

**EFFECT OF PRUNING ON YIELD AND QUALITY OF SELECTED
INDETERMINATE TOMATO (*Solanum lycopersicon* L.) LINES**



BY

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**A DISSERTATION SUBMITTED IN PARTIAL FULLFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP
SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE.
MOROGORO, TANZANIA.**

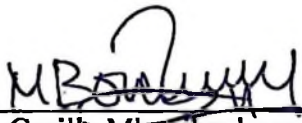
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ABSTRACT

Preliminary evaluations at Sokoine University of Agriculture have shown that indeterminate tomato breeding lines are tolerant to late blight and produce high yield of large fruits. These large fruits are least accepted by the local consumers in Tanzania. Pruning system has been reported to regulate tomato fruit size, overall yield performance and foliar disease incidence. A study to evaluate the effect of pruning levels (non pruning, single stem, two stems and three stems) on yield, quality and late blight disease incidence of five breeding lines of indeterminate tomato and one commercial variety was conducted from November 2009 to March 2010 at the Horticulture Unit of Sokoine University of Agriculture, Morogoro, Tanzania. The experiment was laid in a split-plot in a randomized complete block design with three replications. The collected data were subjected to analysis of variance (ANOVA), mean separation was done based on Student-Newman-Keuls using statistical software COSTAT6.4 ($P < 5\%$). Results showed that two stem pruned plants gave the highest number of marketable fruits per plant. The highest number of non marketable tomato fruits (damaged by pests, cracked or rotten) per hectare were observed in unpruned plants. Tomato lines differed in their performance, with the longest period of harvest, many flowers, higher percentage of fruit-set, the highest yield, high number of marketable fruits observed in lines P20-03 and S186-2(07) probably as a result of their genetic characteristic. Non pruned plants were more attacked by late blight disease whereas single and two stem plants were least affected by late blight. It is concluded that, the large fruit size of the new tomato breeding lines can be reduced to meet consumer's needs without reducing yield by two and three stem pruning in lines P20-03 and S186-2(07). It is therefore recommended that creation of awareness through demonstration trials is needed for further promotion of these new lines combined with two and three stem pruning in order to improve tomato production in terms of quantity and quality.

DECLARATION

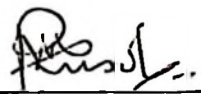
I **CYRILLE MBONIHANKUYE** do hereby declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work and has neither been submitted nor being concurrently submitted for degree award in any other Institution.



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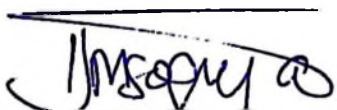
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ACKNOWLEDGEMENT

I would like to express my sincere appreciation to my supervisors, Dr P. Kusolwa and T. Msogoya whose tireless guidance and positive criticism ensured the successful implementation of the research and the timely preparation of this dissertation.

I am greatly thankful to the staff and classmates from the Crop Science and Production Department for their various assistance during the whole period of my study at Sokoine University of Agriculture (SUA).

I am heavily indebted to my dear wife Marie Bucaziza and our son Irampaye Mboni Gift for their unlimited patience during my long detachment from them. Special thanks to my brother Zackarie Bigirimana, for taking over the fatherly responsibility. I am truly grateful to my other family members and relatives for their prayers and moral support.

I also owe a great deal of appreciation to my employer, the Institute of ISABU (Agronomic Sciences of Burundi) for the release during the period of this Master degree. This research study could not have been without being financed. I would like to express my sincere thanks to SCARDA-EC project of ASARECA for the financial support granted to me in form of scholarship. My sincere appreciation goes to Dr. W.N. Ekaya, the Training and Quality Assurance Manager of RUFORUM, for the immense moral and financial support offered to me during the course of study.

Above all, I thank the almighty God for the good health during the entire period of study. I will always praise and seek His Divine intervention, when faced with problems beyond my capacity.

I acknowledge all those people not enumerated whose generosity and collective efforts contributed towards the successful study time.

DEDICATION

To my mother Sabukwigura Angline and my late father Misago Cassien, whose sacrifice laid the foundation for my education. I also dedicate this work to my wife Bucaziza Marie and our son Irampaye Mboni Gift.

TABLE OF CONTENTS

ABSTRACT	ii
DECLARATION	iii
COPYRIGHT	iv
ACKNOWLEDGEMENT	v
DEDICATION	vi
TABLE OF CONTENTS	vii
LIST OF TABLES.....	xi
LIST OF FIGURES.....	xii
LIST OF APPENDICES.....	xiii
LIST OF ABBREVIATIONS AND SYMBOLS	xiv
CHAPTER ONE.....	1
1.0 INTRODUCTION	1
CHAPTER TWO.....	4
2.0 LITERATURE REVIEW	4
2.1 Botanical Description of Tomato.....	4
2.2 Cultural Practices	4
2.2.1 Pruning and multiple stems.....	4
2.2.2 Staking.....	8
2.2.3 Spacing	9
2.3 Effects of Pruning on Diseases Pressure.....	10
2.4 Influence of Fruit Set and Number of Fruit Clusters on Yield	12
2.4.1 Cluster number	12
2.4.2 Quality.....	13
2.4.2.1 Nutritional quality	13
2.4.2.2 Marketable quality of tomatoes	16

CHAPTER THREE.....	18
3.0 MATERIALS AND METHODS.....	18
3.1 Plant Materials	18
3.2 Experimental Design.....	19
3.3 Crop Management.....	19
3.3.1 Nursery establishment.....	19
3.3.2 Field preparation and transplanting.....	20
3.3.3 Fertilizer application	20
3.3.4 Other crop management practices.....	20
3.4 Data Collection	21
3.4.1 Reproductive growth parameters	21
3.4.1.1 Physiological characteristics	21
3.4.1.2 Yield components.....	22
3.4.2 Quality (fruits characteristics).....	23
3.4.3 Yield parameters	24
3.4.4 Late blight infestation	25
3.5 Data Analysis.....	25
CHAPTER FOUR	26
4.0 RESULTS.....	26
4.1 Horticultural and Developmental Characteristics.....	26
4.1.1 Plant height and stem diameter	26
4.1.2 Flowering stages.....	27
4.1.3 Fruiting and fruit maturity stages.....	28
4.1.4 Leaf length and width.....	29
4.1.5 The length of harvest period	29
4.2 Yield Components	32
4.2.1 Number of flowers per plant	32

4.2.2 Number of flowers per cluster.....	33
4.2.3 Number of fruits per plant and fruit set.....	33
4.2.4 Fruit weight	35
4.2.5 Tomato fruit yield	35
4.2.6 Marketable fruit yield.....	36
4.2.7 Non marketable tomato fruits yield.....	37
4.3 Correlation Analysis between fruit weight and other yield Components and Horticultural Variables.....	40
4.3.1 Correlation analysis between fruit weight and other yield components	40
4.3.2 Correlation analysis between fruit weight and vegetative characteristics	41
4.4 Quality Characteristics.....	41
4.4.1 Acidity level.....	41
4.4.2 Total soluble solids (TSS).....	42
4.4.3 Fruit size.....	42
4.4.4 Fruit firmness	43
4.5 Late Blight Infestation and other Physiological Disorders.....	44
4.5.1 Late blight incidence and severity.....	44
4.5.2 Fruits cracking and Blossom end rot.....	45
CHAPTER FIVE.....	47
5.0 DISCUSSION.....	47
5.1 Horticultural and Plant Developmental Characteristics.....	47
5.1.1 Plant height and stem diameter	47
5.1.2 Flowering time and harvest duration.....	48
5.1.3 Fruiting and fruit maturity stages.....	48
5.1.4 Leaf length and width.....	49
5.1.5 Length of harvest period	49
5.2 Yield and Yield Components.....	50

5.2.1 Number of flowers per plant	50
5.2.2 Number of flowers per cluster.....	50
5.2.3 Number of fruits per plant.....	51
5.2.4 Fruit set.....	51
5.2.5 Fruit weight	52
5.2.6 Fruit yield	53
5.2.7 Marketable tomato fruits yield	55
5.2.8 Non marketable tomato fruits yield.....	56
5.3 Correlation Analysis between Fruit Weight and other Yield Components and Developmental Variables	56
5.4 Fruit Quality Characteristics.....	57
5.4.1 Acidity level	57
5.4.2 Total soluble solids (TSS).....	57
5.4.3 Fruit size.....	58
5.4.4 Fruit firmness	59
5.5 Late Blight Infestation and Fruits Physiological Disorders.....	59
5.5.1 Fruit cracking and Blossom end rot	59
5.5.2 Late blight incidence and severity.....	60
CHAPTER SIX.....	62
6.0 CONCLUSION AND RECOMMENDATION.....	62
6.1 Conclusion	62
6.2 Recommendations.....	63
REFERENCES	65
APPENDICES.....	78

LIST OF TABLES

Table 1: Some meteorological data at the site during experimental period	18
Table 2: Mean values of plant developmental characteristics as observed among pruning treatments	31
Table 3: Mean values of plant developmental characteristics observed among tomato lines.....	31
Table 4: Mean values of total yield and yield components observed on different pruning levels.....	38
Table 5: Mean values of yield and yield components observed among tomato lines	39
Table 6: Correlation analysis between fruit weight and other yield components	40
Table 7: Correlation between fruit weight and other yield components and horticultural variables	41
Table 8: Mean values of fruit quality characteristics observed on different pruning levels	43
Table 9: Mean values of fruit quality characteristics observed among lines	44
Table 10: Mean values of late blight infestation and fruits physiological disorders observed on pruning levels	46
Table 11: Mean values of late blight infestation and fruits physiological disorders observed among lines.....	46

LIST OF FIGURES

Figure 1: Effect of pruning level on final height of the six tomato breeding lines as
observed at the last harvest 27

Figure 2: Effect of pruning on number of days to first flowering of six tomato
breeding lines 28

Figure 3: Pruning effect on harvest period (days) of six tomato breeding lines 30

Figure 4: Pruning effect on the number of flowers per plant of six breeding lines..... 33

Figure 5: Pruning effect on fruit set of six tomato lines..... 35

Figure 6: Effect of pruning on yield of six tomato breeding lines 36

Figure 7: Effect of pruning on fruit length of six breeding lines..... 42

Figure 8: Effect of pruning on late blight severity of six breeding lines..... 45

LIST OF APPENDICES

Appendix 1: Experiment layout.....	78
Appendix 2: Table of percentage and score of late blight severity	79
Appendix 3: Anova table for statistical model (Split plot).....	80
Appendix 4: Anova table for all parameters.....	81

LIST OF ABBREVIATIONS AND SYMBOLS

1 st	First
<	Less than
>	Greater than
%	Percentage
°C	Celsius degree unit
ANOVA	Analysis of variance
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AVRDC	Asian Vegetable Research and Development Center
BER	Blossom End Rot
Ca	Calcium
CAN	Calcium Ammium Nitrate
cm	Centimeter
CV	Coefficient of Variation
CHO	Carbohydrates
DF	Degree of Freedom
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
Fig.	Figure
g	gram
ha	hectare
ISABU	Institut des Sciences Agronomiques du Burundi.
K	Potassium
kg	kilogram

LSD	Leaf Significant Difference
m	meter
mg	milligram
ml	milliliter
mm	millimeter
MS	Mean Squares
N	Nitrogen
np	non pruning
P	phosphorus
pH	negative logarithm of hydrogen ion concentration
RUFORUM	Regional Universities Forum for Capacity Building in Agriculture.
SCARDA	Strengthening Capacity for Agricultural Research for Development in the Eastern and Central Africa Region.
SS	Sum of Squares
SUA	Sokoine University of Agriculture
SV	Source of Variation
TSP	Triple Super Phosphate
TSS	Total soluble solids
USA	United States of America
var	variety

CHAPTER ONE

1.0 INTRODUCTION

Tomato (*Solanum lycopersicon* L.) cultivars belong to the family *Solanaceae*, they are perennials but in some regions are grown as annual crops (Kalloo, 1993). Among the cultivars, flowering habit ranges from highly indeterminate to strongly determinate, and flowers are self-pollinated. They have erect to prostrate stems, pubescent foliage with glandular trichomes (Rubatzky, 1996). Indeterminate cultivars develop into vines that never top off and continue producing flowers until they are killed by drought or disease attack in tropics. They have main stem which extends regularly while issuing a cluster of flowers, on average at an interval of every 3 leaves. They are preferred by home growers and local-market farmers who want ripe fruits throughout the season (Peralta, 2001). Indeterminate tomato types are normally trellised and cultivated more intensively than determinate ones (AVRDC, 1980). On the other hand, determinate tomato cultivars develop 1-2 leaves after each inflorescence and have a main stem that stops growing by producing a terminal inflorescence after having issued 2-6 trusses (Raemaekers, 2001).

Among the constraints that prevent farmers from achieving potential yield are excessive insects and disease damage, unavailability of quality seed, the use of unadapted varieties and the lack of appropriate cultural practices especially pruning systems (Villareal, 1980). Davis and Esters (1993) reported that two management practices, which greatly influence tomato yield, are spacing and pruning, especially for indeterminate cultivars. Guan and Janes (1991) reported that pruning tomato plants regulates nitrogen-carbon ratio within the plant, and enhances fruiting. Pruning of tomato improves air circulation within the canopy, which reduces foliar diseases, and facilitates insecticide spraying and harvesting.

Indeterminate varieties should always be pruned so that they do not produce too much vegetative growth (AVRDC, 1999).

In Tanzania, tomato production is divided into regions that are specialized in production of indeterminate (Money maker Type) while others are specialized on determinate (Roma type) tomato cultivars. The management practices for these two types of tomato vary. For example, indeterminate types are normally desuckered (pruned) to retain a single main stem while the determinate type is left with no pruning and consists of several main branches. The old cultivars such as 'Marglobe', 'Money maker' and 'Roma' are still the cultivars of choice of many East and Central Africa farmers (Kagiraneza, 2007). The main weaknesses of these old cultivars are low productivity due to the lack of resistance to pests and low fruit-setting. It is important to search for improved tomato lines so as to increase tomato productivity and consumption. To solve these weaknesses, new improved tomato (determinate and indeterminate) lines have been introduced and are being evaluated under Tanzanian conditions.

Preliminary evaluations of these improved indeterminate tomato lines revealed that they have large fruit size weighing from 140 to 190 g/fruit except for medium sized fruit of line P20-03 weighing about 100g/fruit. All these lines are also found tolerant to late blight (Palangyo, 2009). However, the majority of local consumers in Tanzania prefer medium sized tomato fruits (70-120g/fruit). Cultural practices like plant stress due to reduced irrigation, fertilization, spacing and increased number of branches per plant are known to reduce fruit size in tomato, especially in indeterminate tomato cultivars (Villareal, 1980). Pruning tomatoes maximizes the efficiency of photosynthesis and minimizes the risk of late blight infestations.

The effect of pruning is related to increase in quantity and quality as well as productivity of tomato (Frank, 2007). The efficacy of single stem, double, three or multiple stems on fruit size and general performance of the recently introduced tomato lines, is not well documented under field conditions in Tanzania. There is therefore a need to establish an optimal pruning system for enhanced yield productivity and quality of selected lines and varieties of tomato grown in the fields.

This research therefore aimed at evaluating the effects of different pruning systems on fruit size and general performance of selected tomato breeding lines. The overall objective of this study was to determine the most effective pruning system for increased fruit yield and quality of selected tomato breeding lines.

The Specific objectives were:

- i. To assess the effect of pruning systems on plant developmental cycle and yield of selected indeterminate tomato lines.
- ii. To determine the influence of pruning systems on fruit quality of selected indeterminate tomato lines.
- iii. To assess the effect of pruning systems on late blight infestations on selected indeterminate tomato lines.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Botanical Description of Tomato

The species of the genus *Solanum* belong to the family Solanaceae and originates in the narrow west coast of the South America from Ecuador to Chile, between the Andes and the sea (Raymond, 1985). *Solanum lycopersicon* Mill. ($2n=24$) is herbaceous annual plant with creeping plants, covered with single and glandulous hairs.

There are two types of growth habits, namely indeterminate and determinate. Plants with an indeterminate growth habit have main stem which extend regularly while issuing a cluster of flowers, on average at an interval of every 3 leaves while in the determinate growth habit 1-2 leaves are produced after each inflorescence and have a main stem that stops growing and produces a terminal inflorescence after having issued 2 to 6 trusses (Raemaekers, 2001). Although some cultivars have 30 or more flowers per cluster, usually 4-12 flowers develop. Self-pollination is commonly observed. Fruits of most cultivars are globoid while other shapes are elongated. Ripe fruit colours are usually solid, red, pink, and orange or yellow (Rubatzky, 1996). There are three main types of tomato based on fruit size: the cherry type, with small fruit, some 10 to 20g and 20 to 30 fruits; the standard type, with medium-sized fruits of 80 to 120g with five to six fruits per truss and the beefsteak type, with fruits of up to 250g, with one to three fruits per truss (Mike and Hilmi, 2009).

2.2 Cultural Practices

2.2.1 Pruning and multiple stems

Pruning in tomato, pruning is the removal of side shoots or suckers when they are 8 to 10 cm long and leaving a chosen number of stems to form the axis or axes of the plant.

Pruning may cause fruits to mature earlier and grow to greater size and uniformity (Chen and Lal, 1999). Pruning improves air circulation within the canopy, which reduces foliar diseases, and facilitates insecticide spraying and harvesting. Indeterminate varieties should always be pruned so that they do not produce too much vegetative growth (AVRDC, 1999). The degree of pruning varies according to season. AVRDC (1999) recommends that indeterminate plants must be pruned to one branch during the cool season and to maintain two stems per plant (main branch and second branch below the first fruit cluster) during the hot-dry season. Too many branches provide more shade to the fruit, thereby reducing sunburn blotchy ripening (Chen and Lal, 1999).

As a tomato grows, side shoots, or suckers, form in the crotches, or in axils, between the leaves and the main stem. If left alone, these suckers will grow just like the main stem, producing flowers and fruits. Suckers appear sequentially from the bottom of the plant upwards. The further up on the plant a sucker develops, the weaker it is, because the sugar concentration gets lower as one moves up the plant (Ferrandino, 2007). On the other hand, side stems arising from below the first flower cluster, although stronger, compromise the strength of the main stem. For a multi-stemmed plant, the aim is to have all stems roughly the same size, although the main stem should always be stronger, because it has to feed the entire plant (Chen and Lal, 1999).

Pruning indeterminate varieties involves removing axillary shoots as they grow when 4 to 6 branches of fruit have formed, cut off the growing tip so that no more fruits can be set. This helps the already formed tomatoes to grow bigger.

In Tanzania indeterminate types are normally pruned once a week to a single stem. Small scale farmers remove all shoots from the main stem. Pruned and supported single-

stem tomato plants have all their fruits in the air, leaves are exposed to the sun, and flavor-enhancing sugar going to the developing fruits. The fruits become larger and tastier, and develop more quickly. In addition, leaves of pruned and supported plants, dry off faster, reducing therefore the bacterial and fungal infections.

Determinate tomatoes need no pruning than removing suckers, because pruning does not affect their fruit size or plant vigor. Any pruning at above the first flower cluster on determinate tomatoes, causes the throwing away potential fruits. Indeterminate tomatoes can have from one to many stems, although four is the most recommend. Sibuga and Sibuga (2004) reported that indeterminate tomato varieties should be pruned every week to leave only one main stem. The fewer the stems, the fewer the fruits but larger, and the less room the plant needs in the garden. For a multi-stemmed plant, the second stem should be allowed to grow from the first node above the first fruit. The third stem should develop from the second node above the first fruit set. Keeping the branching as close to the first fruit as possible means those side stems will be vigorous but will not overpower the main stem (Frank, 2007).

Pruning indeterminate tomatoes is a bit more complex but it is a necessary task. Indeterminate tomato plants will form many vines, if left on their own. This means that the plant ends up lodging to the ground and become an easy target for disease and pests. Tomatoes that are produced are more susceptible to rot (Ara *et al.*, 2007).

The first step, just as with determinate tomatoes, is to remove all blossoms until the plant is between 30 and 46 cm tall. The next step is the removal of all suckers below the first fruit cluster and for the development of a single vine all suckers are removed (Frank, 2007). However, most farmers prefer to let two or three vines grow. To do this, the second

stem is left to grow just above the first fruit cluster the same procedure is applied if a third stem is to be left by letting the sucker just above this stem grow. Keeping the side stems close to the first fruit cluster ensures that they will be strong and have enough energy to produce abundant fruits (Sandersfeld, 2008).

Kagiraneza (2007) found that plant height was not significantly affected by spacing and pruning treatments. Pruned plants were more exposed to sunlight which led to good distribution of carbohydrates (CHO) accumulation; whereas in non pruned plants, there were high competitions of assimilates between leaves to achieve maximum photosynthesis. Pruning and training have been recommended for increased earliness, fruit size and fruit quality (Frank, 2007). In general, pruning increases fruit size within the same variety as well as among the different varieties, while training by staking produces cleaner fruits compared to those on natural habit (Nganga, 1971). In his study, Kagiraneza (2007) observed that pruning treatment increased the growth rate of cherry tomato compared to non pruning treatment. Good pruning in general enhances fruit size and earliness for vigorously growing plants (Mnzava, 1984). In their study, Navarrete and Jeannequin (2000) found that pruning frequency (every 7, 10, 14 and 21 days) had effect on both vegetative growth and yield in indeterminate tomato type. Low frequency of pruning (every 21 days) reduced plant vigour and the number of fruits per unit area leading to significantly lower yield. When the axillary buds were eliminated at a frequency of 7 days, vegetative growth was reduced but not yields. After desuckering for the first time, the axillary buds had no time to fruiting; therefore, the frequency of desuckering was close one to another (7days) until the time of harvesting, they showed that the yield was not affected. Therefore, from a biological point of view, the optimal desuckering frequency lies between 7 and 14 days, probably depending on climate and of vigour of the cultivar.

Nganga (1971) found in a study with tomato varietal and pruning trial that although pruning resulted in reduced yields, it did improve fruit to leaf ratio, fruit size and quality. Pruning tomatoes maximizes the efficiency of photosynthesis and minimizes the risk of disease. This is best accomplished by ensuring that each leaf has enough room and is supported up off the ground. When a tomato plant lies on the ground, or when its growth is extremely dense, many of its leaves are forced into permanent shade, greatly reducing the amount of sugar they produce. If more stems are allowed to develop, some of the sugar production is diverted from fruits to multiple growing tips. The result is a nearly continuous supply of fruits throughout the season (Frank, 2007). In general, more stems means more but smaller fruits, which are produced increasingly later in the season (Ara *et al.* 2007). Abdel-Al (1962) showed that defoliation increased earliness and leaf efficiency, as well as the percentage of fruits affected by Blossom End Rot.

2.2.2 Staking

Previous work conducted on pruning and staking of tomatoes indicated certain advantages and disadvantages of these practices. Staking tomatoes facilitates easy operations, handling of the crop, and disease control, and in combination with pruning produces clean fruit of marketable sizes and quality (Nganga, 1971).

Staking of tomatoes keeps the fruit clean and promotes slightly earlier ripening. Staked tomatoes produce more fruit per row though less per plant, than those that are not staked (Bubel, 1988). Excessive rainfall can harm a tomato crop, particularly if it is unstaked due to the spread of leaf diseases in humid conditions (Tindall, 1983).

Abdel (1962) showed that greater yields were obtained from staked and pruned tomatoes when compared with staked and non-pruned or non-staked and non-pruned tomato plants.

Chapman and Acland (1973) reported a significant increase in yield with increasing population densities and confirmed that an increased yield was obtained from staked and pruned treatments. Mnzava (1984) studied the effects of pruning on the yield of eleven tomato cultivars. He indicated that seven cultivars produced greater yields when pruned and staked, while four showed reduced yields with pruning and staking.

2.2.3 Spacing

Tomato plant spacing depends upon cropping systems, soil type, and plant growth. Rubatzky (1996) recommended the typical spacing to range from 60 to 75 cm within rows and 120 to 150 cm between rows. AVRDC (1999) recommends two rows per one meter wide bed at spacing of 50 cm between rows and 40 cm between plants within the row for indeterminate tomato varieties. This gives a plant population of 333 333 plants per hectare. Plant spacing has a large influence on tomato plant growth, yield and fruit maturity. For non pruned determinate varieties one row per bed with 40 cm between plants and 60 cm between rows is recommended (16 666 plants/ha) (Chen and Lal, 1999). Increasing plant population beyond optimal plant spacing has shown to reduce overall plant vigour, enhance earliness, yield concentration, and often results in increased early and total marketable yield per unit area.

Previous studies have shown that spacing and pruning play an important role in increasing marketable and total yield of fresh and cherry tomatoes. Spacing has appreciable effects on yield and fruit quality because high population density enable harvesting of more fruits per unit area. Closer spacing induced flowering and fruit maturity significantly earlier than wider spacing (Agostinho, 1994).

Zhang (1998) conducted an experiment with three pruning and two spacing treatments using determinate tomato type and observed that non pruned plants at a spacing of 80×40

cm gave the highest yield of up to 41t/ha. Training to maintain two stems combined with 60×40cm plant spacing plant gave the highest yield of 55.34t/ha of indeterminate tomato type (Rafi, 1996). Other results (Myint, 1999) have indicated that in experiment with three pruning methods (no pruning, one stem, two stems) and three planting spacing between plants (30×60 cm, 40×60 cm, 50×60 cm) using an indeterminate tomato variety; the two stem pruning method and 30×60 cm spacing gave the highest marketable yield. Fruit size (length and width), percentage of cracked fruits, and epiderme fruit thickness were significantly affected by pruning, but were not affected by spacing (Myint, 1999).

In a study on the effect of plant density on different types of tomato, Wen (1992) compared the spacings of 100×50, 100×40, 100×30 and 100×20 cm and found out that the spacing of 100×20 cm gave the highest marketable yields for all types of tomato. However, the results from this work have shown that horticultural characters (plant height, flowering, fruiting stage, maturity stage) and fruit quality (fruit width, fruit length, pH and sugar content) had no significant difference among the different spacing tested. In his study, Kagirazeza (2007) found that spacing and pruning treatments have influence on tomato growth and development.

2.3 Effects of Pruning on Diseases Pressure

Cultural control is a method that can greatly reduce the impact of late blight and should be part of every grower disease management strategy. The goals of a good cultural control program are to prevent introduction of inoculums, reduce inoculums buildup, reduce infection rate, and create conditions unfavorable for disease development. Growers can achieve these goals by incorporating several different techniques including training and pruning.

In Tanzania tomato production is usually associated with biotic and abiotic stresses. The biotic stresses include insect pests such as fruit worm (*Helicoverpa armigera*), leafminer (*Lilioryza spp*) and whitefly (*Bemisia tabaci*); diseases namely late blight, early blight, anthracnose, *speptoria* and virus (Rwezaura *et al.*, 2005).

Tomato is affected by a number of fungal diseases, including Late blight caused by *Phytophthora infestans*, Early blight caused by *Alternaria solani* (Agrios, 1997). Late blight symptoms appear on foliage and fruits as irregular, greasy- appearing grayish areas that expand rapidly during moist conditions. Early blight symptoms are dark brown spots with dark concentric rings develop first on the oldest leaves. Late blight is one of the most destructive diseases of tomato in the world, and serious losses may result. Moisture is more important than temperature during late blight outbreaks as the disease generally is favored by a wide range of temperatures (Stevenson, 2009). Other foliar fungal diseases affecting tomatoes are: leaf mold (*fulvium fulva*) and powdery mildew (*Leveillula taurica*). Several insects each with a wide host range may infest tomatoes including cutworms, flea beetles, leaf miners, and Spider mites (Pierce, 1987).

The most important way of controlling late blight is to prevent its spread by removing all damaged leaves and fruits. Factors related to the improvement in late blight control include extensive grower training, improved rotation (Stevenson, 2009). Essentially, staked and pruned plants have fewer problems with fruit rots and leaf spots because their leaves stay drier, and the plant has good airflow around it (Valera *et al.*, 2003). Pruning affects plant health and improves the plant odds of avoiding fungus invasions and other diseases (Nancy, 2008). The leaves of a pruned plant dry off faster, so bacterial and fungal pathogens have less opportunity to spread. Because soil-borne diseases attack plants when

the spores living in the soil are splashed up on the lower leaves when it rains, lower leaves are removed and the soil covered with mulch (Frank, 2007).

2.4 Influence of Fruit Set and Number of Fruit Clusters on Yield

2.4.1 Cluster number

In most areas, tomato production is based on the cropping of indeterminate multiple-cluster plants. In tomato, yield is related to the number of cluster and the fruits. Several researches have been conducted to find whether higher efficiency in tomato production could be achieved by fewer cluster cropping. Dullforce (1965) reported that the second truss reduced the total weight of the fruit in the first truss. However, total yield was greater, as was expected than from single truss plants. Earliness, high yield concentration and high total yields are primary objectives in tomato production. Plant population density invariably affects them. In tomato, yield is related to cluster number and the fruits thereof. Holliday (1960), working with various crops concluded that yield per acre is maximum when yield per plant is far below its genetic potential. Studies on cropping behavior of tomato indicate that efficiency of cropping declines after a certain number of clusters have developed. It has been suggested that the continuation of fruit set after the usable crop has been set diverts the growth activities of the plant in an unproductive manner (Dullforce, 1965). Efforts to keep the genetic potential of the plant low have taken various forms, namely increasing plant density coupled with severe pruning and chemically regulating the number of fruits that develop. These have resulted in high concentrated yields while fruit size decreased. Tip removal and limiting cluster numbers that develop with subsequent readjustment of plant population to optimize yield per unit area is another alternative that received much less attention that it deserves (Mnzava, 1984). Restricting vine growth to single fruit cluster has been suggested as a means of increasing efficiency of production in

tomatoes. Single cluster culture has been shown to be more beneficial than conventional multicluster trellis type culture (Evan, 1983).

The number of fruits set on the first clusters determines early yield of tomato crop. Growers in cool climates frequently experience difficulty in obtaining satisfactory set of fruit on the first inflorescence and therefore plant early varieties which have greater capacity to set fruits. Went and Cospser (1964) reported the influence of the environmental factors specially the mean night minimal temperatures on the set of fruits in the first cluster as dependent on variety. Khan and Sagan (1967) established that the efficiency of plants with regards to fruit production was greatest when total leaf area was small and emphasized that the first truss was a major sink for all leaves.

2.4.2 Quality

2.4.2.1 Nutritional quality

For consumers the quality of tomatoes is determined by external appearance (colour, size and shape), and nutritional properties like total soluble solids and acidity. Fruit quality is highly dependent on type of genetic and physiological characteristics, climatic factors and cultural practices (Slas *et al.*, 2000).

Carotenoids

Major carotenoids found in tomato products are β -carotene and lycopene. β -carotene is the major source of dietary vitamin A due to its high provitamin A activity. Vitamin A deficiency rarely occurs in the developed countries but it is still a major public health problem in the developing countries. Tomatoes contain several other components that are beneficial to health, including vitamin E, trace elements, phytosterols, and several water-

soluble vitamins (Beecher, 1998) Carotenoids represent one of the most widespread groups of naturally occurring pigments.

In order to maximize the content of carotenoids in plants, which is an important phytonutrient, the influence of genetics, agricultural practices, specially training and pruning and environment have been investigated. Dumas *et al.* (2002) reviewed several studies that addressed to agronomic and environmental factors that influenced lycopene concentrations in tomatoes. Moisture stress, for example, reduced lycopene content in some tomato varieties but increased it as well as β -carotene content in others. Nitrogen and phosphorus fertilizers have been shown to increase lycopene concentrations but results were consistent and dependent on seasonal variations in climate (Bruulsema *et al.* 2004).

Tomato harvested at full ripeness exhibited the highest level of carotenoids and antioxidant activity in the water-insoluble fraction. A study done by Rembialkowska and Ewelina (2006) showed that organic cultivation has positive influence on the quality of tomato fruits. Tomatoes from organic cultivation contained higher levels of total sugars, β -carotene and flavonoids in comparison to conventionally produced fruits which contained more sugar, lycopene and had higher titratable acidity. Briefly, many factors may influence the concentration of lycopene and β -carotene in tomato fruit namely environmental factors (light, temperature) and cultural practices (variety, mineral nutrition, water availability, harvest date through ripening stage, pruning and training). It is important to control crop management in order to obtain raw material well supplied with lycopene and β -carotene (Dumas *et al.*, 2002).

Acidity level

Fruit pH usually ranges between 4.3 and 5.3. Processed fruits with pH values above 4.5 must be acidified to prevent growth of *clostridium botulinum*. Most fruit acid in tomato

fruits is contained in locules with citrate being the major fruit acid (Lincoln, 1987). Studies done at AVRDC (2002) on nutritional quality, especially the pH of fresh market and high β -carotene cherry tomato lines indicated significant difference among varieties or lines evaluated. Molla *et al.* (2003) found that water stress throughout the growing season of greenhouse tomato affected negatively the quantity of soluble solids content and fruit colour but not pH. Franco (1998) observed in pruned tomato that two pruned plants had the lowest values of acidity of tomato fruits.

Total soluble solids (TSS)

Tomato fruit is 94-95% water and 5-6% organic compounds. Translocation of assimilates (a major constituent of total soluble solids) within plant parts is also known to be affected by growing conditions and plant age. There is significant correlation between TSS levels in the mature fruit and in the plant stem at particular growth stages. This suggests the opportunity for agronomic management of plant growth to control fruit soluble solids accumulation in the fruit (Quadir *et al.*, 2004). There is a relationship between growth habit of plants and fruits solids content. The indeterminate forms have higher soluble solids than determinate and vary among tomato cultivars (Atherton and Rudich, 1986). Total soluble solids and yield in tomato are influenced by a number of factors - genetics, growing environment and management practices. Most of the sugar of a proper pruned single tomato plant is directed to the developing fruit, since the only competition is a single growing tip. If more stems are allowed to develop, some of the previous sugar production is diverted from fruits to multiple tips (Frank, 2007). Sugars (fructose, glucose, sucrose which are found primarily in the fruit wall) make up about 50% of TSS, pectins, cellulose, proteins, polysaccharide (alcohol insoluble solids) compose 25% of TSS; organic acids such as citrate and malate make up 1-2% of TSS, and the remainder of the

solids consists of carotenoids, volatile compounds, amino acids and inorganic compounds (Jose *et al.*, 2009).

Indeterminate growth habit favours lower solids content (Hanson, 1999). There is a high correlation between percentage of solids and juice viscosity and firmness (Hanson, 1999). Leonardi *et al.* (2001) mentioned some factors which increase soluble solids in tomato fruits. These are genetic factor, water salinity and solar radiation. Antonio *et al.* (2002) found that soluble solids increase in tomato picked at later stages of ripeness. Jose *et al.* (2009) observed increasing the number of stems per plant in tomato did not affect the total soluble solids of fruit in indeterminate tomato.

Minerals

Tomato has a small quantity of macronutrients and micro-nutrients. The macronutrients include potassium, calcium, phosphorus and sodium. Potassium is the highest mineral in tomato. Micro nutrients include iron, iodine, copper and manganese (Rubatzky, 1996). Mineral levels in vegetables can be affected by factors such as the variety of the produce, time of harvest, ripeness, climate soil conditions including fertilizer application, and storage and marketing conditions. As biological materials, vegetables are also subject to random variation in mineral content (Greenfield and Southgate, 1992; Torelm and Danielson, 1998). Kagiraneza (2007) observed that minerals elements (Ca, P and K) were influenced by pruning treatment.

2.4.2.2 Marketable quality of tomatoes

Studies on quality are of importance for fresh market and processing due to the consumer's awareness on quality. In the tomato market, quality is assessed based on fruit size, shape, cleanliness, ripeness, firmness, colour, sugar/acid ratio and texture. These

parameters vary considerably with environmental factors, season, variety, fertility and cultural practices (Walls, 1972). Colour is an extremely important tomato-quality characteristic. For the consumer, it is an important indicator of the eating quality and for the processor, colour of the fruits is a primary determinant of the quality of tomatoes required to make high-quality products (Atherton and Rudich, 1986).

CHAPTER THREE

3.0 MATERIALS AND METHODS

Location of the study

The study was conducted at the Horticultural Unit, Department of Crop Science and Production, Sokoine University of Agriculture (SUA) in Morogoro, Tanzania. The area is located at 6°05'South latitude, and 35°37 East longitude, at an altitude of 525 m above sea level. The location has generally a warm tropical climate with moderate annual rainfall of 600-1000mm. The soils of the area are fertile with dark sandy loams with a pH of around 7. The experiment was conducted under field conditions from November 2009 to March 2010. The rainfall and temperatures during the period of the experiment are in Table 1 shown below.

Table 1: Some meteorological data at the site during experimental period

Month	Year	Maximum temperature (° C)	Minimum temperature (° C)	Total rainfall (mm)
October	2009	32	19.1	34.9
November	2009	32.8	21.1	29.1
December	2009	33.2	22.2	93.1
January	2010	31.4	22.4	97.3
February	2010	34.3	20.5	80.6
March	2010	32.1	21.5	87.3

Source: Tanzania Meteorological Agency, Morogoro Station, 2010

3.1 Plant Materials

Five tomato breeding lines (S178, S181-1(06), S186-2(07), S175, and P20-03) and one commercial variety (Tengeru 97) all indeterminate tomato were used during the study. All indeterminate tomato breeding lines were developed from Oregon State University for late blight resistance whereas P20-03 with a purple pigment skin tomato line was developed

for high anthocyanin content. Tengeru 97 is a commercial variety that was used as a standard control. The mature fruits of other lines were having orange-red skin. Seeds for the five breeding lines these lines were obtained from SUA (Horticulture Section) while seeds of Tengeru 97 variety were purchased from local seed stores.

3.2 Experimental Design

The field experiment was laid in a split plot design with 3 replications. The main factor was tomato breeding lines and sub factor was the branching levels. Different tomato breeding lines and the control were randomly assigned in each replicate while different pruning levels were randomly assigned as sub plots of each main plot. In the main plots, six treatments (five tomato breeding lines plus one commercial variety) were randomly assigned. There were four treatments for sub plots (training level) i.e. no pruning, single stem, two stems and three stems. Desuckering was done as new unwanted suckers appeared. For single stem (SS) system, all suckers and old leaves were removed and for two stem (2S) system; the main stem and the first sucker were retained while other suckers were removed. For the three stem (3S) system, the main stem, the first and second suckers were retained and subsequent suckers removed. There was no removal of suckers for the no pruning system.

3.3 Crop Management

3.3.1 Nursery establishment

The seeds of the selected lines were sown in the primary nursery on 30 October, 2009 using a mixture of soil, loam sand and compost which was heat sterilized at 70-80°C. The seeds germinated within six days and the seedlings were previously pricked to the second nursery onto compost medium. The seedlings were watered twice a day and a systemic Fungicide, Metalaxyl-M+ Mancozeb (Ridomyl) at a rate of 2 g/l and an insecticide

Lambda-Cyhalothrin, (Karate: $C_{23}H_{19}ClF_3NO_3$) at a rate of 1 ml/l of water were applied after at least week interval from germination depending weather conditions. Pesticides application was done once at seven days interval.

3.3.2 Field preparation and transplanting

The experimental field used was previously planted with beans 12 months before establishing the experiment. Land was ploughed and then harrowed with a tractor and was followed by further leveling using hand hoes. Raised beds were used to facilitate irrigation and to improve the drainage. The beds were leveled using a manual bed shaper. The plot size was 3.6 m x 2.8 m = 10.08 m² and plants were spaced at 70 x 60 cm, 2 m separated two replications and 1m separated two main plots. The area for the entire experiment was 74.2 × 16.8 m² = 1246.56 m². Seedlings were transplanted in the field on 30 November, 2009 when they were about 15 cm tall with 5 to 6 true leaves. The seedlings were immediately irrigated after transplanting.

3.3.3 Fertilizer application

Application of fertilizer was done three times during the duration of the experiment. Firstly, a basal application of Triple Super Phosphate (TSP) (P_2O_5 46%) at the rate of 150 kg /ha before transplanting; the second application was done at four weeks after transplanting at the rate of 60 kg of urea (46-0-0) per hectare and the last one was applied at six weeks after transplanting at the rate of 150 kg Calcium Ammonium Nitrate (CAN) (27% N) per hectare. Furrow irrigation was done after each fertilizer application.

3.3.4 Other crop management practices

One month after transplanting, plants were supported using one stake per plant. Five weeks later, all plots were mulched with grass to prevent loss of soil moisture through

evaporation and to suppress weed growth. Hand hoe weeding was done every time that the weeds were becoming too much. Watering was done every morning and evening during one month after transplantation using watering cans and after that it was done using pipes. Desuckering was done every week from three weeks of experiment establishment. In order to avoid spreading of virus from one plant to another during the pruning operation, suckers and old leaves were removed using a hand secateur that had been previously disinfected in disinfectant (dettol at a rate of 50 ml/l of water). Application of pesticides was done weekly using insecticide karate ($C_{23}H_{19}ClF_3NO_3$) at the rate of 1 ml/l of water and a dual purpose curative and protective fungicide, Linkomyl (Metalaxyl 80 g/kg +Mancozeb 640 g/kg) at the rate of 3 g/l of water.

3.4 Data Collection

Data were collected at different stages of plant growth. From each plot, central plants were marked and used for data collection on vegetative, reproductive growth parameters and fruits characteristics. However, for the measurement of yield parameters fruits harvested in the plot were used. All data were measured and collected from a sampling unit of six plants from each variety per plot of every treatment (Pruning system).

3.4.1 Reproductive growth parameters

3.4.1.1 Physiological characteristics

- (i) Number of days to the 1st flowering: The number of days from transplanting to when the 1st flower appeared was recorded.
- (ii) Number of days to the first fruiting: Number of days from transplanting to when plants started bearing fruits was recorded through daily observation.
- (iii) Number of days to the first fruit ripe: Number of days from transplanting to when fruits started to be mature was recorded.

(iv) Number of days to the last harvest from which the harvest duration was calculated as the difference of number of days between first harvest and the last harvest.

(v) Plant height to the first fruit cluster: the plant height to the first fruit truss was taken from the ground to the first fruit cluster when plants started fruiting.

(vi) Plant Height to the last harvest: This was measured using a tape measure at the last harvest day.

(vii) Stem diameter: the diameter of the stem was measured using a vernier caliper (0-150mmx0.05/6" x1/28", Japan). It was taken for each branch just after the branching point for the two stem and three stem systems, and after four nodes from the branching point. For the single stem system, the diameter was taken before the first leaf and after four nodes from the branching point. For free-branching - pruning system, the diameter was taken before the branching point and after the branching point, the diameter was taken for three branches and from there, diameter was taken at the fourth nodes.

(viii) Leaf length: this was measured using a ruler from four leaves after the branching point.

(xv) Leaf width: this was measured using a ruler from the four leaves after the branching point.

3.4.1.2 Yield components

(i) Number of flowers per plant: flowers were counted and recorded all the every times that new flowers appeared for each plant. After each counting; plants were marked with a cello tape to distinguish the counted flowers from the new flowers which appeared after the previous flower counting.

(ii) Number of flowers per cluster: number of flowers per truss was done by counting the number of flowers for each cluster. After each counting plants were marked using a tape tagged above the cluster in order to differentiate with the newly

formed subsequent clusters after the previous counting. This counting was done four times from first flowering to the time when plants have stopped to produce flowers.

- (iii) Number of fruits per cluster, number of trusses per plant: the number of fruits per cluster was determined by counting fruits for each cluster on six plants from each variety per plot of every treatment (Pruning system). After each counting plants were marked using cello tape for the similar purpose as with the clusters described above. This counting was done four times when plants had stopped to produce flowers.
- (iv) Weight of a single fruit: ten fruits from each plot were weighed three times (for the first, the second and the third harvests) in order to determine the weight of a single fruits.
- (v) Number of fruits per a plant: this was done by adding the fruits of all trusses for the tagged sample plants.
- (vi) Fruit set: fruit set was calculated as number of fruits per plant in percentage of all flowers per plant.
- (vii) Fruit yield per plant (kg/plant): was calculated by weighing all fruits harvested on each plant and par plot to calculate yield/ ha.

3.4.2 Quality (fruits characteristics)

Quality analysis of tomato fruits was done in the Laboratory at horticulture unit of SUA. A sample of six red ripe fruits of each plot was selected at random for quality analysis based on fruit size (width and length), fruit weight, acidity, TSS, fruit acidity and fruit firmness. The quality analysis was done three times for three successive harvests and for each quality characteristic.

(i): Fruit size (length and width): it was measured in terms of length & width using vernier caliper (0-150mmx0.05/6" x 1/28", Japan).

(ii) Fruit weight: was determined by using an electronic balance (Mettler Model, FNR 217045 132 03, from Switzerland).

(iii) Fruit pulp acidity (pH): tomato fruits were cut into pieces using a sharp knife and then a clear extract was made. An electronic pH meter (Hanna Model 8519, Singapore) was used to determine the pH of the extract. The electrode of the pH meter was dipped into the sample extracts and pH readings were recorded. A total of 74 composite samples were analyzed (using one composite extract from six fruits sample for each plot).

(iv) Fruit Total soluble solids content: the was determined by the re-fractometry method, using an electronic refractometer. Sample preparation was as described above for pH. A drop of the extract sample was spread on the surface of the prism and the readings recorded as Brix. A total of 74 composite samples were used in determination of TSS using one composite sample for each plot.

(iv) Fruit pulp firmness. Firmness of the tomato fruits was determined using a penetrometer expressed as the resistance to force applied to the fruits in kg/cm^2 . Fruit firmness was measured the same day of harvest when the fruits were still fresh.

3.4.3 Yield parameters

Harvesting was done every time that fruits were at the stage of ripeness. After harvesting, all tomato fruits were sorted and graded into marketable and non marketable fruits and weighed on a balance. Marketable fruits were constituted of only by, non damaged fruits suitable for selling while non marketable fruits constituted fruits damaged by pests, cracked or rotten. The weight of the non marketable fruits unsuitable for selling was also determined. The total fruit yield was calculated as the sum of weights of marketable and none marketable fruit yields.

3.4.4 Late blight infestation

Plants were inspected for late blight infestation.

(i) Late blight incidence: was determined by the percentage of plants affected by late blight over total plants in each plot.

(ii) Late blight severity: This was scored as the percentage of number of leaves affected by late blight over total number of the leaves for each plant infected by late blight. Late blight rating according to severity was 1 = 0%, 2 = ≤ 5%, 3 = 5-10%, 4 = 10-20%, 5 = 20-30%, 6 = 30-40%, 7 = 40-60%, 8 = 60-80% and 9 = 80-100% (Appendix 2).

3.5 Data Analysis

The data collected was subjected to analysis of variance (ANOVA) using statistical software COSTAT6.4 (Cohort Software, Minneapolis, USA, 2006). All tests were carried out at 5% level of significance and mean separation was done using Student-Newman-Keuls to determine differences among treatment means (Appendix1). Multiple correlation were used to establish the degree of relationship between parameters such as yield , yield components , developmental characteristics and fruit weight by using linear regression as described by Gomez and Gomez (1984).

The analysis model for the split plot design was:

$$Y_{ijk} = \mu + \beta_i + \alpha_j + \omega_{ij} + \gamma_k + (\alpha\gamma)_{jk} + \epsilon_{ijk}$$

where:

Y_{ijk} = Response

μ = General effect

β_i = block effect

α_j = Main factor effect

ω_{ij} = Main plot random error effect

γ_k = Subplot factor effect

$(\alpha\gamma)_{jk}$ = Interaction effect

ϵ_{ijk} = Subplot factor random error effect

CHAPTER FOUR

4.0 RESULTS

4.1 Horticultural and Developmental Characteristics

4.1.1 Plant height and stem diameter

Pruning treatment did not significantly influence the height of the plants at the first fruit cluster and at the last harvest period. There was no significant difference between lines tested in terms of stem diameter to the fourth node, but there was high significance difference ($P < 0.001$) due to the pruning levels, with single stem plants being more much vigorous with 1.08cm diameter while three stem pruning was the thinnest with 0.84 cm as diameter at 4th node (Table 2). For the same pruning treatment plant height was significant different ($p < 0.05$) among the six lines tested as observed from the first cluster (Table 3). The tallest plants at the first fruit cluster were of var. Tengeru 97 with a height of 43.07 cm and the shortest line at the first fruit cluster was S175 with a height of 27.27 cm. Similarly, in terms of final plant height to the last day of harvest, highly significant ($p < 0.0001$) differences were observed among the six lines tested (Table 3). The tallest line was P20- 03 at 1.52 m and the shortest line was S175 at 0.60 m.

The results in Fig.1 show the interaction effects between the six tomato breeding lines and four pruning treatments. Single stem pruned plants exhibited an increased plant height all the way to the time of harvest while multiple stem plants had shorter plant height across the tomato genotypes tested.

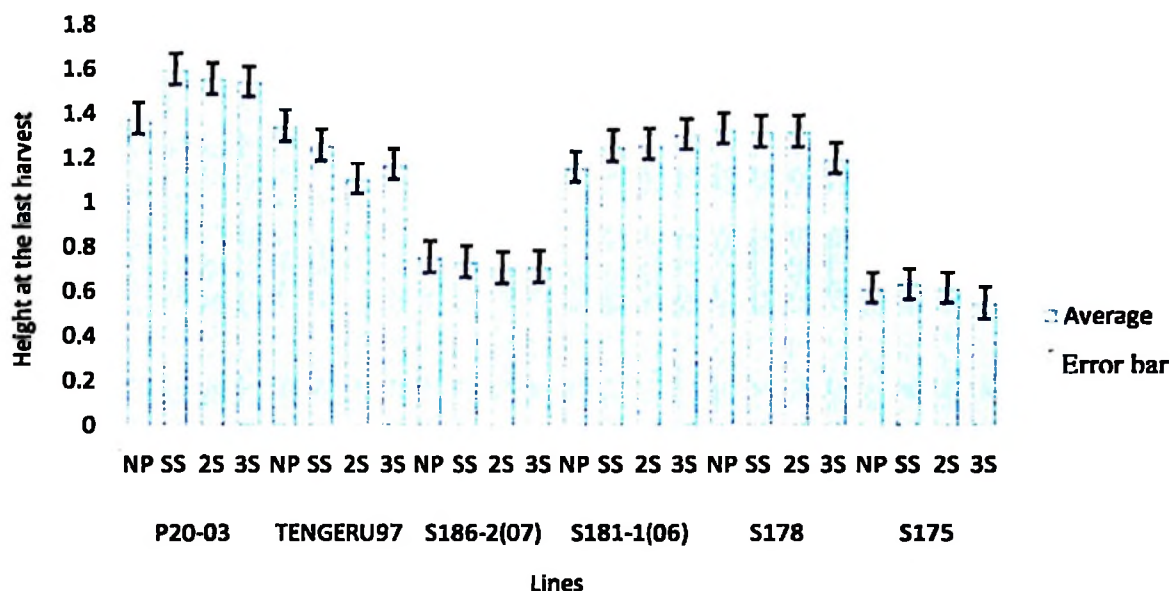


Figure 1: Effect of pruning level on final height of the six tomato breeding lines as observed at the last harvest

4.1.2 Flowering stages

The pruning level did not significantly influence the length of period to the first flowering. The number of days to the first flowering day was highly significant different ($P < 0.001$) at 5% level between the lines tested within the same pruning system (Table 2). With the exception of var. Tengeru 97, all the remaining tomato breeding lines in the experiment had earlier flowering time ranging from 37 days to 39 days for onset of first flowering while the commercial variety Tengeru 97 flowered on the 45th day after transplanting (Table 3).

Fig. 2 presents the interaction effects between the four pruning treatments and the six lines on the number of days to the first flowering. The results show that the single stem pruned plants increased the number of days to the first flowering in lines P20-03, S178 and S175, whereas the same number of days to the first flowering was the highest in two stem

pruned plants of variety Tengeru97 and line S186-2(07). Three stem plants increased significantly the number of days to the first flowering in var. Tengeru 97, and line S175. Non pruning resulted into delayed flowering in line S186-2(07) only.

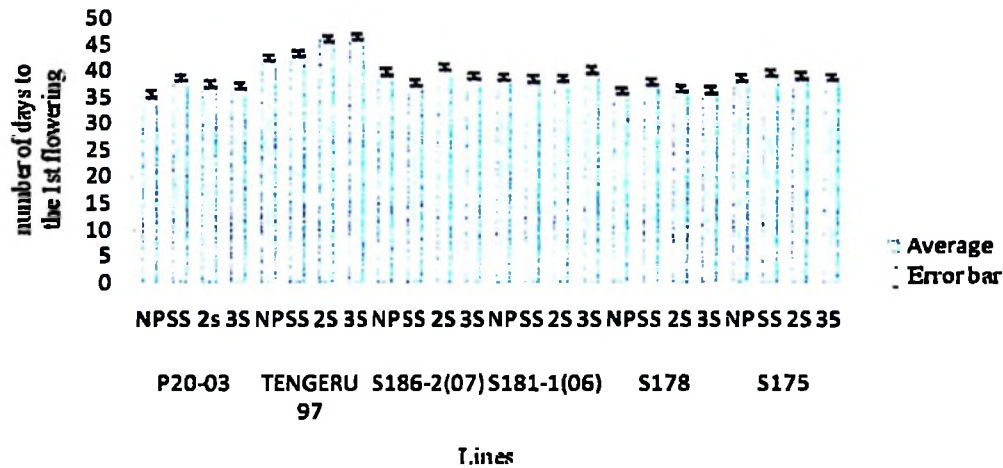


Figure 2: Effect of pruning on number of days to first flowering of six tomato breeding lines

4.1.3 Fruiting and fruit maturity stages

Plants with single, three stem system and two stem plants had only a difference of one day to first fruit set (46th and 47th days), in the similar manner non pruned plants set fruits on the same day as two stem plants (Table 2). The pruning level did not significantly influence the number of days to the first fruit formation period. Within the same pruning treatment, there were significant differences ($P < 0.05$) between the lines used for the number of days to the first fruiting (Table 3). Line S186-2(07) and P20-03 reached the first fruiting at 44th day from the date of transplanting and the last was var. Tengeru 97 with setting fruits at 51st days.

The number of days to the first fruit maturity was significantly different ($P < 0.001$) between the pruning levels (Table 3). The plants with single stem demonstrated very early

fruit maturity with first mature fruits observed on 76th days after transplanting while the pruning at two and three stems had the fruit maturing at the same day at 78th day after transplantation. On the other hand, fruits from non pruned plants matured 4 days later (80 days) than the single pruned ones.

The number of days that the plants took for the first fruit maturity was very highly significant ($P < 0.001$) among the lines identically pruned (Table 3). There was a high precocity for the line S186-2(07) which took 73 days to mature, and variety Tengeru 97 was the last to mature with 87 days after the transplanting day.

4.1.4 Leaf length and width

Pruning level affected the size of leaf with single stem pruned plants having the longest leaf with 32.72 cm, and no pruned plants having the shortest leaf of 28.89 cm (Table 2). The pruning level affected significantly ($P < 0.01$) the leaf width, where leaves of single pruned plants were the largest followed by two, three and those from no pruned plants were the smallest with width of 26.05 and 20.52 cm respectively. In addition, significant differences ($P < 0.01$) were observed among the lines tested in terms of the leaf width (Table 3). Line S181-1(06) was observed to have the highest leaf width of 25.94 cm and line S175 the lowest leaf width of 21.11 cm.

4.1.5 The length of harvest period

The pruning level influenced highly ($P < 0.01$) the length of the harvest period (Table 2). The first plants which took the longest period of harvest were three stem pruned plants with 26 days and the non pruned plants took the shortest period of harvest 21 days. Differences in fruit harvest period were high significant ($P < 0.001$) between the tomato breeding lines tested for the same pruning treatment (Table 3). Line P20-03 was harvested

for a longer period of 36 days when S181-1(06) was harvested for a shorter period 18 days from the first harvest.

The results from Fig. 3 show the interaction between the six tomato lines and the pruning treatments on the number of days for the period of harvest. Two stem pruned plants increased the number of days of the period of harvest for line P20-03, while single stem pruned plants increased length of harvest for line S186-2(07). At the same time, three stem pruned plants increased the harvesting period of line S178 and line S175 of 21 and 29 days of extension respectively.

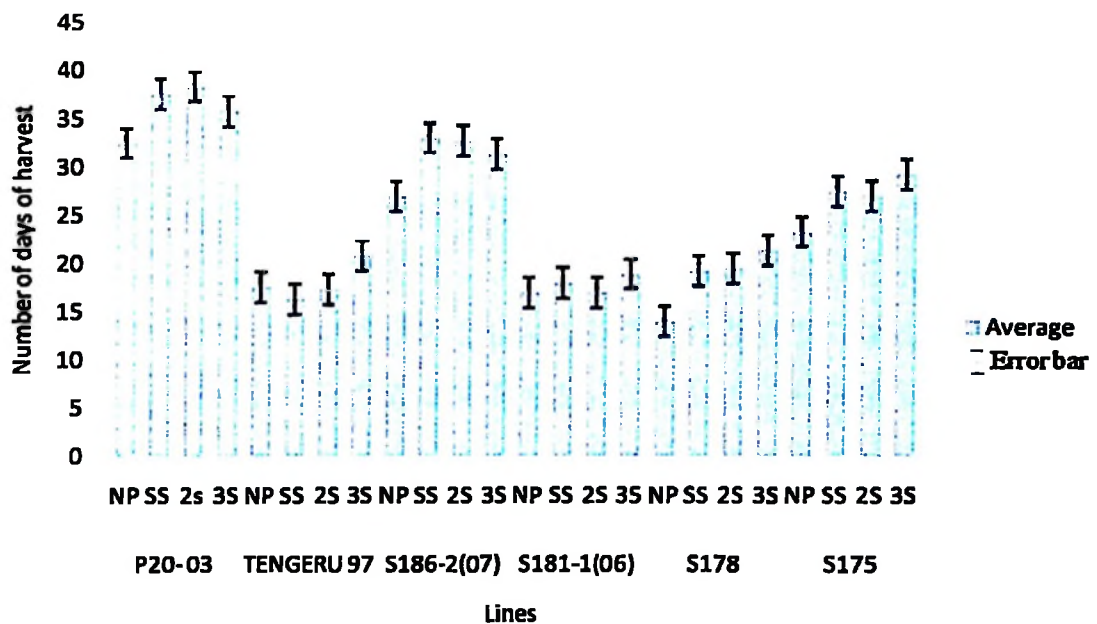


Figure 3: Pruning effect on harvest period (days) of six tomato breeding lines

Table 2: Mean values of plant developmental characteristics as observed among pruning treatments

Pruning treatment	Number of days to 1 st Flowering	Plant height to 1 st fruit cluster (cm)	Number of days to 1 st fruit maturity	Harvest Duration (days)	Plant height at last harvest (m)	Stem diameter at 4 th node (cm)	Leaf length (cm)	Leaf width (cm)
Single stem	39.35a	33.47a	76.47c	25.23a	1.14a	1.08a	32.72a	26.05a
Two stem	39.83a	33.01a	77.71b	25.27a	1.1a	0.94b	29.63b	23.34b
Three stem	39.73a	33.96a	77.91b	26.21a	1.08a	0.84 b c	29.06b	22.59b
Non pruning	38.91a	34.56a	80.36a	21.83b	1.1a	0.89 b c	28.89b	20.52c
Mean	39.46	33.75	78.11	24.64	1.1	0.93	30.07	23.1
LSD0.05	0.81	1.4	0.7	1.79	0.08	0.06	1.13	1.42
F-test	ns	ns	***	***	ns	***	***	***
CV(%)	7.66	15.51	3.39	27.13	19.57	25.45	14.13	23

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns =not significant, *= significant (P< 0.05), **= highly significant(P< 0.01),***= very highly significant (P< 0.001)

Table 3: Mean values of plant developmental characteristics observed among tomato lines

Lines	Number of days to the 1 st flowering	Plant Height to 1 st fruit cluster (cm)	Number of days to 1 st fruit maturity	Harvest duration (days)	Plant height at last harvest (m)	Stem diameter at 4 th node (cm)	Leaf Length (cm)	Leaf width (cm)
S186-2(07)	39.35b	28.85c	72.76	30.97ab	0.73c	0.98a	28.60c	22.82bc
P20-03	37.64b	31.79bc	79.25b	36.08a	1.52a	0.82a	27.56c	21.76bc
S181-1(06)	39.07b	36.71b	78.69b	17.65c	1.25b	0.96a	32.54ab	25.94a
S175	39.15b	27.27c	74.81bc	26.69b	0.61c	0.87a	27.17c	21.11c
S178	36.90b	34.82b	75.5bc	18.44c	1.30b	0.94a	30.15bc	22.24bc
Tengeru 97	44.63a	43.07a	87.67a	17.97c	1.22b	1.06a	34.43a	24.90ab
Mean	39.46	33.75	78.11	24.64	1.1	0.93	30.07	23.13
LSD0.05	2.89	4.07	3.35	6.15	0.07	0.19	3.05	2.4
F-test	**	***	***	***	ns	Ns	**	**
CV(%)	7.66	15.51	3.39	27.13	19.57	25.45	14.13	23.04

Means followed by the same letters(s) within the column are not significant different at 5% level based on Student-Newman-Keuls. ns=not significant, *= significant (P< 0.05), **= highly significant(P< 0.01),***= very highly significant (P< 0.001). P20-03, S186-2(07),S175, S178, S181-1(06) are new tomato breeding lines, Tengeru 97 is a local variety (control).

4.2 Yield Components

4.2.1 Number of flowers per plant

There were high significant differences between the pruning treatments on the number of flowers per plant and among the lines. On the other hand, non pruned plants across the genotypes had the highest number of flowers followed by plants with three, two, and single main stems with their means as being 66, 49, 45 and 31 flowers per plant, respectively (Table 4). The number of flowers was highly significant different ($P < 0.001$) between the tomato genotypes though this was influenced by the pruning systems. For the same pruning system, line P20-03 had the highest number of flowers bearing 71 flowers per plant followed by line S181-1(06) with the lowest number of flowers of 36 flowers per plant (Table 5).

The results in Fig. 4 show the interaction effects between the pruning treatments and the six lines. The non pruning system resulted into significantly higher number of flowers per plant of line P20-03, S181-1(06), S178 and S175. Three stem pruning treatment resulted into higher number of flowers per plant of var.Tengeru 97 while two stem pruning treatment resulted into higher number of flowers per plant of line SS186-2(07) only.

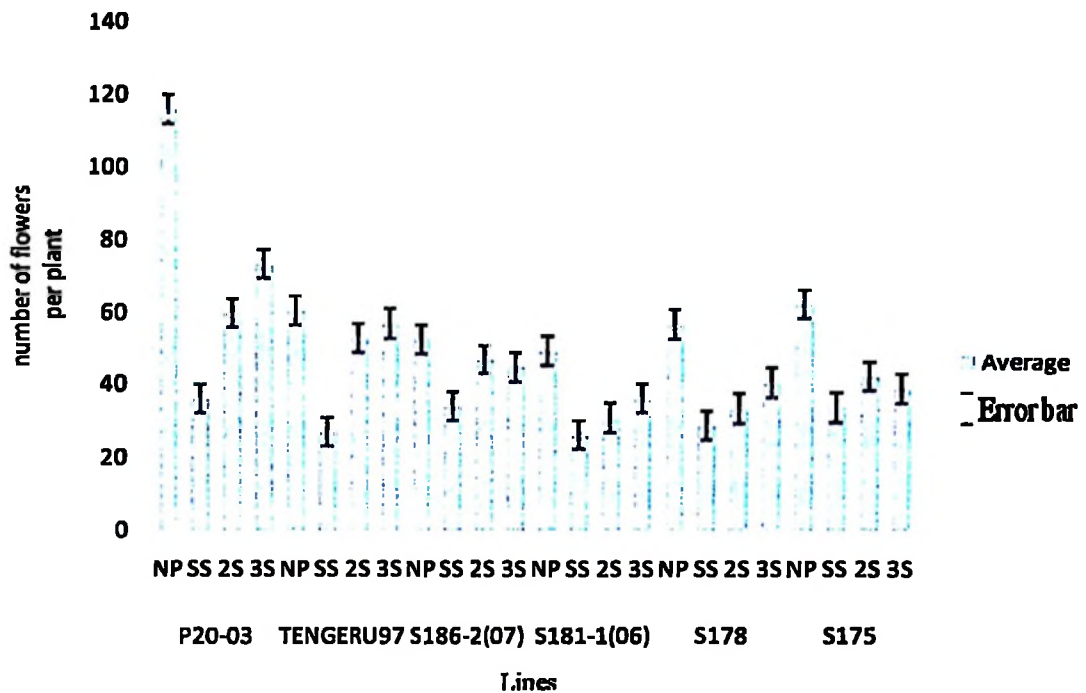


Figure 4: Pruning effect on the number of flowers per plant of six breeding lines

4.2.2 Number of flowers per cluster

Highly significant ($P < 0.001$) differences were observed for the number of flowers per cluster between the pruning treatments (Table 4). Single pruned plants had the highest number of flowers per cluster and non pruned plants had the lowest with 4.37 and 3.93 flowers per cluster respectively. There were highly significant differences ($P < 0.001$) in the number of flowers per cluster between tomato lines under the same pruning treatment. Line P20-03 and var.Tengeru 97 produced high number of flowers per cluster and with 7 and 4 flowers per cluster, respectively (Table 5).

4.2.3 Number of fruits per plant and fruit set

Differences were highly significant ($P < 0.001$) between pruning levels in respect to the total number of fruits per plant. The highest number of fruits per plant was observed when

no pruning was conducted (13 fruits) in any of the tomato breeding lines during the experiment. The decreasing trend in the number of fruits per plant indicated that single stem pruned plants had the lowest number of fruits per plant with 9 fruits per plant (Table 4).

The number of tomatoes per plant was significantly ($P<0.001$) different among the lines tested and the pruning level. However, within each pruning treatment higher number of fruits per plant was found in line P20-03 with a mean number of fruits of 22.84 of fruits per plant and the lowest number of fruits per plant was observed in line S181-1(06) with 4.47 of fruits per plant (Table 5).

On the other hand, high significant differences ($P<0.001$) were observed on fruit set between the tomato lines tested, with line P20-03 bearing 35% of fruit-set as highest number of fruit set, followed by S186-2(07) with 34%. Variety Tengeru 97 and line S181-1(06) had the lowest number of fruits per plant giving only 14 and 13 % respectively for the same pruning treatment (Table 5). A highly significant difference was observed with respect to the pruning systems with the single stem demonstrating the highest fruit set followed by two stem, three stem and non pruned plants showing the lowest number of fruit set per plant (Table 4). In all lines non pruned plants gave the lowest % of fruit set, whereas single stem pruned plants gave the highest percentage fruit set in all lines (Fig. 5).

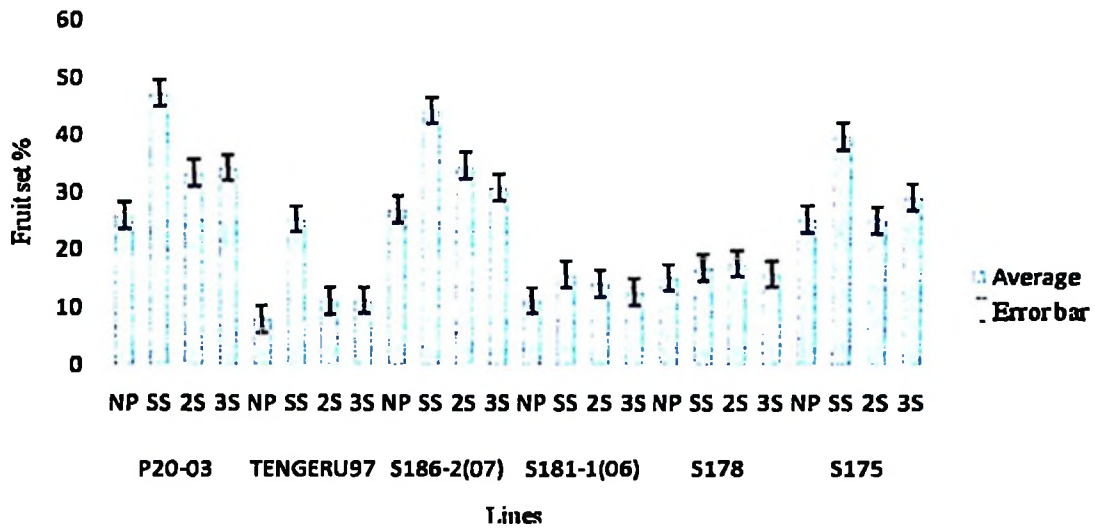


Figure 5: Pruning effect on fruit set of six tomato lines

4.2.4 Fruit weight

Significant difference in fruit weight were observed between the pruning systems where the single stem system had fruits with the highest weight of 159.89 g followed by the tomato plants with three stems, two stems with 153 g and 152 g respectively. The non pruned multiple stem tomato plants had the lowest fruit weight of 126.88 g (Table 4). Fruit weight was highly significant different ($P < 0.001$) between tomato lines within the same pruning treatment (Table 5). The highest weight per fruit under the same pruning level was observed in line S181-1(06) with 210.92 g followed by S178, S186-2(07), S175 and var.Tengeru 97. Line P20-03 had the lowest fruit weight with only 99.58 g per fruit in each pruning treatment (Table 5).

4.2.5 Tomato fruit yield

No significant differences in tomato yield were observed between pruning levels. The two stems system produced a slightly higher mean yield compared to other pruning systems (Table 4). There was significant difference ($P < 0.05$) in total fruit yield between the tomato

lines within each pruning system, with line S186-2(07) and P20-03 having the highest yield of 20.64 and 18.81t/ha while variety Tengeru 97 had the lowest yield of 9.68 t/ha (Table 5). Figure 6 indicates the interaction effects between the four pruning treatments and the six tomato breeding lines on yield. The results show that non pruning increased the yield of line P20-03, three stem treatments increased the yield of line P20-03 and S186-2(07) and single stem increased the yield of line S181-1(06) and variety Tengeru 97 whereas two stem treatments increased the yield of line S186-2(07) and S178. Non pruning and three stem pruning treatments effect were low in line P20-03.

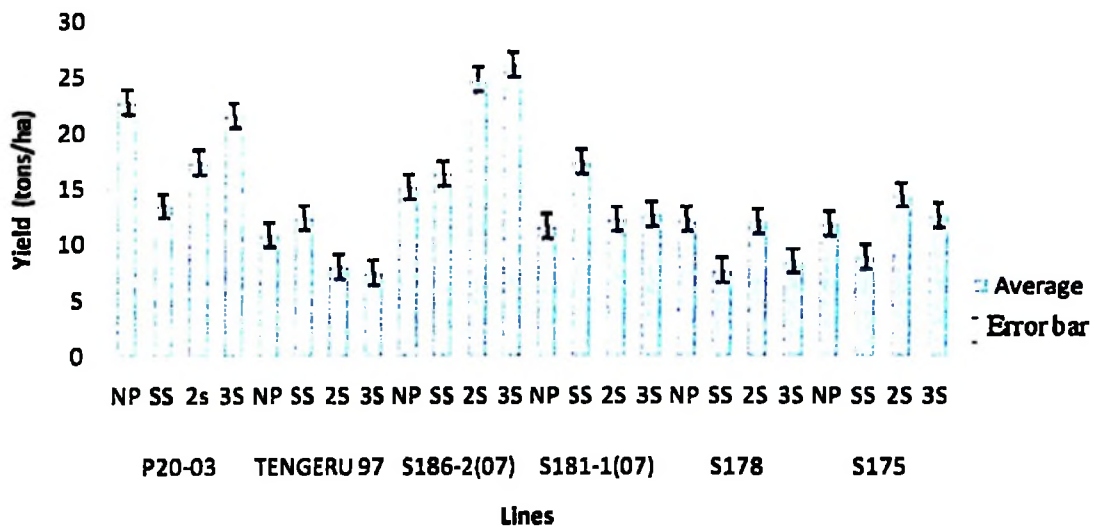


Figure 6: Effect of pruning on yield of six tomato breeding lines

4.2.6 Marketable fruit yield

Highly significant ($P < 0.01$) differences were found between pruning level for the number of marketable fruits per hectare and per plant (Table 4). The two stem pruned plants gave the highest number of marketable fruits per hectare of 136 519 and single stem plants gave the lowest number of marketable fruits per hectare of 91 270. Similarly, two stems gave the highest number of marketable fruits per plant of 6 whereas single pruned plants gave the lowest number of marketable fruits per plant of four. Non pruned plants were observed

to give many marketable plants per kg of 8 marketable fruits per kg while single pruned plants were observed to give a few marketable fruits per kg of 7 (Table4).

There were highly significant differences ($P < 0.001$) in the number of marketable tomatoes per ha, per plant and number of fruits per kg, between the tomato lines (Table 5). Line P20-03 and S186-2(07) had the highest number of marketable tomatoes per hectare with 319 692 and 163 773 tomatoes per hectare and highest number of marketable fruits per plant of 13 and 7 marketable fruits respectively. Line S175, var.Tengeru 97, lines S178 and S181-1(06) gave the lowest number of marketable tomatoes per hectare, with the lowest marketable yield per plant of three marketable fruits per plant. Line P20-03 was observed to give many fruits per kg of 10 fruits and line S181-1(06) gave a few fruits of 5 fruits per kg when within the same pruning system.

4.2.7 Non marketable tomato fruits yield

Significant differences ($P < 0.05$) in non marketable fruit yields were observed among the pruning treatments for the number of non marketable fruits per hectare and per plant (Table 4). The highest number of non marketable tomato fruits per hectare was observed in non pruned plants followed by two stem pruned plants and the lowest number of non marketable fruits was observed in single stem pruned plants. Difference was not significant between the pruning treatments for the weight of non marketable yield.

Table 4: Mean values of total yield and yield components observed on different pruning levels

Pruning treatment	Number of fruits/plant	Number of Flower/cluster	Number of flowers/plant	Fruit set (%)	Fruit set	Weight of single fruit(g)	Total fruit yield(t)/ha		Number of non marketable fruits/ha		Number of marketable fruits/plant		Number of marketable fruits/kg
							single fruit(g)	marketable fruits/ha	marketable fruits/ha	marketable fruits/plant	marketable fruits/plant	marketable fruits/plant	
Non pruning	12.91a	3.93b	66.43a	18.84b	126.11b	14.09a	132.716a	77.160.49a	5.57a	3.24a	8.42a		
Single stem	9.95b	4.37a	31.19c	31.71a	159.89a	12.71a	91.269b	49.272.49b	3.83b	2.069b	6.96b		
Two stems	9.94b	4.29a	44.64b	22.82b	152.26a	14.83a	136.519a	71.318.34ab	5.73a	2.99ab	7.12b		
Three stems	10.72b	3.94b	48.69b	22.47b	153.18a	14.81a	135.251a	67.791.01ab	5.68a	2.84ab	6.98b		
Mean	10.75	4.13	47.73	23.96	147.86	14.11	123.939	66.385.58	5.21	2.79	7.37		
LSD0.05	1.78	0.24	4.62	3.65	13.54	2.64	26.797	19.320.62	1.12	0.81	0.96		
F-test	***	***	***	***	**	Ns	**	*	**	**	*		
CV(%)	61.97	21.64	36.25	56.97	13.55	27.71	31.98	43.05	31.98	43.05	18.24		

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns=not significant, *= significant (P<0.05), **= highly significant(P<0.01), ***= highly significant(P<0.001).

Table 5: Mean values of yield and yield components observed among tomato lines

Lines	Number of fruits /plant	Number of flowers /cluster	Number of flowers /plant	Fruit set (%)	Weight of single fruit (g)	Total fruit yield (t/ha)	Number of marketable fruits per ha	Number of non marketable fruits/ha	Weight of marketable yield (t/ha)	Weight of non marketable yield (t/ha)	Number of marketable fruits/plant	Number of non marketable fruits/plant	Number of marketable fruits/kg
P20-03	22.84a	5.69a	71.38a	35.21a	99.58ab	18.81ab	319 692a	138 227a	13.17a	5.65b	13.42a	5.81a	10.18a
S186-2(07)	13.84b	3.62c	44.44bc	34.36a	143.41a	20.64a	163 773b	144 097a	10.88a	9.76a	6.88b	6.05a	7.26b
S175	11.43b	3.75c	44.69bc	30.11a	134.66b	11.95b	83 250b	327 738b	8.45a	3.51b	3.40b	1.38b	7.44b
S178	6.36c	3.78c	40.18bc	16.51b	177.17b	10.12b	56 547b	17 278b	7.77a	2.35b	2.38b	0.72b	5.71c
Tengeru97	5.59c	4.25b	49.44b	14.00b	121.4b	9.68b	65 807b	42 824b	5.87a	3.81b	2.76b	1.80b	8.47b
181-1(06)	4.47c	3.62c	35.88c	13.54b	210.92ab	13.42ab	54 563b	23 148b	9.36a	4.13b	2.29b	0.92b	4.87c
Mean	10.75	4.13	47.73	23.96	147.86	14.11	123 939	66 385.58	9.25	4.87	5.20	2.79	7.37
LSD0.05	2.1	0.36	9.16	4.54	24.86	6.23	82 698.87	48 193	5.07	3.53	3.47	2.02	1.11
F-test	***	***	***	***	***	*	***	***	ns	*	***	***	***
CV(%)	61.97	21.64	36.25	56.97	13.55	27.71	31.98	43.05	32.05	41.75	31.98	43.05	18.24

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns=not significant, *= significant (P<0.05), **= high significant (P<0.01), ***= very significant (P<0.001). P20-03, S186-2(07), S175, S178, S181-1(06) are new tomato breeding lines, Tengeru 97 is a local variety (control).

4.3 Correlation Analysis between fruit weight and other yield Components and Horticultural Variables

4.3.1 Correlation analysis between fruit weight and other yield components

In the case of the number of marketable fruits per ha and number of non marketable number of total fruits per ha, the correlation between the two variables and the weight of a single fruit was very highly significant but negatively (Table 6). This shows that as the weight of a single fruit increases, the number of marketable and number of total fruits per ha decreases. The number of non marketable tomato fruits negatively correlated significantly with the weight of a single fruit. Non marketable fruits were contributed by a higher number of small fruits (under 10g) and fruits damaged by insects and fruit cracking, therefore the weight of single non marketable fruit was low. The correlation between the weight of single fruit and the number of flowers per plant, number of flowers per cluster, number of fruits per plant and the percentage of fruit set were very highly significant negatively (Table 6).

Table 6: Correlation analysis between fruit weight and other yield components

Yield components (variables)	Coefficient of correlation (r)	R ² (%)
Fruit weight	1	100.00
Yield (t/ha)	-0.079 ns	0.62
Number of marketable fruits per ha	-0.481 ns	23.14
Number of non marketable fruits per ha	-0.355**	12.60
Number of fruit per ha	-0.355***	12.60
Marketable yield (t/ha)	-0.082 ns	0.67
Non marketable yield (t/ha)	-0.038 ns	0.14
Number of flowers per cluster	-0.294***	8.64
Number of fruits per plant	-0.445***	19.80
Fruit-set (%)	-0.257***	6.60
Number of flowers per plant	-0.424***	17.98

ns=not significant,*= significant (P< 0.05), **= highly significant(P< 0.01),***= very highly significant (P< 0.001) at 5 % and 1% level of significance

4.3.2 Correlation analysis between fruit weight and vegetative characteristics

Leaf length and width, number of days to the first fruit maturity, stem diameter at the 4th node, number of days to the first flowering, correlated significantly with the fruit weight. The number of days to the 1st fruit maturity and number of days to the first flowering increased proportionally with the fruit weight but inversely. Leaf size (leaf length and width) and stem diameter increased proportionally with the weight of a single fruit (Table 7).

Table 7: Correlation between fruit weight and other yield components and horticultural variables

Yield components (variables)	Coefficient of correlation (r)	R ² (%)
Fruit weight	1	100.00
Plant height at the last harvest (m)	0.032 ns	0.10
Leaf length (cm)	0.263***	6.92
Leaf width (cm)	0.231**	5.34
Number of days to the 1 st fruit maturity	-0.249***	6.20
Number of days to the first flowering	-0.151**	2.28
Plant stem diameter at 4 th node (cm)	0.145**	2.10
Plant height to the first fruit cluster (cm)	0.081 ns	0.66
Number of days to the 1 st fruit formation	0.071 ns	0.50
Harvest duration	-0.374***	13.99

ns=not significant,*= significant (P< 0.05), **= highly significant(P< 0.01),***= very highly significant (P< 0.001) at 5 % and 1% level of significance

4.4 Quality Characteristics

4.4.1 Acidity level

There were highly significant differences in the acidity of fruit juice (P<0.0001) between the lines tested for the same pruning treatment. Line S186-2(07) had the highest pH of 5.03 and line P20-03 had the lowest pH of 3.49 (Table 9). On the other hand, there was no significant difference in pH for pruning treatments.

4.4.2 Total soluble solids (TSS)

There was no significant difference in TSS between the pruning levels. There was highly significant difference ($P < 0.001$) in total soluble solids (TSS) between the tomato lines used in this experiment for the same pruning treatment. Line S175 gave the highest TSS value of 5.16% and the lowest was line P20-03 with TSS value of 3.74% (Table 9).

4.4.3 Fruit size

High significant ($P < 0.001$) difference in terms of tomato fruit length was observed among the pruning level. Fruits of two stem pruned plants were the longest with 5.53 cm long and those from the non pruned plants being the shortest with 5.24 cm long (Table 8). Fig. 7 presents the interaction between the four pruning treatments and the six breeding lines where single stem increased the fruit length in lines S181-1(06), S186-2(07) and S178. Two stem pruning system increased the fruit length in line S175 and three stem pruning increased fruit length in var. Tengeru and line P20-03.

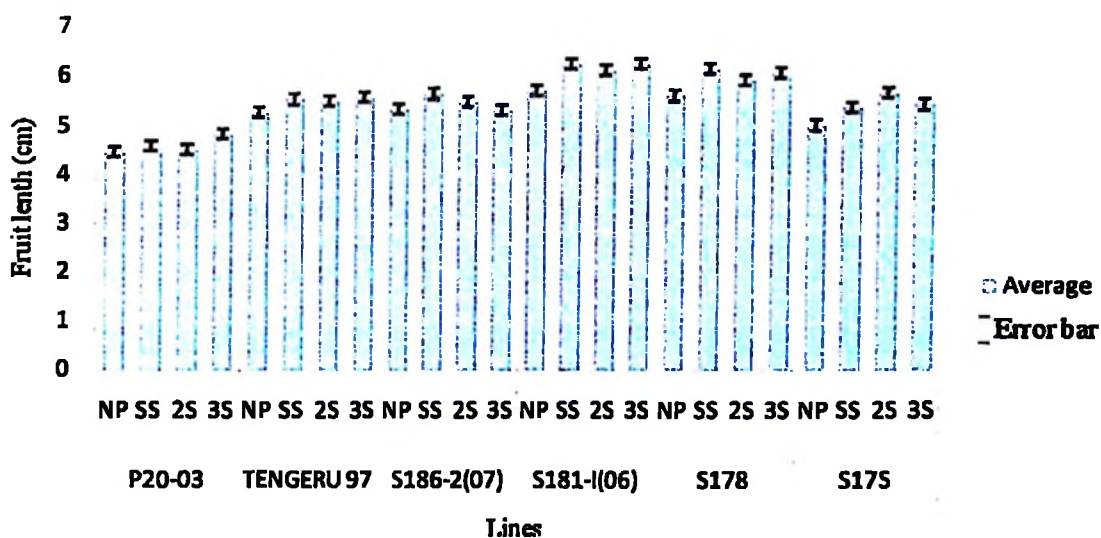


Figure 7: Effect of pruning on fruit length of six breeding lines

The difference in terms of width of tomatoes, was high significant different among the pruning levels, where fruits from three stem pruned plants were observed to have the highest width of 6.5 cm and those from non pruned plants were the smallest width with 5.93 cm (Table 8). Fruit width was highly different ($P < 0.001$) between the tomato lines tested under the same pruning level. Line S178 produced largest tomato fruits with a mean diameter of 7.0 cm and fruits from line P20- (03) had the smallest width with a mean of 5.2 cm (Table 9). Non pruning resulted in smaller fruits measured in terms of fruits length and width.

4.4.4 Fruit firmness

There was no significant effect on tomato firmness for all pruning treatments. Within each pruning system, there was a high significance difference ($P < 0.001$) between lines tested in terms of tomato fruit firmness. Var. Tengeru 97 had the highest mean fruit firmness with 4.78 kg per cm², and line P20-03 had the lowest fruit firmness with 3.59 kg/cm² (Table 9).

Table 8: Mean values of fruit quality characteristics observed on different pruning levels

Pruning levels	Fruit pH	TSS	Fruit length (cm)	Fruit width (cm)	Fruit width (cm)	Fruit firmness (kg/cm ²)
Non pruning	3.96a	4.24a	5.26b	5.93b	5.93b	3.57a
Single stem	4.23a	4.66a	5.52 a	6.48a	6.48a	3.65a
Two stem	4.13a	4.61a	5.53a	6.42a	6.42a	3.70a
Three stem	4.13a	4.66a	5.50a	6.50a	6.50a	3.60a
Mean	4.12	4.54	5.45	6.33	6.33	3.63
LSD0.05	0.23	0.38	0.12	0.17	0.17	0.15
F-test	ns	ns	***	***	***	ns
CV (%)	8.24	12.51	7.29	8.94	8.94	3.72

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns= not significant, *= significant ($P < 0.05$), **= highly significant ($P < 0.01$), ***= highly significant ($P < 0.001$).

Table 9: Mean values of fruit quality characteristics observed among lines

Lines	Fruit pH	TSS	Fruit length (cm)	Fruit width(cm)	Fruit firmness(kg/cm ²)
S186-2(07)	5.03a	4.68b	5.42b	6.37b	3.51b
Tengeru 97	4.35b	4.56b	5.45b	6.04c	4.78a
S181-1(06)	4.04bc	4.46b	5.99a	6.86a	3.30c
S178	4.02bc	4.66b	5.94a	6.99a	3.53b
S175	3.76bc	5.16a	5.34b	6.48b	3.59b
P20-03	3.49c	3.74c	4.58c	5.25d	3.07d
Mean	4.12	4.54	5.45	6.33	3.63
LSD0.05	0.51	0.26	0.32	0.35	0.46
F-test	***	***	***	***	***
CV(%)	8.24	12.51	7.29	8.94	3.72

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns=not significant, *= significant ($P < 0.05$), **= highly significant ($P < 0.01$), ***= very highly significant ($P < 0.001$). P20-03, S186-2(07), S175, S178, S181-1(06) are new tomato breeding lines, Tengeru 97 is a local variety (control).

4.5 Late Blight Infestation and other Physiological Disorders

4.5.1 Late blight incidence and severity

Difference was high ($P < 0.001$) between the pruning treatments on the late blight incidence. Single stem plants had the lowest incidence, followed by two stems and three stems and non pruning with disease of incidence of 9.58, 11.47, 20.75, and 29.44 % respectively. Single stem pruned plants and two stem pruned were not statically significant for late blight incidence (Table 10). There was significant ($P < 0.05$) difference among the lines used in this experiment about the incidence of late blight with line S181-1(06) being susceptible to late blight with incidence of 26.50 %, whereas line S186-2(07) was observed to be less susceptible to late blight with incidence of only 11.89% (Table 11). For Late blight resistant Tengeru 97 is a reported variety for check and was not significantly different from line S186-2(07).

Differences were highly significant between the pruning treatments (Table 10). Non pruned plants were severely attacked by late blight disease followed by three stem, two stem and single stem with a score of 4.24, 2.94, 2.37, and 1.9 (Appendix 2). Difference was also highly significant ($P < 0.01$) between the lines tested about late blight severity (Table 11). Line S178 and variety Tengeru 97 were more susceptible to late blight severity with a score of 3.6 and 3.4 respectively whereas P20-03 less susceptibility on late blight severity of 1.92 score. In all tomato breeding lines tested, non pruned plants were more susceptible to late blight severity and three pruned plants were much susceptible in lines P20-03 and S178 (Fig. 8).

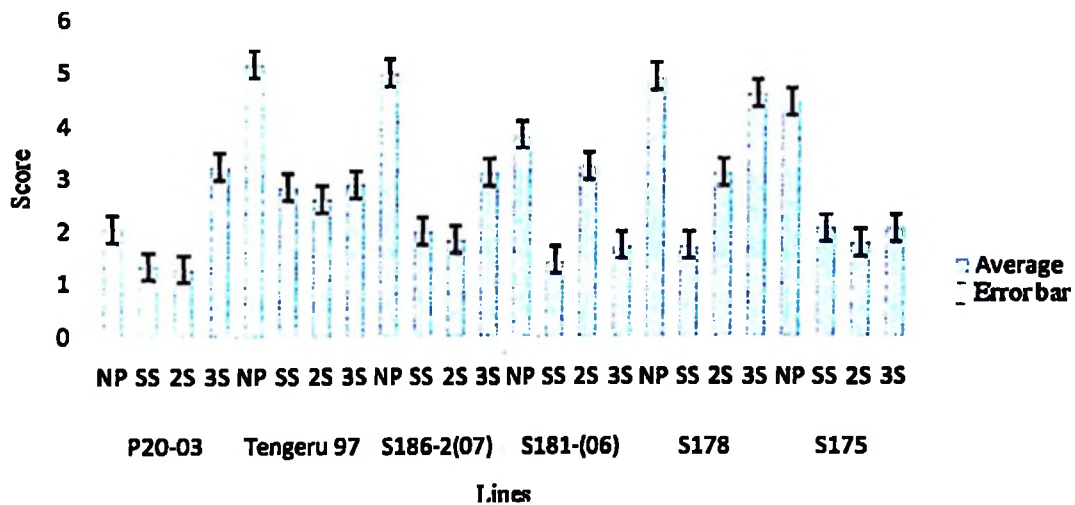


Figure 8: Effect of pruning on late blight severity of six breeding lines

4.5.2 Fruits cracking and Blossom end rot

Pruning levels had no effect on the percentage of cracked fruits and blossom end rot. There was significant difference between the lines tested in the percentage of cracked fruits. Line S186-2(07) was most susceptible to fruit cracking with cracked fruits at 23.53 % and line P20-03 was observed to be tolerant, with fruits cracked at 6.14 % (Table 11).

Table 10: Mean values of late blight infestation and fruits physiological disorders observed on pruning levels

Pruning levels	Late blight incidence (%)	Late blight severity (score)	Cracking (%)	Blossom end rot%
Single stem	9.58c	1.9b	16.74a	7.83a
Two stem	11.47c	2.37bc	14.71a	8.28a
Three stem	20.75b	2.94b	13.27a	6.37a
Non pruning	29.43a	4.24a	14.58a	12.77a
Mean	17.81		14.82	8.81a
LSD0.05	5.98	0.66	5.53	4.82
F-test	***	***	ns	ns
CV (%)	66.44	89.54	55.19	80.96

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns= not significant, *= significant ($P < 0.05$), **= highly significant ($P < 0.01$), ***= highly significant ($P < 0.001$)

Table 11: Mean values of late blight infestation and fruits physiological disorders observed among lines

Lines	Late blight incidence (%)	Late blight severity (score)	Cracking (%)	Blossom end rot (%)
S186-2(07)	11.89b	2.99ab	23.53a	7.41a
Tengeru97	12.15b	3.38a	6.93b	11.09a
S181-1(06)	26.50a	2.56ab	21.14a	11.09a
S178	24.31ab	3.60a	15.52ab	9.46a
S175	18.33ab	2.68ab	15.66ab	9.22a
P20-03	13.67ab	1.97b	6.14b	3.97a
Mean	17.81	2.86	14.82	8.81
LSD0.05	9.76	0.84	8.52	9.19
F-test	*	**	**	ns
CV(%)	66.44	89.54	55.19	80.96

Means followed by the same letters(s) within the column are not significant at 5% level based on Student-Newman-Keuls. ns=not significant, *= significant ($P < 0.05$), **= highly significant ($P < 0.01$), ***= very highly significant ($P < 0.001$). P20-03, S186-2(07), S175, S178, S181-1(06) are new tomato breeding lines, Ten97= Tengeru 97 is a local variety (control)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Horticultural and Plant Developmental Characteristics

5.1.1 Plant height and stem diameter

Plant height to the first fruit cluster was not affected by pruning levels. This probably implies that the effect of pruning on nutrient and water up-take occurs at much latter stage. Similar results were obtained by Rawshan (1996), Fecadu and Teshome (1998) and Kagiraneza (2007). Differences observed between lines for the height at the first fruit cluster and height at the last harvest period corresponds to the different types of growth pattern influenced by the genetic character of these tomato lines as also reported by Bitala (2001).

There was no significant difference between the pruning levels for the height of the plants at the last harvest period as also reported by Kagiraneza (2007). Murneek (cited by Nganga (1984), reported that maximum crop of fruits has a strikingly retarding effect on vegetative growth and development. These results are in contradiction with the results of Nganga (1984), who reported that many stems in general increased plant height. The major limiting factor of plant height was the senescence character of these lines. Although "stopping" was not practiced in the crop, the plants appeared to age naturally, and had little tendency to regenerate. The lines tested did not differ for the stem diameter but due to the pruning effect, single stem plants were more much vigourous than other pruning levels. Pruning has also positively affected root system development, as also explained by Epstein (1977) in his review on the role of roots, and hence poor nutrient up-take. The interaction between pruning level and different lines on plant height was highly

significant, and therefore the pruning level were affecting stem diameter in the different lines.

5.1.2 Flowering time and harvest duration

Pruning affected flowering time and harvest duration though the effect varied with tomato lines. The results show that the single, two stem and three pruning systems increased significantly the number of days to the first flowering in tomato line P20-03, var.Tengeru 97, S178 and S175. In contrast, non pruning and two stem increased the number of days to the first flowering in line S186-2(07). This difference of response to the pruning treatments between the lines is associated with the difference in genetic makeup of morphological habit in these lines combined with the pruning treatment. Pruned and staked tomato plants produce flowers two three weeks earlier than non pruned plants.

5.1.3 Fruiting and fruit maturity stages

Plants with single stem system matured earlier after transplanting followed by two stem, three stem and non pruning systems between the breeding lines but this differed between these breeding lines. It is clear that as the number of stems increases, as the fruits delay their maturity. These results show that pruning accelerates earlier fruiting and fruit maturity due to photosynthetic efficiency. Growth, flowering and fruiting responses are regulated and reproduction occurs when plants are pruned (Mnzava, 1984). The removal of apical and lateral vegetative growth hence reducing sink number, makes available more assimilates for fruit setting in indeterminate types. Proper pruning in general enhances fruit size and earliness for growing vigorously plants (Mnzava, 1984). The difference observed among the lines tested on the response of pruning treatments in terms of the

number of days to the first fruiting can be attributed to the genetic factors. Difference of the number of days to the first fruit maturity observed in different lines was caused by the genetic characteristic of the lines tested associated with the pruning treatments. The time of planting until first fruit harvest is dependent on cultivar and growing conditions (Rubatzky, 1996).

5.1.4 Leaf length and width

Plants pruned to single stems had bigger leaves followed by two, three and non pruned plants though varied among the breeding lines. This shows that pruning encourages the growth due to the photosynthetic efficiency. Because in pruned plants, many branches were removed, there was no competition within leaves, leading to good assimilation and hence to bigger leaf length. In unpruned plants there was competition within canopy resulting to a reduced length of leaves (Nganga, 1984). This situation shows that the more plant branches, the smaller the leaf size. Abdel-AI (1962) reported that pruning increases leaf efficiency.

5.1.5 Length of harvest period

Three stem pruned plants had the longest period of harvest followed by two, single stem, and no pruned plants. The two stem pruned plants resulted into higher number of days of harvest in line P20-03 while single stem pruned plants increased the length of harvest in plants of line S186-2(07). At the same time, non pruned plants increased the length of harvest in plants of variety Tengeru 97, two stem plants in line S181-1(06), three stem pruned plants in lines S178 and S175. The effect of pruning on the harvest duration was longer in lines P20-03, S186-2(07) and S175. For each pruning system line P20-03 was

harvested for a longer period than other lines and this difference was possibly due to the genetic factors for the same pruning treatment.

This results show that the two and three stem pruning might probably increase the period of vegetative and productive stages in tomato plants by making available more assimilates for fruit setting period in indeterminate types because of reduced completion within the plant stems. These results are similar to those of Sandersfeld (2008) who reported that, two stem pruned plants have a long harvest period than unpruned.

5.2 Yield and Yield Components

5.2.1 Number of flowers per plant

Plants of line P20-03 were observed to have many flowers per plant and S181-1(06) gave the lowest number of flowers per plant for each pruning system. Differences in the number of flowers per plant among lines are possibly due to the genetical make up of these tomato breeding lines tested. Non pruned plants were the first to bear many flowers followed by three, two, and single pruned plants. Mbinga (1983) also found that the severer the pruning, the smaller the number of flowers per plant was hanging but the bigger were the fruits. The non pruning resulted into significantly higher number of flowers per plant of line P20-03, S181-1(06), S178 and S175 lines. Three stem pruning treatment resulted into higher number of flowers per plant for variety Tengeru 97 and two stem pruning treatment resulted into higher number of flowers per plant of line S186-2(07).

5.2.2 Number of flowers per cluster

Line P20- (03) produced high number of flowers per cluster and this difference was possibly attributed to genetic characteristics of this line in all pruning treatment. In this

study it was observed that severe pruning increased the number of flowers per cluster except in line P20- (03). Similar results were reported by Ara et al. (2007) and Myint (1999) that single pruned plants produced a high number of flowers per cluster than multiple stem pruning.

5.2.3 Number of fruits per plant

The higher number of fruits per plant was observed in line P20-03 in all pruning treatments and these differences could be due to the genetic factors in all pruning systems. Differences were highly significant between pruning levels in respect to the total number of fruits per plant with the highest number of fruits per plant observed in non pruned plants, followed by three stems, two stems and single stem pruned plants. These results are similar to those of Ara et al. (2007) who also observed that one stem pruning gave the lowest number of fruits per plant. In his study, the severer the pruning was, the smaller was the number of fruits per plant. The same trend was observed by Zhang (1998) and Myint (1999). This was due to the fact that during pruning, many branches are removed, leading to reduced number of fruits. However, unpruned plants bear many fruits due to the higher number of reproductive branches and subsequent flowers. This leads to the small size of fruits and non marketable fruits from non pruned plants. In general, plant with more stems implies more but smaller fruits which are produced (Resh, 1997).

5.2.4 Fruit set

The lines which had the highest percentage of fruit-set was P20-03 and S186-2(07) in all pruning treatments. This difference between lines, possibly originated from the genetic character of each line. Villareal (1980) reported that for optimum fruit-setting, tomatoes

require night temperature of 15^o-20^oC. Unfortunately, the minimum temperature during our experiment was 19.1^oC and maximum 34.3^oC; this could have caused the low fruit-set obtained in this experiment of these breeding lines. High day-time temperatures are unfavorable for normal development of pollen grains and fruits (Villareal, 1980). Single stem pruned plants produced the highest fruit set followed by two stem, three stem and non pruned plants. This is because, in pruned plants, there were few leaves and the spray of pesticides arrived on flowers consequently reduced the number of diseases on flowers and therefore fruit formation was improved. The same results were found by Ara et al. (2007) who observed that the highest proportion of flowers formed fruits under single stem system. Mnzava (1984) reported in his study that pruning to a single stem had an effect of increasing fruit set. Nganga (1984) found in his experiment that pruning resulted in a higher flower- fruit ratio in general, and it is suggested that a higher fruit: leaf ratio achieved on fewer leaves through pruning may enhance fruit yield production in a plant. When plants are pruned, flowering and fruiting responses are regulated and underlying principle implicit in the practice is that a relationship between vegetative growth and reproduction exists. Pruning controls carbon producing apparatus and thus affects the ratio and hence fruitfulness (Resh, 1997).

5.2.5 Fruit weight

The fruit weight was higher in fruits from single pruned plants of line S181-1(06) followed by three, two and non pruned plants. This difference was possibly attributed to genetic background of line S181-1(06) associated with the response of this line to the environment created by the single pruning system leading to bigger fruits compared to those of other pruning systems. Similar results were reported when pruned and non pruned

indeterminate tomato were compared by (Kagiraneza, 2007; Ara *et al.*, 2007; Bitala, 2001; Mulungu *et al.*, 1995). Rubatzky (1996) reported that pruning allows for some regulation of fruit size and flowering. Fruit size can be improved by removing the axillary shoots and regulating the number of fruits per cluster. This indicates that plants receive enough light when they are pruned. The light utilization in the canopy is not limited by much foliage, and thus the supply of assimilates to all the fruits is sufficient to sustain the growth of the majority of fruits. Pruning helps to control the amount of light reaching each plant and allows for better ventilation around each plant. It also keeps a better balance with the root system and usually produce larger fruit than would a plant that is allowed to grow bushy (Opena *et al.*, 1995). Unpruned tomato produces many branches per plant which increases competition for assimilate. This competition leads to poor fruit setting and small fruits. Nganga (1981) reported that pruning results in a plant having a higher peak fruit count to leaf count ratio compared with a non pruned plant. This indicates that leaf production does compete with fruit production at some stages. The role of pruning would be to achieve a balance between maximum fruit and leaf produced to sustain fruit development.

5.2.6 Fruit yield

The tomato breeding lines showed a difference in the total fruit yield with lines S186-2(07) and P20 giving the highest yield per hectare and the control variety Tengeru 97 had the lowest yield per ha for all pruning treatments. The tomato S tomato lines tested in this work are of a similar pedigree selection and therefore not expected to demonstrate significant difference in yield with the exception of heterosis (hybrid vigor) that might have happened in some of them. FAO (2003), reported that the average tomato yield in the world is 26.29 t/ha and Kagiraneza (2007) found that the first productive indeterminate

line gave 16.4 t/ha at Sokoine University of Agriculture in Tanzania. Differences in yield in any crop species could be attributed to the effects of many factors including weather, water availability, soil fertility status, seedbed condition and varieties. The experiment of this study was carried out during the period from November 2009 up March 2010, during this time; the weather was not favourable for tomato production due to the high temperature and shortage of water. Irrigation was applied during this period but it was possible that high temperatures (day/night) and water stress may have affected significantly the yield and yield components. High temperatures limit tomato production whenever daytime temperatures exceed 30°C and/or nighttime temperatures exceed 21°C (Mary and Willits, 1993). High temperatures are known to limit tomato fruit set because of simultaneously and/or sequentially impairing series of reproductive processes such as pollen production and ovule development, pollination, pollen grain germination, pollen tube growth, fertilization and fruit initiation (Fernandez *et al.*, 1991). High temperature reduces photosynthesis but increases respiration and transpiration. Carbohydrate stress can cause low fruit set (Markus *et al.*, 1981). Reid *et al.* (1996) reported that inadequate irrigation in field crop tomato showed a significant greater incidence of blossom end rot than a well irrigated one. Giardini *et al.* (1988) showed that lower irrigation rates generally decrease yield and fruit size. However, all stages of development are equally sensitive to soil moisture deficits; the flowering and fruit setting stages of tomato have been known to be the most sensitive to water deficits in terms of yields. Hot ambient conditions are known to retard flower initiation, reduce pollen viability and induce malformation of flower organs, resulting in poor fruit setting and low yield. High temperature (day/night) decrease photosynthesis, leading to low productivity (Lutfor *et al.*, 1997).

Two stems pruned plants produced a high mean of fruit yield than other pruning system. Kanyomeka (2005) found that pruning tomatoes did not have benefits to tomato yield. In fact there was a reduction in yield due to pruning, especially in case of single pruning system. This finding is similar to the results reported by Resh (1997) and Kanyomeka *et al.* (2005). They reported that pruning causes marginal reduction in tomato yield due to fewer branches on which to produce fruits. The results show that non pruning and three stem treatments increased the yield of line P20-03 and line 186-(06) and single stem pruned treatments increased the yield of line S181-1(06) and variety Tengeru 97. Non pruning and three stem pruning treatments effect on yield was more pronounced in line P20-03. It is clear that these lines were responding differently to the pruning practice for yield and this was due to the genetic character of each line.

5.2.7 Marketable tomato fruits yield

The two stem pruned plants gave the highest number of marketable fruits per ha and the number of marketable fruits per plant when single stem pruned plants gave the lowest number of marketable fruits per hectare and per plant. These results are similar to those of Myint (1999), who indicated that the two stem pruning method gave the highest marketable yield compared to single stem and non pruned plants of indeterminate tomato varieties. Pruning facilitates insecticide spraying and harvesting (AVRDC, 1999) thus increasing the number of marketable fruits in pruned plants. In terms of the weight of marketable fruits yield, no significant differences were observed among the pruning levels for the breeding lines. This means that the lines with the small number of marketable fruits had the highest weight of a single fruit.

5.2.8 Non marketable tomato fruits yield

The highest number of non marketable tomato fruits per hectare and per plant was observed in non pruned plants and single stem pruned plants gave the lowest number of non marketable tomato fruits. In his study, Kagiraneza (2007) reported that the highest number of non marketable fruits was observed in unpruned plants and the lowest in the pruned treatment. De Kreij *et al.* (1992) reported that excessive vegetative growth and low fruit load (severe pruning) is said to favour disequilibrium between xylem and phloem sap absorption by the fruit, in favour of the phloem sap. This leads to calcium deficiency in the fruit and increases the appearance of blossom-end rot. Generally, fruit cracking is associated with rapid movement of water and sugars towards the fruit when cuticle elasticity and resistance are weak during the ripening (Dorais and Papadopoulos, 2001). High foliage: fruit ratio resulting from fruit pruning significantly increases the number of fruit affected by cracking (Ehert and Ho, 1886).

5.3 Correlation Analysis between Fruit Weight and other Yield Components and Developmental Variables

The yield variables (number of fruits per ha, total marketable yield and total non marketable fruits) correlated significantly but negatively with the weight of fruit. This shows that as the weight of a single fruit increases, number of fruits per plant, number of fruits per ha. These results are similar to those found by Mnzava (1984) who reported that total fruit yield increased with the number of clusters and number of flowers per cluster.

5.4 Fruit Quality Characteristics

5.4.1 Acidity level

There was no difference in pH due to pruning treatments as also found by Rafi (1996), Zhang (1998) and Myint (1999) though this varied between the breeding lines. The composition of sugars and acids within the fruit depends on cultivar, cultural practices, light and temperature conditions during the growth which sets the rates of biosynthesis and metabolism within the fruit (Ho, 1996). The concentration of sugars and acids in the juice can also be affected directly by fruit water relationships.

Line S186-2(07) had the highest pH and line P20-03 had the lowest. This difference is due to the different genetic factors of these lines. According to Rubatzky (1996), tomato fruit pH usually ranges between 4.3 and 4.7. Lorena (1996) found in cherry tomato varietal trial a pH range between 4.5 and 5.3, while Myint (1999) reported on the effect of pruning and spacing on fresh market tomato a pH ranging from 3.1 to 4.3. In a comparative study, (George *et al.*, 2004) evaluated titrable acidity in fruits of 12 tomatoes genotypes and reported that the acidity varied from one cultivars to another.

5.4.2 Total soluble solids (TSS)

No differences in Total Soluble Solids (TSS) were observed due to the pruning levels. These results are similar to those found by Zhang (1998) and Myint (1999) but are in contrast with those of Ara *et al.* (2007) who reported significant highest Brix in fruits from two stem pruning systems. For the same pruning system line S175 gave the highest TSS value followed by line 186-(06) and the lowest was P20-03. This difference might be attributed to genetic variation among lines. Leonardi *et al.* (2001) reported that differences in TSS content can be partially attributed to genetic factors and/or the relatively high salinity of irrigation water and solar radiation which further enhances dry matter and

soluble solids accumulation in fruits also Quadir *et al.* (2003), found significant differences in TSS between cultivars.

5.4.3 Fruit size

Non pruning resulted in smaller fruits measured in terms of fruit length and width. Fruits from two stem pruned plants were the longest followed by single stem, three stem and non pruned plants. Ara *et al.* (2007) and Myint (1999) found that in case of pruning, significance variations were observed in fruit length and fruit width. They observed that highest fruit length was obtained from single stem but highest fruit width was produced by one stem pruning which was statistically similar to two stem pruning. Three stem pruning treatment increased the length of the tomato fruits from line P20-03, variety Tengeru 97 and single stem pruning treatment increased the length from line S181-1(06), S186-2(07), S178 whereas two stem pruning treatment increased those from line S175. Non pruning treatment resulted in lowest tomato fruit length. The pruned plants produced larger tomato fruits with higher diameter than non pruned plants. Kagiraneza (2007) also reported that pruning resulted in larger fruits when compared with fruits from unpruned plants. Similar results have been reported by Bitala (2001) and Mulungu *et al.* (1995) who observed larger fruits in pruned indeterminate tomato as compared to determinate types. Ara *et al.* (2005) reported that highest fruit diameter was produced by one stem pruning which was statistically similar to two stem pruning. Fruit size can be improved by removing the axillary shoots and regulating the number of fruits per cluster. Pruning helps to control the amount of light reaching each plant and allows for better ventilation around each plant (Resh, 1997). It also keeps a better balance with the root system and will usually produce larger fruit bushy plants (Opena *et al.*, 1995).

5.4.4 Fruit firmness

Variety Tengeru 97 had a highest mean fruit firmness followed by line S175 and line P20-03 had the lowest firmness though this varied with the pruning treatment. It has been reported that high Ca content in fruit increased firmness (Resh, 1997). This difference can be attributed to the genetic factors between the lines in absorbing Ca. The textural quality of tomatoes is influenced by skin toughness, fresh firmness, and internal fruit structure (pericarp/locular material ratio) which vary greatly among cultivars (Atherton and Rudich, 1986). Firmness is a criterion often used to evaluate fruit quality as it is directly related to fruit development, maturity, ripening and storage potential. It is also related to the likelihood of bruising when fruits are subjected to impact during handling (Lesage et al., 1996). A decrease in fruit firmness observed from day 1 to 10 between the introduced lines and checks was associated with softening and cell wall degradation (Jamila *et al.*, 2002). There was no significant effect on tomato firmness due to pruning treatments though firmness varied with lines. Myint (1999) observed that fruit firmness was not significantly different among three pruning methods.

5.5 Late Blight Infestation and Fruits Physiological Disorders

5.5.1 Fruit cracking and Blossom end rot

Pruning level did not affect fruit damage by cracking but this varied with line. These results were also reported by Vincent (2000) who found that difference in fruit cracking was not significant among the pruning treatments. The study showed large number of fruits with cracks in all line and pruning treatments. Fruit cracking was present during fruit ripening, and could be attributed to cultural practices, like irregular irrigation and delayed harvesting, some varietal traits and weather conditions. This physiological damage was probably due also to the prevailed high and an unevenly distributed rains and temperatures

which caused moisture fluctuations resulting to rapid increase in the fruits hence cracking. Ohta *et al.* (1997) reported that fruit cracking occurred as a result of an increase in fruit size due to rapid uptake of solute. The study suggests that the period of low soil moisture followed by frequent rainfall increases cracking. Similar opinion was given by Rweyemamu *et al.* (1998) who reported that damage of fruits by growth crack and splitting due to heavy rains did not improve crop quality. This implies that fruits should be harvested at early stage of ripening when rains are prevailing.

Blossom end rot was not influenced by the lines or the pruning treatments. Both blossom end rot (BER) and fruit cracking in tomato are physiological disorders. These results are in contrast of those of Abdel-Al (1962) who observed that pruning decreased the percentage of fruits affected by blossom end rot and suggested breeding plants with sparse foliage.

5.5.2 Late blight incidence and severity

This study shows that, the severer the pruning was, the lower was the late blight incidence of foliar diseases. Therefore single stem plants were less affected by the late blight, followed by two stems, three stems and non pruned plants. Kanyomeka (2005) also found that unpruned tomato plants were more attacked by late blight disease compared with pruned ones. Rubatzky (1996) reported that pruning is an important cultural procedure to enhance disease management. Pruning is required, in many zones to improve the plants odds of avoiding fungus invasions and other disease. Overcrowded plants can create little humid or environments with moist air stuck inside and limited air circulation (Ara *et al.*; 2007).

Late blight severity was more pronounced in non pruned plants, followed by three stem, two stem and single stem. In tomato breeding lines used in this study, non pruned plants were more susceptible to late blight severity and three pruned plants were much more susceptible in lines P20-03 and S178. AVRDC (1999) reported that pruning improves air circulation within the canopy, which reduces foliar diseases, and facilitates spraying and harvesting. The leaves of pruned and supported plants dry off faster, fungal pathogens have less possibility to spread (Daniel, 2008). According to William (1998), late blight development is favoured by moderate temperatures and wet conditions. The low moisture and high temperatures during this experiment could have an influence on the late blight incidence and severity.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Results of this study showed that the pruning levels have influence on plant developmental characteristics, yield, fruit quality and late blight resistance of the new indeterminate tomato breeding lines.

These results indicate that single stem pruned plants were more vigorous among the lines tested to the 4th node and had the biggest leaf size. Single stem pruned plants gave the highest proportion of flowers which formed fruits, in contrast the yield did not differ among the pruning systems. The two stem pruned plants produced the highest number of marketable fruits per ha whereas unpruned plants gave the highest number of non marketable fruits per hectare. The length of harvesting period was high for fruits from three stem pruned plants. The severer was the pruning, the smaller was the number of flowers and fruits per plant. Single pruned plants increased fruit weight whereas the medium fruit weight was observed in three stem and two pruned plants and the lowest fruit size in non pruned plants. For the same pruning treatment, lines S186-2(07) and P20-03 were precocious in terms of the first fruiting day. Variety Tengeru97 was the tallest to the first fruit cluster and line P20-03 was the tallest at the last harvest within the same pruning system. Lines P20-03 and S186-2(07) were associated with the longest period of harvest, many flowers and fruits per plant, higher percentage of fruit-set, the highest yield, number of marketable fruits.

Fruits from three pruned plants were the longest in line P20-03 while fruits from single stem pruned plants longest in line S181-1(06), S186-2(07) and S178 and two stem pruned

plants increased the length of fruits in line S175. Definitively, two stem pruned plants produced the biggest number of marketable fruits per ha for line P20-03, S186-2(07), with medium fruits size without loss in yield in terms of tones per ha and fruit quality in terms of TSS, fruit acidity and fruit firmness in all lines. This fruit weight is comparable to the weight of fruits required by the consumers in Tanzania, which ranges from 80 to 120g/fruit.

Pruning decreased the incidence and severity of late blight disease infestation. Therefore, non pruned plants were severely attacked by late blight disease in all tomato breeding lines. Like single pruned plants, the two pruned plants exhibited more tolerance to the late blight disease though this varied with the breeding lines.

6.2 Recommendations

In view of this study it appears that the tomato breeding lines tested combined with pruning systems gave promising high yield quality and high levels of resistance to late blight. It is therefore recommended that these lines should be object of multilocational trials before their release.

Two stem and three stem pruning systems per plant should be recommended to the tomato growers as the best husbandry practice for increased marketable tomato fruits yield of medium sized fruits especially for lines S186-2(06) and P20-03.

In order to improve tomato production in terms of quantity and quality, creation of awareness through demonstration trials is needed for further promotion of these new lines combined with pruning systems especially on lines S186-2(07) and P20-03 for their high yield, and tolerance to late blight.

The crossing of these improved lines of high fruit size (S178, S181-1(06), S175) with local varieties should be recommended in order to incorporate favorable traits such as high yield and tolerance to late blight disease.

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APPENDICES

Appendix 1: Experiment layout

Replication I																							
P20-03				Tengeru 97				S186-2(07)				S181-1(06)				S178				S175			
2S	NP	3S	SS	3S	2S	NP	SS	SS	3S	NP	2S	3S	SS	NP	2S	2S	NP	SS	3S	NP	2S	3S	SS
Replication II																							
S178				S186-2(07)				S175				P20-03				S181-1(06)				Tengeru 97			
NP	2S	SS	3S	3S	NP	SS	2S	NP	3S	SS	2S	3S	NP	SS	2S	SS	3S	NP	2S	2S	3S	SS	NP
Replication III																							
S186-2(07)				S175				S178				Tengeru 97				P20-03				S181-1(06)			
3S	SS	NP	2S	SS	NP	3S	2S	3S	2S	NP	SS	SS	NP	3S	2S	SS	3S	NP	2S	3S	NP	SS	2S

Size plot: $3.6 \times 2.8 \text{m}^2 = 10.08 \text{m}^2$

Pathway between two plots: 1m

Pathway between two replications: 2m

Area of the experiment: 1246.56m^2

Appendix 2: Table of percentage and score of late blight severity

Disease score	% leaf damage	Severity
1	0	No visible disease symptoms
2	0-5	Very light symptoms
3	5-10	
4	10-20	Visible and conspicuous symptoms
5	20-30	
6	30-40	
7	40-60	Severe to very severe symptoms
8	60-80	
9	80-100	

Appendix 3: Anova table for statistical model (Split plot)

Source of variation	df	Mean square
Replication	3-1	Replication MS = $\frac{\text{replication SS}}{r-1}$
Lines (A)	6-1	AMS = $\frac{\text{ASS}}{a-1}$
Main plot error(a)	$(3-1) \times (6-1)$	Error(a) MS = $\frac{\text{Error(a)SS}}{(r-1)(a-1)}$
Pruning (B)	4-1	BMS = $\frac{\text{BSS}}{b-1}$
Line \times Pruning	$(6-1) \times (4-1)$	$A \times BMS = \frac{A \times BSS}{(a-1)(b-1)}$
Sub plot error (b)	$6 \times (3-1) \times (4-1)$	Error (b) MS = $\frac{\text{Error (b) SS}}{a(r-1)(b-1)}$
Total	$(3 \times 6 \times 4) - 1 = 71$	

Appendix 4: Anova table for all parameters

4.1: Anova table for height to the first fruit cluster

SV	df	SS	MS	F	P
Blocks	2	625.86	312.93	1.60	1.1228ns
Lines(A)	5	12003.10	2400.62	19.98	0.0001*
Error(a)	10	1201.27	120.13		
Pruning(B)	3	142.78	47.59	1.73	0.1593ns
Pruning * line	15	771.07	51.40	1.87	0.0243*
Error (b)	396	10864.81	27.43		
Total	431	25608.90			
$R^2 = 0.58$					
CV = 15.52%					

4.2: Anova table height at the last harvest

SV	df	SS	MS	F	P
Blocks	2	0.03	0.01	0.25	0.7842 ns
Lines(A)	5	45.78	9.16	183.29	0.0000 ***
Error(a)	6	0.34	0.06		
Pruning(B)	3	0.16	0.05	0.96	0.4707 ns
Pruning * line	15	1.45	0.10	1.93	0.0190 *
Error (b)	400	19.98	0.05		
Total	431	67.73			
$R^2 = 0.60$					
CV = 66.45%					

4.3: Anova table for number of days to the first flowering day

SV	df	SS	MS	F	P
Blocks	2	57.732	28.86	0.487	0.6346 ns
Lines(A)	5	2649.07	529.81	8.74	0.0020 **
Error(a)	10	606.33	60.63		
Pruning(B)	3	57.25	19.08	2.09	0.1014 ns
Pruning * line	15	346.13	23.08	2.52	0.0014 **
Error (b)	396	3620.67	9.14		
Total	431	7337.16			
$R^2 = 0.51$					
CV = 7.66%					

4.4: Anova table for number of days to the 1st fruiting day

SV	df	SS	MS	F	P
Blocks	2	51.46	25.73	0.24	0.7880 ns
Lines(A)	5	2450.65	490.13	4.65	0.0188 *
Error(a)	10	1054.70	105.47		
Pruning(B)	3	53.99	17.99	1.20	0.3094 ns
Pruning * line	15	258.86	17.26	1.15	0.3086 ns
Error (b)	396	5937.78	14.99		
Total	431	9807.44			
R ² = 0.39					
CV = 8.26%					

4.5: Anova table for number of days to the 1st fruit maturity

SV	df	SS	MS	F	P
Blocks	2	467.46	233.73	2.87	0.1034 ns
Lines(A)	5	10028.40	20.68	24.64	0.0000 ***
Error(a)	10	814.04	81.40		
Pruning(B)	3	858.43	286.14	40.78	0.0000 ***
Pruning * line	15	186.66	12.44	1.77	0.0363 *
Error (b)	396	2778.44	7.02		
Total	431	15133.44			
R ² = 0.82					
CV = 3.39%					

4.6: Anova table for leaf length

V	df	SS	MS	F	P
Blocks	2	112.25	56.13	0.83	0.4639 ns
Lines(A)	55	3020.43	604.09	8.93	0.0019 **
Error(a)	1010	676.13	67.61		
Pruning(B)	3	1041.25	347.08	19.21	0.0000 ***
Pruning * line	15	105.80	7.05	0.39	0.9813 ns
Error(b)	396	7154.74	18.07		
Total	341	0.59			
R ² = 0.41					
CV = 14.13%					

4.7: Anova table for leaf width

SV	df	SS	MS	F	P
Blocks	2	17.93	8.96	0.21	0.8106 ns
Lines(A)	5	1284.93	256.99	6.15	0.0074 **
Error(a)	10	417.82	41.78		
Pruning(B)	3	1691.87	563.96	19.87	0.0000 ***
Pruning * line	15	460.48	30.70	1.08	0.0000 ***
Error(b)	396	11239.19	28.38		
Total	431	15112.21			
R ² = 0.26					
CV = 23.04					

4.8: Anova table of for number of days of harvest period

SV	df	SS	MS	F	P
Blocks	2	9.64	4.82	0.02	0.9826 ns
Lines(A)	5	22099.18	4419.84	16.11	0.0002 ***
Error(a)	10	2743.75	274.37		
Pruning(B)	3	1198.41	399.47	8094	0.0000 ***
Pruning * line	15	733.29	48.89	1.09	0.3596 ns
Error(b)	396	17693.67	44.68		
Total	431	44477.94			
R ² = 0.60					
CV = 27.13%					

4.9: Anova table for number of flowers per plant

SV	df	SS	MS	F	P
Blocks	2	10125.17	5062.58	8.32	0.0074 **
Lines(A)	5	55950.14	11190.03	18.40	0.0001 ***
Error(a)	10	6081.19	608.12		
Pruning(B)	3	68410.38	22803.46	76.16	0.0000 ***
Pruning * line	15	29609.51	1973.97	6.59	0.0000 ***
Error(b)	396	118573.53	299.43		
Total	43				
R ² = 0.59					
CV = 36.25%					

4.10: Anova table for number of flowers per cluster

SV	df	SS	MS	F	P
Blocks	2	3.23	1.62	1.73	0.2261 ns
Lines(A)	5	229.48	45.90	49.16	0.0000 ***
Error(a)	10	9.34	0.93		
Pruning(B)	3	16.52	5.51	6.89	0.0002 ***
Pruning * line	15	17.72	1.18	1.48	0.1098 ns
Error(b)	396	316.57	0.80		
Total	431	592.86			
$R^2 = 0.47$					
CV = 21.64%					

4.11: Anova table of tomato fruit set

SV	df	SS	MS	F	P
Blocks	2	838.09	419.04	3.05	0.1218 ns
Lines(A)	5	38563.54	7712.71	40.23	0.0000 ***
Error(a)	6	823.86	137.31		
Pruning(B)	3	9691.75	3230.58	23.53	0.0010 **
Pruning * line	15	3764.61	250.97	1.31	0.1928 ns
Error(b)	400	76683.61	191.71		
Total	431	130365.46			
$R^2 = 0.41$					
CV = 57.79%					

4.12: Anova table for number of tomato fruits per ha

SV	df	SS	MS	F	P
Blocks	2	1.78	8.89	0.69	0.5218 ns
Lines(A)	5	1.49	2.97	23.24	0.0000 ***
Error(a)	10	1.28	1.28		
Pruning(B)	3	5.99	1.99	6.37	0.0014 **
Pruning * line	15	1.52	1.02	3.24	0.0019 **
Error(b)	36	1.13	3.13		
Total	71				
$R^2 = 0.94$					
CV = 29.42%					

4.3: Anova table for weight of a single fruit

SV	df	SS	MS	F	P
Blocks	2	55.16	27.58	0.04	0.9639 ns
Lines(A)	5	96715.19	19343.04	25.90	0.0000 ***
Error(a)	10	7467.45	746.75		
Pruning(B)	3	11975.54	3991.85	9.94	0.0001 ***
Pruning * line	15	7246.55	483.10	1.20	0.3135 ns
Error(b)	36	14456.29	401.56		
Total	71	1416.20			
$R^2 = 0.90$					
CV = 13.55%					

4.14: Anova table for weight in t of nom marketable per ha

SV	df	SS	MS	F	P
Blocks	2	31.22	15.61	1.02	0.3962 ns
Lines(A)	5	412.46	82.49	5.37	0.0117 *
Error(a)	10	153.49	15.35		
Pruning(B)	3	3.86	1.29	0.31	0.8170 ns
Pruning * line	15	133.65	8.91	2.15	0.0298 *
Error(b)	36	148.86	4.14		
Total	71	148.86			
$R^2 = 0.83$					
CV = 41.75%					

4.15: Anova table for number of marketable tomato per ha

SV	df	SS	MS	F	P
Blocks	2	1.57	7.85	0.95	0.4192 ns
Lines(A)	5	6.52	1.30	15.77	0.0002 ***
Error(a)	10	8.27	8.27		0.0034 **
Pruning(B)	3	2.57	8.58	5.46	0.0074 **
Pruning * line	15	6.35	4.24	2.70	
Error(b)	36	5.66	1.57		
Total	71	8.96			
$R^2 = 0.94$					
CV = 31.98%					

4.16: Anova table for number of non marketable tomato per ha

SV	df	SS	MS	F	P
Blocks	2	4.85	2.43	0.86	0.4504 ns
Lines(A)	5	2.06	4.12	14.68	0.0002 ***
Error(a)	10	2.81	2.81		
Pruning(B)	3	7.83	1.61	3.20	0.0348 *
Pruning * line	15	2.94	1.96	2.40	0.0159 *
Error(b)	36	2.94	8.17		
Total	71	3.06			
$R^2 = 0.90$					
CV = 43.05%					

4.17: Anova table for PIH

SV	df	SS	MS	F	P
Blocks	2	1.05	0.53	1.64	0.2425 ns
Lines(A)	5	17.09	3.42	10.63	0.0009 ***
Error(a)	10	3.22	0.32		
Pruning(B)	3	0.68	0.23	1.96	0.1367 ns
Pruning * line	15	2.09	0.14	1.21	0.3075 ns
Error(b)	36	4.14	0.12		
Total	71	28.29			
$R^2 = 0.85$					
CV= 8.24%					

4.18 Anova table for total soluble solids (TSS)

SV	df	SS	MS	F	P
Blocks	2	0.58	0.29	3.47	0.0717ns
Lines(A)	5	12.69	2.54	30.19	0.0000***
Error(a)	10	0.84	0.08		0.0879ns
Pruning(B)	3	2.28	0.76	2.36	0.1720ns
Pruning * line	15	7.08	0.47	1.46	
Error(b)	36	11.66	0.32		
Total	71	35.09			
$R^2 = 0.67$					
CV= 12.507646%					

4.19: Anova table for width of tamato fruit

SV	df	SS	MS	F	P
Blocks	2	0.63	0.32	0.59	0.5856 ns
Lines(A)	5	120.76	24.15	73.36	0.0000 ***
Error(a)	10	3.23	0.54		
Pruning(B)	3	19.69	6.56	12.19	0.0058 **
Pruning * line	15	8.15	0.54	1.65	0.0595 ns
Error(b)	328	107.98	0.33		
Total	359	260.44			
$R^2 = 0.59$					
CV = 9.06%					

4.20: Anova table for firmness

SV	df	SS	MS	F	P
Blocks	2	4.32	2.16	17.28	0.0032 **
Lines(A)	5	106.93	21.39	75.95	0.0000 ***
Error(a)	10	0.75	0.13		
Pruning(B)	3	0.86	0.28	2.30	0.1768 ns
Pruning * line	15	2.31	0.15	.55	0.9129 ns
Error(b)	328	92.36	0.28		
Total	359	207.53			
$R^2 = 0.55$					
CV = 14.62%					

4.21: Anova table for incidence of late blight

SV	df	SS	MS	F	P
Blocks	2	217.30	108.63	2.02	0.2139 ns
Lines(A)	5	2427.72	485.54	3.47	0.0107 *
Error(a)	10	323.27	53.88		
Pruning(B)	3	4533.29	1511.10	28.05	0.0006 ***
Pruning * line	15	756.13	50.41	0.36	0.9821 ns
Error(b)	40	5601.76	140.04		
Total	71	13859.46			
$R^2 = 0.60$					
CV = 66.45%					

4.22: Anova table for late blight severity

SV	df	SS	MS	F	P
Blocks	2	17.056	8.53	2.16	0.1971 ns
Lines(A)	5	125.11	25.02	3.81	0.0022 **
Error(a)	10	23.74	3.96		
Pruning(B)	3	332.31	110.77	27.99	0.0006 ***
Pruning * line	15	170.13	11.34	1.73	0.0434 *
Error(b)	400	2625.31	6.56		
Total	431	3293.67			
$R^2 = 0.20$					
CV = 89.54%					

4.23: Anova table of blossom end rot

SV	df	SS	MS	F	P
Blocks	2	0.28	.14	0.001	0.9986 ns
Lines(A)	5	476.25	95.25	0.93	0.4991 ns
Error(a)	10	1020.29	102.03		
Pruning(B)	3	411.30	137.10	2.69	0.0606 ns
Pruning * line	15	643.62	42.91	0.84	0.6276 ns
Error(b)	36	1833.48	50.93		
Total	71	4385.22			
$R^2 = 0.58$					
CV = 80.96%					

4.24: Anova table of the percentage of cracked tomato fruits

SV	df	SS	MS	F	P
Blocks	2	107.03	53.52	0.60	0.5654 ns
Lines(A)	5	3056.21	611.24	6.90	0.0049 **
Error(a)	10	886.03	88.60		
Pruning(B)	3	110.78	36.93	0.55	0.6503 ns
Pruning * line	15	358.74	23.92	0.35	0.9820 ns
Error(b)	36	2409.51	66.93		
Total	71	6928.32			
$R^2 = 0.65$					
CV = 55.1%					

4.25: Anova table for late blight incidence

SV	df	SS	MS	F	P
Blocks	2	217.30	108.65	2.017	0.2139 ns
Lines(A)	5	2427.72	485.54	3.47	0.0107 *
Error(a)	10	323.27	53.88		
Pruning(B)	3	4533.29	1511.10	28.05	0.0006 ***
Pruning * line	15	756.13	50.41	0.36	0.9821 ns
Error(b)		5601.76	140.04		
Total	71	13859.46			
R ² = 0.60					
CV = 66.45%					

4.26: Anova table for marketable fruits per kg

SV	df	SS	MS	F	P
Blocks	2	0.06	0.03	0.022	0.9782 ns
Lines(A)	5	219.36	43.87	24.40	
Error(a)	6	72.37	1.8		.0000 ***
Pruning(B)	3	26.78	8.93	6.397	.0268 *
Pruning * line	15	9.02	0.60	0.332	.9878 ns
Error(b)	40	8.37	1.40		
Total	71	335.96			
R ² = 0.78					
CV = 18.24					

4.27: Anova table for non marketable fruits per plant

SV	df	SS	MS	F	P
Blocks	2	8.56	4.28	0.86	0.4504 ns
Lines(A)	5	363.43	72.69	14.68	0.0002 ***
Error(a)	10	49.51	4.95		
Pruning(B)	3	13.82	4.61	3.20	0.0348 *
Pruning * line	15	51.82	3.45	2.40	0.0159 *
Error(b)	36	51.87	1.44		
Total	71	539.87			
R ² = 0.90					
CV = 43.05					

4.28: Anova table for marketable fruits per plant

SV	df	SS	MS	F	P
Blocks	2	27.69	13.84	0.94	.4192 ns
Lines(A)	5	1149.33	229.87	15.77	..0002 ***
Error(a)	10	145.80	14.58		
Pruning(B)	3	45.42	15.14	5.46	.0034 **
Pruning * line	15	112.10	7.47	2.70	.0074 **
Error(b)	36	99.78	2.77		
Total	71	1580.12			
$R^2 = 0.94$					
CV = 31.98					