Adaptation of Newly Released Open Pollinated Tomato (*Lycopersicon Esculuntum* Mill.) varieties in Northwestern zone of Tigray

Abstract

Tomato (Lycopersicon esculentum Mill.) is one of the most important vegetable crops grown worldwide under outdoor and indoor conditions. It is the most cultivated and high market value of vegetable crops in Tigray Northern Ethiopia. However, Tomato production is highly constrained by several factors such as disease infestation, lack of improved variety, plant spacing and variation in cultural practices like plant population. The purpose of this study was to test the adaptability of tomato varieties and evaluate the yield potential of the technologies. Therefore, field experiment was conducted to evaluate the newly released Open Tomato varieties in 2017 and 2018 under irrigation conditions. Seven improved OPV namely: Gelilama, Mersa, Sirinka-I, Woyno, Tekeze-1, Melkashola and Melkasalsa as standard check were used and laid out in randomized complete block design with three replications. The performance of improved Tomato varieties has shown significant difference among varieties and across locations. The current findings showed that the highest marketable yield were obtained in Gelilama variety at (55.58 t ha^{-1}) & (49.59 t ha^{-1}) in Tselemti & M/zana woreda respectively followed by Melkasalsa (49.42 & 45.81 t ha^{-1}) in Tselemti & M/zana woreda respectively and Melkashola (44.13t ha^{-1}) in M/zana woreda. Based on the overall pair-wise comparisons by locations, Variety Gelilama and Melkasalsa took the first and second places in Tselemti woreda specific location Maitsebri tested sites and Gelilama, Melkasalsa & Melkashola varities have not significance difference among varities which (49.59, 45.81 &44.13t ha^{-1}) in M/zana woreda specific location in Selekeleka site respond very good yield over the others. Therefore, Gelilama and Melkasalsa can be safely suggested for demonstrate and scale-up of the crop across the tested areas.

Keywords: Tomato, OPV varieties, adaptability, yield

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops grown worldwide under outdoor and indoor conditions. It has become an important commercial crop so far as the area, production, industrial values and its contribution to human nutrition is concerned. It is the second most consumed vegetable next to potato and belongs to the family Solanaceae, which includes more than 3000 species (Kalloo, 2012). Tomatoes originated in South America, in the general area of Peru and Ecuador, but were first domesticated in Mexico and that the name of tomato was derived from the 'tomatil' in the Nahua tongue of Mexico (Ara *et al.*, 2007; Atherton and Rudich, 2012).

Commented [SC1]: Grammatical error

Commented [SC2]: 'infestation' refers to insect attack. Not applicable for microbial pathogen

Commented [SC3]: Meaning not clear

Commented [SC4]: This term has a very specific meaning in biology, in the context of evolution. It should be avoided in the context of casual parlance

Commented [SC5]: Not clear what this means

Commented [SC6]: What does this mean?

Commented [SC7]: The whole paper should be written in past tense as a general practice. Correct the entire manuscript based on this comment

Commented [SC8]: What does this mean?

Commented [SC9]: This is not a scientific parlance. Rephrase the sentence

Commented [SC10]: Too confusing sentence. Meaning not clear. Break up sentence into two

Commented [SC11]: Meaning not clear

Commented [SC12]: Crops are cultivated, not grown

Commented [SC13]: Where? Is this area specific? Local scale? Reference?

Commented [SC14]: Replace with 'around'

Commented [SC15]: These is not a scientific way to write

Commented [SC16]: How is this sentence relevant to the study?

Tomato is the highest production in the world and it's primarily production is in Asia. The production area in Europe, north and Latin America tends to stop increasing but the production is sustained by the increase of yield per hectare, probably using high yielding varieties and other improved agronomic practices (Zhang, 2010).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).

Tomato (*Lycopersicon esculuntum* Mill) also widely grown vegetable in Ethiopia as a reach source of vitamins A and C as well as minerals iron and phosphorus. Tomatoes contribute to a healthy, well-balanced diet. It is important for bone formation and growth, cell division and differentiation, for helping the regulation immune system since it contain vitamin A and forming collagen, a protein that gives the structure to bones, cartilage, muscle and blood vessels. This crop contains lycopene which is very power full antioxidants that help to prevent the development to cancer (Shankara *et al*., 2005).

In Ethiopia, it is produced in altitudes between 700 and 2000 m.a.s.l., which is characterized as warm, dry day and cooler night with having annual precipitation of 700 to more than 1400 mm in different areas and different season, in different soil types and provides different yields (Birhanu and Ketema, 2010). Tomato is fairly adapted and grows well in warm condition and requires optimum temperature of 20-25 ºC during the day and 15-17 ºC at night and can be grown in well-drained friable sandy or light loam soil with high organic matter content with pH 5 to 7.5 is preferable for early and high fruit yield. It must be also noted that tomato flowers fail to set fruits as the result of poor nutrient imbalances and poor managements (Lemma, 2002; Birhanu and Ketema, 2010; Tuan *et al*., 2015, Desalegn, 2016).

Both fresh and processed tomato varieties are popular and economically important vegetable crops produced in the country (Geleta *et al*., 1995). The total production of this crop in the country has shown a marked increase (Lemma *et al*., 2003) since it became the most profitable crop providing a multiple harvests potential of year round production per unit area and higher income to small scale farmers compared to other vegetable crops. It is also widely accepted and commonly used in a variety of dishes as row, cooked for making local sauce (Wot) or processed and sliced used as salad more than any other vegetables (Lemma, 2002).

Small-scale and large-scale farmers mainly produced the bulk of fresh and processing types of tomatoes respectively in Ethiopia. The processed products such as tomato paste, tomato juice, tomato ketchup and whole peel-tomato are produced for local market and export. Recently tomato is recognized for treating various human diseases. Such diverse uses make the tomato an important vegetable in irrigated agriculture in the country and the production is also rapidly increasing in many parts of the country (Lemma, 2002).

However, tomato production is highly constrained by several factors especially in developing nations like Ethiopia. The national average of tomato fruit yield under farmers' condition is 9 t ha^{-1}, which is very low compared to 25 and 40 t ha^{-1} at demonstration and experimental research plots, respectively (Lemma, 2002). According to FAOSTAT (2018), also the

Commented [SC17]: Wrong sentence construction

Commented [SC18]: Meaning not clear

Commented [SC19]: Rephrase this as: Tomatoes are cultivated on approximately 4.5 million hectares of land worldwide

Commented [SC20]: Check spelling

Commented [SC21]: Iron and phosphorous are not minerals. Either say 'minerals rich in iron or phosphorous' or more appropriately, 'elements iron and phosphorous'

Commented [SC22]: 'bone formation'? Did you mean 'bone development'?

Commented [SC23]: Break up this sentence into 2 or 3 sentences. Also reference?

Commented [SC24]: Check spelling

Commented [SC25]: Wrong construction

Commented [SC26]: Wrong construction

Commented [SC27]: Seasonal or annual?

Commented [SC28]: No space between number and unit. Correct this throughout

Commented [SC29]: What does this mean?

Commented [SC30]: Did you mean 'raw'?

Commented [SC31]: What is this?

Commented [SC32]: What does this mean?

Commented [SC33]: Wrong use of word. 'treating' specifically refers to medicine. You can use the term 'alleviating' in this context

Commented [SC34]: What does this mean?

productivity of tomato in Ethiopia (5.2 ton ha^{-1}) is by far very low when compared to the world average productivity (37.6 ton ha^{-1}), and Africa (16.5 ton ha^{-1}) .

Increasing production of the crop has a great role to strengthen the growing vegetable industries in the country. Mehla *et al*., (2000) also reported yield variation in tomato occurred due to disease infestation, lack of improved variety, plant spacing and variation in cultural practices like plant population per given area.

There are numbers of released varieties in our country and have been tested and selected the best performance one in our agro ecology, but know also released new varieties in Melkasa Agricultural Research Center (MARC), Sirinka Agricultural Research Center(SARC) and Humera Agricultural Research Center (HARC). So, it was found promising to evaluate new released and highly accepted improved Tomato varieties undertake adaptation trial and selected the best adapted and high yielding (superior) variety/ies to increase the production of the livelihood of farmers of the zone.

Objective

To select agro ecologically adaptive and high yielder Tomato varieties

Materials and Methods

Description of the study Area

The experiment was conducted at Tselemti & Medebayzana woreda specific location at Maitsebri and at Selekeleka Shire-Maitsebri Agricultural Research Center (SMARC) research stations respectively during 2017 & 2018 under off season condition. Tselemti woreda specific location Maitsebri research station is located 400 km west of Mekelle and 85 km from Shire along the way Shire to Gondar (Figure-1). The research station lies at latitude $13^{0}05'$ North and longitude $38^{0}08'$ East and has an altitude of 1304 m.a.s.l. The Agro-ecological zone of the woreda is hot to warm-moist lowlands and Tepid to cool-moist mid highlands with 2.65% 'Dega' (cool highland), 19% 'Weinadega' (mid highland) and 78.35% 'Kola' (hot lowland). The mean annual temperature ranges from a minimum of 18.4^{o}C (November-January) to an average annual maximum of 32.7^{o}C (February-May). It is a low altitude area with average (6 years) annual rainfall of 1176.7 mm. Generally, rainfall starts in June and ends in September (Metrological data, 2016).

Medabayzana woreda specific location selekeleka research station is also located at 378 km west of Mekelle and 22 km from shire to east direction along the way Shire to Axum (Figure-2). The research station lies at 14°6′43″ N, 38°27′50″E, and at an altitude of 1951 m above sea level. The mean annual rainfall is 680 mm. The rainy season extends from June to September and the maximum rain is received in the months of June to August.

Commented [SC35]: Isn't Ethiopia part of Africa. Did you mean to say 'rest of Africa'

Commented [SC36]: Wrong sentence construction

Commented [SC37]: Again use of the term 'infestation'

Commented [SC38]: What does this mean

Commented [SC39]: Wrong sentence construction

Commented [SC40]: Not clear what this means

Commented [SC41]: Wrong sentence construction, also meaning not clear

Commented [SC42]: If it is already tested and accepted, what is the use of this study?

Commented [SC43]: Not clear what this means

Commented [SC44]: Objective not clear

Commented [SC45]: Not clear what this means

Commented [SC46]: Not relevant information for a study site description

Commented [SC47]: What does this mean?

Commented [SC48]: Is this common to both the areas?

Commented [SC49]: This phrase have been constantly used throughout the manuscript. What do the authors mean by this?

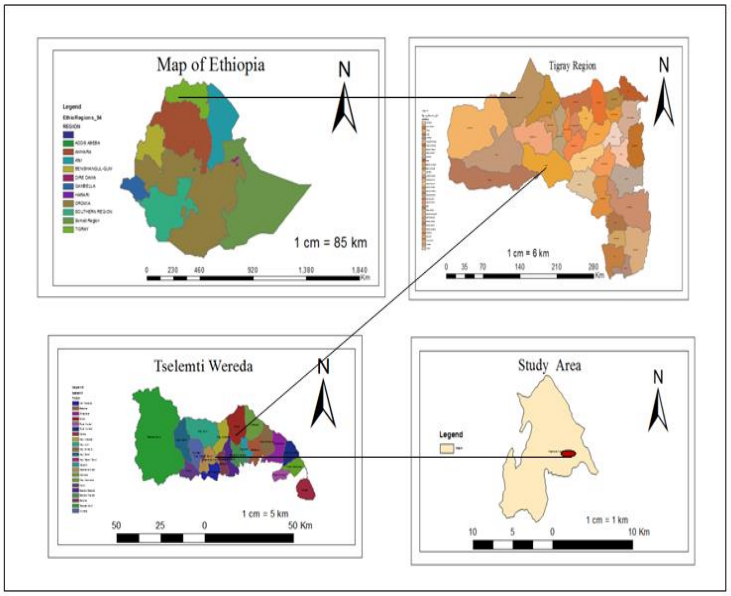

Figure 1. Maps of the country, Tigray Region, Tselemti woreda and Maitsebri station

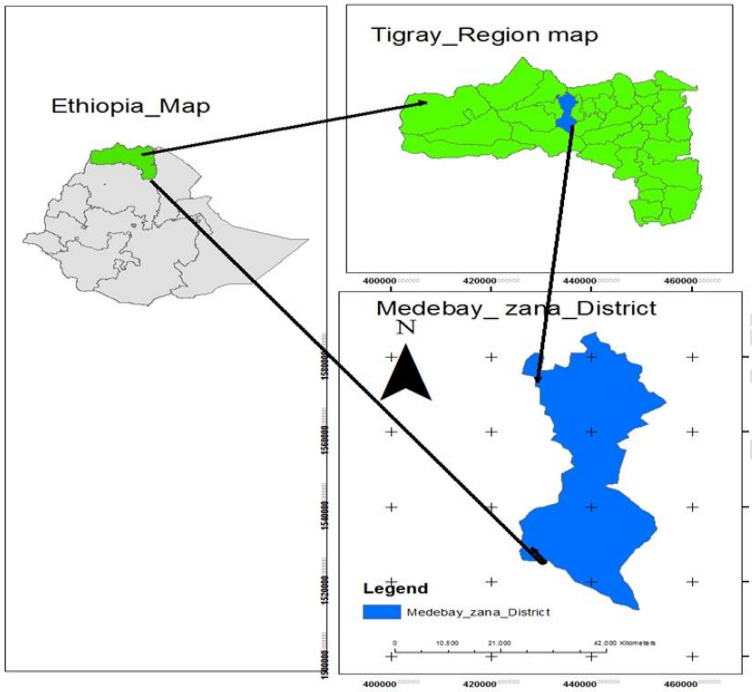

Figure 2. Maps of the country, Tigray region, and Medebayzana woreda

Experimental Treatments, Design and Procedure

Seven improved and released Tomato verities collected from Melkasa, Sirinka & Humera Agricultural Research Centres namely Gelilama, Melkashola, Melkasalsa, Mersa, Sirinka-1, Woyno & Tekeze-1 were evaluated for their performance in the studies area (Table-1). The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Each experimental plot has a plot size of 4.0 m*3.9 m, separated by 1 m between plots and 1.5 m b/n blocks. Each plot was consisted 5 rows of 4.0 m length with a spacing of 30 cm between plants and 80 cm between rows. Gross area 33.3 m * 15 m (499.5 m^2) and Net area 27.3 m * 12 m (327.6 m^2) was used for each location. All management practices (ploughing, cultivation, watering, weeding and others) was applied uniformly to all plots.

Commented [SC50]: Why are both these maps different. Put these in the same map with panels for different districts/locations (3rd panel) in both and just mark the locations of the sites with a pin.

Commented [SC51]: Incorrect wording

Commented [SC52]: There should be a figure with the schematic of the block design, with the measurements and pictures of actual plots during experiment

Commented [SC53]: Do not use abbreviations like this in a scientific literature

Commented [SC54]: The details of experimental design is not sufficient. Need details of how the varieties were grown? Were they all grown together at the same time? How many plots and blocks? All of these details need to be broken down systematically.

From the description it seems like the authors have used 2 plots, one in each site. For each plot these should be 7 varieties * 3 replicates = 21 blocks. Is this the case? If so it should be clearly broken down like mentioned

Other information required like: what were the growing conditions? Temperature, watering regime, growing season and duration? Grown in shade house or in open? What type of soil used? Is it with added fertilizers etc. What was the individual plant density in each block? All these details are important in interpreting the results

Table 1: Released tomato varieties used for the study and some of their descriptions.

Variety name	Year of release	Environmental requirements		Growth habit	Utilization	Days to maturity	Fruit size (gm)	Yield (t ha^{-1})		Responsible Research Center or Breeder/Maintainer	Unique character
		Altitude (m)	Rainfall (mm)					Research field	Farmer` s field		
Gelilama	2015	700-2000		Determinate	Processing	85-100	80-92	50	20-25	MARC	Firmness & Oval red fruit shape
Melkashola	1998	700-2000	1400	Determinant	Processing	100-120	60-70	43	14-18	MARC	Red Pear and Globular fruit shape
Melkasalsa	1998	700-2000	1400	Determinant	Fresh	100-110	40-50	45	13-17	MARC	Small fruit size, Slightly cylindrical fruit shape
Mersa	2006	800-2000	1400	Indeterminate	Fresh	100-120	42-50	27.6	15.9	SARC	Carman fruit shape
Sirinka-1	2006	800-2000	1400	Indeterminate	Fresh	95-100	60-65	38.2	14.4	SARC	small fruit size & Cardinal or Round fruit shape
Woyno	2006	800-2000	1400	Determinant	Fresh	85-90	40-50	24.9	14.4	SARC	small fruit size & Fireball or Oval fruit shape
Tekeze-1	2015	700-2000		Determinant	Processing	70-75	34-38	40	30-35	Humera ARC/TAR	Very small fruit size & Oval red fruit shape

Source: Directory of released crop varieties & variety release booklet, Ministry of Agriculture, Addis Ababa (2009 & 2016) and Meseret *et al.,* (2012)

Commented [SC55]: This table clearly demonstrates that the optimal growing conditions for each variety are different. It make sense to apply common conditions to all these varieties, thereby biasing the results

Data to be collected

All data relating to yield and yield components were collected from the central three rows by excluding plants from either end of the rows. For the purpose of crop data collection 6 plants per plot were selected randomly and observations on growth, yield and yield components of the crop such as Days to 50% flowering, Days to maturity, Plant height (cm), Fruit number per plant, Fruit diameter (cm), Fruit length (cm), Fruit weight (gm) and Marketable yield (t ha^{-1}) were recorded periodically.

Days to 50% flowering: Taken when half of the plant population on the net plot area gets to flower.

Days to 50% maturity: The number of days from transplanting to maturity stage was recorded.

Plant height (cm): Height of six sample plants per plot were measured from the ground level to the top at the end of mid stage of the crop using a ruler.

Fruit number per plant: Number of fruits was determined by counting the number of fruits of each plant at each harvesting time from six randomly selected plants from each plot.

Fruit diameter (cm): Average diameter of six randomly selected ripened fruit was measured using caliper from each plot.

Fruit length (cm): Average length of six randomly selected ripened fruit was measured using caliper from each plot.

Fruit weight (gm): Average fruit weight of six randomly selected ripened fruit was measured using a sensitive balance from each plot.

Total marketable fruit yield (t ha^{-1}): Weight of healthy and marketable fruit yield per plot was determined and converted to t ha^{-1}.

Data Analysis

The data was subjected to analysis of variance (ANOVA) using Gen Stat 14th edition statistical software according to Gomez and Gomez (1984) statistical procedure. When the treatments were significant, least significance differences (LSD) by Dunken's multiple range comparison were used for mean separation at 5% probability level.

Result & Discussion

Flowering & Maturity Date

The analysis of variance of 50 % flowering & maturity date in Tselemti Woreda (Maitsebri on-station) and Medabay Zana Woreda (Selekeleka Sation) showed significantly ($P<0.05$) influenced by varieties. The mean average 50 % flowering and 50% maturity date ranging from

Commented [SC56]: Why? Does this imply non-uniform growing conditions even within a plot?

Commented [SC57]: The base of comparison should be individuals of one variety to another, not at a community level. It would make more sense to measure the number of days to peak flowering for each individual, averaged for a variety

Commented [SC58]: No idea what this means. Is it maturity of the entire plant? Or maturity of fruits? What is meant by 'transplanting'. It has not been described earlier in the methodology

Commented [SC59]: Not at all relevant for comparing fruit yield

Commented [SC60]: This name has been capitalised differently all throughout the manuscript. Make a consistent way to write the proper noun

Commented [SC61]: Wrong interpretation of statistics

38.83 to 47.33 and 84.17 to 103.83 respectively in Tselemti woreda and 45.00 to 68.00 & 95.17 to 110.67 ranging 50 % flowering and maturity date respectively in Medabayzana woreda. Tekeze-1 variety is significantly earlier than the other varieties at about 38.83 & 84.17 days at flowering & maturity respectively in Tselemti woreda and 45.00, & 95.17 days at flowering & maturity respectively in Medebay Zana woreda (Table-2).

Tselemti woreda result of 50% flowering date is in agreement with the finding of Meseret *et al*., (2012) and Debela *et al*. (2016) reported that the period 50% flowering date ranged from 38 to 49 and 37.66 to 46.33 days respectively among the ten tomato varieties. In Medabayzana woreda result of 50% flowering date also similarly with the finding of Masho *et al*. (2016) reported among fourteen tomato verities mean average days to 50% flowering from 49.7 to 57.3. According to Parvej (2010), days to 50% flowering are one of important phenological parameters and determinant factors for growth and productivity of tomato plants. Moreover the difference in 50% flowering days can also be attributed by the genetic makeup of genotypes as observed by Abdelmageed and Gruda (2003).

In the present study, the tested tomato varieties took 84.17 to 103.83 days and 95.17 to 110.67 days to produce horticultural matured fruit in the first harvest in Tselemti & Medabayzana woreda respectively. Various researchers reported that tomato varieties give the first harvest in 70-120 days after transplanting (Fayaz *et al*., 2007 and Masho *et al*., 2016). In the present study, sixteen & nineteen day's difference was observed between late & early variety respectively. Late varieties such as Gelilama (100.50 days), Melkasalsa (102.00 days) and Melkashola (103.83 days) in Tselemti woreda & Mersa (110.67 days) in Medabayzana woreda and early variety Tekeze-1 (84.17 & 95.17 days) in both locations which is relatively a normal range as observed by various authors as mentioned above.

Moreover, the delay in flowering can correspondingly lead to the delay of fruit maturity in tomato and the early or late maturity is attributed by genotypic character and in the extent influenced by the environmental factors of any particular growing area (Fayaz *et al*., 2007).

Table-2: Effect of varieties on Growth Parameters of Tomato Production

S/N	Variety	Tselemti (Maitsebri on-staion)			M/zana (Selekeleka on-staion)		
		FLD	MD	PH (cm)	FLD	MD	PH (cm)
1	Gelilama	46.33 c	100.50 c	63.16 c	62.00 ab	104.85 b	67.53 b
2	Sirinka-1	42.33 b	92.67 b	78.92 b	56.33 b	106.17 b	84.84 ab
3	Mersa	46.17 c	93.50 b	88.44 a	68.00 c	110.67 c	97.53 a
4	Woyno	42.17 b	92.67 b	78.86 b	56.33 b	106.34 b	104.67 a
5	Tekeze-1	38.83 a	84.17 a	40.25 d	45.00 a	95.17 a	44.72 c
6	Melkashola	45.00 c	103.83 c	54.53 c	62.67 ab	106.5 b	67.67 b
7	Melkasalsa	47.33 c	102.00 c	57.39 c	62.33 ab	105.52 b	63.14 b

Commented [SC62]: 'earlier' is applied to date. Here you are describing duration. Use 'shorter'

Commented [SC63]: The place names are all over the place. In the same paragraph it is written differently. Stick to a single naming scheme

Commented [SC64]: This parameter is indeed important. But it is highly sensitive to growing environmental conditions. Therefore, all of these can only be evaluated in the context of growth parameters. This follows that growing these varieties under sub-optimal conditions would drastically bias results towards the variety that is best suited for those conditions. For example, changes to altitude, rainfall and temperature, in the order of importance will significantly influence crop yield. Therefore it is impossible to select a one-size-fits-all variety as defined by the objective of the paper

Commented [SC65]: What is 'horticultural' matured fruit. This is not a scientific term

Commented [SC66]: Not an appropriate way to write scientific literature

Commented [SC67]: This is exactly how the results are to be interpreted. It is not enough to mention this. You need to discuss your results primarily in the context of these factors

Commented [SC68]: Another way the name is written?

Mean	44.02	95.62	65.9	58.95	105.03	76
CV (%)	4.7	4.8	10.8	1.9	1.9	11.1
LSD (0.05)	3.483	7.744	11.96	2.772	3.193	15.5

Means within the same column followed by different letters are significantly different at P ≤ 0.05. FLD = Flower Date, MD = Maturity Date, PH = Plant Height, CV=coefficient of variation & LSD = Least Significant Difference

Commented [SC69]: No idea what does this mean. What is the significance of the letters

Plant height (cm)

The analysis of variance revealed that the plant height showed significantly (P<0.05) influenced by Tomato varieties studied. The mean value of plant heights ranged from 40.25 to 88.44 cm in Tselemti woreda and ranges from 44.72 to 106.67 cm in Medabayzana woreda. The tallest plant was recorded by Mersa Tomato variety (88.44 cm) which is significantly higher than the other varieties in Tselemti woreda and Woyno (104.67cm) which were not statistically difference with Mersa (97.53 cm) and Sirinka-I (84.84 cm) Tomato verities in Medabayzana woeda. While, the shortest plant was recorded Tekeze-1 (40.25 & 44.72 cm) in Tselemti and Medebayzana woreda respectively followed by Melkashola (54.53 & 67.67 cm), Melkasalsa (57.39 & 63.14 cm) and Gelilama (63.16 & 67.53 cm) which were not statistically difference among the verities in Tselemti and Medebayzana woreda respectively (Table-2).

Commented [SC70]: Wrong interpretation of statistics. The result of ANOVA is described as: x trait significantly between y varieties. The test never measures influence of a variety. 'influence' always indicated causation. Statistical tests can never distinguish between correlation and causation

In agreement with the results of this study, Meseret *et al*., (2012), reported the mean range of plant heights 40.20 to 107cm. Debela *et al*. (2016) reported the mean ranges of plant heights among the ten Tomato verities from 39.50 to 74.33 cm. The mean plant height of the fourteen tested tomato varieties was reported in the range of 51.7 cm to 115.5 cm (Masho *et al*., 2016). Sirinka-1 (115.45 cm) was the tallest variety followed by Mersa (110.8 cm) and Eshet (102.20 cm) varieties. On the other hand Melkasalsa (51.7) was found to be the shortest variety among the 14 tested varieties (Masho *et al*., 2016). Cherenet and Zibelo (2014) also obtained wide difference plant height (62.1-105.3 cm) among the nine tomato varieties evaluated in western lowland of Tigray, Northern Ethiopia. Hussain *et al*., (2001) reported wide range of difference (61.6-126.5cm) in plant height among the ten tomato genotypes evaluated in Pakistan. Similarly, Dufera (2013) obtained wide difference (51.5-129.7 cm) for plant height in tomato.

The tallest tomato varieties generally require long growth period and special management practices such as stalking and may also face the incidence of diseases and insect pests in tropical climate. On the other hand the short varieties may not need stalking and their production may require less labor expense that makes them highly popular for commercial cultivation in tropical conditions (Naika, 2005). According to Baudoin (1995) short tomato varieties are most suitable to produce two crops per season. Moreover, tallest tomato varieties needs more cost for stalking and pesticide application. On the other hand tall varieties can be harvested five times per cropping while short varieties three times.

Commented [SC71]: No evidence of this

Commented [SC72]: No evidence of this

Commented [SC73]: You can talking about varieties, not different species altogether. Taller varieties on the contrary tend to grow faster, accumulate more resources and also tend to produce higher yield than shorter varieties

Table-3: Effect of varieties on Fruit weight (gm), Fruit diameter & Length (mm)

S/N	Variety	Tselemti (Maitsebri on-staion)			M/zana (Selekeleka on-staion)		
		FW (gm)	FD (mm)	FL (mm)	FW (gm)	FD (mm)	FL (mm)
1	Gelilama	80.67 a	66.57 a	77.58 ab	82.5 a	65.21 a	79.75 ab
2	Sirinka-1	53.64 c	47.35 bc	46.43 c	65.5 b	54.39 bc	53.25 c
3	Mersa	70.83 b	49.30 bc	87.18 a	61 bc	64.02 ab	97.16 a
4	Woyno	50.83 c	48.20 bc	45.20 c	62.17 bc	64.00 ab	60.54 c
5	Tekeze-1	33.89 d	40.38 c	40.85 c	30.5 d	45.63 c	47.52 cd
6	Melka shola	70.28 b	56.33 ab	72.40 b	62 bc	62.43 b	86.26 ab
7	Melka salsa	71.11 b	59.98 ab	76.70 ab	65.46 b	59.24 bc	80.9 ab
	Mean	61.6	52.6	63.8	61.5	59.05	72.35
	CV (%)	12.5	10.6	13.7	9.8	10.9	12..5
	LSD (0.05)	12.91	18.02	14.68	10.98	11.52	16.08

Means within the same column followed by different letters are significantly different at P ≤ 0.05. FW = Fruit Weight (gm), FD = Fruit Diameter (mm), and FL = Fruit Length (mm), CV=coefficient of variation & LSD = Least Significant Difference

Commented [SC74]: Same comment as above table

Fruit Weight (gm), Diameter & Length (mm)

Fruit weight, diameter & fruit length were recorded significantly (P<0.05) difference affected by improved tomato varieties (Table-3).

Commented [SC75]: What is meant by 'improved'?

The average ranging of fruit weight from 33.89 to 80.67gm in Tselemti woreda and from 30.5 to 82.5 gm in Medabayzana woreda. Accordingly, the highest fruit weight was recorded Gelilama (80.67 gm) followed by Melkasalsa (71.11 gm), Melkashoal (70.28 gm) and Mersa (70.83 gm) tomato verities. While, the lowest fruit weight was scored by Tekeze-1 (33.89 gm) followed by Woyno (50.83 gm) and Sirinka-1 (53.64 gm) of tomato varieties in Tselemti woreda. In Medabayzana woreda also the highest fruit weight was recorded Gelilama (82.5 gm) followed by Melkasalsa (65.46 gm), Sirinka-1 (65.5 gm), Weyno (62.17 gm), Melkashoal (62 gm) and Mersa (61 gm) tomato verities. While, the lowest fruit weight was scored by Tekeze-1 (30.5 gm) tomato variety.

The fruit sizes of the tested varieties are within the standard ranges for tomato fruits as reported by Lemma (2002). According to the report, the average weight of tomato fruits is in the range of 20 to180 gm. The tomato fruits produced differ in size from small cherry types (20 gm) to extra large of beefsteak (180 gm). The fruits that are commonly available in the markets can be categorized as small (less than 50 gm), medium (70 - 110 gm), big (100-170 gm) and very big (> 170 gm) sized. According to Rubatzky and Yamaguchi (1997) tomato fruits are categorized into small, medium, large and very large based on the fruit weights with the value of <50gm, 70-110gm, 110-170 gm & > 180gm, respectively. Medium and large fruit categories are preferred generally for fresh market.

The average ranging of fruit diameter from 40.38 to 66.57 mm in Tselemti woreda and from 45.63 to 65.21 mm in Medabayzana woreda. Larger fruit diameter were recorded Gelilama (66.57 mm) with no statistically difference with Melkasalsa (59.98 mm) & Melkashoal (56.33 mm) tomato verities. While, the shortest fruit diameter of tomato varieties were recorded Tekeze-1 (40.38mm) with no statistically difference with Sirinka-1 (47.35 mm), Woyno (48.20 mm) & Mersa (49.30 mm) in Tselemti woreda. Larger fruit diameter were recorded Gelilama (65.21 mm) with no statistically difference with Mersa (64.02 mm) & Weyno (64.00 mm) followed by Melkashola (62.43 mm)tomato verities. While, the shortest fruit diameter of tomato varieties were recorded Tekeze-1 (45.63 mm) with no statistically difference with Sirinka-1 (54.39 mm) & Melkasalsa (59.24 mm) in Medabayzana woreda.

The average ranging of fruit length from 40.85 to 87.18 mm in Tselemti woreda and from 47.52 to 97.16 mm in Medabayzana woreda. The tallest fruit length were recorded Mersa (87.18 mm) with no statistically difference with Gelilama (77.58 mm) & Melkasalsa (76.70 mm) followed by Melkashoal (72.40 mm) tomato verities. While, the smallest fruit length of tomato varieties were recorded Tekeze-1 (40.85 mm) with no statistically difference with Weyno (45.20 mm) and Sirinka-1 (46.43 mm) in Tselemti woreda. The tallest fruit length were recorded Mersa (97.16 mm) with no statistically difference with Melkashola (86.26 mm), Melkasalsa (80.9 mm) & Gelilama (79.75 mm) tomato verities. While, the smallest fruit length of tomato varieties were recorded Tekeze-1 (47.52 mm) with no statistically difference with Sirinka-1 (53.25 mm) & Weyno (60.54 mm) in Medabayzana woreda.

Depending on the type of variety, tomato fruit diameter is at the range of 32-109.7 mm (Kaushik *et al.*, 2011 and Masho *et al*., 2016) which is in line with the findings of the present study (Table-3). The present study of the fruit length is agreement with the reported Masho *et al*. (2016) with ranging fruit length 40.4 to 80.5 mm in the Tselemti woreda, but not agreement with Masho *et al*. (2016) who reported that the average fruit length of tomatoes is ranging from 40.4 to 80.5 mm in Medebayzana woreda (Table-3). The weight, diameter and length of tomato fruits are influenced by the genetic makeup of the varieties (Atherton and Rudich, 2012).

Number of fruits per plant and fruit yield per plant (gm)

The results indicated that there was significantly difference ($P<0.05$) showed in the number of fruits per plant and fruit yield per plant (Table -4).

The number of fruits per plant is averagely ranging from 36.67 to 62.83 fruits of tomato verities. The highest number of fruits per plant was recorded Tekeze-1 (62.83) followed by Melkasalsa (55.00), Gelilama (49.83) and Melkashola (48.33) tomato varieties. While, the lowest number of fruits per plant was recorded Sirinka-1 (36.67) followed by Mersa (42.67) and Woyno (42.67) tomato varieties in Tselemti woreda. The number of fruits per plant is averagely ranging from 39.84 to 60 fruits of tomato verities. The highest number of fruits per plant was recorded Tekeze-1 (60) followed by Melkasalsa (56.72), Melkashola (55.83) and Gelilama (53.34) tomato

varieties. While, the lowest number of fruits per plant was recorded Woyno (39.84) with no significant difference Mersa (40.17) and Sirinka-1 (43.84) tomato varieties in Medabayzana woreda (Table -4).

The present study is similar with the study of Mulualem & Tekeste (2014) reported in the average ranging from 38.25 to 53.45 tomato fruits per plant. Binalfew *et al.* (2016) reported also averagely ranging from 18.16 to 40.49 numbers of fruits per plant. The number of fruits per plant is affected by the number of flowers & fruits per cluster (Meseret *et al*., 2012). It is one of the major criteria to select variety for its higher yielding potential. In general, the higher the number of fruits per plant the more fruit yield is expected, although fruit size also determines the yield estimation (Pandey *et al*., 2006).

The fruit yield per plant is averagely ranging from 1800 to 4400.55 gm fruits of tomato verities. The highest fruit yield per plant was recorded Gelilama (4019.79 & 4400.55 gm) with no significant difference Melkasalsa (3911.05 & 3712.89 gm) and followed by Melkashola (3396.63 & 3461.46 gm) and Mersa (3022.32 & 2450.37gm) in Tselemti & Medabayzana woreda respectively. While, the lowest fruit yield per plant was recorded Sirinka-1 (1966.98 gm) & Woyno (2168.92 gm) in Tselemti woreda but Tekeze-1 (2129.31 & 1800 gm) lowest fruit yield in Tselemti & Medabayzana woreda respectively (Table -4). Chernet and Zibelo (2014) and Balcha *et al.* (2015) reported averagely ranging 5343 to 8640 gm and 140 to 950 gm fruit yield per plant respectively. Therefore, the higher the fruit yield per plant the more fruit yield is expected (Pandey *et al*., 2006).

Commented [SC76]: This is not appropriate term

Table-4: Effect of varieties on number of fruits per plant, fruit yield per plant (gm) and Marketable yield per hectare (t ha^{-1})

S/N	Variety	Tselemti (Maitsebri on-staion)			M/zana (Selekeleka on-staion)		
		NFpP	FYpP (gm)	MYpHa (t ha^{-1})	NFpP	FYpP(gm)	MYpHa (t ha^{-1})
1	Gelilama	49.83 bc	4019.79 a	55.58 a	53.34 b	4400.55 a	49.59 a
2	Sirinka-1	36.67 e	1966.98 c	38.95 d	43.84 c	2871.52 b	37.21 b
3	Mersa	42.67 de	3022.32 b	40.73 cd	40.17 c	2450.37 b	35.25 b
4	Woyno	42.67 def	2168.92 c	38.03 d	39.84 c	2476.85 b	37.65 b
5	Tekeze-1	62.83 a	2129.31 c	33.28 e	60 a	1800 c	31.99 c
6	Melkashola	48.33 bc	3396.63 b	43.12 c	55.83 b	3461.46 ab	44.13 a
7	Melkasalsa	55.00 b	3911.05a	49.42 b	56.72 b	3712.89ab	45.81 a

Mean	48.29	2945. 0	42.73	49.96	3024.81	40.22
CV (%)	10.3	16.3	7.4	7.55	8.7	6.55
LSD (0.05)	8.329	509.4	5.325	7.81	403.25	4.69

Means within the same column followed by different letters are significantly different at $P \leq 0.05$. NFpP = Number of Fruits per Plant, FYpP = Fruit Yield per Plant (gm), MYpHa = Marketable Yield per Hectare, gm = gram, CV= coefficient of variation, LSD = Least Significant Difference, t = tone & ha = hectare

Marketable fruit yield (t ha^{-1})

According to Pandey *et al*. (2006) marketable fruit yield is the major determinant variable for selection of a particular tomato variety, as it directly affects commercialization and thus income generation of the farms. In the present study the highest marketable fruit yield was recorded by variety Gelilama (55.58 & 49.59 t ha^{-1}) followed by Melkasalsa (49.42 & 45.81 t ha^{-1}) & Melkashola (43.12 & 44.13 t ha^{-1}) in Tselemti & Medabayzana woreda respectively. While, the lowest marketable yield was recorded also Tekeze-1 (33.28 & 31.99 t ha^{-1}) in both location (Table-4).

The marketable yields of the above mentioned tomato varieties were relatively good compared to the findings of Masho *et al*. (2016) and Chernet & Zibelo (2014) who reported the marketable fruit yield ranging from 29.51 to 58.75 t ha^{-1} and 17.89 to 56.07 t ha^{-1} respectively. The marketable yield averagely ranging from 14.88 to 47.55 t ha^{-1} also reported by Balcha *et al.* (2015). However Lemma (2002), Rida *et al*. (2002) and Meseret *et al*. (2012) reported the marketable yield of tomatoes in the range of 30 to 73.9, 37.1 to 76.2 and 6.46 to 82.50 t ha^{-1}. The observed varietal differences of marketable yields in the present study might be due to the difference in fruit pericarp thickness (Capuno *et al.*, 2007).

Summery and Conclusions

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crops grown worldwide under outdoor and indoor conditions. It is also widely grown vegetable in Ethiopia as a reach source of vitamins A and C as well as minerals iron and phosphorus. Tomatoes contribute to a healthy, well-balanced diet. It is important for bone formation and growth, cell division and differentiation, for helping the regulation immune system since it contain vitamin A and forming collagen, a protein that gives the structure to bones, cartilage, muscle and blood vessels. This crop contains lycopene which is very power full antioxidants that help to prevent the development to cancer. However, tomato production is highly variation or constrained by disease infestation, lack of improved variety, plant spacing and variation in cultural practices like plant population per given area.

The objective of this study was to selected agro ecologically adaptive and high yielder Tomato varieties in Tselemti & Medabayzana woreda under irrigation production system. The tested varieties namely Gelilama, Melkashola, Melkasalsa, Mersa, Sirinka-1, Woyno & Tekeze-1 performed differently in growth, yield and yield parameters. Tekeze-1 variety is significantly earlier than the other varieties at about 38.83 & 84.17 days at flowering & maturity respectively

Commented [SC77]: Same lines copied from Introduction

Commented [SC78]: No idea what is term means

in Tselemti woreda and 45.00 & 95.17 days at flowering & maturity respectively in Medebay Zana woreda. The tallest plant was recorded by Mersa Tomato variety (88.44 cm) which is significantly higher than the other varieties in Tselemti woreda and Woyno (104.67cm) which were not statistically difference with Mersa (97.53 cm) and Sirinka-I (84.84 cm) Tomato verities in Medabayzana woeda. While, the shortest plant was recorded Tekeze-1 (40.25 & 44.72 cm) in Tselemti and Medebayzana woreda respectively followed by Melkashola (54.53 & 67.67 cm), Melkasalsa (57.39 & 63.14 cm) and Gelilama (63.16 & 67.53 cm) which were not statistically difference among the verities in Tselemti and Medebayzana woreda respectively.

On the yield and yield parameters were also the highest fruit weight was recorded Gelilama (80.67 & 82.5 gm) followed by Melkasalsa (71.11& 65.46 gm), Melkashoal (70.28 & 62gm), and Mersa (70.83 & 61 gm) tomato verities. While, the lowest fruit weight was scored by Tekeze-1 (33.89 &30.5 gm) tomato varieties in Tselemti & Medabayzana woreda respectively. Larger fruit diameter was recorded Gelilama (66.57 & 65.21 mm) tomato verities While, the shortest fruit diameter of tomato variety was recorded by Tekeze-1 (40.38 & 45.63 mm) in Tselemti & Medabayzana woreda. The tallest fruit length was recorded Mersa (87.18 & 97.16 mm) While, the smallest fruit length of tomato variety was recorded Tekeze-1 (40.85 &47.52 mm) in Tselemti & Medabayzana woreda.

The highest number of fruits per plant was recorded Tekeze-1 (62.83 & 60) While, the lowest number of fruits per plants were recorded Sirinka-1 (36.67 & 43.84) and Woyno (42.67 & 39.84) tomato varieties in Tselemti & Medabayzana woreda respectively. The highest fruit yield per plant was recorded Gelilama (4019.79 & 4400.55 gm) with no significant difference Melkasalsa (3911.05 & 3712.89 gm) and followed by Melkashola (3396.63 & 3461.46 gm) and Mersa (3022.32 & 2450.37gm) in Tselemti & Medabayzana woreda respectively. While, the lowest fruit yield per plant was recorded Sirinka-1 (1966.98 gm) & Woyno (2168.92 gm) in Tselemti woreda but Tekeze-1 (2129.31 & 1800 gm) lowest fruit yield in Tselemti & Medabayzana woreda respectively.

In the present study the highest marketable fruit yield was recorded by variety Gelilama (55.58 & 49.59 t ha^{-1}) followed by Melkasalsa (49.42 & 45.81 t ha^{-1}) & Melkashola (43.12 & 44.13 t ha^{-1}) in Tselemti & Medabayzana woreda respectively. While, the lowest marketable yield was recorded also Tekeze-1 (33.28 & 31.99 t ha^{-1}) in both location. Therefore, Gelilama will be promoted to demonstration with the standard check Melkasalsa & Melkashola in the study area.

Commented [SC79]: Result and Discussion is being repeated all over again

Commented [SC80]: It seems the authors concluded this just on the basis of fruit yield. If that is the primary criteria, why did they study all these other parameters?

References

Abdelmageed, A. H., Gruda, N., and Geyer, B. 2003. Effect of high temperature and heat shock on tomato (*Lycopersicon esculentum* Mill.) genotypes under controlled conditions. In *Conference for International Agricultural Research for Development* , Pp.1-7.

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.

Atherton, J. and Rudich, J. 2012. The tomato crop: a scientific basis for improvement. Springer Science & Business Media.

Balch K, Belew D, and Nego J.2015. Evaluation of Tomato (*Solanum lycopersicum* Mill.) Varieties for Seed Yield and Yield components under Jimma Condition, South Western Ethiopia. J Agron 14:292-97.

Baudoin,W. O.1997.Protected cultivation in the Mediterranean region. In *International Symposium Greenhouse Management for Better Yield & Quality in Mild Winter Climates, Pp*. 23-30.

Binalfew T, Alemu Y, Gelto J, Wondimu G, and Hinsermu M. 2016. Performance of Introduced Hybrid Tomato (*Solanum lycopersicum* Mill.) cultivars in the Rift Valley, Ethiopia. Int J Res Agric For 3:25-8.

Birhanu K., and Ketema T. 2010. Fruit yield and quality of drip-irrigated tomato under deficit irrigation. *Afr. J. Food, Agric, Nutr. Dev*.

Capuno, O. B., Gonzaga, Z. C., Loreto, M. B., Briones, E. D., Tulin, A. T., Gerona, R. G. and Rogers, G.S. 2007. Cultivation of tomato (*Lycopersicon esculentum* Mill.) under a rain shelter and in the open field in Cabintan, Ormoc City, Leyte, Philippines.

Chernet S., and Zibelo H. 2014. Evaluation of tomato varieties for yield and yield components in western lowland of Tigray, Northern Ethiopia. Int J Agri Res, 9:64-259.

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

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

Desalegn, R., T. Wakene and S. Addis, 2016. Tomato in Borana zone, Yabello district, southern Ethiopia. J. Plant Breed. Crop Sci., 8(10): 206-210.

Dufera, J.T. 2013. Evaluation of agronomic performance and Lycopene variation in tomato (*Lycopersicon esculantumm* Mill.) genotypes in Mizan, Southwestern Ethiopia. *World Applied Sci. J., 27: 1450-1454.*

FAOSTAT. 2018. Statistical Database of the Food and Agriculture of the United Nations. FAO, Rome, Italy. Retrieved from: http:// faostat.fao.org/ site/612/default.aspx#ancor).

Fayaz , O. K, S. S, A H and S. A. 2007. Performance evaluation of tomato cultivars at high altitude.
Sarhad J. Agric. Vol. 23, No. 3.

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.

Hussain, S.I., K.M. Khokhar, M.H. Laghari and M.M. Mahmud. 2001. Yield potential of some exotic and one local tomato cultivars grown for summer production. *Pakistan J. Biol. Sci. 4:1215-1216.*

Kalloo, G. 2012. Genetic improvement of tomato. Springer Science & Business Media.

K.B. Debela, D. Belew & J. Nego. 2016. Evaluation of Tomato (*Lycopersicon Esculentum* Mill.) Varieties for Growth and Seed Quality under Jimma Condition, South Western Ethiopia. *International Journal of Crop Science and Technology (IJCST)***,** ISSN: 2458-7540, Volume 2, Issue 2, Pp 69-77.

Kaushik, S. K., Tomar, D. S., and Dixit, A. K. 2011. Genetics of fruit yield and it's contributing characters in tomato (*Solanum lycopersicom* Mill.). *Journal of Agricultural Biotechnology and Sustainable Development*, *3*(10), 209-213.

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

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

Masho Aklile, Melkamu Alemayehu and Getachew Alemayehu. 2016. Performance evaluation of tomato varaieties for irrigation production system in Mecha District of west Gojiam Zone, Amhara Region, Ethiopia. College of Agriculture and Environmental Sciences, Bahir Dar University**.** Pp. 145-154.

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.

Meseret D., Ali M. and Kassahun B. 2012. Evaluation of Tomato (*Lycopersicon esculentum* L.) Genotypes for yield and yield component. *The African Journal of Plant Science and Biotechnology pp 45-49.*

Metrological data. 2016. Tigray, Mekelle Metrological data of six years average.

Mulualem and Tekeste. 2014. Evaluation of improved tomato *(Solanum lycopersicum* Mill.*)* Varieties in Southern Ethiopia. *Herald Journal of Agriculture and Food Science Research Vol. 3 (2): 055 – 060.*

Naika, S., de Jeude, J. V. L., de Goffau, M., Hilmi, M., & van Dam, B. 2005. *Cultivation of tomato*. Didigrafi Publishing. Netherlands.Pp.34-57.

Pandey, Y. R., Pun, A. B. and Upadhyay, K. P. 2006. Participatory varietal evaluation of rainy season tomato under plastic house condition. *Nepal Agric. Res. J*, *7*, 11-15.

Parvej, M. R., Khan, M. A. H., & Awal, M. A. 2010. Phenological development and production potentials of tomato under polyhouse climate. *The Journal of Agricultural Science*, *5*(1), 19-31.

Rida,A.S., A.A. Muhammad, I.E. Ereifij and A. Hussain. 2002. Evaluation of thirteen open pollinated cultivars and three hybrids of tomato (*Lycopersicon esculentum* Mill.) for

yield, physiological disorders, seed production and vegetative growth. Pak. J. Agric. Res. 17(3): 290-296.

Tuan, N.M. and N.T. Mao. 2015. Effect of plant density on growth and yield of tomato at Thai Nguyen, Vietnam. International Journal of Plant & Soil Science, 7(6): 357-361.

Variety Release Booklet. 2016. Plant and Animal Quarantine Regulatory, Ethiopian Ministry of Agriculture. Addis Ababa, Ethiopia

Zhang, X., Q. Huanguang and H.Zhorng, 2010. Apple and Tomato Chains in China.