34.5%N) and Potassium Sulphate (50% K_20) at a rate of 100kg ha^{-1} each. Top dressing was split applied into two equal doses, the first one 3 weeks after transplanting and the last one at 5 weeks after transplanting.

3.3.4 Weed, insect pest and disease control

Plots were kept weed free as much as possible using hand hoes .Uniform pest and disease control was done to the treatments at a weekly routine operation with emergency sprays done after every rain. For ball worms (*Heliothis armigera*), white flies (*Bemisa tabaci*) and aphids (*Aphis gossypii*) were controlled using Dimethoate 40% EC (rogor) and Metasystox applied at the same rate of 400 ml/ha. Dithane M-45 and copper oxychloride at the same rate of 200g/100 litres of water were used as full cover to control dumping off complex diseases (*phytophtora parasitica*, *Rhizoctonia spp and Pythium spp*), early blight (Altenaria solania), late blight (*Phytophtora infestas*) and bacterial blight (*Pseudomonas solanacearum*). A 15-litre capacity hand operated knapsack sprayer was used to achieve the spraying activity.

3.3.5 Irrigation

The crop was planted during the rainy season therefore, three supplementary irrigations after dry spell and about 35 mm water was applied per each irrigation. Flood irrigation was used for supplementary irrigation. The crop received about 450-550 mm water throughout the growing season.

3.3.6 Trellising

Trellising was done according to the treatments on table 3.1 above.

3.3.7 Harvesting

Hand harvesting was done and subsequent practices like sorting, counting, weighing and measuring were done soon after harvesting.

3.3.8 Fruit grading

Fruits were graded soon after harvesting according to rotted, sunscald, cracked and size.

3.4 Data collection and measurements

3.4.1 Days to 50% flowering

The number of days was noted from transplanting date to the day on which 50% of the plants in a plot flowered.

3.4.2 Plant height at 50% flowering

Plant height was recorded by measuring the height of randomly selected plants in each plot from the ground level to the main apex; mean values were expressed in cm.

3.4.3 Number of fruits per plant

The mean number of fruits per plant was calculated by counting the number of fruits of successive harvests per plant.

3.4.4 Marketable yield (t/ha)

At each harvest, fruits were categorized by marketable or unmarketable. Fruits with cracks, damaged sunscald, rotted and with some physiological disorders were considered unmarketable

(Lemma, 2002). Those which were free from the above damages were considered marketable and the yield was expressed in tones per hectare.

3.4.4 Total yield (t/ha)

The mean total yield per hectare was obtained by adding marketable and unmarketable yield and was expressed in tones.

3.4.6 Fruit sunburn

Fruits affected by sunburn were counted and recorded during successive harvesting period.

3.4.7 Fruit rot

Number of rotted fruits was counted during the successive harvesting period.

3.5 Data analysis

All the data was subjected to Analysis of Variance using Gensat 14^{th} Edition statistical package. Discrete data was transformed using the square root prior to analysis. The separation of means was done using Least Significant Difference (LSD) at 5% level of significance.

CHAPTER FOUR

RESULTS

4.1 Effect of timing and method of trellising on days to 50% flowering.

There was an interaction ($p<0.05$) on timing and method of trellising on days to 50% flowering as shown on Figure 1. Trellising at transplanting showed the highest number of days to 50% flowering in both trellis posts and stake and weave methods and was not significantly different from 2WAT. Timing at 4WAT was significantly different from 6 and 8WAT in trellis posts method while 4WAT was not significantly different with 6 and 8WAT in stake and weave method. The results also showed that no trellising gave the least significant days to 50% flowering and was not statistically different from 6WAT and 8WAT.

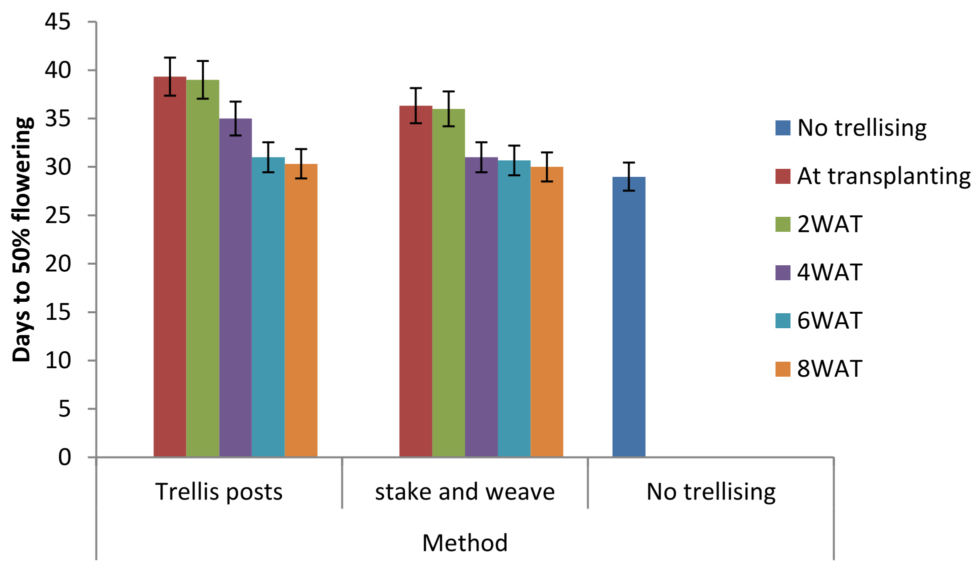

Figure 4 1: Effects of timing and method of trellising on days to 50% flowering

4.2: Effect of timing and method of trellising on tomato plant height at 50% flowering.

There was an interaction ($p<0.05$) on timing and method of trellising on days to 50% flowering as shown on Figure 2. Trellising at transplanting showed the highest plant height at 50% flowering in both trellis posts and stake and weave methods and was not significantly different from 2WAT. Timing at 2WAT was not significantly different with 4WAT in trellis posts while 2WAT showed a signifiacant difference with 4WAT in stake and weave method. Also, 6WAT was significantly different with 8WAT in trellis post whereas 6WAT was not significantly different from 8WAT in stake and weave method. The results showed that no trelliasing gave the least heights at 50% flowering and was not statistically different from 8WAT in both trellis posts and atake and weave methods.

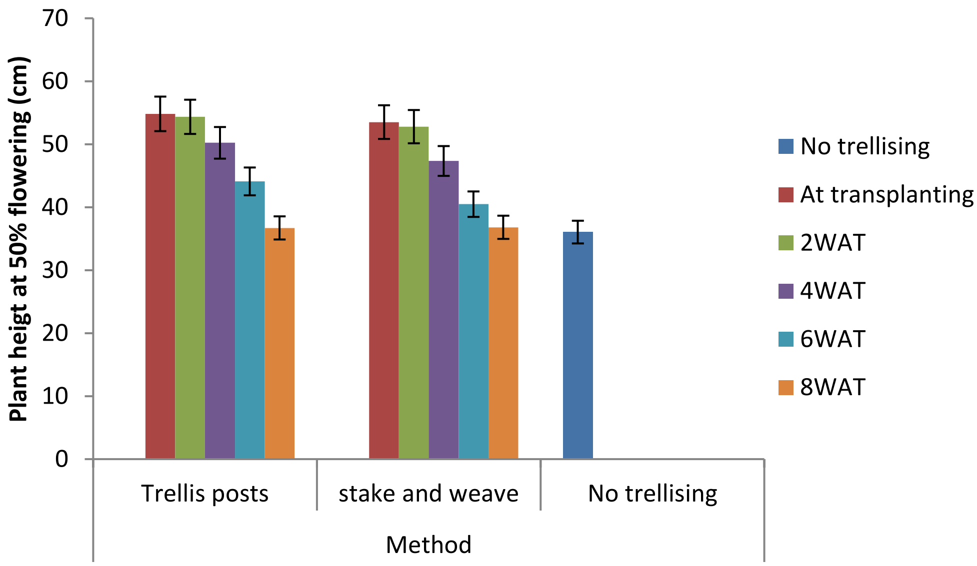

Figure 4 2: Effect of timing and method of trellising on average plant height at 50% flowering.

4.3: Effect of method of trellising on number of tomato fruits per plant.

There was no interaction ($p<0.05$) between timing and method of trellising on number on fruits per plant. However, there were significant differences ($P<0.05$) among methods of trellising on number of fruits per plant as shown in Table 4.1. No trellising gave the highest number of fruits per plant and was statistically different from trellis posts and stake and weave methods. The least significant ($p<0.05$) method on number of fruits per plant was trellis post method.

Table 4 1: Effect of method of trellising on number of fruit per plant

Method	Mean fruit rots
Trellis posts	4.36^{a} (19.00)
Stake and weave	4.68^{b} (21.87)
No trellising	5.10^{c} (26.00)
LSD	0.23
CV	2.9
F-Probability	<.001

Means followed by the same letter are no significantly different at $P<0.05$

Figures in brackets are the original means before data was transformed.

4.4: Effect of timing on number of tomato fruits per plant.

There was no interaction ($p<0.05$) between timing and method of trellising on number of fruits per plant. However, there were significant differences ($p<0.05$) among timing of trellising as shown on Figure 4.3. Trellising at 4WAT showed the highest number of fruits per plant. The least significant number of fruits per plant was shown at transplanting and was not statistically different from 8WAT.

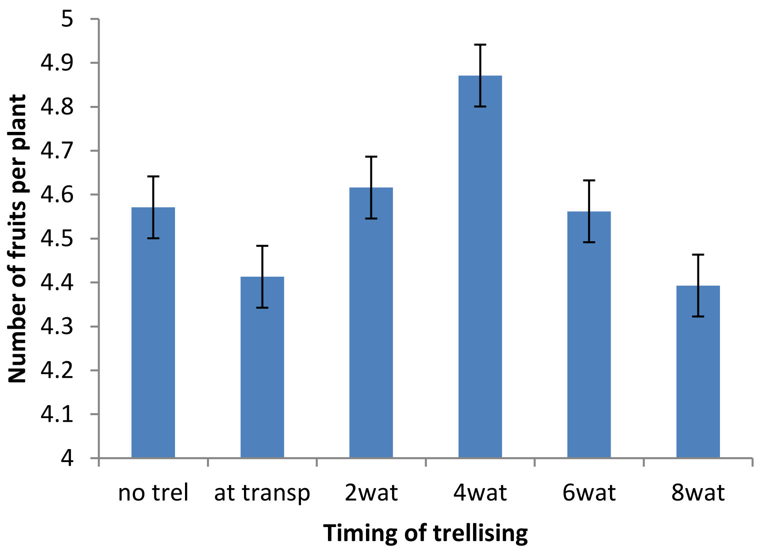

Figure 4 3: Effect of timing and method of trellising on number of fruits per plant

4.5: Effect of timing and method of trellising on tomato marketable yield (t/ha).

There was an interaction ($p<0.05$) between timing and method of trellising on the marketable yield as shown in Figure 4.4. The highest significant marketable yield was obtained from timing at transplanting and was not statistically different from 2WAT in trellis posts method. Trellising at 2WAT was significantly different with 4WAT in trellis posts method while trellising from transplanting, 2WAT and 4WAT in stake and weave was not significantly different. The results showed that the least significant marketable yield was obtained from no trellising.

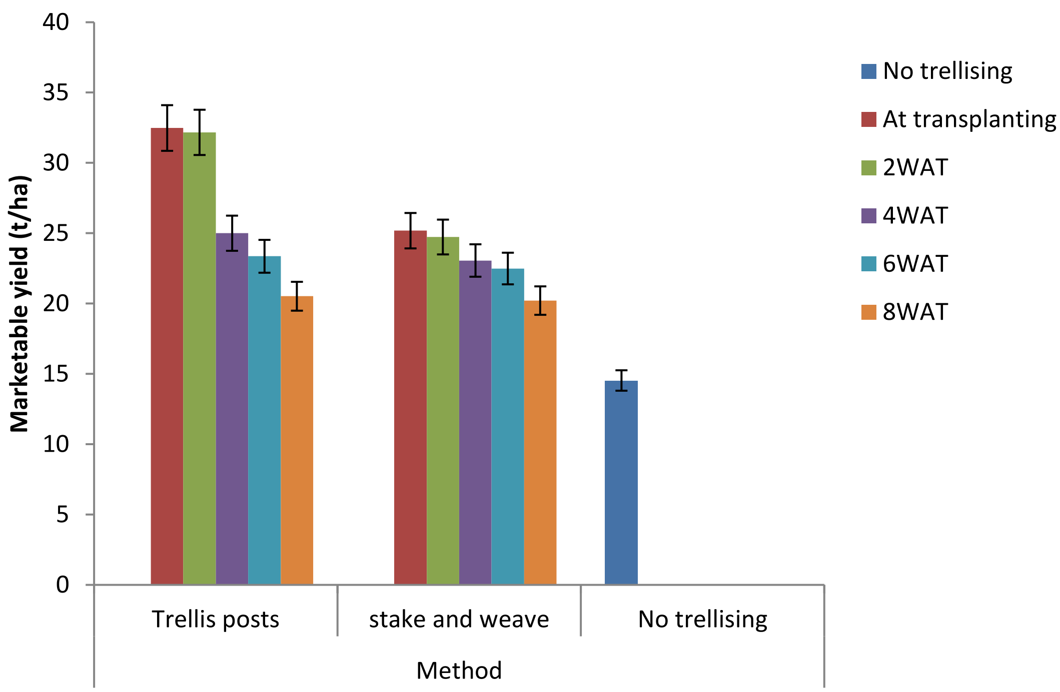

Figure 4 4: Effect of timing and method of trellising on marketable yield per hectare

4.6: Effect of timing and method of trellising on tomato total yield (t/ha).

There was an interaction ($p<0.05$) between timing and method of trellising on the total yield as shown in Figure 4.5. Trellising at transplanting showed the highest total yield in trellis post method and was not significantly different from 2WAT. Trellising at 6WAT was not significantly different from 8WAT in trellis post while 6 and 8WAT are significantly different in stake and weave method. The results also showed that no trellising gave the least significant total yield and was not statististically different from 8WAT in both trellis post and stake and weave methods.

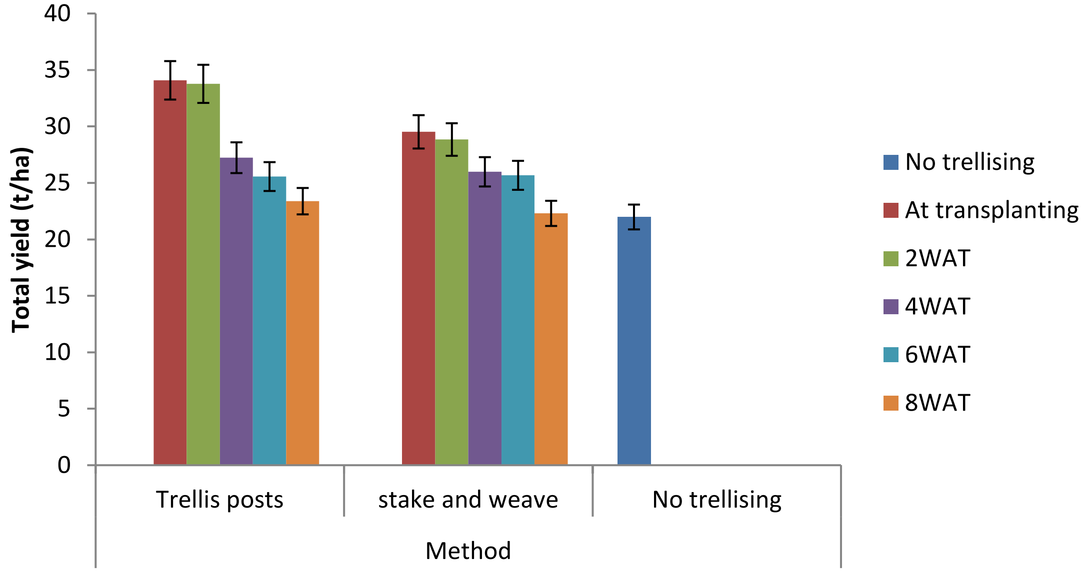

Figure 4 5: Effect of timing and method of trellising on marketable yield (t/ha).

4.7 Effect of method of trellising on tomato fruit sunscald per plant.

There was no interaction ($p<0.05$) between timing and method of trellising on fruit sunscald. However, there were significant differences ($p<0.05$) among methods of trellising as shown in Table 4.2. No trellising gave the highest significant fruit sunscald and was statistically different from trellis posts and stake and weave method. Stake and weave method showed the least significant ($p<0.05$) number of fruit sunscald per plant.

Table 4 2: Effect of method of trellising on tomato fruit sunscald per plant

Method	Mean sunburn fruits
Stake and weave	0.65^{a} (0.53)
Trellis posts	1.27^{b} (1.60)
No trellising	1.84^{c} (3.33)
LSD	0.54
CV	30.6
F-Probability	<.001

Means followed by the same letter are no significantly different at P<0.05

Figures in brackets are the original means were data was transformed.

4.8 Effect of timing and method of trellising on tomato fruit rots per plant.

There was an interaction ($p<0.05$) between timing and method of trellising on number of fruit rots per plant as shown in Figure 4. 6. No trellising showed the highest number of fruit rots per plant but were not significantly different from trellising at 8WAT in both trellis posts and stake and weave methods. Timing at transplanting and 2WAT was significantly different from 4WAT in trellis posts method while trellising at transplanting, 2WAT and 4WAT showed no significant difference in stake and weave method. Trellising at transplanting in trellis posts showed the least number of fruit rots per plant and was not statistically different from 2WAT.

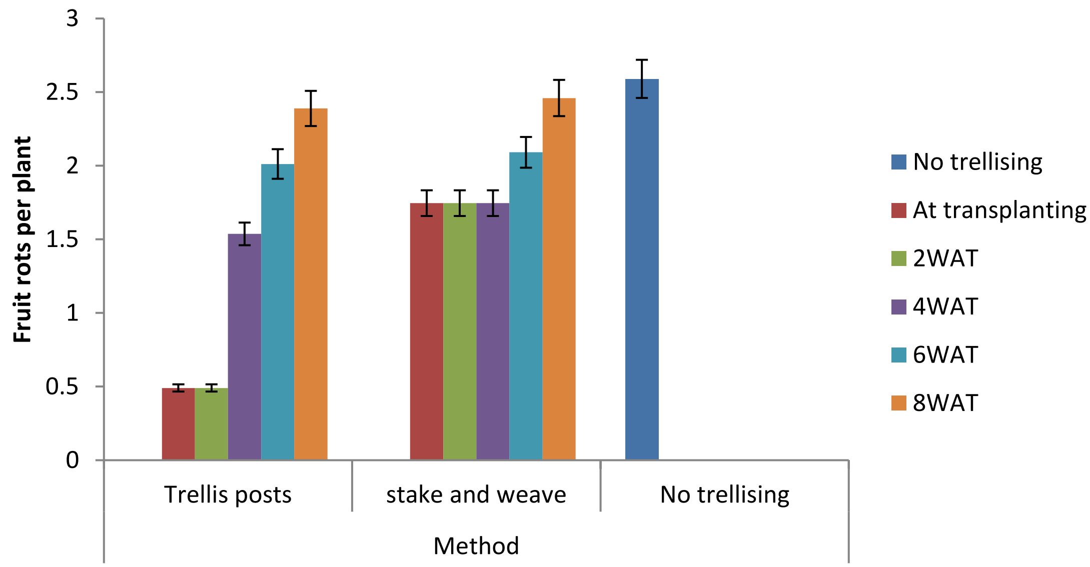

Figure 4.6: Effect of timing and method of trellising on fruit rot

CHAPTER 5

DISCUSSION

5.1 Effect of timing and method of trellising on days to 50% flowering after transplanting

Trellis posts at transplanting and 2WAT gave the highest number of days to 50% flowering while untrellised plant, 6and 8WAT in both trellis posts and stake and weave methods gave the least days to 50% flowering. Early flowering could have been attributed by stress. The seedlings from early flowered plants might have been stressed by excessive rains causing stunted growth as the whole plant was in contact with the soil most of their times. The plants therefore responded to stress by taking fewer days to flowering. This is in agreement with Rice *et al*., (2003) who pointed out that when total plant growth is reduced, plants take fewer days to flowering and this reduces yield as the plant flowers before stronger assimilates storage structures. On the other hand, Default*et al*., (1999) highlighted that as plants grow taller, there is delay in crop maturity and this may have a positive effect on total yield as more assimilates are invested over a longer period.

5.2 Effect of timing and method of trellising on plant height at 50% flowering

Differences observed among trellising time and methods of trellising on plant height at 50% flowering could have been due to early seedling establishment due to trellising at transplanting and 2WAT. Trellis post at transplanting to 4WAT showed no significant difference in trellis posts method while a significant difference was observed on trellising at 2WAT and 4WAT. This could be due to the structure of the crop provided by the trellising methods. Trellis posts allow for a vertically inclined structure whereas stake and weave method gives a compact structure with more lateral branches. Vertically structured plants have a capacity to utilize more terrestrial radiation than a compact and bushy canopy hence faster growth rate is realized. This is in agreement with Went *et al*., (1999) who found highest plant heights at 50% flowering from trellis post method though timing was not considered. Also, Wszelaki*et al*., (2007) revealed that trellis post method gives a stable structure which would maximize terrestrial radiation uptake.

Early trellising (not latter than 2WAT) provides an early seedling establishment hence early and sufficient leaf area for photosynthesis resulting in enough carbohydrates to support the plant height (Default *et al*., 1999). Joslin, (2004) also observed highest plants from trellised plants due to the fact that almost every leaf of the plant received sunlight for photosynthesis since the plants were upright than the control that were left compacted on the ground. On the other hand, shorter plants were found from late trellised plants and un-trellised plants, this could have been attributed by days to 50% flowering and stress. These plants seized growth and started concentrating on reproduction. This is in agreement with Quinn, (2004) and Davis and Ester, (1993) who found that tomato plants that are grown under unfavorable conditions reduced plants heights due to shorter internodes and reduced number of leaves.

5.3: Effect of method of trellising on number of tomato fruits per plant.

The differences in number of fruits per plant observed in the methods of trellising could have been due to the different plant structures provided by the different trellising methods. No trellising gave the highest number of fruits per plant and this might be due to the bushy and compact structure of the un trellised plants which does no allow dropping of flowers and berries due to the excessive rainfall, wind and high light intensity. The findings are in line with the study of Quinn, (2004) who highlighted that a compact and bushy plant does not allow light penetration deep down the plant canopy and this allows high fruit set percentage though many small sized fruits will be realized. Also, un trellised plant did not get problems of flower and fruit drop and even breaking of trusses due to human interference. On the other hand, the least significant number of fruits per plant from trellising posts at Transplanting and 2WAT might also be due to the vertical structure provided by the method of trellising. Default *et al*., (1999) found that a vertically structured plant allows dropping of flowers and berries especially during the rainy season and this reduces fruit set percentage. Saunyama and Knapp, (2003) also highlighted that due to the structure provide by trellis posts method, fruit set percentage is low but this will lead to production of large sized fruits of high quality due to maximum capturing and utilization of terrestrial radiation by the canopy.

5.4 Effect of time of trellising on number of tomato fruits per plant.

Trellising at transplanting showed the least number of fruits per plant. This could have been attributed by factors like days to 50% flowering, plant height at 50% flowering and the structure provided by trellising method. The plants from trellis posts at transplanting quickly established forming a structure which predisposed the flowers to direct sunlight, wind and rainfall hence increased dropping of flowers and berries leading to reduced number of fruits per plant. MAFES,

(2003) also found that a vertically structured plant predispose the flowers and fruits to direct sunlight leading to dropping of flowers, berries and increased fruit sunscald. On the other hand, Diver *et al*., (1999), highlighted that trellis posts produce fewer fruits but these will be larger and ripen earlier than the plants trained in other ways. These fruits will have a thicker and tough skin which is less easily damaged (MAFES, 2003). Also, plants trellised at transplanting gave the highest plant heights at 50% flowering in both trellis posts and stake and weave methods as they promoted vegetative growth at the expense of reproduction structures.

Trellising latter than 4WAT showed decline in number of fruits per plant and this might have been attributed by reduced fruit set due to dropping of flowers and breaking of stems during trellising. This is in agreement with Cadwell, (2005) and Ariyarathne (1999) who highlighted that late trellising leads to dropping of flower buds, flowers, berries and also leads to breaking of trusses during the operation.

5.5 Effect of timing and method of trellising on tomato marketable yield (t/ha).

The differences observed among timing and methods of trellising on marketable yield was contributed by the differences onfruit rots per plant, fruit sunscald per plant and the structure provided by the trellising method. The highest marketable yield was obtained from trellis posts at transplanting and 2WAT which gave the least number of fruit rots per plant and least number of fruit sunscald. Plant structure provided by trellis post minimized number of fruit rots as it allowed for better pest and disease control. This in agreement with Saunyama and Knapp, (2003) who found that trellis post gives vertically structured plants which is makes pest and disease control easy as it allows spraying of fungicides from both sides of rows therefore better deposition of fungicides deposit on leaves.

Branches and leaves of plants from trellis post at transplanting and 2WAT did not get in contact with the ground for too long therefore minimized incidence of soil dwelling disease causing pathogens. Also, trellis post at transplanting and at 2WAT showed the tallest plants (Fig 2). Default *et al*., (1999) supported that tall plants gives a sufficient leaf area for photosynthesis resulting to higher storage of carbohydrates which will be translocated to the sink (fruits) thereby increasing fruit weight.

No trellising at all meant that the plant leaves and fruits will be always in contact with the soil surface as the tomato plant stem could not support itself. This resulted in very few branches exposed to favorable conditions for bearing hence the low yields that were realized. Also, branches, leaves and fruits were lying in the water way such they were soaked during irrigation times and this resulted in serious bacterial leaf diseases which destroyed most leaves hence exposing fruit to direct sunlight which influenced fruit sunscald and fruit rots. Delaying trellising latter than 2WAT resulted in some yield penalties as trellising when plants are at an advanced maturity stage caused stems to break resulting in reduced number photosynthesizing parts like loss of leaves and branches. This is supported by Cadwell, (2005) who suggested that trellising should be done early so as to reduce dropping of flowers, breaking of stems and dropping of berries.

5.6 Effect of timing and method of trellising on tomato total yield (t/ha).

The differences observed among the timing and trellising systems for yield could be explained by plant height and days to 50% flowering, plant height at 50% flowering, fruit sunscald, fruit rots and environmental conditions such as atmospheric temperature, rainfall, light intensity and humidity. The highest total yield has been shown from trellising posts at transplanting and 2WAT and these also gave the highest plant heights at 50% flowering. Rice *et al.*, (2003) explained that there is a correlation between plant heights with total yield as plant height determines canopy size with taller plants producing bigger canopies which enhance more light capture and production of more photosynthesis which is used for total soluble solutes accumulation. Also, there was early seedling establishment in trellis posts at transplanting and 2WAT and this might have promoted rapid crop development for extraction of nutrients and minerals and gave rise to taller plants that improved photosynthetic efficiency leading to highest yield.Less fruit rots, pest, disease and sunscald were observed from trellising posts at transplanting and 2WAT.

The canopy provided by trellis posts also playedvital a role in reducing pest and disease attack as the system allows for better spray coverage. This in in agreement with Saunyama and knapp, (2003) who observed lower incidence pests and disease in trellised plots due to better spray deposits of fungicides and less favorable microclimate for fungal diseases in less dense canopies of trellis posts.

Rice *et al.*, (2003) highlighted that late flowering in tomato plants result in production of adequate carbohydrates to support growth of leaves, lateral branches, flowers and fruit development. Plants trellised latter than 4WAT showed a decline in number of fruits per plant. This could be attributed by dropping of flowers, fruits and breaking of trusses during trellising as the plants have already flowered and set their fruits. This is in agreement with Ariyarathne, (1999) and Cadwell, 2005) who reported that trellising should be done at the initial stages of plant growth especially soon after transplanting to minimize root damage, breaking of trusses, dropping of flowers and even berries.

Lower yields from untrellised plants and 8WAT in trellis posts and stake and weave methods could be due to shorter plant heights, structure provided by trellising and shorter days to flowering.Stem rot and leaf blights were observed which were observed from 4WAT in both stake and weave and trellis posts method and untrellised plants. Bidwell, (2004) also noted that stem rot reduce translocation of nutrients and minerals to support growth, development and survival of a plant. Also, the treatments which produced the least yield were shorter at 50% flowering meaning they flowered before production of stronger sinks. These results are in agreement with Rice *et al*., (1999) who asserted that increase in plant height gives a plant and advantage in competing with other plants for light and that formation of new more efficient and better positioned leaves at the top enhances photosynthesis. The photosynthates produced are used in dry matter accumulation which will lead to larger fruits which weighs more. Bidwell, (2004) also highlighted that plant height is a function of fast growth rate and yield. Fast growth observed from the trellis post at transplanting and at 2WAT could have enhanced higher yield. This could have enabled the plants to quickly develop the photosynthetic machinery which in turn produces more photosynthates for dry matter accumulation.

AVRDC (1998) acknowledged that the number of fruits harvested per plant is a dependent of 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.

The leaf blights which were observed in trellising at 4, 6 and 8WAT and no trellising reduced photosynthetic area hence reduced photosynthesis and carbohydrates to support growth of leaf, flowers and fruits.

5.7 Effect of timing and method of trellising on tomato fruit Sunscald per plant.

The highest number of fruit sunscald was observed from untrellised, timing at 6 and 8WA. This could be due to reduced foliage due to excessive rains which soaked the plant for a longer period of time. The crop was compact in structure that aeration was poor resulting to incidence of disease attack. Went, (1999) highlighted that when a crop is soaked in heavy rains, most leaves and stems rot. Extensive leaf damage which was observed from leaf blights contributed to the highest number of fruit sunscald in no trellised, 6 and 8WAT treatments. This is in line with the study of Fayaz*et al*., (2007) who found highest number of fruits sunscald from un- trellised plants due to late blight disease which defoliated the plants exposing them to sunlight. In trellis posts, trellising at transplanting and 2WAT showed a significant difference from 4WAT while trellising at transplanting, 2WAT and 4WAT showed no significant difference in stake and weave method. The least number of fruit sunscald from stake and weave method might have been attributed by the dense canopy provided by the method. This method could not allow deep light penetration into the plant canopy. The results are in line with the findings of Diver *et al*., (1999) who found that stake and weave method produce more fruits that are less likely to suffer from cracking or sunburn.

5.8 Effect of timing and method of trellising on tomato fruit rots per plant.

Differences observed among the timing and method of trellising could be explained by excessive rainfall and humidity. High numbers of rotted fruits was obtained from no trellising, stake and weave at 8WAT and trellis posts at 8WAT. This could be due unfavorable conditions of excessive rains since most leaves and fruits were in contact with the soil where most disease causing pathogens hibernate. Also, Rice *et al*., (2003) revealed that when plants have been stressed for a longer period of time, they produced fruits which are not firm enough to withstand disease attack. On the other hand, less number of rotted fruits was recorded from trellis posts at transplanting and trellis posts 2WAT because of favorable conditions that reduce disease attack. Trellis posts also gave an upright plant which was less dense than stake and weave. This allows for better chemical spraying for pests and disease. Also, trellis posts allow for increased air circulation within the plant hence reduced favorable environment for most fungal diseases. If tomato fruits hang low and touch the ground, fungal problems such as fruit rot are enhanced thereby reducing marketable yield (Rice *et al.*, 2003).

The results of the trial are in agreement with those of Saunyama and Knapp, (2003) who observed lower incidence pests and disease in trellised plots due to better spray deposits of fungicides and less favorable microclimate for fungal diseases in less dense canopies of trellised plots.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

- The number of days to 50% flowering reduced with delay in trellising. Trellising at transplanting and 2WAT in trellis posts gave the highest number of days to 50% flowering. Trellising at 4WATin stake and weave method was not different from late trellising treatments and no trellising.
- The plant height reduced with delay in trellising. The highest plant height was obtained from trellising at transplanting, 2WAT and 4WAT in trellis posts. While the highest plant height was at transplanting and 2WAT for stake and weave method.
- Thenumber of fruits per plant increased with delay in trellising with no trellising giving the highest number of fruits per plant but was small in size. The least fruits per plant were from trellising at transplanting and 2WAT in trellis post while in stake and weave method trellising at transplanting, 2WAT and 4WAT and no trellising gave the highest fruits per plant.
- The marketable yield (t/ha) reduced with delay in trellising. The highest marketable yield was obtained from trellising at transplanting and 2WAT in trellis post while in stake and weave method trellising at transplanting, 2WAT and 4WAT gave the highest yield.
- The highest total yield (t/ha), was obtained from trellising at transplanting and 2WAT in trellis post while the least was from no trellising and 8WAT in both trellis posts and stake and weave methods.
- Fruit sunscald was highest in no trellising and lowest in stake and weave method.
- Fruit rots increased with delay in trellising. The highest numbers of fruit rots per plant were observed from no trellising and 8WAT in both trellis posts and stake and weave method.

6.2 Recommendations

- Trellis posts method should be used ahead of stake and weave trellising method for higher marketable and total yields.

- Trellising should be done between transplanting and 2WAT in both trellis posts and stake and weave methods to reduce incidences of fruit rots and sunscalds.
- The trial needs to be repeated in subsequent seasons to verify findings.
- Further research on economic analysis on trellising systems should be carried out.

REFERENCES

Acquaah, G. (2005).Horticulture principles and practices third edition. Pearson Education, New Jersey.

Ahmad, A. and Singh, A. (2005). Effects of staking and row-spacing on the yield of tomato(*Lycopersicon lycopersicum* Mill.) cultivar "Roma VF" in the SokotoFadama, Nigeria, Nigerian Journal of Horticultural Science**10**: 94-98.

Ariyarathne, H. M. (1999). Effect of staking methods and mulching on tomato production Sri Lanka.ARC Training, Sri Lanka. Available on:http://dc352.4shared.com/doc/mh9pDwAL/preview.html. (Accessed: 21 November 2013).

AVRDC, (1998) Tomato and Pepper production in the tropics, Proceedings of the International Symposium on International Management Practices, Taiwan 21-22 March 1998, publication no.**1-317**: 55-76

Bidwell, R.G. (2004). Plant physiology-second edition, Macmillan Publishing, New Zeland.Pp 533-547.

Cadwell, J.S. (2005). Assessing rainy season vegetable production alternatives: a case study in "upstream" farming systems research 2004.Asia Vegetable Research and Development Centre.

Chadha, K.L. (2001). Handbook of Horticulture. Indian Council of Agricultural Research, New Delhi, India, Pages: 1031.

Chen, J.T. and Lal, G. (2009).Pruning and Staking Tomatoes. International Cooperator's Guide,AVRDC, UK.pp: 490.

Davis, J.M. and Esters, E.A. (1993).Spacing and pruning affect growth, yield and economicreturns on staked fresh-market tomatoes. Journal of American Society Horticulture Science**118(6):**719-725.

Default, R.J, J.R Schulthesis.(2004). Bell pepper seedlings growth and yield following pre-transplant nutritional conditioning.Hort Science **29**: 940-973.

Diver, S., G. Kuepper, and H. Born.(1999). Organic tomato production [Online]. National Center for Appropriate Technology (ATTRA) Publication #CT073/149. Available at: http://attra.ncat.org/attra-pub/tomato.html#training (Accessed: 16 September 2013).

EARO, (2004).Directory of released crop varieties and their recommended cultural practices.Ethiopian Agricultural Research organization, Addis Ababa, Ethiopia.

Evans, W. (2004).Bringing Up Tomatoes.Organic Gardening Magazine.June/July. p. 34-37.

FAO,(2006).FAO Production Yearbook, Basic Data Unit, Statistics Division, FAO, Rome, Italy, No. 55, pp 125-127

FAO, (2007).Green beans integrated pest management. An Ecological Guide Training.Resource Text on Crop Development, Major Agronomic Practice, Disease and Insect Ecology, Insect Pest, Natural Enemies and Diseases of Green Beans.Food and Agriculture Organization, Rome, Italy.

FAOSTAT. (2010). Food and Agricultural Commodities Production; Available online: http://faostat.fao.org (accessed 21 July 2013).

Fayaz A, Obedullah K, Sair S, Akhtar H, Sher A (2007).Performance evaluation of tomato cultivars at high altitude.Sarhad Journal of Agriculture**23 (3),** 581-584

Food and Agriculture Organization (FAO), (2004): Corporate Document Repository. Socio-Economic Impact of smallholder Irrigation Development in Zimbabwe. http://www.fao.org/Docrep/html (Accessed 10/11/13).

FAO (2005) Year book of production, Rome.

Franco, J.L., Diaz, M., Dianez, F. Camacho, F. (2009). Influence of different types of pruning on cherry tomato fruit production and quality. Journal of Food Agric. Environment**7**: 248-253.

Fruit and Vegetable Company, (2010). Fruit and Vegetable Project Evaluation draft final report, Hertfordshire.UK.

Gore, C., Katerere, Y. and Moyo, S (1992). The case for sustainable development in Zimbabwe, conceptual problems, conflicts and contradictions, ENDA-Zimbabwe and ZERO, Harare, Zimbabwe.

Gleason, M. and F. Edmunds.(2006). Tomato Diseases and Disorders.Iowa State University Extension.PM 1266.

Heuvelink, E., (1996). Dry matter partitioning in tomato: Validation of a dynamic simulation model. Ann. Bot **77**: 71-80. Available on: http://dx.doi.org/10.1006/anbo.1996.0009(Accessed 10/11/13).

Joslin, K. R. (2004). Control of the foliar disease, Septorialycopersici, in organic tomato production. Iowa State University: Graduate Thesis.

Kanyomeka, L. and Shivute B. (2005). Influence of pruning on tomato production under controlled environments. AgriculturaTropicaetSubtropica**32(2)** 79-81.

Karen Collins, R.D. (2007). Benefits of eating tomatoes remain bountiful: Lycopene may not reduce cancer risk, but its still part of a healthy diet. Available on: http://www.msnbc.msn.com/id/19979174/ns/health-diet_and_nutrition/t/benefits-eating-tomatoes-remain-bountiful/ (Accessed: 12 March 2013).

Kelley, W.T. (2006). Production using plastic mulch.Commercial tomato production handbook [Online].University of Georgia Cooperative Extension Bulletin 1312. Available at: http://pubs.caes.uga.edu/caespubs/pubs/PDF/B1312.pdf (Accessed: 17 March 2013).

Kemble, J.M., L.M. Curtis, and T.W. Tyson,(2000). Guide to commercial staked tomato production in Alabama [Online]. Auburn University Extension Publication ANR-1156. Available at: http://www.aces.edu/pubs/docs/A/ANR-1156/ (Accessed: 16 September 2013).

Lemma, D. (2002).Research experience and production prospects. Ethiopian Agricultural research Organization (AERO), Addis Ababa, Ethiopia, pp 15-25.

Lushi1, L. Haxhinasto, N. Balaj., F. Hasani. (2012). Comparison of different mulch materials on some tomato (*Solanum lycopersicum*) cultivars under controlled environment conditions of Anadrini, Kosovo.Research journal of Agricultural Sciences, **44 (1)**: 67-84.

Mahungu, R. M. and Otiende J. E. (2004). Learn to grow Yams. Metro Language and Communication Centre.Nairobi-Kenya pp. 10-12.

Mississippi Cooperative Extension Service and Experiment Station (MAFES) (2006). Vegetable gardening: Staking and training tomatoes [Online]. Available at: http://msucares.com/lawn/garden/vegetables/tomatoes/index.html (Accessed: 17 March 2013).

Muhammad, A. and A. Singh, (2007).Yield of tomato as influenced by training and pruning in the Sudan Savanna of Nigeria. Journal of Plant Sciences**2**: 310-317 [Online]. Available on: http://www.scialert.net/abstract/?doi=jps.2007.310.317(Accessed: 17 March 2013).

Muhammad, A. and Singh, A. (2007a). Intra-row spacing and pruning effects on fresh tomato yield in Sudan Savanna of Nigeria. Journal of Plant Sciences**2**: 153-161

Muhammad, A. and Singh, A. (2007b). Yield of tomato as influenced by training and pruning in the Sudan Savanna of Nigeria. Journal of Plant Sciences**2**: 310-317.

Musulwe, N, and K, Chogo (2003).Vegetable production in Southern Province, vegetable Research and Development in Zambia. Proceedings of the First National vegetable research , held in Lusaka, Zambia.

Norman, J.C (2003). The Horticultural industry in Tropical Africa. Ghana. *Journal of Horticulture* **3**: 36:46.

Nwosu, N. A. (2005). Recent developments in vegetable propagation of edible yam (*Dioscorea species*), Proc. Agric Soc. Nigeria, 12, 15.

Nzanza, B.(2006). Yield and quality of tomatoes as influenced by different Ca, Mg, K nutrition.Msc Thesis, University of Pretoria, South Africa.

Nsowah, G.F. (1999). Review of tomato variety and staking trials in Northern Ghana. 1995-1997.

Quinn, J. C. (1973). An evaluation on method of Mulching and Staking tomatoes grown during the rains at Sumaru, Nigeria. Hort. Res **13**:87-97.

Rawson, J.M. (2007). Organic Agriculture in the U.S: Program and Policy Issues. Organic Agriculture in the U.S. p. 37-53.

Rice, R. P., Rice, L. W. and Tindall, H. D. (2003). Fruit and vegetable production in Africa,Macmillan Publishers Ltd. London and Basingstoke.

Saunyam, I.G.M. and M. Knapp, (2003).Effect of pruning and trellising of tomatoes on red spider mite incidence and crop yield in Zimbabwe.African Crop Science journals**11**: 269-277. Direct link: http:/www.bioline.org.br/abstract?cs05028

Sibanda, T., Dobson, H.M., Cooper, J.F., Manyangira, W, and Chiimba, W. (2000). Pest management challenges for smallholder vegetable farmers in Zimbabwe. Journal of Crop protection **19**: 805-815

Wahundeniya, W.M.K.B., C. Wicremathunga and W.A.P. Weerakkody, (2006). Comparison of growth and yield performance of tomato varieties under controlled environment conditions. Ann. Dep. Agric**8**:251-262.

Went, F (1999).Plant growth under controlled conditions. II. Thermo-periodicity in growth and fruiting of tomato. American journal**31**:151-162.

Wszelaki, A. L. and Miller, S. A. (2005).Determining the efficacy of disease management products in organically-produced tomatoes.Plant Health Progress doi: 10.1094/PHP- 2005-0713-01-RS.

Wurster, R.T. and Nganga, S. (1991). The effect of staking and pruning on the yield and quality of fresh market tomatoes in East Africa.Acta Hort. (ISHS) **21**:110-115.

Zitsanza, (2006). Ecological studies on Heliocorverpa armigera (Lepidoptera: Noctuidae) in intensive cropping systems in Zimbabwe. Technology and medicine.Silkwood ParAscort, Berkshire, UK. 164.

APPENDICES

A 1: ANOVA for effect of timing and method of trellising on days to 50% flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	0.0606	0.0303	0.13	
Method	2	98.7273	49.3636	214.34	<.001
Timing	5	315.4667	63.0933	273.96	<.001
Method*Timing	3	17.2000	5.7333	24.89	<.001
Residual	20	4.6061	0.2303		
Total	32	436.0606			

A 2: ANOVA for effect of timing and method of trellising on plant height at 50% flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	2	1.0510	0.5255	1.78	
Method	2	359.6465	179.8232	607.95	<.001
Timing	5	1347.7820	269.5564	911.32	<.001
Method*Timing	3	12.5340	4.1780	14.13	<.001
Residual	20	5.9157	0.2958		
Total	32	1726.9292			

A 3: ANOVA for effect of timing and method of trellising on number of fruits per plant.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.09722	0.04861	2.73	
Method	2	1.71524	0.85762	48.21	<.001
Timing	5	0.89339	0.17868	10.04	<.001
Method*Timing	3	0.10166	0.03389	1.90	0.161
Residual	20	0.35577	0.01779		
Total	32	3.16328			

A 4: ANOVA for effect of timing and method of trellising on marketable yield (t/ha).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	2.086	1.043	0.92	
Method	2	389.896	194.948	171.21	<.001
Timing	5	319.816	63.963	56.17	<.001
Method*Timing	3	74.229	24.743	21.73	<.001
Residual	20	22.773	1.139		
Total	32	808.800			

A 5: ANOVA for effect of timing and method of trellising on total yield (t/ha).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	2.7919	1.3959	3.05	
Method	2	128.4013	64.2007	140.33	<.001
Timing	5	352.0838	70.4168	153.92	<.001
Method*Timing	3	32.3014	10.7671	23.54	<.001
Residual	20	9.1497	0.4575		
Total	32	524.7281			

A 6: ANOVA for effect of method of trellising on fruit sunscald.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.0665	0.0333	0.33	
Method	2	4.9543	2.4772	24.49	<.001
Timing	5	0.6488	0.1298	1.28	0.310
Method*Timing	3	0.3009	0.1003	0.99	0.417
Residual	20	2.0234	0.1012		
Total	32	7.9939			

A 7: ANOVA for effect of timing and method of trellising on fruit rots.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block	2	0.09159	0.04579	0.99	
Block					
Method	2	4.77574	2.38787	51.78	<.001
Timing	5	7.94141	1.58828	34.44	<.001
Method*Timing	3	2.34195	0.78065	16.93	<.001
Residual	20	0.92238	0.04612		
Total	32	16.07307			

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