EFFECT OF INTRA-ROW SPACING AND VARIETY ON FRUIT YIELD AND QUALITY OF FRESH MARKET TOMATO (*Lycopersicon esculentum* Mill.) UNDER JIMMA CONDITION

M.Sc. Thesis

Submitted to the School of Graduate Studies
Jimma University College of Agriculture and Veterinary Medicine

In Partial Fulfillment of the Requirements for the Degree of
Master of Science in Horticulture
(Vegetable Production)

By

Menberu Kitila

March, 2011

Jimma University

School of Graduate Studies
Jimma University

As Thesis Research advisors, we here by certify that we have read and evaluated this thesis prepared, under our guidance, by Menberu kitila, entitled "Effect of intra-row spacing and variety on fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.) under Jimma, condition." we recommend that it be submitted as fulfilling the thesis requirement.

Derbew Belew (PhD) _____________ _____________

Major advisor Signature Date

Ali Mohammed (PhD) _____________ _____________

Co-advisor Signature Date

As member of the Board of Examiners of the M.Sc Thesis Open Defense Examination, We certify that we have read and evaluated the thesis prepared by Menberu Kitila, and examined the candidate. We recommended that the thesis be accepted as fulfilling the thesis requirement for the Degree of Master of Science in Horticulture (Vegetable Science).

______________________ _____________ _____________

Chairman person Signature Date

______________________ _____________ _____________

Internal Examiner Signature Date

______________________ _____________ _____________

External Examiner Signature Date

.

DEDICATION

I dedicate this thesis manuscript to my wife Yemisrach Beyene, my daughter Lelise**,** and my son Nafiyad (Guche) Menberu for their cooperation and kind support.

.

STATEMENT OF AUTHOR

First, I declare that this thesis is my bona fide work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements of M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to users under rules of the Library. I seriously declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is for scholarly interest. In all other instances, however, permission must be obtained from the author.

Name: Menberu Kitila Daba Signature: ……………………

Place: Jimma University

Date of Submission: March, 2011

.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my Lord God for directing me with his true spirit all the time with success. I would like also to express my sincere gratitude to Jimma city administration for giving me chance to pursue my post graduate study, and JUCAVM for funding my research and other study expenses, and I would like to extend my heartfelt thanks to my major advisor Dr. Derbew Belew and co-adviser Dr. Ali Mohammed for their valuable advice, insight and guidance starting from proposal development to the completion of the research work and thesis write up. I keep recording my thanks to Mr.Yehenew Getachew for his helpful comment and guidance during statistical data analyses of this research result by devoting his precious time.

I would like also to thank Mr. Osman Rhameta for his hospitality, kind cooperation and immediate response on requested issues, commitment and dedication. I would like also to express my sincere gratitude to my wife Yemisrach Beyene, my daughter Lelise and my sons Yohannes and Nafiyad Menberu for their dedication and strong support throughout my study and typing the manuscript. I also extend special thanks to my brother Dr. Tamene Kitila, Mr. Seleshi Delelegne, Trualem Zerihun, and their family members, Daniel Alemu, Nazif Abachabsa, Yetnayet Abera, Dereje Ademe and Sintayehu Musie for their unreserved contribution for the successes of my study.

At last but not least, I would like to thank Melkassa Agricultural Research Center in general and Dr. Lemma Dessalegne in particular for their support in providing me with seed and references material.

BIOGRAPHICAL SKECH

The author, Menberu Kitila Daba was born in Haru District (West Wellega) of the Oromiya Regional State on 13th, February 1973. He attended his elementary and junior school education in the same district and later attended his High-school education at Ghimbi and Mettu Comprehensive High School. After completion of his high school education, he joined Jimma Agricultural College and completed two years Diploma program in General Agriculture. After graduation he was employed at Ministry of Agriculture and served the Organization for more than 13 years. He got an opportunity to join Jimma University College of Agriculture and Veterinary Medicine, for his BSc degree in Horticulture in continuing education program from 2002 to 2007. During his study and after completion of the under graduate degree, he served as head, Environmental Protection and Urban Agriculture Office of the Jimma city for four years and rejoined Jimma University College of Agriculture and Veterinary Medicine to attend his post graduate study in 2008.

TABLE OF CONTENTS

Tables **page**

Dedication ii

Statement of the author iv

Acknoledgement iv

Biographical sckech vi

List of tables ix

List of tabels in the appendices xi

List of abbreviations xii

Abstract xiii

1. INTRODUCTION 1

2. LITERATURE REVIEW 4

2.1 Importance of tomato fruit 4

2.2 Origin, Botany and Ecology of tomato crop 5

2. 3. Factors affecting tomato fruit yield and quality 6

2.3.1. Climatic conditions and cultural practices 6

2.3.2. Cultivars 8

2.3.3. Plant population 10

2.3.4. Disease incidence 10

2.3.5. Total soluble solids (TSS) 12

2.3.6. pH and titratable acidity 13

2.4. Research Achievements of Tomato in Ethiopia 13

3. MATERIALS AND METHODS 15

3.1 Description of the Experimental Site 15

3.2 Experimental materials 15

3.3 Experimental Design and Field Layout 15

3.4. Management of the Experiment 16

3.5. Data Collected 17

3.6. Statistical Analysis 20

4. RESULTS AND DISCUSSION 21

4.1 Growth Parameters 21

4.1.1. Number of primary branches per plant 21

4.1.2. Plant height 22

4.1.3. Days to 50% flowering 23

4.1.4. Flower number per cluster 25
4.1.5. Fruit set percentage 25
4.1.6. Days to first harvest 25
4.1.7. Stem and root dry matter contents 26

4.2. Yield Parameters 29
4.2.1. Fruit number per cluster 29
4.2.2. Fruit number per plant 30
4.2.3. Fruit length and diameter 31
4.2.4. Average fruit weight (g) 32
4.2.5. Fruit weight per plant 33
4.2.6. Number of seeds per fruit 33
4.2.7. Total fruit yield per hectare 34
4.2.8. Marketable yield per hectare 35
4.2.9. Unmarketable yield per hectare 37

4.3. Quality parameters 37
4.3.1 Fruit Dry matter contents 37
4.3.2. Fruit shape index 38
4.3.3. Fruit pericarp thickness 39
4.3.4. Total soluble solid (TSS) 41
4.3.5 Titratable Acidity 43
4.3.6 pH value 44

4.4 Disease reaction 44

4.5 Correlation coefficient 46

5. SUMMARY AND CONCLUSION 48

6. REFERENCES 50

7. APPENDICES 58

LIST OF TABLES

Tables **page**

1. Treatment combinations…………………………………………………………………..16

2. Description of the varieties used ……………………………………………………………16

3. Mean values of plant growth parameters as affected by the interaction between variety and intra-row spacing…………………………………………………….....22

4. Mean values of fruit yield parameters as affected by the interaction between variety and intra-row spacing……………………………………………………………..27

5. Mean values of fruit yield parameters as affected by the interaction between variety and intra-row spacing……………………………………………………………..29

6. Main effects of intra-row spacing on stem and root dry matter content……………….30

7. Main effects of variety on stem and root dry matter content……………………........36

8. Mean values of yield quality parameters as affected by the interaction between variety and intra-row spacing……………………………………………………38

9. Mean values of disease incidence as affected by the interaction between variety and intra-row spacing………………………………………………………………...45

LIST OF FIGURES

Figures Page

1. Main effects of intra-row spacing on days to 50% flowering……….. 23

2. Main effects of varieties on days to 50% flowering…………………..24

3. Main effects of variety on seed number per fruit……………………..33

4. Main effects of intra-row spacing on fruit pericarp thickness………...39

5. Main effects of variety on fruit pericap thickness…………………….40

6. Main effects of variety on TSS………………………………………..41

7. Main effects of variety on titrable acidity……………………………..43

8. Main effects of variety on pH…………………………………………44

LIST OF TABLES IN THE APPENDICES

Appendix Table **page**

Appendix Table 1 Mean squares for plant Growth parameters of fresh market tomato varieties…….. ……………………………………….58

Appendix Table 2 Mean squares for plant Growth parameters of fresh market tomato varieties…….. ……………………………………...58

Appendix Table 3 Mean squares for yield parameters of fresh market tomato varieties ……………………………………........59

Appendix Table 4 Mean squares for yield parameters of fresh market tomato varieties ……………………………………………59

Appendix Table 5 Mean squares for fruit quality parameters of fresh market tomato varieties……………………………………………60

Appendix Table 6 Mean squares for fruit quality parameters of fresh market tomato varieties……………………………………………60

Appendix Table 7 Mean squares for disease reaction of fresh market tomato varieties……………………………………………61

Appendix Table 8 Correlation Tables showed relationship between tested parameters……………………………………………61

LIST OF ABBREVIATIONS

USDA	United State Department of Agriculture
EARO	Ethiopian Agriculture and Research Organization
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
JUCAVM	Jimma University college of Agriculture and Veterinary Medicine
SAS	Statistical Analysis System
BPEDORS	Bureau of Planning and Economic Development of Oromia Regional State
MoARD	Ministry of Agriculture and Rural Development

Effect of intra-row Spacing and Variety on Yield and Yield Quality of Fresh Market Tomato (*Lycopersicon esculentum* Mill.) under Jimma condition

Abstract

*A field experiment was conducted at Jmma University College of Agriculture and veterinary medicine (JUCAVM) during 2009/2010 cropping seasons with the objective: to investigate the response of yield and yield quality of fresh market tomato varieties in different level of intra-row plant spacing. The treatment consisted of factorial combination of three released (Marglobe, Fetane ,Bishola) and one local varieties and four intra-row spacing (25cm,30cm,35cm and 40cm with 70 cm inter-row) using Randomized Complete Block Design in a factorial arrangement(4x4) with three replications. Growth, yield, fruit quality parameters and disease reaction were recorded and analyzed using SAS version 9.2 computer packages. As a result, Bishola planted at 30 and 35 cmx70 cm had higher marketable yield, higher dry matter and fruit shape index, as well as fruit pericarp thickness which can contribute to better shelf life of the product. This variety is also highly resistance to late blight disease. Similarly, Fetane performed well at plant spacing 35cmx70cm in producing higher marketable yield, total soluble solid, fruit dry matter contents and average fruit weight. Marketable fruit yield was very highly significant and strongly and positively correlated with fruit yield per plant (r=0.90***), fruit yield per hectare(r=0.99***), fruit diameter (r=0.83***), fruit length(r=0.86***) and fruit weight (r=0.82***). In general this clearly indicated that varieties have different behaviors as a response to intra-row plant spacing, with regard to marketable yield per hectare and fruit quality. From the finding of this study it could be concluded that appropriate plant spacing with variety selection could be practiced to increase the yield and quality of fresh market tomato production. Thus, to produce better fruit yield and quality tomato growers in the study area should be encouraged to use intra-row spacing 30 cm x 70 cm with the determinate type of Fetane and Bishola varieties, since these perform far better than the Marglobe and unimproved local tomato varieties. However, further researches are recommended with optimization of fertilizer and water requirement for the different varieties under different intra- and inter row plant spacing and different growing conditions and type of production (home stead, farmer and commercial) to understand their yield performance .*

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to the *Solanaceae* family and self crossing annual crop. This family also includes other well-known species, such as potato, tobacco, hot peppers and eggplant (aubergine). The center of origin of the world tomato is considered to be Andean zone, whereas it is considered that the tomato was domesticated in Mexico, and that the name of tomato was derived from the 'tomatil' in the Nahua tongue of Mexico. (Ara *et al*, 2007). Presently, the tomato is one of the vegetables with the highest production in the world and its production is increasing all over the world, primarily, in Asia. The production area in Europe, North and Latin America tends to stop increasing, or to decrease, but the production is sustained by the increase of yield per hectare, probably using high yielding varieties.

The importance of tomato as a vegetable crop is reflected in its large-scale cultivation in the world. Tomato is grown on about 4.5 million hectares worldwide, the largest producer being China with 32 million metric tons. India produces about 7.6 million metric tons of tomatoes from about 540,000 ha (Daniel, 2007). Now-a-days tomato is grown in most of the countries around the globe except the colder region It can be grown on a small scale in the kitchen garden, where a few plants yielding fruits for the whole family and a commercial scale as a cash crop by the vegetable growers (David ,2010).

In the tropics, tomato is mostly produced by transplanting. Good quality of seedling usually leads to higher yield and earlier maturity. Tomato that mature early not only could receive higher price on fresh market, but also could reduce the risk involved in growing tomatoes in the tropics (AVRDC-TOP, 1997).Tomato is among the most important vegetable crops in Ethiopia. Both fresh and processed tomato varieties are popular and economically important vegetable crops produced in the country (Geleta *et al*., 1995).

Lemma *et al.*, (2003) indicated that the total production of tomato in the country has shown a marked increase since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, the production and productivity of the crop in the country is influenced by different factors among which improper plant spacing is the notable reasons of low productivity of this crop

A number of improved varieties and other agronomic packages have been recommended to the users to overcome the low productivity and quality of tomato in the country. However, the average national yield still remains very low which is around 7 ton/ha (CSA, 2009) and less than 50% of the current world average yield of about 27 ton/ha (FAOSTAT, 2007). Increasing temperature, viral diseases and salinity are the major limiting factors in sustaining and increasing tomato productivity (Fikadu and Dandena, 2006). Lack of adaptive cultivars and poor fruit setting varieties is one of the challenging farmers are facing in tomato production even though there is potential land for cultivation.

According to Lemma, (2002) the national average of tomato fruit yield under farmers' conditions is very low compared to 25 and 40t /ha at demonstration and experimental research plots, respectively. Increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. The author further explained that plant spacing greatly influenced fruit yield in both fresh market and processing tomatoes. Mehla *et al*, (2000) also reported the importance of plant spacing on yield and quality parameters in tomato crop.

Yield variation in tomato may be occurred due to disease infestation, lack of improved variety and variation in cultural practices like plant population per given area. Plant spacing is the most important factor that affects yield and fruit quality of tomato. (Tesfaye, 2008)

According to the author in Ethiopia, so far plant spacing and fertilizer rates were determined for tomatoes only at Melkassa research center, in addition, such study was done in tomatoes under vertisol condition and the whole of such previous agronomic studies were confined only to sandy loam soils of the Rift Valley regions of the country. The author further expressed that, although tomato growers in the Rift Valley regions can directly use the recommendation from this research center, the same recommendation however, can not apply for the other tomato growing regions with completely different climate and soil condition.

In our country, farmers get lower yield mainly due to in appropriate agronomic practices and lack of improved variety. Improper plant spacing is among the notable reasons of low productivity of this crop. Plant spacing greatly influenced growth, yield, and quality parameters both in fresh market and processing tomatoes. Additionally, understanding the variability of varietal response to different plant spacing is crucial in improving the tomato fruit yield and quality.

Tomato is becoming an important homestead crop in small gardens and semi-commercial production under Jimma condition. However, there is no recommended optimum management practices including plant spacing determined and suitable variety identified. Therefore, the present study was undertaken with the following objectives:

1. To determine optimum plant population for better growth, fruit yield and quality of three released and one local tomato varieties.
2. To identify best performing variety under Jimma condition.
3. To determine the interaction effect between varieties and plant spacing.

.

2. LITERATURE REVIEW

2.1. Importance of tomato fruit

Tomato (*Lycopersicon esculentum* Mill), is cultivated both in backyard for home consumption and commercially for domestic and export market. It is one of the world's most popular vegetables. Cultivation of tomatoes improves diet of the people, as they are a part of every salad in combination with leaf vegetables, green onions, cucumbers, peppers, and other vegetables (AVRDC, 2005). As a processing crop, it ranks first among all vegetables grown throughout the world. It also possesses valuable medicinal properties, an excellent purifier of blood and a rich source of vitamins like vitamin A and C than any other vegetables.

It is an important cash-generating vegetable crop to small-scale growers and provides opportunities for employment in the production and processing plants (Lemma, 2003). Its production is more attractive than any other vegetable crops for its multiple harvests, which results in high profit per unit area of land. According to the author, tomato is the most profitable vegetable with net income of about 11,000 to 14,000 Birr per hectare. Both fresh and processing tomato varieties are popular and economically important vegetable crops produced in the country (Geleta *et al*., 1995).

Besides its importance for consumption, fruit acidity affects the industrialization processes by reducing of pH of the pulp and preventing the growth of microorganisms that are harmful to the conservation of the product (Frusciante *et al.,* 2000). Moreover, low pH decreases the period of heating needed for sterilization during processing. Total soluble solids contents (TSS) are important for the industrialization process as product yield is directly related to ºBrix, especially when the objective is dehydration, concentration of the pulp, or both. Lycopene, ascorbic acid (vitamin C), and potassium contents are important for the nutritional value of tomato; they have beneficial effects on human health.

Franceschi *et al.* (1994) and Frusciante *et al,* (2000) reported that the consumption of the tomato and its sub products (i.e., ketchup, paste) is negatively correlated with the development of tumours in the digestive tract and prostate cancer. Vitamin C plays an important role in human health and it is found in tomato fruits and vegetables in the form of ascorbic acid. Its main functions are in the prevention of scurvy and maintenance of skin and blood vessels (Lee and Kader, 2000).

Zvi Howard (2009) indicated that tomatoes contribute to a healthy, well-balanced diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibers. It contains much vitamin B and C, iron and phosphorus. Tomato fruits are consumed fresh in salads or cooked in sauces, soup and meat or fish dishes. They can be processed into purées, juices and ketchup. Canned and dried tomatoes are economically important processed products. According to author lycopene is a very powerful antioxidant which can help prevent the development of many forms of cancer. Cooked tomatoes and tomato products are the best source of lycopene since the lycopene is released from the tomato when cooked. A raw tomato has about 20% of the lycopene content found in cooked tomatoes. However, raw or cooked tomatoes are considered the best source for this antioxidant.

2.2 Origin, Botany and Ecology of tomato crop

Tomato (*Lycospersicon esculentum* Mill) is a member of the *Solanaceae* family and was first domesticated in the Central America as early as 700 B.C. Tomato plants are dicots, and grow as a series of branching stems, with a terminal bud at the tip that does the actual growing. When that tip eventually stops growing, whether because of pruning or flowering, lateral buds take over and grow into other, fully functional, vines. Tomato plant vines are typically pubescent (covered with fine short hairs). These hairs facilitate the vining process, turning into roots wherever the plant is in contact with the ground and moisture, especially if there is some issue with the vine's contact to its original root.

The leaves are 10–25 centimeters long, odd pinnate, with 5–9 leaflets on petioles, each leaflet up to 8 centimeters long, with a serrated margin; both the stem and leaves are densely glandular-hairy (David, 2010)

Tomatoes can be grown both in temperate and tropical zones. Its fruit is fleshy berry, globular to oblate in shape and 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. It is usually round, smooth or furrowed. Tomato fruits mature in about 25-30 days after fertilization (Giovabbibu, 2001).

According to the author maturity is correlated with increased fruit size, weight, specific gravity, total acidity, and hydrogen concentration. Time from transplant to first harvest is 70-75 days for cherry types, 75-80 days for the plum types and 80-90 for the large fruited type tomatoes. The ripening phase of tomato fruit is also characterized by fruit softening, coloring, and sweetening.

MoARD (2009) reported that in Ethiopia, tomato is produced in altitudes between 700 and 2000, which is characterized as warm and dry day and cooler night, are favorable for optimum growth and development of tomatoes. A temperature range between 21 to 27^0C day and 10 to 20^0C night is favorable for plant development, and fruit set in the country. It grows better at a constant day and night temperature. A difference of 6^0C between day and night temperatures was found sufficient for good plant growth and development. Fruit setting is poor when the temperature is either high or low. Extreme temperatures cause flower drops and poor fruit set.

2.3. Factors affecting tomato fruit yield and quality

2.3.1. Climatic conditions and cultural practices

Climate is a primary determinant of agricultural productivity and as such, it influences the types of vegetation that can grow in a given location. It is now well recognized that tomato production is very sensitive to climate change. The study of climate change impact shows that there is a general reduction in potential of tomato yields and quality in many parts of the developing world (McCarthy *et al.,* 2001).

Ziska (2003) indicated that changes in climatic factors such as temperature, solar radiation and precipitation influenced tomato production. The location of production, the season in which plants are grown and cultural practices can determine tomato fruit quality like, ascorbic acid, carotene, riboflavin, thiamine, and flavonoid contents.

Hewitt *et al.* (2006) revealed that the lower the light intensity; the lower the ascorbic acid content of plant tissues. The duration, intensity and quality of light also affect the quality of tomato at harvest. According to Hewitt *et al.* (2006), fruit growth and transpiration rates greatly varied during daylight hours, which could be enhanced under high vapour pressure deficit conditions. As a result, a significant reduction in fruit weight and fruit water content and an increase in soluble solids were observed, an increase in environmental vapour pressure, therefore, can affect not only growth but also quality of tomato fruits.

Management of harvesting operations, whether manual or mechanical, can have a major impact on the quality and shelf life of perishable fruits and vegetables like tomato (FAO, 2004). The method of harvesting (hand vs. mechanical) and plant density per unit area can also significantly affect the composition and post-harvest quality of fruits and vegetables. Mechanical injuries (such as bruising, surface abrasions and cuts) can accelerate loss of water and quality resulting in increased susceptibility to decay-causing pathogens (Lee and Kader, 2000). Susceptibility to mechanical injuries can also be affected by stage of fruit ripeness and cultivars.

A limitation to marketing of tomatoes is the time that green fruit remain in an unripe condition and/or the time that ripe fruit remain in an acceptable condition for consumers. Stage of maturity and ripeness varies from cultivar to cultivar and growing type (determinate or indeterminate) in tomato and other horticultural crops (Arias *et al*., 2000).

The percentage of the solid component in fruits varies for a number of reasons including variety and cultural practices (Gould, 1992). Good land preparation (ploughing, leveling, harrowing etc.) is important for better seedling establishment and field management especially for even distribution of irrigation water in the field. Early and timely ploughing is necessary to expose the soil to solar treatments that are useful to reduce diseases and insect pest incidence. Tomato can be grown throughout the year provided diseases control measures and irrigation water are available. It has been demonstrated that rain free, clean dry worm conditions and moderately uniform temperatures are favorable for high fruit set, clean fruits, less diseases incidence and for high quality fruit production. However, heavy rainfall is detrimental to the plant and can result in poor fruit set and low fruit yield and quality.

One of the management practices that greatly influences tomato fruit yield is plant population and spacing. The distance between rows and between plants depends on the methods and purpose of production, soil fertility, plant structure and vine types, the farm equipment and the method of production intended to use. Tomato cultivars are spaced 70 cm between rows and 30 cm between plants. Generally plant spacing of 100-120 cm between rows and a 10-30 cm between plants with either single or double rows could be used. Plant population per hectare is estimated to be 42,000-100, 000 (MoARD, 2009).

2.3.2. Cultivars

Tomato is an herbaceous plant. It is self pollinated, but occasionally out crossing occurs under high temperatures of above 35 and 20 day and night, respectively, due to exertion of the stigma beyond the anther cone of the male floral part. Apparently, there are diverse tomato species and genotypes that are tolerant to biotic (diseases and insect pests) and abiotic stresses (heat, salinity, moisture stress) that have potential to improve the commercial tomatoes for different growing regions and production purposes (MoARD, 2009).

According to MoARD (2009) the plants differ in fruit characteristics (size, shape, color, flesh thickness, number of locules, blossom end shape, quality (TSS%, pH, acidity, juice viscosity, and juice volume). The fruits may be globe-shaped almost round, oval or flattened and pear shaped. They differ in skin and flesh colour in that the red ones are the most preferred in the local market. High TSS% (4.5-6.0), intensive red color of both skin and flesh, low acid, resistant to cracking are some of the attributes important for processing industry; the sugar and acid ratio makes an important contribution to the flavor of tomatoes.

Yield and quality can be affected by different factors such as cultivars, growing condition, and ripening on or off the vine. Tomato fruits are usually harvested at the mature green stage ripened off the vine during the transit to the final marketing place. There is a general belief that tomatoes ripened on the vine have better quality, mainly in terms of flavor, increasing the price of this commodity (Ramatu, 2006).

As regards to cultivar, the greatest need is to produce new fruit genotypes with better quality. Flavor quality factors include sweetness, sourness or acidity, stringency and aroma or odor. The relative importance of each of these factors and there inter actions depends upon the cultivar and cultural practices (Arias *et al.,* 2000). Cultivar selection is one of the most important decisions made during the crop production process (FAO, 2004). Selection of cultivars adapted to the local growing conditions and seed quality are significant production factors which deserve careful planning and consideration. Which variety to choose depends, on local conditions, growing purpose and management practices.

Lee and Kader (2000) pointed out that variety selection criteria are based on characteristics such as type of fruit, shape of plant, vitality and resistance to pests and diseases, but also on factors related to climate and management condition. According to these authors, plant breeders have been successful in selecting tomato cultivars with comparably high carotenoid levels and vitamin A content, cultivars that maintain their sweetness longer after harvest; cultivars with higher sugar content and firmer flesh, and cultivars with higher contents of ascorbic acid, sugars and yield.

Hewitt *et al.* (2006) stated that a great deal of plant breeding has been done to provide a wide range of varieties with different quality attributes. This can be seen in the wide range of commercial fruit and vegetable varieties available to growers for planting.

Varieties vary in terms of fruit shape, size, colour, productivity level, dry matter and taste attribute, as well as the ripening time, rate and post harvest longevity.

2.3.3. Plant population

Spacing between plants and within rows may vary with variety, type and fertility of the soil, and purpose of production. Optimum spacing forms fast canopy cover of the ground, allowing efficient utilization of all the available area in the shortest possible time when compared with other spacing. If plants are growing too close together they compete with one another for light, water, minerals and air. Spacing requirement of tomato depends on soil type, its inherent fertility and the type of cultivars (Lemma, 2001).

Hewitt *et al.* (2006) indicated that environmental conditions such as light intensity and duration, temperature, water availability and nutrition affect fruit quality at different management practices. Different varieties, however, respond relatively similarly to changes in these conditions. Providing optimum conditions for cropping like plant population, timing of harvest, storage conditions, post harvest and marketing methods are important in determining final product quality at the consumer level.

Frost and Kretchman (1998) reported that yield per unit area increased with plant population to a certain point, beyond which further population increase cause yield reduction in tomato. For successful production of mechanically harvested fresh market tomatoes, high yield, concentrated maturity and earliness are essential. Plant spacing has a large influence on tomato plant growth, yield and fruit maturity. The authors further described that, increasing plant population has been shown to reduce overall plant vigour, enhance earliness and yield concentration, and often results in increased early and total marketable yield per unit area.

2.3.4. Disease incidence

Disease is one of the major constraints affecting tomato production at different plant growth stages and at post harvest. Diseases reduce yield and causes complete loss of the crop in the field. Climatic conditions such as temperature and moisture especially high relative humidity, less sunshine, high night temperature increases the disease incidence

Foliage density increases due to higher plant populations or less equidistant plant arrangements, fruit quality may decrease due to a higher incidence of diseases or insects (Stoffella *et al.,* 1998). This may be attributed, in part, to higher relative humidity and inadequate pesticide coverage in a dense plant canopy. Bacterial diseases caused by *Pseudomanas syringae* pv. *tomato* (Okabe) Young, Dye and Wilkie (bacterial speck) and *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye (bacterial spot) can cause serious losses in tomato yield and quality (Cuppels and Elmhirst, 1999; Cuppels and Ainsworth, 2001). Little is known about the effects that row arrangements and plant density have on the incidence and severity of bacterial diseases.

Blossom-end rot is a physiological disorder of the fruit associated with calcium deficiency and drought stress, and other stress factors (Mehla, *et al*., 2000). A relationship between the incidence of blossom-end rot and plant population density or row arrangement, however, has not been established.

Early blight is worldwide tomato disease caused by *Alternaria solani.* The leaves, stems and fruit on the vine may be affected. Symptoms on leaves are most likely to appear on the older foliage. Small dark spots enlarge into circular lesions consisting of concentric rings. The tissue surrounding the lesions becomes yellow and the spots later become irregular in shape. The leaf becomes yellow as greater parts of the tissue are affected. The lesions turn brown and eventually drop from the plant. Defoliation occurs under prolonged periods of leaf wetness and high temperatures; exposed fruit become susceptible to sunburn damage. Extended periods of leaf wetness on plants and dense plant populations facilitate the incidence of the disease (AVRDC, 2005).

Recommendations for both blights are to use healthy seed and resistant varieties, to destroy harvest residues and plant seedlings with great distance between plants and rows to reduce humidity. Fungicides should be used as prevention; examples of effective fungicides are Mancozeb, Clorotalonil and Maneb, there are also systemic fungicides like Metalaxyl (Cuppels and Ainsworth, 2001).

The most common disease in tomato production fields are septoria leaf spot (*Septoria lycopersici*), late blight (*Phytophtra infestant)*, early blight (*Alternaria solani)*, powdery mildew (*Leveillula taurica*) and viruses as well as rootknote nematodes especially *Melidogene cognita* which is the dominant species in Rift Valley. Control measures will be taken at the right stage (MoARD, 2009).

2.3.5. Total soluble solids (TSS)

Fruit total solids, consisting of the water-soluble solids and insoluble solids, have important economic value for tomato processing industry. An increase in TSS content increases yield and decreases the cost of dehydration Tomatoes usually contain 7-8% of total solid (Young *et al.,* 1993). According to the authors the water-soluble portion of the fruit dry matter, glucose and fructose are estimated to be 25 and 22%, respectively. The dry matter of tomato consists of about 9% citrate, 4% malate and dicarboxylic amino acids and lipids 2% and 25% each, and 8% minerals. Soluble sugars (mainly fructose and glucose) and organic acids (citric acid, malic acid, etc.) are major components of the soluble solids. These components and their interaction are important for fruit quality and for processed concentrate as they affect sweetness, sourness and flavor intensity.

Young *et al.* (1993) further reported that a decrease in the percent dry matter of two tomato genotypes throughout maturation of the fruits due to respiration and a dilution effect resulting from fruit water uptake. The rate of assimilate export from leaves; rate of import by fruits and the fruit carbon metabolism are the factors that may also influence the solid content of tomato.

Both total solids and total soluble solid decreased as colour increased in a typical cultivar and the soluble solids content of some tomato lines increased as fruits ripen (Salunkhe *et al*., 1991). The author further stated the existence of the greatest differences between varieties of tomato in the concentration of the components measured at ripe stage and reported that the best stage to select varieties for TSS would be at red-ripe.

2.3.6. pH and titratable acidity

The quality characteristics of tomato are also determined by the pH at harvest. It is the most important factor accounting for flavor. The harvesting of tomatoes before they are ripe has an effect, not only on the peak sugar content, but also on the development of the full flavor spectrum, thus affecting consumer acceptability. Moreover, pH and sometimes- titratable acidity are known to be less favorable in fully ripe fruit (Davies and Hobson, 1981). The authors showed that pH was highly correlated with H^+ and TA with citric acid and malic acid, while the correlation between pH and TA was very low in some cases, although the pH of mature tomatoes may exceed 4.6. Tomato products are generally classified as acid foods (pH $<$ 4.6.). Nevertheless, pH 4.4 is suggested as the maximum desirable to avoid potential spoilage caused by thermophilic organisms (Monti, 1990).

2.4. Research achievements of tomato in Ethiopia

In Ethiopia, extensive research has been undertaken on the economically important vegetables that includes tomatoes, onion and *capsicum*. Over years of research, about six determinate and indeterminate fresh market and processing type tomatoes that fit to the different production practices have been released. Recently short set cultivars (Bishola and Fetane) that are about 25-30% high in fruit yield and quality and tall set cultivars (Eshet and Metadel) that are about 20-28% superior in fruit yield and quality to the currently produced commercial cultivars were released (Lemma, 2002).

Two different types of tomato plants can be distinguished: determinate (bush) type and indeterminate (tall) type. The tall and bush types are entirely different kinds of crops. Tall set varieties are the most commonly produced in the country. They are produced with plant support, Such practice is commonly used to improves the marketable yield and quality of fruits, produce clean and healthy fruit and improve in the field management and harvesting operations that, such tall varieties have extended harvest and better yield than short set cultivars are adaptable to small-scale intensive production system. This type of varieties are widely grown both in homestead and commercial farms in most production belts, in Upper Awash and the lake Zewai region (Lemma *et al.,* 2003). According to the authors, in the last few years, seven advanced tall set cultivars were compared with the standard check, Marglobe at Melkassa (Upper Awash), Zewai (Lake region) and Werer (Middle Awash) Agricultural Research Centers (2001-2004) to identify superior cultivars for the different tomato production belts.

Lemma *et al.* (2003) further explained that recently at Melkassa, row spacing of 80, 100, 120, 130 and 140 cm and plant spacing of 10, 20, 30 cm with population range of 21000 to 1000,000 were investigated with Marglobe and Heint 1350, in both cultivars yields were directly correlated with total number of fruit. Apparent in yield difference between cultivars, although they are different in growth habit, plant spacing of 100 to 120 cm between rows and 10 to 30 cm between plants (42000 to 100000 plants/ha) could be used. Short and tall set cultivars without support and applying low input; do not bring much yield difference.

A field experiment was conducted on vertisol at Ambo (Ethiopia) during 2003/2004 and 2004/2005 cropping seasons to investigate the response of tomato cultivars varying in growth habit to rates of Nitrogen (N) and Phosphorus (P) fertilizers and plant spacing, using two cultivars (Margelobe and Melka shola) (Tesfaye, 2008). According to the author the results revealed that fertilizer rates and spacing significantly affected the total and marketable fruit yields as well as % marketable fruit yield. Similarly, plant vigor (plant height), number of fruits per cluster and 10 fruit weight were significantly influenced by all of the main factors. Besides the main factors effect, fertilizer rate by spacing and cultivar by spacing interaction effects were also observed on % marketable fruit yield and 10 fruit weight, respectively. Closer plant spacing of 30 x 80 cm, and 45 x 60 cm gave higher total as well as marketable fruit yield than the wider spacing of 30 x 100 cm.

.

3. MATERIALS AND METHODS

3.1 Description of the Experimental Site

The Experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine research field in 2010. The site is situated at about 350 km to the South West of Addis Ababa. The college site is located at 7, ^{0} 39^{0}N latitude and 36, ^{0} 57^{0}E longitude at an altitude of 1710 meters above sea level. The mean maximum and minimum temperature is 26.8^{0}C and 11.4^{0}C respectively. The mean maximum and minimum relative humidity are 91.4%and 31.2%, respectively. The annual rain fall of the area is 1500 mm. The soil of experimental site is well drained clay to silt clay with pH of 5.5 (BPEDORS, 2000).

3.2 Experimental materials

The experiment consisted of 4 varieties, two determinate (Fetane and Bishola), two indeterminate (Marglobe and local land race) and 4 intra-rows spacing (25, 30, 35 and 40 cm) with 70 cm inter-rows for all levels of spacing.

3.3 Experimental Design and Field Layout

The experiment was laid out in 4 x 4 factorial arrangements of 16 treatments combinations using randomized complete block design (RCBD) with three replications. The size of each experimental plot was 7 m^2 (3.5 m wide and 2 m long). Treatments were randomly assigned to the experimental plots (Table 1).

Marglobe, Fetane and Bishola were released and collected from Melkassa Agricultural research center (Table 2), while the local variety was collected from "*Buture Gabisa*" peasant association (Mana district) of the Jimma zone.

.

Table 1.Treatment combinations

Treatments	Description	Treatments	Description
1	V1 x S1	9	V3 x S1
2	V1 x S2	10	V3 x S2
3	V1 x S3	11	V3 x S3
4	V1 x S4	12	V3 x S4
5	V2 x S1	13	V4 x S1
6	V2 x S2	14	V4 x S2
7	V2 x S3	15	V4 x S3
8	V2 x S4	16	V4 x S4

Where; V1=Marglobe; V2= Fetane; V3= Bishola; V4= Local. V= Variety. S1= 25 cm; S2= 30 cm; S3= 35 cm and S4= 40 cm. S= spacing

Table 2 Description of the released varieties

Cultivars	Year of release	Altitude (m)	Growth habit	Fruit shape	Fruit size (g)	Maturity (days)	Research yield t/ha
Marglobe	1976	700-2000	tall	Round	-	100-110	32.00
Fetane	2005	”	Short	Cylinderical	110-120	75-80	45.4
Bishola	2005	”	Short	Slightly cylindrical	140-150	85-90	34.0

Source: MoARD, 2009

3.4. Management of the Experiment

The seeds of each tomato variety were sown in rows of 15 cm on well prepared seedbed of 1x10 m on November 11, 2009. The seeds were covered with light soil and mulching grasses until emergence to protect seeds from washing away during watering

The beds were watered with watering can followed by surface irrigation to individual plant , the seedlings were thinned at 3 cm spacing within rows at first true leaf stage to maintain optimum plant population. Proper management (weeding, watering) practices were followed to produce healthy and vigorous seedlings.

Land preparation (ploughing, leveling, harrowing etc.) was practiced in advance for better seedling establishment and to expose the soil to solar treatments that could be useful to reduce diseases and insect pest incidence. Seedlings were hardened before transplanting to the field to enable them withstand the field conditions.

Healthy and uniform seedlings having a pencil size from all varieties were transplanted at the age of 30 days after sowing following the treatment and spacing assigned (MoARD, 2009). The seedlings were watered after transplanting and shade was provided to each seedling for ten days to protect from direct sunlight.

The inorganic fertilizers, diammonium phosphate (DAP) and urea were applied to each plot at the rate of 92 kg/ha P_2O_5 and 96 kg/ha N, respectively. The whole amount of phosphate fertilizer was applied at transplanting whereas nitrogen was given at two equal splits (half at transplanting and the rest half 30 days after transplanting) as basal application (EARO, 2004).

Plots were irrigated every other day, and then at three days intervals. Recommended fungicides (Ridomil + MZ, 63%-3.5 kg/ha) were sprayed at seven to ten days from transplanting to 20 days before first harvest to control leaf disease (both early and late blight) (Lemma, 2003).

Different intercultural operations (weeding, cultivation, watering, staking, chemical spray etc.), were applied as required to the experimental plots for better growth and development of the plants.

3.5. Data Collected

The following traits were recorded from nine randomly selected plants in each plot.

Number of primary branches per plant: The actual number of primary branches on the stem was recorded at 100% flowering from nine randomly selected sample plants of each plot.

Plant height: Mean height of nine sampled plants was measured using a meter tape from ground level to the tip of matured leaf at 100% flowering and expressed in cm.

Number of flower per cluster: Mean number of flowers per cluster of sampled plants was considered, in that flowers per cluster were counted from lower, middle and upper flower clusters from nine sampled plants.

Days to first harvest: The number of days from transplanting to first picking of fruits from the sample plants.

Fruiting set percentage: The number of flowers that are converted in to fruits were recorded and expressed in percentage.

Days to flowering: The number of days from transplanting to date of 50% of plants flowering was recorded from each plot.

Dry matter content (%): The average dry matter content of the fruit, shoot and root of nine sampled plants was recorded. It was determined by drying stem, root and fruit in oven at 104^0C until a constant weight was reached.

Number of fruits per cluster: Mean of fruits per cluster of sampled plants. Those plants selected for flower counting were used for counting of fruits per cluster.

Number of fruits per plant: Mean number of fruits harvested from nine sampled plants.

Mean fruit length and diameter (mm). Mean length and diameter of twenty randomly selected fruits from nine sampled plants and measured using a vernier caliper.

Average fruit weight (g) The average weight of randomly selected twenty fruits from sampled plant.

Fruit weight per plant (kg): Mean weight of twenty fruits of sample plants.

Number of seeds per fruit: Mean number of seeds was recorded from 20 sampled fruits in each plot.

Fruit yield per hectare (t): The total fruit yields obtained from the net plot was measured in kg and converted into tone per hectare.

Marketable and unmarketable fruit yield per hectare: Fruits from nine sampled plants were categorized at each harvest time as marketable and unmarketable fruits, based on the demand parameters described by MoARD for fresh market type tomatoes. Round, large, free from defects, good flavor and attractive red-colored fruits are demanded characteristics for use, fruits should also be firm, healthy, evenly colored, good appearance and good keeping quality.

The tomato fruits currently produced differ in size from small cherry types (20 g) to extra large of beefsteak (180 g). The fruits can be categorized as small (<50 g), medium (50 - 100 g), big (101-170 g) and very big (> 170 g) sized. The two size extremes have low acceptance in the market (MoARD, 2009). Fruits damaged by insect, birds, diseases and with cracks and sunburn as well as extra small sized or under sized fruits were considered as unmarketable while, those, fruits free from any damage and in the standard range indicated above, were considered as marketable fruit.

Fruit shape index: The ratio of twenty randomly selected fruit from nine sampled plant, fruit length to the horizontal diameter provided the values for fruit shape index.

Fruit pericarp thickness (mm): The pericarp thicknesses of twenty selected fruits from nine sampled plants were measured using caliper and the values was expressed in mm.

Total soluble solids (%): It was determined by refractrometer (Model Misco$^{@}$) by placing one to two drops of tomato juice (extracted from 20 fruits using a juice extractor (6001x Model No.31JE35 6x.00777) on the prism. Between samples the prism of the refractrometer was washed with distilled water and dried before use (Waskar *et al.,* 1999).

Titratable acidity (%): An aliquot of tomato juice was extracted from twenty selected tomatoes fruit of nine sampled plants with a Kenwood juice extractor (6001x model No.31JE35 6x.00777). The decanted clear juice was used for the analysis. The titratable acidity expressed as percentage citric acid, was obtained by titrating 10 ml of tomato juice to pH 8.2 with, 0.1N NaOH (Nunes and Emond, 1999).

pH: An extract of an aliquot of juice was prepared according to Nunes and Emond ,(1999). The aliquot of juice is first filtered with cheesecloth and the pH value of tomato juice was measured with a pH meter.

Disease and insect pest incidence: The type and percentage disease and insect pest incidence were recorded from each experimental plot and expressed in percentage.

3.6. Statistical Analysis

The mean values of all the above parameters were subjected to the analysis of variance (ANOVA) using SAS statistical package (SAS, 2002 version 9.2). Least Significant Difference (LSD) procedure was used to determine differences between treatment means whenever the treatment effects were significantly different. Simple linear correlation was applied to establish relationship between different parameters.

.

4. RESULTS AND DISCUSSION

Data on growth, yield, selected quality parameters, and reaction to disease were recorded during the study period. Significant differences between varieties, spacing and their interactions were observed for most of the parameters tested. The results of the experiment are presented and discussed as follows.

4.1 Growth Parameters

4.1.1 Number of primary branches per plant

A very highly significant ($p<0.001$) interaction effect of variety with intra-row spacing was observed for number of primary branches per plant (Table 3 and Appendix Table 1). Fetane and Bishola planted at all tested spacings gave the highest branch number per plant. The branch number obtained under the combination of these factors was statistically similar and varied from 7.06 to 7.73 branches per plant for both varieties whereas the least branch number (5.78 and 5.80) was obtained from local variety planted at intra-row spacing of 25 and 30 cm, respectively. The maximum branch number per plant for determinate type varieties could be due to variation in genetic behavior of the varieties.

For short set type Fetane and Bishola 30 cm and for tall set Marglobe and local varieties 40 cm intra-row plant spacing could be recommended for better branch number per plant. This result is in agreement with Khushk *et al.* (1990) who reported that increase in planting density resulted in reduction in number of leaves of tall setting tomato plant. When intra-row spacing increases, the number of plants per unit area becomes less. More mineral nutrients, light, moisture and space become available for the vegetative growth to increase the efficiency of photosynthesis than in dense plantation. Muhammad (2002) demonstrated increased number of branches per plant in determinate type tomato plants than indeterminate type, which is in agreement with the results of the present study. Similarly, Tesfu and Charlesp (2010) also reported decreased number of branches of carrot as a result of increased planting density.

Table 3. Mean branch number, plant height, flower number per cluster, days to first harvest, and fruit set percentage as affected by the interaction effect of variety and intra-row spacing

Varieties x Intra-row spacing (cm)	Branch No/plant (No)	Plant height (m)	Flower No/cluster	Fruit set percentage	Days to first harvest
V1x S1	6.10 fg	1.52cd	4.36 de	90.33 i	91.00 g
V1 x S2	6.23 f	1.54 bc	4.33 e	92.66 fg	92.66 f
V1 x S3	6.40 ef	1.58ab	4.63 d	93.66 fg	95.00 c
V1 x S4	6.66 e	1.58ab	4.33e	93.66 fg	96.33 b
V2 x S1	7.06ab	0.91 h	5.23 bc	94.33 eg	76.33 m
V2 x S2	7.50a	0.92 h	5.66a	95.66 de	77.66 l
V2 x S3	7.50a	0.90 h	5.75a	96.33 cd	79.00 k
V2 x S4	7.73a	0.94 gh	5.70a	97.33 cd	80.33 j
V3 x S1	7.06 ab	0.98 g	5.06c	97.33 cd	85.66 i
V3 x S2	7.40ab	0.97 g	5.26 bc	97.66 bc	86.00 i
V3 x S3	7.46a	0.98 g	5.31 bc	99.33 ab	85.66 i
V3 x S4	7.60a	1.03 fg	5.48ab	100.00a	88.00 h
V4 x S1	5.76 g	1.45 e	3.63 f	85.66 j	93.33 e
V4 x S2	5.80 g	1.48 de	4.20de	90.66 hi	94.33 d
V4 x S3	6.73 de	1.57 b	4.40de	92.33 gh	96.00 b
V4 x S4	7.03 cd	1.62a	4.55de	93.66 fg	97.66a
LSD(0.05)	0.33	0.043	0.28	1.86	0.65
CV(%)	2.16	2.10	3.56	0.88	0.77

Mean within the same column followed by a common letter are not significantly different, V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25cm, S2=30cm, S3= 35cm, S4= 40cm

4.1.2. Plant height

A very highly significant ($p<0.001$) interaction effect of variety with intra-row spacing was observed for plant height (Table 3 and Appendix Table 1). The maximum height was recorded from Marglobe at 35 and 40cm and local variety at 40cm. The results of this experiment indicated that the combination of varieties and wider intra-row spacing resulted in maximum plant height for both indeterminate type varieties, while the short set varieties Fetane and Bishola gave the highest plant height under all spacings. From this result it could be concluded that for those indeterminate type tomato Marglobe and Local varieties, wider plant spacing 35 and 40 cm intra-row spacing and for determinate type Fetane and Bishola closer spacing of 30 cm known to be resulted in better plant height. The difference in plant height is high between varieties but not much difference between spacing of each variety. This could be due to maximum competition of plants for nutrient; light and air for those tall set varieties and variation in genetic make up for all varieties. Various studies (Abdalla, 2003; El Naim, 2003; Nile, 2003) revealed differences between cultivars in plant height under different levels of plant spacing.

Rawshan (1996) and Yohannes and Tadesse (1997) reported that spacing between plants did not show any significant differences in tomato plant height, which is in disagreement with this finding.

4.1.3. Days to 50% flowering

The analysis of variance for the main effect of intra-row spacing showed very highly significant ($p < 0.001$) difference on days to 50% flowering (Figure 1 and Appendix Table 1).

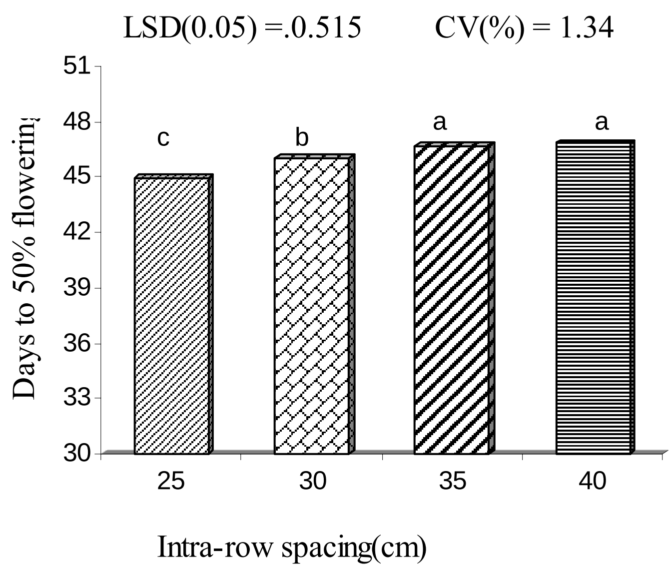

Fig. 1. Main effect of intra-row spacing on days to 50% flowering

Intra-row spacing showed very highly significant ($p < 0.001$) difference on days to 50% flowering. Accordingly, plant grown at 25 cm intra-row spacing reached to 50%

flowering date within a short period of time (45 days). The result of this experiment indicated that the shortest days to reach 50% flowering were recorded at closer intra-row spacing (25 cm). Densely populated plants reduced the number of days required to reach fifty percent flowering by only about two days compared to sparsely grown plants. In line with this, El-Naim (2003) confirmed that closer spacing could reduce vegetative growth and enhance flower formation. Similarly, Nile (2002) observed differences among cultivars in time to 50% flowering and maturity.

Varieties showed a very highly significant ($p<0.001$) effect on days to 50% flowering (Figure 2 and Appendix Table 1). The minimum number of days to achieve fifty percent flowering was recorded from Fetane cultivar (42), followed by Bishola (44 days). Local varieties were achieved 50% flowering at the longest days (52), which was greater by about ten days compared to Fetane variety.

The superiority in maturity of two determinate cultivars (Fetane and Bishola) could be due to the genetic variation in maturation period of the varieties. Therefore, growing of determinate type tomato than indeterminate type for fresh market can reduces cost of production which could be minimized due to short period of harvesting time.

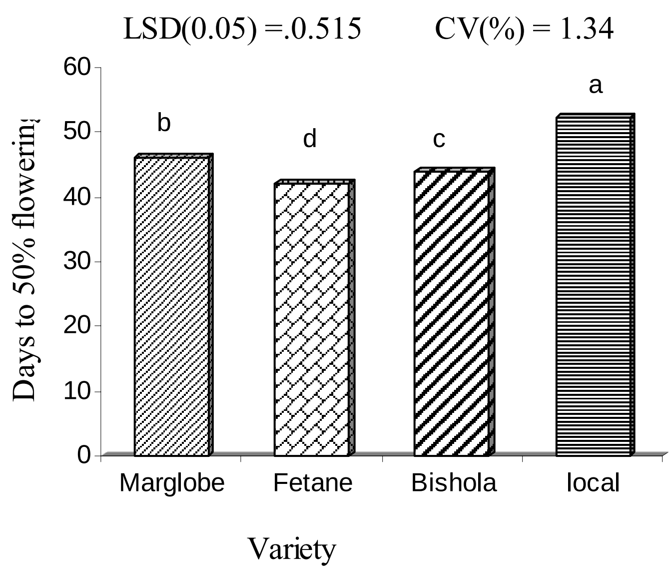

Fig. 2. Main effect of varieties on days to 50% flowering

4.1.4. Flower number per cluster

Interaction effect of variety with intra-row spacing showed a very highly significant ($p<0.001$) difference on number of flowers per cluster (Table 3 and Appendix Table 1).The short set varieties, Fetane and Bishola had the highest flower number per cluster at all spacings. Both tall set varieties Marglobe and local recorded almost similar value at all spacing except for 25 cm for local one. This result revealed that increasing plant spacing more than 30 cm for both determinate and indeterminate type varieties did not add any value to the flower number per plant

4.1.5. Fruit set percentage

A very highly significant ($p<0.001$) interaction effect of variety with spacing was observed for fruit set percentage (Table 3 and Appendix Table 2). Bishola varieties planted at intra-row spacing 35 and 40 cm gave the highest value for fruit set percentage compared to all tested varieties; however, all varieties produced high fruit set at wider plant spacing. This could be due to lack of competition under wider spacing for plant nutrient and uniform aeration movement within the canopy of the plant.

4.1.6. Days to first harvest

Days to first harvest significantly affected ($p\leq0.01$) by plant spacing and varieties. Fetane planted at intra-row spacing of 25 cm attained early maturation period. However, there was a little variation of days among the spacing used for these varieties; plants from closer spacing (25 cm) reached the first harvest earlier than wider spacing. This study clearly indicated that Fetane planted at closer intra-row spacing, took the shortest period to achieve early fruit maturity.

Indeterminate type local variety, planted at wider spacing, reached to maturity latter (96 days) than others. The early maturity of Fetane at closer spacing could be due to maximum plant competition to nutrition, air and other growth factors, there by reduced vegetative growth of plants which in turn enhanced flower formation early.

The late maturity of lower plant population could be due to genetic variation of tall types tomato crop. These results were in line with the findings of Tesfu *et al*. (2010) who revealed that increasing planting density appeared to shorten days to maturity, plants at high density were observed to mature few days earlier than plants at low planting density. The finding also agrees with the reports of George (1999), who suggested that higher plant densities could shorten the overall flowering period and increased the evenness in umbel ripening. This may be due to the fact that higher plant densities considerably reduce the development of higher order umbels, letting a concentration of umbels to be produced in the upper part of individual plant stalk.

Moraru *et al.* (2004) indicated the presence of wider range of variability in days to first harvest amongst ten tomato varieties tested. Bohner and Bangerth (1988) also reported that time from transplant to first harvest of plum types and large fruited type tomatoes ranged between 70 and 90 days, being earlier for plum types and late for large fruited tomatoes, which is in agreement with the results of present investigation.

4.1.7. Stem and root dry matter contents

A very highly significant ($p<0.001$) difference between intra-row spacing and variety was observed for dry matter accumulation of stem and root (Table 4, 5 and Appendix Table 2)

Plant spacing 35 and 40 cm had the highest stem dry matter contents (31.66 and 32.68 % respectively) but not significantly deferent. Where as significant root dry matter content attained at 40 cm intra-row plant spacing (8.93 %). While plant spacing 25 and 30 cm gave the lowest percentage compared with others (28.46 for stem and 5.9 % for root, respectively)

The obtained mean value showed that increasing plant density could result in decreasing biomass, which indicates existence of competition between plants for water and nutrient uptake. The percent stem and root dry matter content, which consisted both soluble and insoluble carbohydrates, was significantly influenced by plant spacing. According to Raupp (2000) percentage of dry matter is an important reference parameter, and is somewhat significant as well to a consumer who does not want to buy watery products like tomato.

Related study was reported by Dragan *et al.* (2007), in which heads of cabbage grown at low spacing produced less dry matter than at wider spacing. Agele *et al.* (1999) also reported that dry matter and TSS contents are indicators of mineral nutrient concentration in tomato fruit and these values generally increase with decrease in plant population and decrease with increase in plant density. This experiment provides clear evidence that closer spacing could decrease plant growth and plant dry matter. Plant yield increased as spacing increased and simultaneously the dry matter contents of stem and root increased with wider spacing of 35 and 40 cm intra-row spacing.

Table 4 . Effect of intra-row spacing on stem and root dry matter content (%)

Intra- row spacing	Dry matter contents	
	Stem dry matter (%)	Root dry matter (%)
25 x 70 cm	28.46^{c}	5.90^{d}
30 x 70 cm	30.09^{b}	6.85^{c}
35 x 70 cm	31.66^{a}	7.64^{b}
40 x 70 cm	32.68^{a}	8.93^{a}
LSD (0.05)	1.52	0.60
CV (%)	5.94	9.86

Means followed by different letter(s) are significantly different at 5%level of significance

A very highly significant ($p<0.001$) difference was observed between variety and intra-row spacing for dry matter accumulation of stem and root (Table 4, 5 and Appendix Table 6)

Local variety had better stem dry matter (38 11%) than the other three varieties, followed by Marglobe, while Fetane and Bishola gave less than 30% stem dry matter contents. On the other hand higher root dry matter was obtained from Fetane (9.23%) followed by Bishola (7.39%) compared to indeterminate type Marglobe (6.63%) and Local (6.09%).

The superiority of indeterminate varieties for stem dry matter content could be due to their growth habit and longest plant height. The highest value of root dry matter contents from both determinate (Fetane and Bishola) varieties could be due to the presence of strong sink source relationship among branches and root system.

In line with this study Heuvelink and Buiskool (1999), reported dry matter distribution is individual sink strengths relative to the total sink strength assimilates equal or exceed the total sink strength of the plant, the growth rates of the vegetative parts and the individual fruit or clusters occur at the potential rates.

Morgan and Lennard (2000) stated that, as fruits are the major sink of the plant, a reduction in fruit load could favor the distribution of dry mass to the vegetative parts of the plant (stem, leaves and root). Dry matter partitioned into the vegetative parts is important because the pattern and amount of fruiting in indeterminate plants are influenced by the size of the vegetative organs at fruiting (Marcelis and Heuvelink, 2007). The authors further indicated that it is essential that good vegetative growth occurs before fruit set; vegetative growth of fruit-bearing plants appears to be regulated by the developing fruit. The pepper plant particularly has the tendency to set fruit low down on the plant, before much foliage has formed.

Table 5 Effect of variety on stem and root dry matter contents (%)

Variety	Dry matter contents	
	Stem dry matter (%)	Root dry matter (%)
Marglobe	30.04[b]	6.63[c]
Fetane	26.53[d]	9.23[a]
Bishola	28.19[c]	7. 39[b]
Local	38.11[a]	6.09[c]
LSD (0.05)	1.52	0.60
CV (%)	5.94	9.86

.Means followed by different letter(s) are significantly different at 5%level of significance

4.2. Yield Parameters

4.2.1. Fruit number per cluster

A very highly significant ($p<0.001$) effect of variety with spacing was observed for number of fruit per cluster (Table 6 and Appendix Table 3).

The short set varieties Fetane and Bishola combined with all intra-row plant spacing gave the highest number of fruit per cluster compared to indeterminate type (5.24-5.53 for Fetane) and (5.09-5.48 for Bishola). Similarly, both tall set varieties Marglobe and local obtained higher fruit number at wider spacing than closer. The local variety planted at spacing 25 cm recorded the least flower per cluster. From these result it can be concluded that plant spacing 30 cm for determinate and 40 cm for indeterminate type were recorded the maximum number of fruit per cluster. In line with this study, Uddin *et al.* (1997) reported that the number of fruit per cluster of tomato decreased with the closer spacing than wider. Altherton and Rudich (1986) also described that the highest fruit-yielding cultivar has more clusters and fruits that would be of great interest to tomato growers or producers.

Table 6. Mean fruit number per cluster, fruit number per plant, fruit length and diameter, average fruit weight and fruit yield per plant as affected by interaction effect of variety and intra-row spacing.

Varieties x Intra-row spacing (cm)	Fruit no./cluster (No)	Fruit no./plant (No)	Fruit length (cm)	Fruit diameter (cm)	Av. fruit weight (g)	Fruit weight /plant (kg) 0.75 ^{fg}
V1 x S1	3.94^{ef}	11.80^{d}	4.28^{dee}	6.09^{d}	63.66^{g}	
V1 x S2	4.01^{def}	14.26^{c}	4.24^{e}	6.16^{cd}	87.33^{bef}	0.96 ^{e}
V1 x S3	4.33^{bcde}	16.26^{b}	4.62^{cde}	6.33^{bcd}	98.50^{cd}	1.59 ^{c}
V1 x S4	4.04^{de}	15.46^{bc}	5.24^{abcd}	6.46^{bc}	111.66^{ab}	1.72 ^{bc}
V2 x S1	5.24^{ab}	14.13^{c}	5.17^{bcd}	6.26^{bcd}	76.66^{f}	0.94 ^{ef}
V2 x S2	5.41^{a}	18.13^{a}	5.43^{abc}	6.59^{b}	86.00^{def}	1.61 ^{c}
V2 x S3	5.53^{a}	15.40^{bc}	5.36^{abc}	7.28^{a}	121.66^{a}	1.95 ^{a}
V2 x S4	5.52^{a}	15.60^{bc}	6.20^{a}	7.42^{a}	120.00^{a}	1.83 ^{ab}
V3 x S1	4.88^{abcd}	11.86^{d}	5.97^{ab}	6.19^{cd}	86.66^{def}	0.94^{ef}
V3 x S2	5.09 ^{abc}	19.26^{a}	5.99^{ab}	6.11^{cd}	87.33^{def}	1.58 ^{c}
V3 x S3	5.28^{a}	19.73^{a}	6.17^{a}	6.16^{cd}	98.00^{cde}	1.86^{ab}
V3 x S4	5.48^{a}	18.40^{a}	6.16^{a}	6.32^{bcd}	103.33^{bc}	1.84^{ab}
V4 x S1	3.08^{f}	6.93^{f}	2.69^{fg}	4.24^{e}	50.73^{h}	0.35 i
V4 x S2	3.08^{ef}	9.80^{e}	2.92^{fg}	4.20^{e}	51.50^{gh}	0.50 ^{hi}
V4 x S3	4.06^{de}	11.86^{d}	3.16g	4.24^{e}	55.33^{gh}	0.65 ^{gh}
V4 x S4	4.25^{cd}	14.53^{bc}	3.18^{f}	4.26e	85.33^{ef}	1.24 ^{d}
LSD(0.05)	0.94	1.85	0.96	0.94	12.73	0.020
CV(%)	2.88	5.65	2.82	2.76	6.56	7.08

Mean within the same column followed by a common letter are not significantly different, V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25cm, S2=30cm, S3= 35cm, S4= 40cm

4.2.2. Fruit number per plant

A very highly significant ($p<0.001$) interaction effect of variety with spacing was observed for fruit number per plant (Table 6 and Appendix Table 3). Fetane variety planted at intra-row spacing of 30cm (18), Bishola at 30, 35 and 40cm gave the highest number of fruit per plant (18.-20) compared to other both indeterminate type. Indeterminate type Marglobe and local varieties obtained higher fruit number per plant at the wider plant spacing compared to each other. From the result it can be concluded that 30cm for short set and 40 cm intra-rows spacing for tall set varieties appeared to be optimum spacing for higher fruit number per plant

This result is in conformity with Gould (1992), who reported variation in yielding ability of the tomato varieties which could be attributed to fruit set and number of fruit, both of which are controlled genetically and affected by plant density per unit area. In contrast, Abdalbagi *et al.* (2010) reported that variety and plant density had no significant effect on number of tomato fruits per plant during one season experiment.

4.2.3. Fruit length and diameter

A very highly significant ($p<0.001$) effect of variety with spacing was observed for fruit length and diameter (Table 6 and Appendix Table 3).

According to the results the largest fruit ranging from (5.36 to 6.20 cm) was obtained from combination of Fetane and all tested plant spacing level except 25 cm. Similarly, Bishola with combination of all intra-row spacing obtained large fruit size (5.97 to 6.17 cm).While the local variety gave the least fruit length than other varieties. This could be due to the fruit size of indeterminate type varieties of tomato which genetically obtained traits. Superior fruit diameter was also obtained from Fetane planted with 35cm and 40 cm intra-row spacing. Marglobe and Bishola were produced moderately improved fruit diameter at 40 cm intra-row plant spacing. While the smallest fruit length and diameter was obtained from local landrace planted with closer intra-row spacing of 25 cm and 30 cm (2.69 and 2.92 cm for fruit length) and (4.24 cm and 4.20 cm for fruit diameter) respectively. This study indicated that for in determinate type tomato reducing plant population per unit area resulted in increasing fruit length and diameter. This clearly indicated that their productivity is mostly controlled by genetic make-up and plant population.

Ali and Kelly (1992), reported that the stress due to plant competition might be attributed to deprivation of the necessary growth factors for cell division in the plant buds because most of the assimilates would be diverted to the growth of the metabolically more active sinks in the older fruit. Consequently, the rate of cell multiplication would be lower and result in smaller buds. These small buds eventually result in a small potential fruit size because the number of cells at the bud stage is a basis for fruit growth by cell expansion at the later stages. The authors revealed that fewer cells multiplication activity and formation of fewer cell tiers in the ovary wall of flower buds and small fruit under competition stress, than those under no competition.

This trend is in conformity with Ahmad and Singh (2005) who reported that wider spacing minimizes competition for nutrients, water and radiation which in turn favored fruit size Wesserman (1985), Kochlar and Joseph (1986) described that, at wider spacing there is better circulation of air and interception of light resulting in lower incidence of diseases and pests, and high dry matter accumulation due to enhanced photosynthesis.

Muhammad *et al.* (2007) reveled that the highest mean fruit diameter was recorded for wider plant spacing than closer intra-row spacing. Wahundeniya *et al.* (2005) also described that fruit size is very important parameter for fresh market tomato end users, but less important for processing purpose. According to Resh (2003) fruit size determines the consumer preference.

4.2.4. Average fruit weight (g)

A very highly significant ($p<0.001$) interaction effect of variety with spacing was observed for average fruit weight (Table 6 and Appendix Table 3). The maximum mean fruit weight was obtained from Fetane planted at intra-raw spacing of 35 and 40 cm (121.66 g and 120 g), respectively. Whereas, the smallest fruit weight was from local variety with very closer plant spacing of 25 cm (50.73 g). Comparison among four types of varieties indicated that the determinate fresh market tomato variety Fetane planted at intra-row spacing 35 and 40 cm had more than two fold average fruit weight than that of indeterminate type Marglobe and local

This indicated that the determinate type fresh market tomato varieties have maximum fruit weight than indeterminate type when combined with appropriate intra-row plant spacing (35 and 40 cm). Muhammad *et al.* (2007) reported similar result in that higher tomato fruit weight was obtained from wider intra-row spacing. This result is in line with the earlier report of Ali (1997), who found higher average fruit weight at wider spacing as compared to closer spacing.

4.2.5. Fruit weight per plant

A very highly significant ($p<0.001$) interaction effect of variety with spacing was observed for fruit weight per plant. (Table 6 and Appendix Table 3). Fetane and Bishola planted at 35 and 40 cm intra-row spacing gave the highest fruit weight per plant (1.95 kg) and (1.86 kg) respectively. Tall set type varieties Marglobe and local obtained higher fruit weight per plant with combination of wider plant spacing than closer. The highest fruit weight at the wider intra-row spacing for both short and tall set varieties might be due to sufficient nutrient availability which favored for minimum competition of the plant and as well as genetic variation of the varieties in fruit production.

4.2.6. Number of seeds per fruit

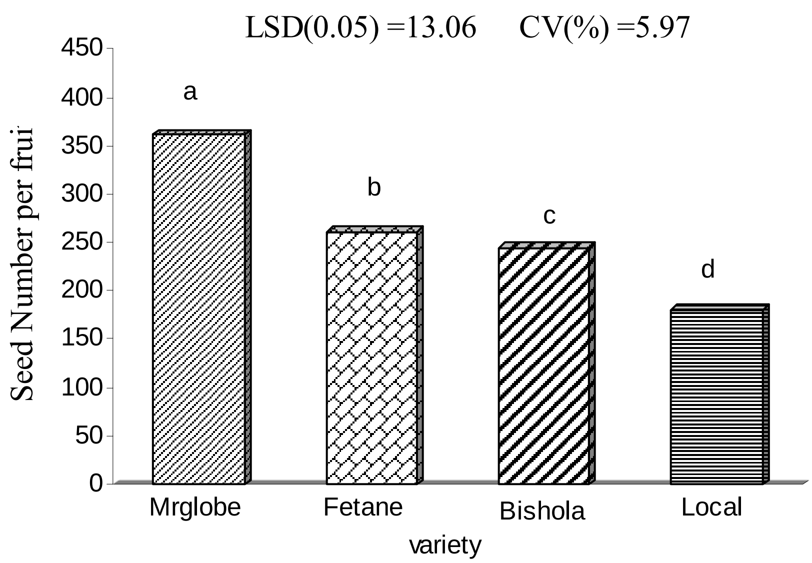

Fig. 3. Main effects of variety on seed number per fruit

A very highly significant ($p<0.001$) effect of varieties was observed on the seed number per fruits (Figure 3 and Appendix Table 4). The maximum number of seeds (363) was obtained for Marglobe, followed by Fetane (261) and Bishola (244), while the least seed number was recorded for local variety. The least number of seeds for local variety could be due to the low potential of seed setting of the small fruit size of the variety, which is a genetically inherited characteristic.

Seeds are well known to be rich sources of plant growth regulators (Hedden and Hoad, 1985). Sjut and Bangerth (1984) reported that auxin production and export by a fruit is predominantly confined to the seeds. As the result of this auxin export, seeds of a fruit may affect competition between fruit, either by increasing the sink strength (competitive ability to attract assimilates) for the fruit or by suppressing the sink strength of other fruit. Thus, the present study result showed the highest fruit seeds from Marglobe variety, which could resulted in lowest fruit dry matter of this variety by limiting the sink strength of the fruit.

4.2.7. Total fruit yield per hectare

A very highly significant ($p<0.001$) interaction effect of variety with intra-row spacing was observed on total yield per ha (Table 7 and Appendix Table 4). The maximum fruit yield per hectare recorded for Fetane and Bishola planted with 30 cm and 35 cm intra-row spacing (53.76 t/ha for Fetane and 52.66 t/ha for Bishola). While the lowest yield was obtained from closer spacing (25 cm) of local variety (14 t/ha). This study clearly indicated that fresh market tomato varieties of tall set type were low yielder at the closer plant spacing compared to short set type.

In line with this study, Wudiri and Henderson (1995) reported non processing tomatoes of indeterminate growth habit are low yielding because vegetative growth is favored over reproductive growth. In contrast to this study, Rafi, (1996), Myanmar (1999) and Zhang (1999) reported the highest number of fruits per plant and per hectare from higher plant density than widely spaced treatment of tomato crop. Tesfaye (2008) reported no interaction effect between variety and intra-row spacing in terms of influencing total fruit yield of tomato at wider spacing. However, Mehla *et al.* (2000) reported significant interaction effects of cultivar with closer spacing for total fruit yield in tomato.

4.2.8. Marketable yield per hectare

A very highly significant ($p<0.001$) interaction effect of variety with intra-row spacing was observed on marketable yield per ha (Table 7 and Appendix Table 4). Fetane and Bishola combined with intra-row plant spacing 30 and 35 cm obtained highest marketable fruit yield than indeterminate type varieties. Both indeterminate type Marglobe and local obtained relatively higher yield at the wider spacing (35 and 40 cm)

According to the result of this study for short set type varieties of Fetane and Bishola the optimum intra-row spacing to produce better marketable yield was 30 cm as well as 35 for Marglobe and 40 cm for local type. The higher marketable yield at 30 cm plant spacing to both short set varieties could be due to greater canopy and growth habit of determinate type varieties (Fetane and Bishola) which could be protected the fruits from sun scalding, thereby contributed to production of damage free fruit, so that unmarketable fruit yield minimized than the indeterminate type.

Related to this result Balibrea *et al*., (1997) reported that absence of defects like sunburn, cracks, blossom end rots; decays, etc are also important criteria for marketable quality of tomato fruits. Likewise, Uddin *et al.,* (1997) revealed that wider spacing with cultivars interaction gave the higher marketable tomato fruit yield (82.39 t/ha). In contrast Lemma *et al.* (2003), reported the highest total pepper pod yield of 20.09 q /ha at Bako and 15.57 q/ha at Didesa planted at closer spacing of 20 cm between plants.

.

Table 7. Mean values of total, marketable and unmarketable yield per ha as influenced by the interaction between variety and intra-row spacing

Varieties x Intra-row spacing (cm)	Total yield/ha (t/ha)	Marketable yield (t/ha)	Unmarketable yield (t/ha)
V1 x S1	30.00 e	26.23^{f}	3..77 ^{abc}
V1 x S2	41.32 ^{bcd}	37.90^{de}	3.42 ^{bcd}
V1 x S3	45.44 ^{b}	42.20^{cd}	3.24^{d}
V1 x S4	43.16^{bc}	40.66^{cd}	2.50^{e}
V2 x S1	37.60 ^{cd}	34.30^{e}	3.30^{cd}
V2 x S2	53.76 ^{a}	50.60^{ab}	3.16^{d}
V2 x S3	55.60 ^{a}	54.26^{a}	1.34^{f}
V2 x S4	45.91 ^{b}	44.76^{c}	1.15 ^{f}
V3 x S1	36.80 ^{d}	34.76^{e}	2.04 ^{e}
V3 x S2	52.66 ^{a}	51.50^{a}	1.16^{f}
V3 x S3	53.01 ^{a}	51.93^{a}	1.08^{f}
V3 x S4	46.08 ^{b}	45.06^{bc}	1.02 f
V4 x S1	14.00 ^{f}	10.13^{g}	3.87^{ab}
V4 x S2	16.56 ^{f}	12.30^{g}	4.26^{a}
V4 x S3	17.95 ^{f}	14.30^{g}	3.65 ^{bcd}
V4 x S4	31.00 ^{e}	27.36^{f}	3.64 ^{bcd}
LSD(0.05)	5.71	5.65	0.53
CV(%)	6.55	6.97	8.93

Means followed by different letter(s) are significantly different at 5%level of significance
V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25cm, S2=30cm, S3= 35cm, S4= 40cm

In this study, using relatively early-maturing (determinate) and late maturing (indeterminate) fresh market tomato varieties with combination of optimum plant spacing, marketable yield was increased up to 16.3 t/ha by increasing the intra-row spacing from 25cm to 30cm for Fetane variety, and 16.74 t/ha for Bishola, while increasing intra-row spacing above 30 cm resulted in statistically similar yield among all spacing tested for both short set varieties

The two indeterminate varieties Marglobe and local had relatively higher fruit yield at the wider spacing 40cm.

4.2.9. Unmarketable yield per hectare

A very highly significant ($p<0.001$) interaction effect of variety with intra-row spacing was observed for unmarketable yield per ha (Table 7 and Appendix Table 4). Local variety planted at 25 and 30 cm gave the highest unmarketable fruit yield per hectare (3.87 t/ha and 4.26 t/ha, respectively). The higher unmarketable yield per hectare for local variety could be due to the growth habit of the plant (tall set) in which contribution of the vegetative part for development of the fungal disease by protecting circulation of air within the canopy of the plant under closer spacing. The same is true for Marglobe and in addition to its growth habit the thin pericarp of the fruit increased the perishablity of the yield at closer spacing.

The least unmarketable yield for both determinate type varieties at the wider spacing could be due to manageable growth habit of the varieties that suitable to control and for application of fungicides uniformly. In line with this study, Peet (1992) reported that physiological disorder causes considerable economic losses in densely populated field-grown tomatoes crop.

4.3. Quality parameters

4.3.1 Fruit dry matter contents

The interaction effects of variety and intra-row spacing showed a very highly significant effect on fruit dry matter content (Table 8 and Appendix Table 5). The highest fruit dry matter was obtained from Fetane(7.6%) and Bishola (7.23%) varieties with combination of intra-row plant spacing of 30, 35 and 40 cm , but not significantly different.

In contrast to this study, Tsedal (2005) reported that the highest number of fruit per plant resulted in source limitation which eventually led to a reduction in dry matter content of individual fruit. Where as Fetane and Bishola had higher fruit number per plant and total yield as well as highest fruit dry matter compared to that of Marglobe and local varieties which attained lower performance both in fruit number per plant and fruit dry matter contents at all levels of intra-row plant spacing. In addition cultivars with thick skinned have fleshy components (both determinate type) and that with thin skinned are watery fruit (Marglobe and local)

Table 8. Fruit dry matter and fruit shape index as influenced by the interaction effects between variety and intra-row spacing

Varieties x Intra-row spacing (cm)	Fruit dry matter	Fruit shape index
V1x S1	4.54^{de}	0.69^{ed}
V1 x S2	4.58^{de}	0.68^{cde}
V1 x S3	4.60^{d}	0.72^{cd}
V1 x S4	4.76^{b}	0.80^{b}
V2 x S1	7.01^{b}	0.82^{b}
V2 x S2	7.00^{ab}	0.82^{b}
V2 x S3	7.30^{a}	0.73^{f}
V2 x S4	7.60^{a}	0.83^{b}
V3 x S1	6.00^{c}	0.95^{a}
V3 x S2	6.90^{b}	0.97^{a}
V3 x S3	7.23^{ab}	0.99^{a}
V3 x S4	7.00^{b}	0.96^{a}
V4 x S1	4.13^{e}	0.63^{e}
V4 x S2	4.28^{de}	0.69^{cde}
V4 x S3	4.45^{de}	0.74^{d}
V4 x S4	4.65^{d}	0.74^{d}
LSD(0.05)	0.48	0.064
CV (%)	5.07	3.58

Means followed by different letter(s) are significantly different at 5%level of significance, V1=Marglobe variety, V2=Fetane, V3= Bishola, V4= Local, S1=Spacing 25cm, S2=30cm, S3= 35cm, S4= 40cm

4.3.2. Fruit shape index

Interaction of spacing with varieties had very highly significant ($p<0.001$) effect on fruit shape index (Table 8 and Appendix Table 5). The highest fruit shape index was obtained from Bishola with all plant spacing levels, followed by Fetane including Marglobe with wider spacing, whereas the smallest fruit shape index was recorded from Marglobe and local varieties under closer spacing of 25 cm and 30 cm. The highest fruit shape index resulted from Bishola variety could be due to its large fruit size obtained during the experiment. This study clearly confirmed that fruit shape is directly related to fruit length and diameter which contributes to better yield and quality of fruit in favor of increasing marketable yield per hectare.

Regarding fruit shape Silivana *et al.* (1996) indicated that fruit shape is an important quality factor for many domesticated plants. Shape differences arise after flowering as the result of unequal growth rates in deferent direction. When the growth rates of length and width after anthesis are unequal the ultimate configuration of the mature fruit can be produced by the interaction between genetic factors governing relative dimensional growth and any genetic change that affects final fruit size.

4.3.3. Fruit pericarp thickness

Highly significant difference ($p<0.001$) was observed between intra-row spacing and variety on fruit pericarp thickness (Figure 4 and appendix Table 5). The highest fruit thickness was obtained at wider intra-raw spacing (35 and 40 cm), while at closer spacing (25 and 30 cm) similar value was obtained, which was less than that of plants planted at wider spacing. This clearly indicated that decreasing plant density is valuable to achieve better fruit quality due to minimum plant competition for growth factors like light and essential nutrient.

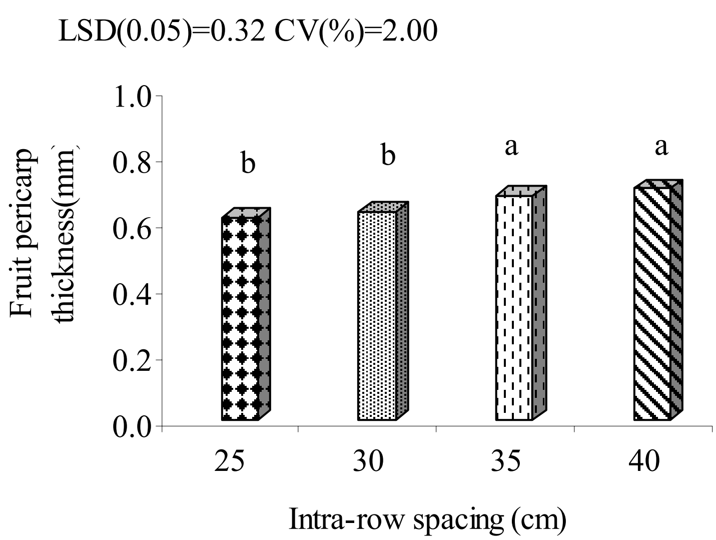

Fig. 4. Effect of intra-row spacing on fruit pericarp thickness.

As of varietal effect the highest value was recorded for Bishola (0.71 mm) and Fetane (0.70 mm) flowed by Local. The lowest fruit pericarp thickness (0.59 mm) was obtained from Marglobe variety at intra-row spacing of 25 cm. The softness of fruit pericarp could increase the susceptibility of the fruit to disease.

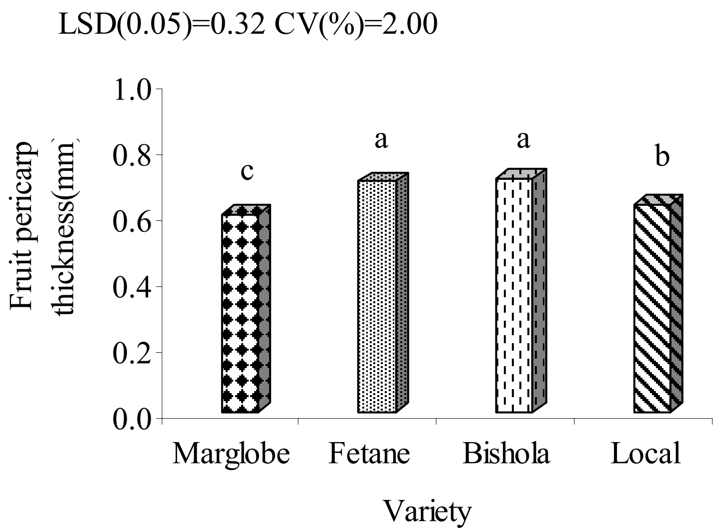

Fig. 5. Effect of variety on fruit pericap thickness

Thick pericarp is a useful character as far as post harvest handling is concerned in transportation. So it could be an added advantage to have a thicker pericarp when selecting tomato varieties. Firmness of pericarp tissue is a key for long storability. Round and thin-skinned cultivars such as Marglobe, Heinz 1350 and Moneymaker are highly perishable as compared to pear or cylindrical and thick skinned ones such as Roma VF (Lemma, 2002). Lee and Kader (2000), selection of the genotype with the highest quality shelf life and yield for a given commodity is a much more important factor than climatic conditions and cultural practices.

4.3.4. Total soluble solid (TSS)

A significant ($p<0.05$) effect of variety was observed on fruit TSS (Figure 6. and Appendix Table 6). Accordingly, total soluble solid varied from 4.64 in Fetane and 5.75

% in Marglobe. The values are low for Fetane, Bishola and local varieties whereas in the range of standard for Marglobe. Arias *et al.* (2000) pointed out that TSS for fresh market tomato is 5.46-5.98%

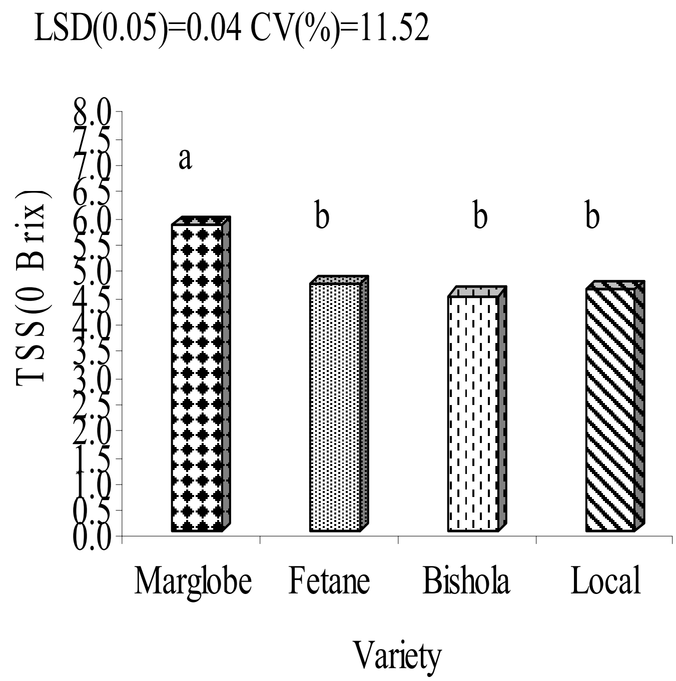

Fig. 6. Effect of variety on TSS

Balibrea *et al*. (1997) reported that there are a lot of variations in tomato varieties for yield characteristics, among factors affect yield and quality of tomato fruits, genotypic variability is the most important one. Important quality parameters of tomato fruit that influence yield and yield quality varies with the types of cultivar including fruit size, total soluble solids (TSS) content, pH, flavor, firmness, colour, etc. The authors further explained that intense fruit transpiration rates are positively related with fruit soluble solids content, it is a major criterion of quality because, there is a relationship between growth habit of tomato plants and fruit solids content.

Duguma (2000) also indicated that genotype is the main determinant of sugars and acid content. The types of antioxidants present in tomato are also used to differentiate tomato cultivars. The main antioxidants in tomatoes are carotenoids, ascorbic acid and phenolic compounds however, the overall antioxidant activity of tomatoes varies considerably depending on the genetic variety, ripening stage and growing conditions (Giovanelli *et al.,* 1999).

Young *et al.* (1993) found that both total solids and total soluble solid decreased as colour increased in a typical cultivar, the soluble solids content of some tomato lines increased as fruits ripen. They obtained the greatest differences between varieties of tomato in the concentration of the components measured at ripe stage. The authors further reported that the best stage to select varieties for TSS would be at red-ripe stage. In general, the values commonly obtained for soluble solid of different varieties of tomato fruit range from 4 to 6 ^{0}Brix (Alcantar *et al.*, 1999; Carmer *et al.*, 2001), which agrees with the present study.

Moraru *et al.* (2004) indicated that TSS content is variety dependent and frequently correlates with greater tomato yield, but in general varieties with high ^{0}Brix values tend to be agronomically less productive. This is in agreement with the present study that Marglobe produced better TSS contents but less productive in yield compared to determinate type Fetane and Bishola, which were more productive but had less TSS values.

4.3.5 Titratable Acidity

A very highly significant ($p<0.001$) difference among the tomato varieties tested was observed for titratable acidity (Figure 7 and Appendix Table 6). It was varied from 0.33 % to local and 0.40% to Fetane, in which Fetane had higher acid (0.40), followed by Bishola and Marglobe (0.39), whereas the local was the leading acidic fruit (0.33). George *et al.* (2004) revaluated that titratable acidity in fruit of twelve tomato genotypes and reported the values of fruit acidity variation from 0.256 to 0.704 g per 100 g^{-1} which is in agreement with the present study.

Large fruits were produced better titratable acidity. This variation could be due to variability in fruit weight. In related to this investigation Tittonell *et al.* (2001) reported that large sized tomato fruit had higher acidity, which supports the present finding.

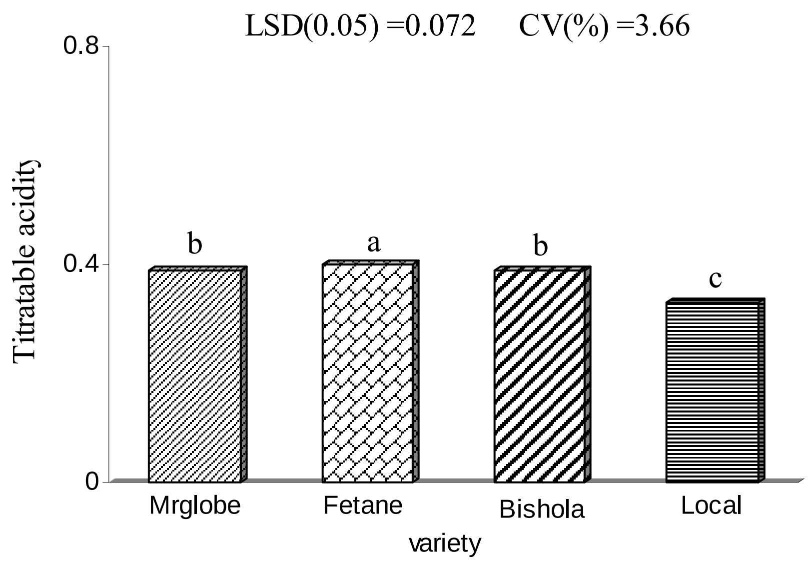

Fig. 7. Effect of variety on titratble acidity

Saliba-Colombani *et al.* (2001) illustrated that total sugars (primarily reducing sugars) were positively correlated with pH and titratable acidity. Nonvolatile compounds such as sugar, titratable acidity and soluble solids play a great role in determining flavor of the fruit.

Georgelis (2002) reported that there was a positive correlation between sugar and pH as well as sugar and titiratable acidity, that showed plants with high sugars have more free organic acids and less hydrogen ion concentration than plants with low sugars.

4.3.6 pH value

The pH values of tomato fruits were significantly ($p<0.001$) different among the tomato varieties (Figure 8 and Appendix Table 6), pH value of fruits ranging from 4.84 in local to 6.16 for Marglobe. Mohammed *et al.* (1999) reported that although the pH of ripe tomatoes may exceed 4.6, tomato products are generally classified as acidic food (pH<4.6). Carlson *et al.* (2006) described that pH below 4.5 is a desirable trait, because it halts proliferation of microorganism. Thus, all varieties tested in this experiment found to be in the range of values reported by different authors.

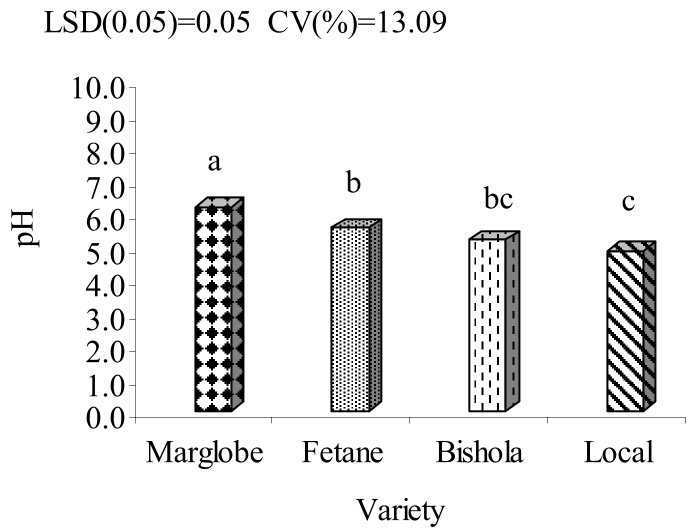

Fig. 8. Effect of variety on pH

From the result of this study it can be concluded that Marglobe, Fetane and Bishola were better for their quality parameter regarding fruit total soluble, titratable acidity and pH, while the local variety was low in all performance tested compared to improved one.

4.4 Disease reaction

The analysis of variance for the interaction effects of variety and intra-row spacing showed a very highly significant ($p<0.001$) effect on disease incidence (Table 9 and Appendix Table 7). Disease incidence was higher when local and Fetane varieties planted at closer plant spacing of 25 cm (29% for local and 27% for Fetane, respectively). Marglobe planted at 25 cm also had higher disease incidence (23%) at lower plant spacing, as well as the local variety planted at 30 cm showed higher percentage (26%), while Bishola variety was healthy plant than the rest.

Table 9. Mean values of disease incidence as affected by the interaction between variety and intra-row spacing

Variety	Intra-row spacing (cm)	Disease Incidence (%)
Marglobe	25	23.33 [cd]
	30	16.00 [ef]
	35	13.33 [fg]
	40	12.00 [g]
Fetane	25	27.33 [ab]
	30	25.33 [bc]
	35	21.33 [d]
	40	17.33 [e]
Bishola	25	13.33 [fg]
	30	13.33 [fg]
	35	8.00 [h]
	40	6.66 [h]
Local	25	29.33 [a]
	30	26.00 [bc]
	35	22.00 [d]
	40	12.00 [g]
	LSD(0.05)	3.24
	CV (%)	10.86

Means followed by different letter(s) are significantly different at 5%level of significance

The extreme yield drop of closer spacing could correspond to weak plant performance and due to minimum aeration. However, the trend of susceptibility of each variety was not similar in all treatments. Differences in yield losses between low and high plant population densities were actually limited for blight resistant varieties, while the opposite was true for the more susceptible ones.

Even though, the fungicide was applied during the experiment based on the recommendation, each treatment was exposed to disease which could be due to un-season rain fall occurrence that resulted in formation of suitable conditions to the development of fungal disease (late blight) and as well as washing away the chemical soon after the plant sprayed.

In line with this result Ho *et al*. (1999) indicated that more equidistant row arrangements may result in better air circulation around plants and lower relative humidity, which increase canopy transpiration. Since calcium moves in the transpiration stream and there is a strong competition between shoots and fruit for calcium, higher transpiration levels will cause calcium to preferentially move to the shoots resulting in an increase in blossom-end rot and susceptibility to various diseases in the tomato fruit. The foliar and fruit disease symptoms observed during the study may be attributed to the abundant rainfall received during the growing season, rapidly spreading of the blight from infected plants, which are thought to be the source of infection.

4.5 Correlation coefficient

The correlation coefficients among major response variables such as growth, yield, yield quality and disease reaction (Appendix Table 8) revealed that, marketable fruit yield was very highly significant and positively correlated with fruit yield per plant (r=0.90***), fruit yield per hectare (r=0.99***), fruit diameter (r=0.83***), fruit length (r=0.86***), fruit number per plant (r=0.89***), and fruit weight (r=0.82***). Marketable fruit yield was also very highly significantly and positively correlated with primary branch number (r=0.74***), flower number per cluster (r=0.74***), fruit number per cluster (r=0.79***), fruit set percentage (r=0.78***), highly significantly and positively correlated with fruit shape index (r=0.58***).

Cluster number and fruit number could be related to the yielding ability of the varieties which could be validated by the positive correlations between these fruits and yield observed. Appendix Table 8 indicated that higher number of fruits per cluster gave superior yield. In line with this result Balibrea *et al.* (1997) indicated that tomato fruit yield was strongly influenced by the number of clusters, number of fruit set per cluster and number of fruits per plant.

A negative and loose correlation was detected between fruit weight and unmarketable fruit (r= -0.63***), as well as fruit weight and number of seed in the fruit (r= -0.28). A positive correlation was also observed between TSS and fruit weight, fruit length, fruit diameter, fruit yield per hectare, fruit pericarp thickness and marketable fruit. Similarly, titratable acidity was exhibited slightly moderate positive association with the above parameter. Fruit weight and fruit seed were positively correlated (r=0.37***).

From the result of the study it could be concluded that some of the growth parameters assessed in this experiment like primary branch, flower and fruit number per plant, fruit set percentage and days to fifty % flowering were directly related to the marketable yield per plant and per hectare. Similarly, fruit length and diameters, fruit weight, as well as fruit TSS could be played an important role in sustaining the increment of the fruit yield.

.

.

5. SUMMARY AND CONCLUSION

Tomato is among the most important vegetable crops in Ethiopia. Since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, tomato production in Ethiopia is highly constrained by several factors.

Farmers get lower yield mainly due to diseases and pests as well as due to in appropriate agronomic practices and lack of improved variety. Improper plant spacing is among the notable reasons of low productivity of this crop. Plant spacing greatly influenced growth, yield, and quality parameters both in fresh market and processing tomatoes. Additionally, understanding the variability of varietals response to different plant spacing is crucial in improving the tomato fruit yield and quality. The performance of each cultivar should be evaluated using growth and yield indicators and chemical indexes.

The study was conducted to investigate the effect of different levels of intra-row spacing on yield and yield quality of four fresh market tomato varieties under Jimma condition. It was carried out under irrigation at open field of JUCAVM research site in 2010. The experiment consisted of two factors; four intra-row spacing (25, 30, 35 and 40 cm x 70 cm) and four varieties (Marglobe, Fetane, Bishola and Local), arranged in randomized complete block design with three replications. All the treatments were planted on the same date.

Data on plant growth parameters including number of primary branch, plant height, days to 50% flowering, flower number per cluster, fruit setting percentage and days to first harvest were recorded before harvest. Yield parameters such as number of fruit per cluster and per plant, fruit weight, fruit yield per plant and per hectare, marketable and unmarketable fruit, fruit length, diameters and number of seeds per fruit. Yield quality parameters: dry matter contents of root, stem and fruit, fruit pericarp thickness, fruit shape index, total soluble solid, titratable acidity and pH were investigated.

Additionally, selecting cultivars for use in specific spacing environments based on relative maturity rating alone may limit the yield potential of the production system. Therefore, in this study both the longer and the shorter maturing cultivars (determinate and indeterminate) were used to evaluation. From the study conducted, intra-row spacing and varietal effect had valid effect on the yield and yield quality of fresh market tomato

.

Bishola planted at 30 and 35 cm x 70 cm had higher marketable yield, higher dry matter and fruit shape index, as well as thick pericarp thickness which can contribute to better shelf life. This variety is also highly resistance to late blight incidence. Similarly, Fetane performed well at 35cmx70cm in producing higher marketable yield, total soluble solid, fruit dry matter contents and average fruit weight.

Marketable fruit yield was positively correlated with, fruit number per plant ($r=0.89^{***}$), fruit yield per plant (r=0.90***), fruit yield per hectare (r=0.99***), fruit diameter ($r=0.83^{***}$), fruit length ($r=0.86^{***}$) and fruit weight ($r=0.82^{***}$). A positive correlation was also observed between TSS and fruit weight, fruit length and diameter. It can be concluded that those parameters that had highly positive correlation with the marketable yield played an important role in sustaining the increment of the fruit yield. In general this clearly indicated that the varieties responded differently to intra-row plant spacing, with regard to total number of fruit per plant and marketable yield per hectare.

Most resource- poor farmers use cultural practices in their tomato production systems. Thus, to produce better fruit yield and quality tomato growers in the study area should be encouraged to use intra-row spacing 30 cm x 70 cm with the determinate type of Fetane and Bishola varieties, since these perform far better than the Marglobe and unimproved local tomato varieties. However, further researches are recommended with optimization of fertilizer and water requirement for the different varieties under different intra- and inter row plant spacing and different growing conditions and type of production (home stead, farmer and commercial) to understand their yield performance

.

6. REFERENCES

Abdalla, A.A., 2003. Effect of sowing date and plant population on performance of sesame. (*Sesamum indicum* L) cultivars under irrigation. M.Sc. Thesis, Faculty of Agricultural., University of Khartoum. *J. Agr. Sci*. **15**: 55–60.

Abdalbagi A. Hamid, Salih O. Salih Abdu E. Abdalla and Ahmed M. El Naim, 2010. Effect of Sowing Date and Plant Density on Growth and Yield of Tomato (*Lycopersicon Esculentum, Mill.*) Research Journal of Agriculture and Biological Sciences, University of Kordofan,Elobeid, Sudan, IN SInet Publication. 6(5): 665-669 ttp://insipub.org/rjabs/2010/665-669./ posted on 15/12/2010

Agele, S.O., Iremiren, G.O., Ojeniyi, S.O. 1999. Effects of plant density and mulching on the performance of late-season tomato (Lycopersicon esculentum) in southern Nigeria. *J. Agr. Sci*. **133**: 397–402.

Ahamd, A. and A. Singh, 2005. Effects of staking and raw-spacing on the yield of tomato (*Lycopersicon esculentum mill*.)Cultivar Roma VF in the Sokoto Fadama.Nigeria. *Nig. J. Horti,Sci*, **10**: 94-98.

Alcantar, G.G., M.R. Villarreal and A.S Aguilar, 1999. Tomato growth *(Lycopersicon escukentum Mill),* and nutrient utilization in response to varying fertigation Acta programs. *Hort*, **481(3):** 385-391.

Ali, A. & Kelly, W. 1992. The effects of inter fruit competition on the size of sweet pepper (*Capsicum annuum* .) fruit. *Scientia Horticulturae*, **52**: 69-76.

Ali, N., 1997. Sesamum Research in Pakistan. In: sesame and safflower status and potentials.

Althertoni, J. and J.Rudich, 1986. The Tomato Crop. Chapman and Hall, London, U.K. *Journal of Food Science*, **15**: 842-859.

Arias,R., T.C. Lee., D.L. Logendra and H. Janes, 2000. Quality comparison of hydroponic tomatoes *(Lycopersicon esculentum*) ripened on and off vine. *Journal of Food Science*, **65**: 545-548.

Ara, N., Bashar, M.K., Begum, S. and Kakon, S.S. 2007. Effect of Spacing and Stem Pruning on the Growth and Yield of Tomato. *Int.J. Sustain. Crop Prod*. **2(3)**: 35-39.

AVRDC, 2005. The world vegetable center, Fact sheet. Publication ,05-635 www.avrdc.org/pdf/tomato/early_blight. Assessed 15/10/2010

AVRDC-TOP 1997. Training report of the fifth regional training program in vegetable production and research. pp. 118-126, 169-184. kasetsart University. Bangkok, Thailand.

Balibrea, M.E., B.K. Dazie and D.J. Cleland, 1997. Reducing gas exchange of fruits surface coatings. Post harvest handling of tomato fruit

Bohner, J. and F. Bangerth, 1988. Cell number, cell size, and hormone levels in semi-isogentic mutants of *Lycopersicon pimpinellifolium* differing in fruit size. Plant arum. 72,316-320.

BPEDORS. 2000, Physical and socio economical profile of 180 District of Oromia Region. Bureau of Planning and Economic Development of Oromia Regional state, Physical planning Development. Finfinne, Ethiopia. pp.248-251.

Carlson, S., M. Gillcrist, B. Mikru, and Q. Nguyen, 2006. Surface Area and Volume Measurement of Salad and Roma Tomatoes for Microbial Enumeration. Govemor's School for Agriculture, Blackburg.

Central Statistical Agency CSA (2009). Agricultural sample survey 2008/2007. Report on area and production of crops (Private peasant holdings, main season). Stat. Bull., Addis Ababa Ethiopia, 01-446.

Cramer, M.D., J.A. Oberholzer and N.J. Combrink, 2001. The effect of supplementation of root zone dissolved inorganic carbon on fruit yield and quality of tomatoes (cv "Daniela") grown with salinity. *Sci. Hort.* **89**:269-289.

Cuppels, D. A. and Ainsworth, T. 2001. Distribution and characterization of xanthomonads causing bacterial-spot disease on tomato in southern Ontario in 2000. *Can. J. Plant Pathol*. **23**: 196–197.

Cuppels, D. A. and Elmhirst, J. 1999. Disease development and changes in the natural *Pseudomonas syringae* pv. *tomato* populations on field tomato plants. Plant Dis. 83: 759–764. Saure, M. C. 2001. Blossom-end rot of tomato (*Lycopersicon esculentum Mill*.) – a calcium- or a stress-related disorder. *Sci. Hortic.* **90**: 193–208.

Daniel Workman, 2007. Top Fresh Tomato Countries www.suite101.com/content/top -fresh-tomato-countries-a 37904-5

Davies, J. and G.E. Hobson, 1981. The constituents of tomato fruit- The influence of environment, nutrition, and genotype. CRC Crit. *Rev. Food Sci. Nutr.* **15(3)**: 205-280.

David Gentilcore, 2010. A History of the Tomato in Italy. Columbia University Press. pp 25-31.

Dragan, Nina ,Jože, and Stanislav, 2007. Yield and quality of early cabbage *(Brassica oleracea L. var. capitata)* in response to within-row plant spacing. *Sci. Hortic.* **42**: 89–93

Duguma, A., 2000. Variety and plant density influence on fruit yield and quality of processing types of tomatoes. An M.Sc Thesis presented to the school of graduate studies of Alemaya University.

EARO, 2004. Directory of Released Crop Varieties and their Recommended Cultural Practices. Ethiopian Agricultural Research Organization, Addis Abeba, Ethiopia.

ElNaim, A.M., 2003. Effect of different irrigation water quantities and cultivars on growth and yield of sesame (*Sesamum indicum* L.). Ph.D.Thesis, faculty. of Agricultural., University of Khartoum. 75p

FAO, 2004. Statistical Bulletin. Plant Production and Protection, Rome Pp 34-40

FAOSTAT (2007). FAOSTAT on-line. Rome: United Nations Food and Agriculture Organization. http://faostat.fao.org/default.aspx?lang=e

Fekadu M, Dandena G,2006. Review of the status of vegetable crops production and marketing in Ethiopia. *Uganda J. Agric. Sci*., **12(2)**:26-30.

Franceschi, S, Bidoli, E, and La vecchia, 1994. Tomatoes and risk of digestive-tract cancers. *International Journal of Cancer*, **59**: 181-184.

Frost, DJ and Kretchman,D.W.1998. Plant special arrangement and density effects on small-and medium vined processing tomatoes. *J.Amer.Soc.Horti.Sci.* **113(1):**15-55.

Frusciante, L., Barone, B., Carputo, D.,Ercolano, M.R.,Della Roca, F., Espostto, S. 2000. Evaluation and use of plant biodiversity for food and pharmaceuticals. *Fitoterapia,* **71**: 66-72.

Geleta L, Shimelis A, Chimdo A, Damtew M, Tiruwork A 1995. In: Proceedings of the 25th Anniversary of Nazareth Agricultural Research Center: 25 years of experiences in low land crops research, 20-23 September 1995. Nazareth, Ethiopia. Nazareth Agricultural Research Center, Nazareth

Gillaspy, G., H. Ben-David and W. Gruissem, 1993. Fruits: a developmental perspective. *The plant Cell* 5:1439-1451.

Giovabbibu, J., 2001. Molecular biology of fruit maturation and ripening. *Annual Review of plant physiology and plant Molecular Biology* **52**: 724 – 749.

George, B., C. Kaur, D.S Khurdiya and H.C. Kapoor, 2004. Antioxidants in tomato (*Lycopersium esculentum Mill.)* as a function of genotype. *Food Chem.* **84**: 45-51.

George RAT 1999. Vegetable seed Production. 2nd ed. Cambridge University Press, UK. p. 328.

Georgelis, N., 2002. High fruit sugar characterization, inheritance and linkage of molecular markers in tomato. An M.Sc. Thesis Presented to the School of Graduate Studies of Florida University. 81p

Giovannoni, E., 1999. Tomatoes and tomato-based products, Iycopene and cancer— Review of plant physiologic literature. *Journal of the National Cancer Institute*, **91(4)**: 317-331.

Gould, W.A., 1992. Tomato Production, Processing and Technology, 3rd Ed., CTI Publishers, Baltimore, MD

Hedden, P. and Hoad, G. 1985. 'Hormonal regulation of fruit growth and development'. In: Jeffcoat, B., Hawkins, A.F., Stead, A.D, eds. Regulation of sources and sinks of crop plants.
Monograph, **12**:211-221.

Heuvelink, E. and Buiskool, R. 1999. Influence of sink-source interaction on dry matter production in tomato. *J. Horti. Sci.* **75**:381-389.

Hewitt, J, D., M. Dinar and M.A. Stevens, 2006. Sink strength of fruits of tomato genotypes differing in total; fruit solids content. J.Amer. Soc. Hort,Sci. 107:896-900.

Ho, L. C., Hand, D. J. and Fussell, M. 1999. Improvement of tomato fruit quality by calcium nutrition. *Acta Hortic*. **481**: 463–468.

K.E. Law-Ogbomo and 2R.K.A. Egharevba 2009.Effects of Planting Density and NPK Fertilizer Application on Yield and Yield Components of Tomato (*Lycospersicon esculentum Mill*) in Forest Location. *Journal of Agricultural Sciences* **5:** 152-158.

Khushk, A.M., N.M. Miano, A.H. Ansari, and M.I. Man. 1990. Influences of inter and intra row spacing on the yield and yield component of onion (*Allium cepa* L.). *Sarhad J. Agric.* **6(2)**: 147-150.

Kochlar, S.L. and R.T. Joseph, 1986. Tropical Crops. Macmillan Publisher, Hong Kong, pp: 220

LEE, S.K. and Kader, A.A. 2000. Pre-harvest and post harvest factors influencing vitamin C content of horticultural crops. *Post harvest Biology and Technology*, **20**: 207-220.

Lemma Desalegn, 2001. Introduction. In: Abera Deressa and Solomon Degnachew (compilers). Training manual on horticultural crops production technologies (volume II: vegetables), Ethiopian Agricultural Research Organization, Melkasa Agricultural Research Center and World Vision Ethiopia. Melkasa, Ethiopia.

Lemma D, Yayeh Z. and Helath.E. 2003. Agronomic studies on Tomato and Capsicum. Pp.153.In: Helath E. and Lemma D, (Eds). Horticultural Research and Development in

Ethiopia. Proceedings of the second Horticultural work shop of Ethiopia, 1-3 December, 1992. Addis Abeba, Ethiopia

Lemma, D., 2002. Tomato Research experience and production prospects. Research report No 43 Ethiopian Agricultural Research Organization.

.Marcelis and E. Heuvelink, L.F.M.2007. Dry matter distribution in tomato and cucumber. International symposium on Growth and Yield Control in Vegetable production Pp 35-39

McCarthy J, Canziani O, Leary N, Dokken D, White K (eds.) (2001). Climate Change Impacts, Adaptation, and Vulnerability. New York, Cambridge University Press.

Mehla, C.P., Srivastava, V.K., Jage, S., Mangat, R., Singh, J. and Ram, M. 2000. Response of tomato varieties to N and P fertilization and spacing. *Indian Journal of Agricultural Research*. **34 (3)**: 182-184.

MoARD 2009. Rural Capacity Building Project. Course for Training of trainers on improved horticultural crop technologies. Addis Ababa , Ethiopia

Morgan and Leonardi, 2000. Antioxidant activity and carotenoid and tomatine contents in different typologies of fresh consumption tomatoes. *Journal of Agricultural and Food Chemistry,* **4**: 23-47.

Mohammed, M., L.A. Wilson and P.L. Gomes, 1999. Post harvest sensory and physiochemical attributes of processing and non-processing tomato cultivar. *J. Food Quality,* **22**:167-182.

Moraru, C., L. Logendra., H. Janes, 2004. Characteristics of 10 processing tomato cultivars grown hydroponically for NASA advanced life support (ALS) program. USA. *Journal of food composition and analysis,* **17**:141-154.

Monti, L.M., 1990. The breeding of tomatoes for peeling, *Acta Hort*. **100**:351-349.

MoARD, 2009. Rural Capacity Building project. Course for Training of trainers on improved horticultural crop technologies. pp 5-19.

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

Muhammad AA, Muhammad A 2002. Influence of mother root size and plant spacing on carrot seed production. *J. Res. Sci.,* **13(2)**: 105-112.

Myanmar, M.A., 1999. Effect of pruning and spacing on performance of fresh market tomato. ARC-AVRDC Training Report. Kasetsart University, Nakhon Pathom, Thailand: ARC-AVRDC. pp: 174-183.

Nunes, M.C.N. and J.P. Emond, 1999. Chlorinated water treatments affects post harvest quality of green bell peppers, *J. Food quality*, **22**:353-361.

Nile, E.S.N., 2003. Effect of water stress applied at different stages of growth on the performance of two sesame (*Sesamum indicum L.*) cultivars. M.Sc .Thesis. Fac. of Agric., University of Khartoum.

PEET, M. 1992. Radial fruit cracking in tomato. , 2, 216-223.

Rafi, U.M., 1996. Stem pruning, spacing and spacing effect on the yield of tomato. *J. Res. Sci.,* **23(3)**: 101-115
.
Ramatu M. Al-Hassan 2006, Sustainable solutions for ending hunger and poverty. Department of Agricultural Economics & Agribusiness, University of Ghana (journal of International Food Policy Research Institute) (http.//www.programs.ifpri.org/pbs/accessed on Aug. 24/2010

Raupp, J. 2000. Fertilization effects on products quality and examination of parameters and methods for quality assessment. http://www.edis.ifas.ufl.edu (assessed on 10. Dec. 2010).

Rawshan, A. S. M., 1996. Effect of plant population density on tomato. In: ARC. – AVRDC training report. Ka: Bankok. Thailand: ARC. – AVRDC. pp. 152-156.

Resh H.M 2003. Hydroponic food production 6th edition. pp 23-27

Rice, R.P., L.W. Rice and H.D. Tindall, 1990. Fruit and Vegetable production in warm climates, Macmillan Education Ltd. London and Basingstoke. *J. Plant Sci.,* **5**: 112-131.
.
Saliba-Colombani, V., M. Causse and D. Langlois 2001. Genetic analysis of organoleptic qualitry in fresh market tomato. I. Mapping QTLs physical and chemical traits. *Theor. Appl. Genet*. **102**:259-272.

Salumkhe, D.K., S.J. Jadhav and M.H. yu, 1991. Quality and nutritional composition of tomato fruit as influenced by certain biochemical and physiological changes. *J. Plant Sci.,* **24**:85-113.

Silvana Grandillon ,Hsin, Mei Ku and Steven D.Tanksley, (1996).Department of plant breeding and Biometry. *J. Food quality*., **2**:251-260.Belgium

Stoffella, P. J., Locascio, S. J., Everett, P. H., Howe, T. K., Scott, J. W. and Olson, S. M. 1988. Yields of two tomato cultivars differing in shoot growth at several plant populations and locations. *J. Hort Science* **23**: 91–99.

SJUT, V. & BANGERTH, F. 1984. Induced parthenocarpy- a way of manipulating levels of endogenous hormones in tomato fruit (*Lycopersicon esculentum* Mill.). Plant Growth Regulation *J. Plant Sci* **2**, 49-56

Tesfu Mengistu and Charles Yamoah 2010 African Journal of Plant Science Vol. 4(8), pp. 270-279. http://www.academicjournals.org/AJPS ISSN 1996-0824 ©2010 Academic Journals (accessed on 15/11/2010)

Tesfaye B., 2008. Response of tomato cultivars differing in growth habit to nitrogen and phosphorus fertilizers and spacing on vertisol in Ethiopia, Department of Plant Sciences, Ambo University College of Agriculture.*http*://aas.bf.uni-lj.si/maj%202008/11balemi. (Accessed on 10/10/2010)

Tsedal Tseggai Ghebremariam, 2005. Yield and Quality Response of Tomato and Hot Pepper to Pruning. Department of plant Production and Soil Science. Thesis Dissertation, Pretoria. http://upetd.up.ac.za/thesis/available/etd-02082006-125505/unrestricted/00dissertation.pdf. assessed on 25/11/2010

Tittonell, P., J. DeGrazia and A. Chiesa, 2001. Effect of nitrogen fertilization and plant population during growth on lettuce (lactuca sativa L.) postharvest quality, Proceedings of the Fourth International Conference on Postharvest Science. *Acta Hort.,* **553(1):** 67-69.

Uddin. M. R. Hossain, M. A. Mian, M. A. K. Uddin M. Z. Reza and A.K.M. Mahtabuddin. 1997. Effect of stem pruning and spacing on the growth and yield of Tomato. Bangladesh *J. Hort Science.,* **25 (1&2):** 41-46

University of Califormia, 2004. Fresh Market Tomato State wide Uniform Variety Trial Report Field and Postharvest Evaluations South San Joaquin Valley. Agriculture and Natural Resources, Oakland, *Academic Journals.,* **(5):**87-96.

W.M.K.B Wahundeniya, R.Ramanani and W.A. P.Weerakkodi, 2005 comparison of growth and yield performances of tomato (*Lycopersicon esculentum mill*.) varieties under controlled environment conditions. Horticultural Crop Research Development institute. Gannoruwa. Peradeniya faculty of agriculture, university of peradeniya *J. Plant Sci.,* **4**:95-110.

Waskar,D.P.,R.MKhedlar and V.k Garande,1999. Effect of post harvest treatment on shelf life and quality of pomegranate in evaporative cooling chamber and ambient conditions. *J. Fooa Sci..and technol*ogy **2(36):**114-117

Wasserman, B.J., 1985. Effect of plant density on vegetable crops. An overview. AVRDC-TOP Training Report. University Bangkok, Thailand*., J. Agri*.,*5*: 85-90.

Wudiri, B.B. and D.W.Henderson, 1995. Effect of water stress on flowering and fruit set in processing tomatoes. J. *Horti Scie.,* **27**:89-98.

Yohannes, F. and T. Tadesse, 1997. Effect of drip irrigation and plant spacing on yield of tomato at Dire Dawa, Ethiopia. *J. Alemaya Univ. of Agric*., **35**: 201-207.

Young, T.E.,J.A.Juvik and J.G. Sullivan, 1993 accumulation of the components of total solids in ripening fruit of tomato, *J. Am. Soc. Hort. Sci.,* **118**: 286-292

Zhang, Y.W., 1999.Spacing and Pruning Effect on Tomato Yield. AVRDC J., 156: 1-5.
Ziska LH (2003). Evaluation of the growth response of six invasive species to past, present and future atmospheric CO2 , *J. Exp. Botan.,* **54(389):** 395-406.

Zvi Howard Wener 2009 Importance of the tomato, growing tomatoes, from planning to market place, Australia Agricultural articles. www.agrisupportonline.com/.../importance_of_the_tomato.htm) (Assessed 20, October 2010)

7. APPENDICES

Appendix Table 1**.** Mean squares for plant growth parameters of fresh market tomato varieties grown under Jimma condition

Source of variation	df	Mean squares				
		Primary branch No/plant (No)	Plant height (m)	Days to 50% flowering (No)	Flower No/cluster (No)	Days to first Harvest (No)
Block	2	0.097*	0.0017NS	0.2708NS	0.1426 *	20.44 NS
Variety	3	4.63***	1.395***	230.8541***	5.3826***	729.18***
spacing	3	1.32***	0.0152***	9 0763***	0.5302***	35.46***
Variety x spacing	9	0.166***	0.0033***	0.2986 NS	0.0918***	1.69*
Error	30	0.221	0.0069	0.381	0.030	0.084

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 2**.** Mean squares for plant growth parameters of fresh market tomato varieties

Source of variation	df	Mean squares		
		Fruit setting percentage	Stem dry matter (%)	Root dry matter (%)
Block	2	3.64*	16.87 NS	0.60 NS
Variety	3	3.64***	316.09***	22.57***
spacing	3	150.66***	40.89***	19.75***
Variety x spacing	9	37.16***	0.24 NS	0.38 NS
Error	30	0.6902	3.334	0.524

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 3**.** Mean squares for yield parameters of fresh market tomato varieties

Source of variation	df	Mean squares				
		Fruit number/cluster(No)	Fruit number/plant(No)	Fruit length (cm)	Fruit diameter (cm)	Average .fruit weight (g)
Block	2	0.0209 NS	0.25 NS	0.03 NS	0.07 NS	9.46 NS
Variety	3	7.7407***	93.80***	21.96***	15.87***	3780.71***
spacing	3	0.7448***	62.80***	1.00***	0.47***	3021.67***
Variety x spacing	9	0.1265***	9.51***	0.14***	0.19***	282.07***
Error	30	0.1760	0.68	0.183	0.0264	32.13

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 4**.** Mean squares for yield parameters of fresh market tomato varieties

Source of variation	df	Mean squares				
		Fruit yield /plant (k.g)	Fruit yield/ha (t)	Marketable fruit/ha (t)	Unmarketable fruit/ha (t)	Seed number/fruit (No)
Block	2	0.009 NS	1.90 NS	2.59 NS	0.17 NS	703.36 NS
Variety	3	2.085***	2070.75***	2382.05***	14.77***	68572.49***
spacing	3	1.99***	459.96***	524.23***	3.55**	206.76 NS
Variety x spacing	9	0.1007***	76.88***	77.74***	0.70***	37.48 NS
Error	30	0.0081	6.47	6.341	0.056	245.45

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 5**.** Mean squares for fruit quality parameters of fresh market tomato varieties

Source of variation	df	Mean squares		
		Fruit dry matter (%)	Fruit pericarp thickness (mm)	Fruit shape index (mm)
Block	2	0.23 NS	0.003 NS	0.004 NS
Variety	3	25.14***	0.033***	0.18***
spacing	3	0.80***	0.023***	0.008***
Variety x spacing	9	0.19***	0.0049NS	0.006***
Error	30	0.4833	0.0075	0.0082

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 6**.** Mean squares for fruit quality parameters of fresh market tomato varieties

Source of Variation	df	Mean squares		
		TSS (^{0}Brix)	TA (%)	pH (%)
Block	2	0.095 NS	0.0063 NS	0.004 NS
Variety	3	4.893***	0.0165***	2.37***
spacing	3	1.119***	0.0013 NS	0.01 NS
Variety x spacing	9	0.430NS	0.0021NS	0.04 NS
Error	30	0.336	0.0075	0.050

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 7**.** Mean squares for disease reaction of fresh market tomato varieties

Source of variation	df	Mean squares
		Disease incidence
Block	2	8.58 NS
Variety	3	417.00***
spacing	3	289.89***
Variety x spacing	9	17.37 ***
Error	30	3.78

df= degree of freedom ns, non significant, ***, significant at $p \leq 0.001$

Appendix Table 8. Pearson correlation

	BN	Pht	DFL	FlNC	FtNC	FtST	FtNP	Ftwt	FtL	FtD	Ftsh	Ftyp
BN	1	-075 ***	-036 *	0.86 ***	0.89 ***	0.84 ***	0.74 ***	0.66 ***	0.77 ***	0.58 ***	0.70 ***	0.75 ***
Pht		1	0.53 ***	-0.84 ***	-0.86 ***	-0.67 ***	-.047 *	0.42 *	-0.76 ***	-0.60 ***	0.63 ***	-0.45 ***
DFL			1	-0.54 ***	-0.55 ***	-0.36 ns	-0.42 *	-0.53 ***	-.06 ***	-.88 ***	-.024 ns	-0.45 ***
FLNC				1	0.96 ***	0.80 ***	0.70 ***	0.65 ***	0.79 ***	0.70 ***	0.61 ***	0.71 ***
FtNC					1	0.87 ***	0.73 ***	0.65 ***	0.83 ***	0.70 ***	0.68 ***	0.73 ***
FtSt						1	0.80 ***	0.68 ***	0.85 ***	0.60 ***	0.83 ***	0.77 ***
FtNP							1	0.66 ***	0.73 ***	0.59 ***	0.65 ***	0.86 ***
Ftwt								1	0.72 ***	0.75 ***	0.41 **	0.89 ***
FtL									1	0.84 ***	0.81 ***	0.76 ***
FtD										1	0.37 **	0.73 ***
Ftsh											1	0.73 ***
Ftyp												1

BN=Primary branch number per plant, Pht= plant height, DFL= days to 50% percent flowering, FlNC= flower number per cluster, FtsT= fruit setting percentage, FtNP=fruit number per plant, Ftwt= fruit weight, FtL=fruit length, FtD= fruit diameter, Ftsh= fruit shape index, Ftyp=fruit yield per plant
NS= non significant, * = Correlation is significant at the 0.05 level. ** = Correlation is significant at the 0.01 level.

.

	Ftyh	MF	UMF	SedN	DI	DFH	FtDM	StDM	RtDM	Ftpth	TSS	TA	PH
Ftyh	1	0.99 ***	-0.72 ***	0.40 **	-0.48 ***	-0.57 ***	0.72 ***	-0.63 ***	0.60 ***	0.19 ns	0.19 ns	0.23 ns	-0.02 ns
MF		1	-0.76 ***	0.38 ns	-0.50 **	-.05 ***	0.74 ***	-0.63 ***	0.62 ***	0.19 ns	0.08 ns	0.23 ns	-0.03 ns
UMF			1	-0.60 ns	0.60 ***	0.46 ns	-0.78 ***	0.43 *	-0.61 ***	-0.16 ns	-0.05 ns	-0.18 ns	-0.12 ns
SedN				1	-0.20 ns	0.02 ns	-0.06 ns	-0.47 *	0.05 ns	-0.02 ns	0.48 ns	0.01 ns	0.42 ns
DI					1	-0.20 ns	-0.23 ns	0.04 ns	-0.28 ns	0.11 ns	-0.46 **	0.11 ns	-0.28 ns
DFH						1	-08 ***	0.74 ***	-0.50 **	-0.20 ns	0.25 ns	-0.22 ns	0.33 ns
FtDM							1	-0.6 ***	0.71 ***	0.20 ns	-0.16 ns	0.22 ns	-0.30 ns
StDM								1	-0.28 ns	-0.09 ns	-0-15 ns	-013 ns	-0.02 ns
RtDM									1	0.22 ns	-0.14 ns	0.24 ns	-0.27 ns
Ftpth										1	-075 ***	0.99 ***	-0.88 ***
TSS											1	-0.73 ***	091 ***
TA												1	-0.86 ***
PH													1

Ftyh= fruit yield per hectare, MF=marketable fruit, UMF=unmarketable fruit,SedN=seed number per fruit, DI= disease incidence, DFH=days to first harvest, RtDM=root dry matter, StDM= stem dry matter, FtDM= fruit dry matter,Ftpth= fruit pericarp thickness, TSS, total soluble solids, A, titratable acidity and pH
NS= non significant, * = Correlation is significant at the 0.05 level. ** = Correlation is significant at the 0.01 level.