Tomatoes

Research Experiences and Production Prospects

Lemma Desalegne

Ethiopian Agricultural Research Organization

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iar@telecom.net.et
Fax: 251-1-461294
Tel: 251-1-462633
P.O. Box 2003
Addis Abeba, Ethiopia

Copyediting and design: **Abebe Kirub**
Graphic works and Layout: **Kidanemariam Hagos**

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Introduction

The cultivated tomato (*Lycopersicon esculuntum* Mill) is the most important and widely grown vegetable in the world. To date, its importance is increasing in Ethiopia. It is widely accepted and commonly used in a variety of dishes as row, cooked or processed products more than any other vegetables.

There is no definite time recorded regarding the introduction of cultivated tomato to Ethiopia. However, cherry type has been growing for long around big cities and in small gardens. Recently, the crop has expanded to commercial production for home use, export and processing industries. The bulk of fresh market tomatoes are produced by small-scale farmer. Processing types are mainly produced in large-scale horticultural farms. Farmers are interested in tomato production more than any other vegetables for its multiple harvests, which results in high profit per unit area. Like in many other countries, it is also becoming important in Ethiopia in a variety of dishes. The fresh produces is sliced and used as salad. It is also cooked for making local sauce (*Wot). T*he processed products such as tomato paste, tomato juice, tomato ketchup and whole peel-tomato are produced for local market and export. It is an important cash-generating crop to small-scale farmers and provides employment in the production and processing industries. It is also important source of vitamin A and C as well as minerals. Such diverse uses make the tomato an important vegetable in irrigated agriculture in the country.

The tomato research program in Ethiopia was started in mid 1960s to address various production constraints. Organized research on tomato began in the National Horticultural Research Center, at Melkassa. To date, Melkassa Research Center coordinates the national vegetable research program, which subsequently has extended different research centers.

Some of the improved technologies have been released to farmers. The initial research achievements especially varieties like Roma VF and Marglobe and crop protection measures have made significant contribution when establishing commercial horticultural enterprises. Recently, released tomato technologies have also been demonstrated and popularized to users in collaboration with development agents and producers. Because of its diverse economic benefits, the Ethiopian Agricultural Research Organization (EARO) has developed research strategy to address the growing local and export demands. In this strategic context, tomato is classified as a high priority crop in vegetable crops research program.

This publication provides a comprehensive account of achievements made and practical experiences gained from tomato research in Ethiopia especially in the Rift Valley, which is climatically and physically favorable for the tomato industry.

The Crop

Tomato is self-pollinated, but occasional out-crossing under high temperatures due to outgrowth of the stigma beyond the anther cone. However, such floral exertion has not been observed in studies made with 150 tomato lines in the warmer season of the year (February to May) at Melkassa, in the Rift Valley (MARC, 1999; MARC, 2000). Apparently, there are diverse tomato species and genotypes in the world that are tolerant to diseases and insect pests and stresses such as heat, salinity, and moisture that have potential to improve the commercial tomatoes for different purposes (Stevens and Rick, 1986). It can produce fertile hybrids with other *Lycopersicon* species with varying degrees of difficulty (IBPGR, 1981). Some of its wild relatives have high yield, good fruit quality and high storability to improve its adaptability and use.

The tomato cultivars currently produced in Ethiopia vary in growth habit as determinate, semi-determinate and in-determinate types (Fig. 1). The indeterminate types are high in stature, produce fruits for extended period, need plant support and produce high fruit yield. Determinate cultivars are bush like, compact and fruits mature in a relatively short time as compared to indeterminate ones. It is favorable for concentrated fruit production for early market and for processing industries. The genotypes also differ in several aspects such as stem strength, leaf type, foliage coverage, fruit set, plant size and response to various stresses Depending on cultivars (Marglobe or Cherry) or growing conditions about 3-8 fruits are produced per cluster.

Tomatoes vary in visible fruit characteristics important for fresh market and processing values. These include shape, size, color, flesh thickness, number of locules, blossom end shape and fruit quality (TSS%, pH, acidity, juice viscosity, juice volume, flavor, nutritive values etc. The fruits may be globe-shaped (Marglobe), oval or flattened (Marmande) and pear shaped (Roma VF), which differ in acceptability in the local market, quality, storability, etc (Fig. 2).

Red skin tomatoes are the most preferred in local markets. High TSS% (4.5-6.0), which is responsible for high yield of processed products intensive red color of both skin and flesh, low acid are some of the attributes favored by processing industries. The sugar and acid ratio

has important contribution to the flavor of tomatoes (Stevens, 1979). The contents of glucose, fructose, citric acid and there inter-relationships also influence the taste and aroma of the fruits (Stevens and Rick, 1986).

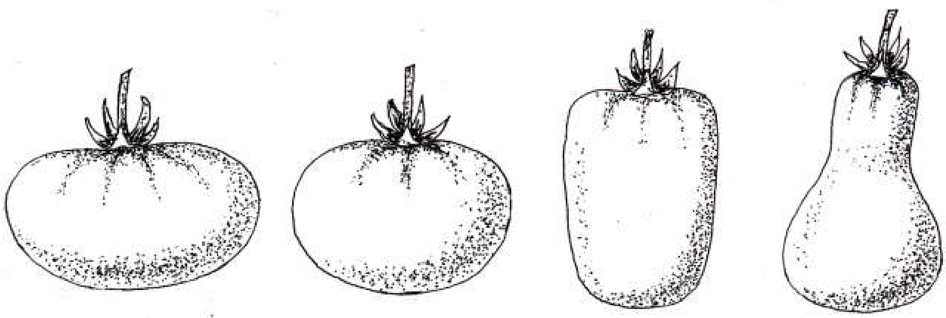
There are special fruit characters that the local market demands from tomatoes. The most recognized ones are fresh market types, round, large, free from defects, good flavor and attractive red-colored fruits. Fruits should also be firm, healthy, evenly colored, good appearance and good keeping quality and high vitamins content. The tomato fruits currently produced differ in size from small cherry types (20 g) to extra large of beefsteak (180 g). The fruits that are commonly available in the markets can be categorized as small (less than 50 g), medium (70 - 110 g), big (100-170 g) and very big (> 170 g) sized. The small ones that resemble the wild types are tolerant to environmental hazards than the large ones. The two size extremes have low acceptance in the market. Cultivars for processing should be:

- firm with thick wall,
- high retaining capacity,
- high processing quality, i.e., high TSS% (4.5-6.0), pH >4.5,
- intensive red color of both skin and flesh,
- better tolerant to diseases and physical damages; and
- high yielding

Fruit quality, especially TSS percentage is negatively related to fruit yield (Stevens, 1979). Therefore, high solid cultivars are of little value unless they also have high yield potential. Currently, the demand for fresh market tomatoes is changing to the processing cultivars (pear/cylindrical) because of their thick flesh and ease of transportation, storability and fitness for multi-purpose use.

Determinate (short set) *In-determinate (tall set)*

Fig 1 Growth habit of the tomato



Flattened *Round* *Cylindrical* *Pear*

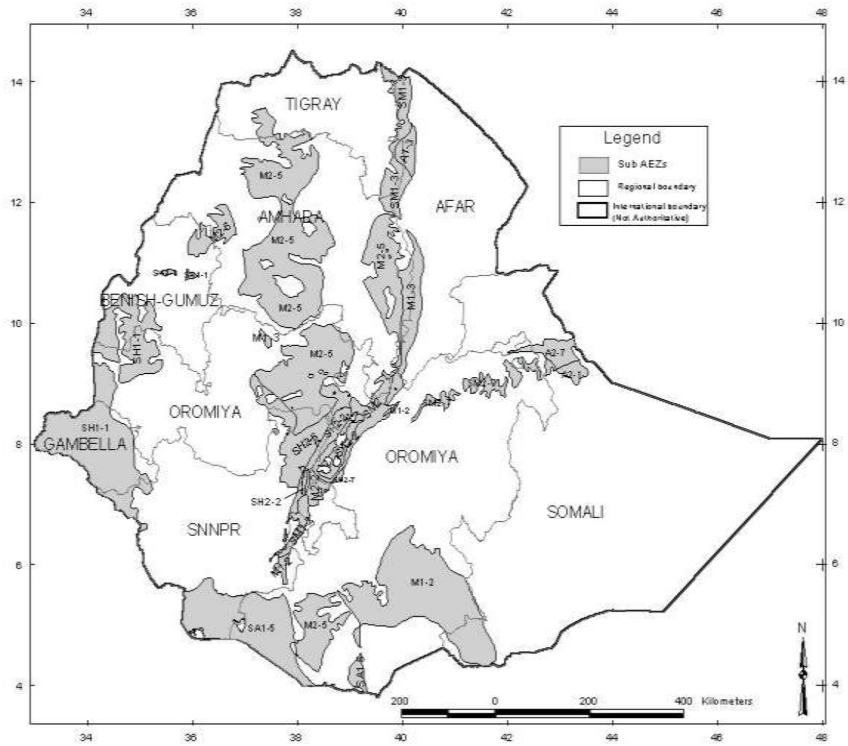
Fig 2 Predominate shapes of tomato fruits

Adaptation Regions

In Ethiopia 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. Experiences under humid or rainy growing conditions indicate that tomato is susceptible to disease. Tomato 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 (Shanmugavehu, 1989). Fruit setting is poor when the temperature is either high or low. Extreme temperatures cause flower drops and poor fruit set (Ho and Hewitt, 1986). A temperature range between 21 and 27^0C day and 10, 20^oC night is favorable for plant development, and fruit set in the Rift Valley region. At high temperatures such as Werer above 35^0C day and 20^0C night temperatures from March to July a high blossom drop is common. The cultivars that are currently in production failed to set fruits and gave low yield when the day and night temperatures were above 32^0C and 21^0C, respectively. Heat tolerant genotypes could be the potential ones for such growing conditions. It must be noted that tomato flowers fail to set fruits if there is poor nutrient imbalances, excessive high temperature for example in Lower Awash from March to July or low temperature (in Addis Abeba and Holetta from October to February) and poor management.

Tomato can be grown in many types of soils. However, well-drained friable sandy loam soil with pH of 6.7 is preferable for early and high fruit yield (Shanmugavehu, 1989). Tomato is produced mainly under irrigation. Production in the rainy season is also possible, but need intensive management.

Studies in different research centers/testing sites such as Debre Zeit, Werer, Jima, Alemaya, Awasa, Gambella, Zwai, Bako, and the Rift Valley region located in various agro-ecological zones as well as research document on horticultural genetic resources in the country indicated that tomato is grown in limited land widely distributed in all Regions of Ethiopia (Map 1). Currently, made commercial production possible in the arid and sub-arid regions of the country under irrigation has become possible. Small-scale production is also possible in moist and sub humid regions particularity in warmer and drier seasons where plant management is less intensive and disease pressure is low. The bulk of tomato production is concentrated in river valleys and lakes especially in the Awash Valley and around Lake Zwai for their favorable growing conditions, good access to market outlets and better infrastructure and facilities. This showed diverse potential production belts in the country for homestead and commercial production.



Map 1 Tomato producing agroecologies

Though tomato is produced in different regions, currently exact agroecological information is not sufficiently available to locate production belts. However, Map 1 shows the various agroecologies where tomato can be possibly grown.

Production Status

Small cherry type tomato fruits have been produced for a long time in Ethiopia in home gardens for household consumption and to some extent as source of income. Lately different fruit types appeared in the big markets such as Addis Abeba, Nazret, and Dire Dawa. Both fresh and processing types of tomatoes are popular. Tomatoes are widely produced by small farmers and commercial growers. The bulk of fresh market tomatoes are produced by small-scale farmers, along riverbanks and lake areas mainly in central, eastern and northern parts of Ethiopia. Tomato production is increasing in areas where irrigation water is available. It has been found to be the most profitable crop to small farmers. For example, at Melkassa Research Center a net income of about 11,000-14,000 birr/ha was estimated from experimental plot yields which were much higher than any other vegetable crops (MARC, 2000). The current productivity under farmers' conditions is 90 q/ha, which is very low compared to 250 q/ha and 400 q/ha the demonstration and research plots, respectively. This seems to indicate that there is a strong need for technology transfer to develop the production.

The establishment of the state horticultural crops production enterprises (UAAIE and HADE) and private farms has contributed to the development of the tomato industry in the country. Favorable weather, adequate water supply and availability of fertile soil encouraged large-scale tomato production in the Rift Valley. Total production has shown a marked increase in the state sector. For example, between 1971 and 2000 the area of production in one of the state horticultural crop enterprises have increased from 62 to 833 hectares and production has increased from 6,600 to 143, 652 q of processing tomatoes (Table 1). About 608 to 1892 tons of tomato pastes, 7-35 tons of ketchup and 13-44 tons of juices have also been reported (HDC, 1990). Tomato is the dominant processing vegetable crop at Melge-Wendo Plant, where about 42 tons of paste has been processed. There is also a plan to expand the production of tomato fruits to 2158 tons in which about 15% expected from out growers by the year 2001.

Table 1 Area and total production of processing tomato in state enterprises

Year	Area (ha)	Total production (q)
1971/1972	62.1	610.4
1972/1973	83.2	330.8
1973/1974	201.2	236.2
1974/1975	368.1	814.2
1975/1976	667.1	1144.3
1976/1977	833.4	3652.6
1977/1978	829.8	619.6
1978/1979	786.2	6825.9
1979/1980	727.2	391.3
1996/1997	374.5	322.7
1997/1998	519.9	853.7
1998/1999	522.9	0996.7
1999/2000	436.5	0517.8

Sources: HDC, 1978-1988; UAAIE, 1997-2000

The bulk of tomato is produced in the dry season, when irrigation water is available. However, production during the rain season is important for fresh market, because of high market demand. Different production practices have been followed by farmers, private growers and state enterprises. Plant spacing like, 150 x 30 or 80 x 30 cm with single row per bed have been used by farmers. In mechanized large-scale production, double row spacing of 110 cm furrow including the, 40 cm between rows on bed and 20 cm between plants (110 x 40 x 20 cm) have been used. The rate of inorganic fertilizers application varied from 2 to 4 q/ha diamonium phosphate (18 N/46 P) at transplanting and two side dressing of 1-3 q/ha Urea (46% N) at flowering and fruiting stages for high yield and return per unit area. The experience in field managements such as irrigation, fertilization, rotation and disease and insect pest management is limited in tomato production.

Shortage of varieties and recommended packages of information, unknown sources, and poor quality seeds, poor irrigation system, lack of information on soil fertility, diseases and insect pests, high post harvest loses, lack of awareness of existing improved technologies and poor marketing systems are the major production constraints in tomato production.

Variety Development

Introduction and evaluation of germplasm

Since 1969, about 300 tomato lines/cultivars of both short and tall set open-pollinated genotypes and hybrids have been imported from international seed companies, and from Asian Vegetable Research Center (AVRDC). These lines have been tested at different research centers to identify lines of high yield and good quality fruits, resistant/tolerant lines to diseases, insect pests and parasitic weeds complex for the different production belts.

In the initial tomato experiment, a set of 40 cultivars was tested in different years and seasons at Melkassa, located in hot to warm and sub moist agro-ecological zones. Higher yield was obtained in the dry season under irrigation than in the wet season. Cultivars such as Tropic, Moneymaker, Rutgers, Heinz 1350, Sanmarzano, Roma VF, and Rossol VFN well adapted. Two pear-shaped cultivars Rossol VFN and Roma produced significantly and consistently higher marketable yield (418-560 q/ha) than the round fruit cultivars (320-420 q/ha). Roma VF was tolerant to fruit cracking while Moneymaker was susceptible. Different varieties such as Marglobe, Homestead, Person Al, Roma VF, Sanmarzano etc have been recommended to growers (NRC, 1973; NRC, 1985; IAR, 1987a,).

From 1990 to 1992 cropping season (August to January), 90 fresh and processing tomato genotypes were tested at Melkassa. Among the fresh market types, early-maturing types that require less than 75 days from transplanting to harvest, those having strong stems, danseur foliage and high fruit set than the standard check were selected. Cultivars and lines such as Pyongyang, H-2543, CL-5915-206-D4-2-5-0, CL-5915-553-D4-3-10, L-272, CL-9-0-0-1-3, L-4138, Floradade, VFN-138, UC-204 A, Heinz selection and Arizona were superior in yield (2 to 4 kg/plant), compared to the standard check and the rest materials (0.5 to 1.98 kg/ plant) in Melkassa and Upper Awash. In processing types, five early-maturing cultivars Giaran, Interpel, Peelo, Super Roma VF and Red ball including two dense foliage cultivars, Serio and M.22, and two heavy bearers RV-1 and RV-44, were identified. Cultivars such as Cardinal, Maremma

Selection, Jago, RV-44, and RV-41 were found superior in marketable yield (2.5 to 3.0 kg/ plant) compared to Marglobe and Roma VF (MARC, 1994).

From 1993 to 2000, different tomato genotypes were tested at Melkassa in the rainy/warmer season (July to September) and during the dry/cool season (October to February). The main objectives of the study were to identify cultivars that are suitable to different growing seasons in the Rift Valley. Processing types with high stand establishment and survival rate were found both in the dry and rainy seasons. The yield potential in the dry season was superior (451 q/ha) to that in the rainy season (181 q/ha) (Table 2). Some cultivars performed well under both conditions while others showed differential responses to growing seasons. Cultivars CL-8d-0-7-1 was significantly superior in yield both in the dry and rainy seasons, while CL-5915-206-D4-2-2 and CL-5915-93D-D4-1-0 significantly out yielded the standard checks in the dry season.

Hybrids imported from different countries have been tested for their yield potential. However, it did not show much difference when compared with the open pollinated ones at Melkassa, which was about 328 q/ha and 321 q/ha for open-pollinated, and hybrids, respectively (Table 3). The hybrids developed for other regions did not perform better than the standard checks in Melkassa.

Table 2 Yield (q/ha) of selected tomato cultivars in dry and rainy seasons (1986)

Cultivars	Rainy	Dry
CL-1131-0-0-7-2-0-9	209	380
CL-1131-0-0-38-4-0	177	397
CL-8d-0-7-1	188	532
CL-5915-93-D4-1-0	148	634
CL-9-0-0-1-3	180	377
Roma VF	188	398
CL-5915-206-D4-2-2	157	478
Marglobe	205	412
Means	181	451

In the Western region of Ethiopia, Bako, which is sub-humid and mid highland agroecology different tomato cultivars were tested from

December to April under irrigation (IAR, 1986; IAR, 1987b). Cultivars Moneymaker, Pearson Improved, Marglobe, Roma VF, Napoli VF and Cherry produced in the range of 502 to 635 q/ha with 15 to 30% unmarketable fruits. The small-fruited cultivar (Cherry) produced the least unmarketable fruit (7%). The main causes for unmarketability of the fruits were insect pests, sunscald, cracks, leaf diseases, and poor water and plant management practices. It was also difficult to produce tomatoes in the rain season due to leaf disease and high insect pest incidence. Reasonable yield can be obtained in the dry season under irrigation.

Table 3 Yield performance some potential cultivars of open pollinated and imported hybrid tomatoes (1994)

Cultivars	Stand at harvest (%)	Mean fruit wt. (g)	No. of fruits/ cluster	No. of cluster/plant	Total yield (q/ha)
Open pollinated					
Picador	93	94	4	11	554.1
Mexico	100	50	3	11	351.7
Marglobe Improved	83	132	3	11	351.1
Castle star	90	71	4	8	328.4
Caribie	90	101	4	13	315.8
Marglobe (check)	95	66	4	11	312.5
Super market	98	99	3	9	280.0
Mogambo	88	106	4	12	260.0
Red river	75	57	5	13	203.0
Means	**92**	**86**	**4**	**11**	**328.1**
Hybrids					
Sun 6002	100	83	5	18	437.4
Hybrid 898	83	63	4	12	387.5
Solar set Hybrid	93	94	3	9	378.0
683 Calipso	95	121	3	9	365.0
Hybrid F_1 Beyene	85	80	4	10	237.5
Hybrid Bantam	75	106	4	11	123.3
Means	**89**	**91**	**4**	**12**	**321.4**

Source: Progress Report of MARC, 1995

At Werer Marglobe, Moneymaker, Pearson Al, Rutgers, Homestead and Roma VF gave high yields ranging from 650 to 830 q/ha compared to less than 400 q/ha of the other test cultivars. Losses due to damages caused by birds, insect pests and virus diseases were high (NRS, 1973).

At Awasa, cultivars Moneymaker, Sanmarzano, Rossol VF, Hienz 1350, and Marmande were promising with a yield range of 107 to

217 q/ha. Moneymaker (177 q/ha), Person Al (217 q/ha), Heinz 1350 (187 q/ha) were superior and recommended for the region (AES, 1972).
At Debre Zeit Marglobe, Moneymaker and Rutgers were recommended for the region (Asfaw, 1995). While at Gambella, Moneymaker gave the highest yield (110 q/ha) (IAR, 1986; IAR, 1987a) about 20% of the fruits of all cultivars were attacked by a fungus disease.

Around Jima the yield of several cultivars (12 to 134 q/ha) were lower than the yield obtained at Melkassa and Bako. The highest yield was produced from Napoli VF (134 q/ha) followed by Moneymaker, Tropic and Heinz 1350 (IAR, 1986; IAR, 1987b; JRS, 1981). The yields of all cultivars in the region were low because of various foliar diseases caused by the humid weather conditions compared to dry conditions in the Rift Valley. Heinz 1350 gave the highest unmarketable fruits compared with others due to damages caused by insects and bird attack leaf disease and cracking of fruits (JRS, 1983; IAR, 1987a).

Processing Tomatoes

Variety Development

The production of processing tomato has increased in the last decade. In advanced varietal studies at Melkassa, Roma VF was the only recommended and widely produced variety for the industry. Currently it has declined in acceptability because of its low yield and low fruit quality and susceptibility to disease complex. It resulted in uneven ripening which affects the color and subsequent acceptability of processed products mainly juice, paste and ketchup.

Recently selected genotypes were evaluated in multi-location trials Melkassa, Zwai and Merti in the central Rift Valley in collaboration with at UAAIE and HADE in order to produce better variety for the processing industry. Cultivars, Serio, Red Pear, Royal ball and Nova 70 A were superior in marketable and total yield across locations. They were less susceptible to foliage diseases, have dense foliage and high fruit coverage compared to the standard check Roma VF. Cultivars Red Pear, Serio, Maremma Selection Jago had high total soluble solids (TSS%= 4.5-5) and performed relatively well in marketable and potential yields (Table 4).

Cultivars *Melkashola* (Red Pear) and *Melkasalsa* (Serio) were found superior in yield, quality and acceptability by tomato processing industries and farmers subsequently released for production to growers. Both varieties were superior to Roma VF in leaf coverage of fruits, relatively better tolerant to leaf diseases, thick skinned, good fruit storability, high juice yield, high TSS% and fruit color. The variety *Melkashola* is semi-determinate, with compact branching habit, medium fruit size (60-70 g), firm fruit at red ripen stage and longer shelf life (Table 5). It has the advantage of long distance shipment with a minimum damage compared to others. Its shape is long and cylindrical. It has both processing and fresh market potential. It is more tolerant to diseases than most of the currently cultivated cultivars.

Melkasalsa is similar in character to *Melkashola* except that it is short set with light green leaves, smaller fruit size (40-50 g), high juice yield (87%) and pear shaped.

In the overall fruit yield *Melkashola* and *Melkasalsa* produced 726 q/ha and 665 q/ha compared to 591 q/ha of the control Roma VF, respectively. However, in Merti Agro-industry enterprise *Melkasalsa* was higher than *Melkashola* in yield potential. The cultivars have been found suitable and acceptable for processing.

Table 4 Mean total and unmarketable fruit yield of processing tomato types in three locations

	Location					
	Melkassa		Merti		Zwai	
Cultivar	Total yield (q/ha)	Unmark. (%)	Total yield (q/ha)	Unmark. (%)	Total yield q/ha)	Unmark (%)
Nova 70 A	504.2	32	440.1	20	835.5	16
Interpel	586.9	35	494.4	19	739.2	12
Serio	728.5	22	562.4	20	703.8	8
M-22	659.2	42	521.0	25	710.3	10
Oval Red	648.5	38	490.9	21	625.7	13
Red Ball	591.9	40	502.3	26	594.6	10
Royal Ball	593.4	32	466.1	24	735.8	10
Red Pear	763.9	31	553.4	26	860.9	6
Maremma Sel.Jago	542.3	25	427.1	27	754.0	7
Roma VF (check)	642.8	23	527.3	25	604.9	2
Means	626.2	32	498.5	23	726.5	9.4

Percent unmarketable fruits include damages caused by sun scorch, decay, disease, physiological disorder and other.

Table 5 Fruit and plant characteristics of recently released processing tomato cultivars (1993- 1997)

Characteristics	Melkashola	Melkasalsa
Growth type	Semi indeterminate	Determinate
Branching habit	Compact	Compact
Length of internode on main stem	Medium	Strong
Stem strength	Weak	Medium
Leaf color	Dark green	Light green
Vine coverage	Thick	Thin
Flower color	Yellow in color	Yellow in color
Plant maturity	3½-4 months	3½-4 months
Fruits size (g)	50-60	40-50
Fruit firmness	Firm	Firm
Fruit shape	Lengthen cylindrical	Pear
Fruit skin crack resistant	Very good	Very good
Fruit pistil scar	Absent	Absent
No. of locules/fruit	2-3	4-5
No. of fruits/cluster	5-6	5-6
No of cluster/plant	25-30	20-25
Fruit - Dark green shoulder	Absent	Absent
External fruit color	Orange red	Cherry
Internal fruit color	Blood red	Crimson
Pericarp thickness	Thick	Thick
Color of the epidermis	Red	Red
Fruit quality - TSS%	5.0 - 5.5	4.5 - 5
Fruit juice yield %	85	87
Fruit pH	4.25	4.33

Fresh Market Tomatoes

Variety studies

The demand for fresh market tomato has been for the round/globular and large fruited cultivars. Recently, pear-shaped cultivars, which have thick flesh, long shelf life, and potential for long distance transportation, are better accepted. In the mid and late 1990s, tomato cultivars were intensively tested in the Upper and Middle Awash Valley. Cultivars VFN-138, Floradade, Homestead and Heinz 1350 Selection Mexico, produced good foliage coverage, which protected the fruit from direct sun burn (MARC, 1996; 1998; 1999). Their yields ranged between 402 and 546 q/ha (Table 6).

Table 6 Yield of fresh market tomato types in three locations

	Location					
	Melkassa		Merti		Zwai	
Cultivars	Total yield (q/ha)	Unmark (%)	Total yield (q/ha)	Unmark (%)	Total yield (q/ha)	Unmark (%)
UC 204 A	362	35	297	23	547	20
Royal ball	442	30	388	22	601	23
H-2543	420	27	374	28	588	27
VFN-138	523	34	382	21	651	20
Floradade	476	31	417	32	575	25
CL-5915-553-D4-3-0	538	38	414	23	555	18
CL-1131-0-0-43-10-1	325	29	271	45	556	23
Heinz 1350 sel. Mexico	548	28	439	27	652	20
Homestead 61	483	45	379	31	466	18
Oval Red	415	41	357	31	620	10
CL-5915-206-D4 -2-5-0	495	25	305	27	603	20
Marglobe (Check)	417	44	311	25	511	18
Means	453	38	361	27	577	21

Means within the same column followed by the same letter are not significantly different at 5% level

In the earlier years, the fresh market tomato research and production have been concentrating on tall cultivars. Since 1996, studies have been geared to tall and short set cultivars to meet the diverse needs of stakeholder. In areas where there is shortage of stakes to support the plants, farmers prefer to produce short set cultivars. Different short set cultivars including Heinz 1350 have been tested in three agroecological regions. Floradade was found to be larger (142 g) than Picador and Cardinal (74-95 g), whereas the rest including the check were intermediate. The yield potential ranged between 297 and 633 q/ha. Cultivars Cardinal, Picador, and VFN-138 were less affected by sunburn and had better fruit retaining capacity on the plant at full red ripening stage. Picador, Floradade, Cardinal and Heinz 1370 Selection Arizona were higher yielder (460-521 q/ha) than the check (324 q/ha).

In areas where there is a need for long and continuous harvest for homestead and commercial production, indeterminate fresh market tomatoes are very important. In the Rift Valley region, advanced fresh market cultivars including the standard check (Marglobe) were evaluated for three years. The yield potential ranged between 301 and 532 q/ha. Cultivars, Caribo, Calipso, Marglobe Improved and Floradade were also better than the rest in yield, quality, growth performance, and better fruit retaining capacity on the plant at full ripening stages. They have yield potential of above 500 q/ha compared to 420 q/ha of the standard check.

Studying the floral development is a prerequisite for effective hybridization and for developing hybrids and superior open-pollinated cultivars. This is also important for seed production and for maintenance of germplasm. Studies on different cultivars at four floral development stages at Melkassa indicated that the potential stage for emasculation and hybridization and good fruit set without contamination was obtained when the anther cone changes to yellowish. Natural out crossing was also minimal since, stigma exertion had not been observed in about 150 lines evaluated in the warmer season of the years (February to May) under Melkassa conditions (MARC, 1999; MARC, 2000).

In addition to variety evaluation, tolerant cultivars to late blight and bacterial wilt and those moderately resistant cultivars to root knot nematodes such as Picador, Fire ball and Rio Grande were identified and systematic breeding is under way to develop superior cultivars tolerant to the major production constraints (MARC, 1999).

Salt Stress Tolerant Tomato Genotypes

Salinity is one of the problems in irrigated tomato production in the Rift Valley. In the absence of tolerant cultivars or lines, variations in commercial cultivars could be exploited until resistant or tolerant lines are developed through systematic crossing program. About 180 tomato cultivars were repeatedly tested for salt tolerance at three salinity levels (0%, 0.1% and 0.2 % NaCl). High relative germination difference was found between cultivars in both 5 and 10 days, after culture. There were very distinct differences between cultivars in which most cultivars were found to be susceptible. As the germination percentage extended from 5 to 10 days there was a delaying effect that all cultured seeds of most cultivars germinated which indicated that salinity to be more of an osmotic effect rather than toxicity. Potentially high yield and quality fruit cultivars such as Caribo, Marmande, Pacesetter, Arizona, Mogambo, CL-5915-206-D4-2-5-0, and Nova 70A were relatively tolerant (MARC, 2000). These cultivars can be used for production under salinity conditions.

Released Tomato Cultivars

Different tomato cultivars have been recommended at different times for production (Table 7). They have been identified superior for fruit yield and quality. Use of recommended inputs and management practices are important to produce good yield and quality tomato fruit.

Table 7 Released tomato cultivars

Cultivars	Growth habit	Fruit shape	Fruit Weight (g)	Fruit Yield (q/ha)
Melkashola (Pr)	short	CL	70-90	620-739
Melkasalsa (Pr)	short	pear	40-50	550-660
Roma VF (Pr)	short	pear	50-60	400-450
Napoli VF (Pr)	short	pear	50-60	350-400
Marglobe (Fr)	tall	globular	120-140	400-600
Money maker (Fr)	tall	round	70-80	300-400
Heinz 1350 (Fr)	short	round	50-60	300-350
Person A-1 (Fr)	tall	globular	60-75	300-380
Marglobe Improved (Fr)	tall	globular	120-140	320-360

CL= Cylindrical, Fr = Fresh market and Pr = Processing type

Melkashola and *Melkasalsa* are highly accepted and produced by farmers in the different regions.

Plant Establishment

Tomato fruits may be produced either by direct sowing of the seed in the field or transplanted from seedbed. Transplanting has the advantage of economic use of seeds, selecting superior and vigor seedlings, easiness for field establishment and early harvest. Direct sowing requires high amount of seed (4000 g/ha), which is more than 10 times when using transplants (300 g/ha). Seedlings, which are thinned out from the direct seeded field, could be used as transplants to establish a different plot. Intensive field management is also important for successful seedling establishment.

Direct sowing and transplanting were studied to find out the advantage and disadvantage of using the two methods under Rift Valley conditions. The direct sown plants were ready for harvest 12 to 15 days earlier than those transplanted and produced large sized fruits. However, there was a need for frequent weeding and irrigation (IAR, 1986; IAR, 1987b). It produced significantly higher marketable fruit yield and relatively lower percentage of cracked fruits than transplanted plots. On the average, yields of 409 q/ha and 296 q/ha were produced from direct sowing and transplanting methods, respectively. Hence, the direct seeded plot produced about 25-35% higher marketable yield over transplanted fields (Table 8). There was also less plant coverage, more fruits were exposed to sunburn, and more physical damages in transplanted fields than the direct seeded plots. However, in situation where farmers and producers have limited experiences on the cultivation and field management of tomato and because of the additional seed cost, it is easier to raise seedlings on nursery bed and start the production with transplants.

Table 8 Effects of roots and or leaf pruning on yield and maturity of tomato cultivars at Nazret

Treatment	Heinz 1350			Money maker			Maturity
	Mark	Total	Days*	Mark	Total	Days*	
Control	32	62	41	17.4	44.3	46	early
Roots pruned	31	60	41	10.7	30.0	44	early
Leaf pruned	25	47	37	13.7	31.3	33	late
Leaf and Roots pruned	25	46	33	10.4	26.0	33	late
Mean	28	53	38	13.1	32.9	39	

** Days= duration of harvest in days, Mark= marketable fruits*
Sources: IAR, 1987b.

Nursery Management

Nursery sites

To produce vigorous and healthy seedlings close attention must be given to the seedbed:

- Seedbeds should be sited in a location, where frequent visits/supervision can be carried out;
- They should be away from obstructions affecting the availability of light and be close to source of irrigation water;
- Preference should be given to well-drained sandy loam soils;
- The soil should be worked to loose and friable conditions;
- The beds should not be on field previously used to produce tomatoes or related crops such as *Capsicum,* potatoes; and
- The seedbeds should be rotated with other no-related species after each batch of seedlings are produced.

It should also be protected from strong winds and the area be kept free from weeds and other plants which are hosts of insect pests, virus and/or other diseases which are common in tomato production areas.

Seed bed preparation and seed sowing

Three kinds of seedbeds are commonly used in producing tomato seedlings (Fig 3).

- **Flat seedbed**: prepared where the land is level with adequate drainage system;
- **Elevated or raised seedbed**: be constructed to avoid excess water on seedbed. Used in rain season or when water logged soil condition is expected; and
- **Sunken seedbed**: For areas with a prolonged dry season and help to conserve and economize water.

The nursery field should be carefully tilled. Roots, stones and clods should be removed. The seedbeds should be easy for cultivation, irrigation and hardening-off operations. A suitable basic design for a seedbed should be one-meter width with 5 or 10 meters length and 40 cm between beds to permit a person to work half the seedbed from each side. About 250-300 g seed with over 90%, germination potential is required for one hectare. About 15 beds (3,000 seedlings/bed) of 300 m^2 are required to produce sufficient number of seedlings from one hectare.

Seeds should be mixed with equal ratio (1:1) of carrier (sand or soil) to facilitate even distribution of the seed. It is sown in the row at 15 cm row apart at the depth of about 0.5-1 cm, covered with pulverized/fine soil, and lightly firmed. The whole bed is mulched with grass or straw to protect seeds from washing away during watering and is removed after the seedlings have emerged. The seedling are then thinned at 3-5 cm spacing at the first true leaf stage and proper management (weeding, watering) practices are followed to produce healthy and vigorous seedlings. No further shade is necessary then after to avoid the development of long and spindly seedlings, which is a common problem in farmers' field. Raising large number of seedlings helps to select vigorous, strong and healthy transplants.

Flat

Sunken

Raised

Fig 3 Cross section of flat, sunken and raised seedbeds

Fertilizer

Chemical fertilizers, organic manure or compost provides nutrients for producing healthy and vigorous seedlings. The amount of fertilizer applied on seedbed depends on the fertility of the soil. Experience at Melkassa showed that on sandy loam soil, 200 g DAP at seeding and 100 g urea at thinning (at first true leaf stage) could be applied to enhance growth. Incorporating well decomposed manure is also good practice.

Irrigation

Water is applied frequently with a watering can. Application could be changed to flooding when seedlings are about 5 to 8 cm height. Caution should be taken in watering the seedbeds. It should be watered with a fine spray with a sprinkling can or with garden hose. Water dashed on seedbed through a hose with large holes wash out the seed. The seeds bed should never be allowed to dry out, nor should be kept soaked but sufficient water should be applied to wet the soil. Until the plants are well established, the soil should be kept moist, but not wet. Keeping the surface wet or over watering is favorable for damping off diseases. Watering is preferred in the morning or late in the afternoon, but not encouraged in strong sun.

Seedling protection

Damping off is the most common seedbed diseases in tomato. The causal agents *Pythim spp, Phytophthora spp* that are soil borne fungi are common in tomato production fields (Tesfaye and Habtu, 1985). At pre-emergence, the disease decays germinating seed before it pushes through the soil and causes poor seedling stand even with seeds of high germination capacity. Whereas, at post-emergence affected seedling shrivels and the entire plant will be lost unless control measures are practiced. Excess amount of moisture, dense seedlings, excess amount of nitrogen, carelessly handling of plants and the presence of weeds favor damping off disease.

Protective seed treatment chemicals, burning straws on seedbed and solarization of seedbed for about one month were reported effective in reducing the incidence (Mohammed, 2000). Thiram at 0.1 kg to 50 kg of seed has been a common practice. Contacting research centers for latest recommended technologies is essential.

Hardening seedlings

Seedlings need to be hardened before transplanting to the field to enabling them withstands the field conditions. This should be done by reducing the frequency of watering and allowing the soil to low moisture status when it is ready for field planting. Withholding irrigation water for two to three days before uprooting the seedlings from seedbed facilitates the removal of transplants. Subsequently good field establishment and higher yield than either longer or shorter watering interval can be achieved.

Transplanting Seedlings

Healthy, vigorous, stocky and succulent seedlings should be selected for transplanting. Seedling will be ready for transplanting 28-35 days after sowing at 2-3 true leaf stages (Fig 4), or at 12-15 cm height for field transplanting. Too young seedlings result in a stunted growth. If they are too tall and leggy there will be poor in field establishment. Prior to transplanting, pruning, seedlings or trimming roots, or leaves or both parts should be done to facilitate transplanting.

A trial was set at Melkassa with tall (Moneymaker) and short set (Heinz 1350) cultivars to see the effect of pruning on crop establishment, maturity and yield potential. Plants that were not pruned gave high and early yield in both cultivars followed by root pruned ones. However, plants with both root and leaves or only leaves pruned gave lower yield and matured later than plants either roots pruned or not pruned (control) (IAR, 1987a;) (Table9). Transplanting without removing any plant part could give good fruit yield and plant establishment. However, root pruning could be sufficient to facilitate transplanting in the case of long rooted seedlings.

Table 9 Direct sowing versus transplanting of different tomato cultivars at Nazret (1985-1986)

Method	Cultivars	Fruit wt. (g)	Cause for unmarketable yield (%) Sun scorch	Crack	Insect	Decay	Blotchy ripening	Blossom end rot	Total yield (q/ha)
Direct	Moneymaker	57	12	2	7	16	1	3	355.3
	Marglobe	87	11	3	12	14	1	3	372.4
	Roma VF	43	11	0	9	8	2	1	500.1
	Mean	62	11	3	8	16	1	2	409.3
Transplanted	Moneymaker	45	14	2	7	6	2	3	276.6
	Marglobe	79	16	2	13	11	1	3	264.9
	Roma VF	33	14	0	5	4	7	1	347.7
	Mean	52	14	1	6	7	3	2	296.4

Source: IAR, 1987a

At transplanting, a hole should be made with dibbles enough to accommodate roots. Seedlings should be placed in the holes about the same depth as they were in seedbed. The soil is pressed around the plant by hand or foot to prevent air pockets near the roots and protect the plant from drying. Transplanting is better done when late in the afternoon or in the morning to reduce the risk of poor establishment under hot environment. Missing plants should be replaced with seven days after transplanting. Seedlings have to be protected with shade and wet straw from

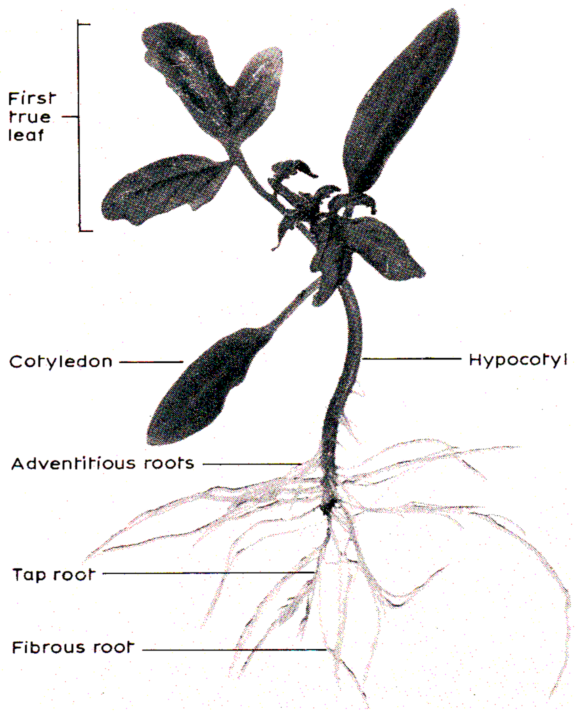


Fig 4 Tomato seedling at first true leaf

sun and dry wind until they are planted in the field.

Field Operation

Good land preparation such as plowing, disking, leveling and cultivation are important for better field and crop management. Early and timely plowing is helpful to expose the soil to ultimately useful to reduce diseases and insect pests. Proper leveling contributes for even distribution of irrigation water. Tomato should be grown on the same field ones every 3 to 4 years to reduce disease build up.

Sowing/planting date

Tomato can be grown throughout the year provided disease control measures and water for irrigation are available. It has been demonstrated that rain free, clean dry warm conditions and moderately uniform temperatures are favorable for high fruit set, clean fruits, less diseases incidence and for high quality fruit production. Heavy rainfall can result in poor fruit set and low fruit yield and quality.

Under Melkassa conditions, 310 to 340 q/ha for Moneymaker and 282 to 369 q/ha for Napoli VF were obtained in the cooler months (August to November) sowings. In the warmer months (March to April), however, the yield of Moneymaker (42 to 62 q/ha) and Napoli VF (26 to 43 ha) were very low (Table 10). Both cultivars also showed good stand establishment for August to January plots seeded from December to April were earlier by about 10 to 20 days than the cooler periods. The marketable yield also showed the same trend indicating that the cooler and drier periods are favorable for high tomato fruit production in the Rift Valley. Such yield difference was attributed to heavy disease infestation, fruit and flower drops; insects attack fruit rot, which were high in the rainy season (IAR, 1987a). Insect attack and sunburn contribute for high percentage of unmarketable fruits in the dry period. High quality fruits especially TSS% (5.0 to 5.4 %) was attained in the June to October sowings or October to February harvest. In the absence of support and chemical inputs, high quality fruits and high gross return of 11,600-13,000 birr/ha could be obtained during August to November (September to April) compared to January to July sowings (1105 to 4160 birr/ha) in the Merti Agro-industry and other locations with similar climatic conditions.

At Werer, June and July sowings gave high fruit yield of 257 and 328 q/ha, respectively. Whereas in the rest sowing dates only 9 -113 q/ha were produced. High day (31-37^{0}C) and night (14-23^{0}C) temperatures combined with virus diseases and insect pests, contribute for the low yield (IAR, 1987 b).

At Jima, high marketable fruit yield of 12 to 15 q/ha was produced from April to July sowings. Low yield was obtained in the January to March sowings (3 to 10 q/ha). The lowest yield was produced in November (3 q/ha). Heavy rainfall, leaf diseases, insect pests were the major causes of low productivity in the region (IAR, 1987a; IAR, 1986; NRC, 1988). Under such humid conditions, unless effective chemical control measures are available and or resistant cultivars are introduced, it is difficult to produce good yield with the current fresh market tomato cultivars in the wet season.

At Bako, August to January sowing dates gave high marketable (173 to 281 q/ha) and total yields (201-359 q/ha); while February to July sowings gave low marketable (13 to 53 q/ha) and total yield (23 to 103 q/ha) (IAR, 1986). It was noted that fresh market tomato production should be restricted to the dry season unless tolerant cultivars are developed or effective control measures are established (IAR, 1987a). With tolerant cultivars alone, a good marketable yield and quality fruits could not be produced without chemical control of diseases and insect pests, even in the delineated optimum production periods.

Table 10 Total and marketable fruit yield (q/ha) of tomatoes in different location

Sowing month*	Harvesting month	Werer (1983/84) Marketable		Werer Total		Jima (1985/86) Marketable	Melkassa (1979-85) Marketable		Melkassa Total		Bako (1979-82) Marketable	Bako Total	Mean Marketable	Mean Total
		1	2	1	2	1	1	2	1	2	1	1		
Jan	May	107	103	113	155	6	46	95.6	153.0	204.6	267.4	359.6	88.1	237.0
Feb	Jun	1	56	29	109	9	26	24.1	90.3	108.5	40.4	67.7	26.1	80.9
Mar	Jul	1	18	9	39	4	13	11.8	45.2	41.2	13.5	23.7	11.9	31.6
Apr	Aug	1	8	1	14	15	13	17.5	42.3	43.4	41.0	53.4	15.8	30.6
May	Sep	39	126	75	244	16	18	5.4	62.7	26.7	45.8	103.6	41.6	102.3
Jun	Oct	178	201	328	433	13	24	20.9	82.9	78.6	53.3	100.4	81.6	204.5
Jul	Nov	107	252	257	466	14	42	56.9	157.1	165.9	37.5	88.6	85.0	226.9
Aug	Dec	35	118	96	199	4	140	133.0	314.2	348.3	184.6	242.4	102.3	239.9
Sep	Jan	36	146	72	186	10	133	172.9	302.6	369.2	173.8	201.9	111.8	226.9
Oct	Feb	38	30	72	57	3	127	158.3	340.5	328.0	211.8	264.1	94.6	212.3
Nov	Mar	19	1	93	5	2	140.9	151.9	309.7	282.8	246.7	290.5	93.4	196.1
Dec	Apr	9	7	22	12	11	109.7	124.0	247.5	221.3	281.7	349.6	90.3	170.5

** First week of the month*
Maglobe, 2= Moneymaker;
Sources: IAR, 1987b; IAR, 1987a; NRC, 1985

Spacing and population

Plant population and spacing are important plant management practices that greatly influence yield and quality of fruit. The distance between plants and between rows depend on the methods and purpose of production, soil fertility, plant structure vine types, and farm equipment (Sajjapongse *et al*, 1989). Recently at Melkassa, row spacing of 80, 100, 120, 130 and 140 cm and plant spacing of 10, 20 and 30 cm with population range of 21,000 to 100,000 were investigated in Marglobe and Heinz 1350 (Table 11). The average fruit weight of Marglobe increased from 83 to 89 with plant spacing 10 to 20 cm. The highest yield of 254 q/ha was also obtained at narrower row spacing of 100 and 120 cm and a similar trend were obtained with Hienz 1350. In both cultivars yield was directly correlated with total number of fruits. There was no apparent yield difference between the cultivars, although they are different in growth habits. Plant spacing of 100 to 120 cm between rows and 10 to 30 cm between plants (42,000 to 100,000/ha) could be used. Short-and tall-set cultivars without plant support and applying low inputs do not bring much yield differences.

Table 11 Effect of plant density on fruit yield and quality of tomato cultivar, Roma VF

Plants/ cm*	Plant density/ha	Avg. no of fruits/ plant	Fruit weight (g)	Marketable Yield q/ha
1/10	100	17	40	240.2
1/20	50	24	38	280.5
1/30	33	19	37	248.8
1/40	25	18	35	258.5
Mean		**20**	**38**	**257.0**
2/10	200	22	41	278.0
2/20	100	22	40	269.0
2/30	66	17	40	254.5
2/40	50	22	37	292.1
Mean		**21**	**40**	**273.4**
3/10	300	26	42	246.2
3/20	150	20	38	265.6
3/30	100	22	38	277.4
3/40	75	19	41	290.2
Mean		**22**	**40**	**269.8**
4/10	400	25	43	202.8
4/20	200	19	42	225.3
4/30	133	20	39	263.8
4/40	100	19	38	267.4
Mean		**21**	**41**	**242.4**

** Number of plants left per hill at the given distances in the row.*
Source: IAR 1987 b

In processing tomatoes, where total yield per unit area is more important than fruit size and appearances, high plant population is common practice in many countries in large scale commercial production under direct seeding of tomato in the permanent production field. In such production, the optimum number of plants per hill should be determined for high marketable fruit yield.

At Melkassa, in order to increase fruit production and reduce sunburn on fruits, close planting was examined. Cultivar Roma VF was directly seeded in the permanent field at 100 cm between rows. One to four plants were left per hill between 10, 20, 30 and 40 cm (25,000-40,000 plants/ ha) at time of thinning. Fruit number increased with increase in plants per hill often associated with decreasing fruit size. The closer the spacing between plants, the minimum was the number of sun-scorched fruits. Marketable fruits increased with increase in rows between spacing of 30 and 40 cm, which gave 145 and 154 q/ha compared to 127 and 137 q/ha of 10 and 20 cm, respectively (Table 11). The highest yield was obtained when 2 and 3 plants were left per hill. Two or three plants grown in clumps in wider spacing of 30 and 40 cm between plants and 100 cm between row spacing, which corresponded to a population of 50,000 and 75,000 plants, optimum for small-scale hand-operated tomato production.

Staking and pruning

Plant support (staking) is an important production practice used by tomato growers mainly in the rain season. Staking has the advantage of:

- protecting fruits from soil contact,;
- ease of fruit harvest;
- cultivation;
- chemical application;
- less diseases incidence;
- early yield;
- clean fruit;
- extended harvest; and
- less fruit and plant damages by wind and other hazards.

Individual or all plants could be staked (a pole placed about every one meter) in and supported with horizontal trellises of two to three wires at 20 cm above the ground. This is commonly used in tomato production by small-scale farmers using different local materials such as bamboo, eucalyptus, etc.

Staking experiment carried out at Melkassa on a Moneymaker and Heinz 1350 produced a yield increase of 6 and 6.5 /ha, respectively, over unstaked plants (NRC, 1974/76). Furthermore, staked tomato plants gave high yield of 583 q/ha and 573 q/ha compared to the low response of 399 q/ha and 334 q/ha for unstaked plants of Marglobe and Moneymaker respectively (MARC, 1993). Staking of tomatoes grown for fresh fruit market increased yield and quality of fruits.

In addition to staking, pruning tomato plants is an important operation where the size of lateral branches on the main stem is reduced to manageable size. It has the advantage for extended harvest of good quality and clean fruits, but could give low total yield compared to the unpruned plants. In an experiment at Melkassa, leaving six stems per plant gave higher yield (515 q/ha) over single stem (311 q/ha) or three stems (467 q/ha) (Table 12). Pruning reduce total yield, but produce large and attractive fruits and enhanced fruit maturity. Plant support and pruning provide good plant management, yield advantages, extended harvest and to continuous income to the producers.

Table 12 Effect of pruning and staking on average fruit weight and yield Marglobe

Treatments	Fruit weight (g)	Yield (q/ha)	
		Marketable	Total
Unstaked and unpruned	109	271.2	416.5
Staked and unpruned	102	395.3	521.2
Staked and pruned to 6 stem	110	414.4	529.2
Staked and pruned to 3 stem	125	352.4	467.7
Staked and pruned to 1 stem	124	215.4	311.4

In addition to staking and pruning, mulching unstaked tomato plants with grass straw reduce the percentage of unmarketable fruits by protecting the fruits from direct contact with the soil. It also to control weeds, conserve soil moisture and influence the root environment for better growth of the tomato plants (NRC, 1947/1976). Depending on the need and experiences of growers, any one of or combinations of these practices could be used for quality fruit production.

Windbreak

Desiccating wind damages tomato crops in the Rift Valley, especially in the dry season. Poor foliage development, dropping of blossom, poor fruit set, breakage of leaves and branches, fall over of plants in irrigation furrow and high dust coverage on the leaves cause poor plant development and reduce fruit yield. In a study at Melkassa, wind

protected tomato plants with strips of maize and sorghum plants gave higher yield (74 /ha) compared to unprotected ones (57 /ha) (NRC, 1974-1976).

Water requirement

Tomato has a high water demand for its large plant biomass and high fruit yield. The fruit contains about 90-96% water. Insufficient water during flowering and fruit development leads to flower and fruit drops, physiological disorder and subsequently to low fruit yield and quality (Rudich and Luchinsky, 1986). Proper irrigation water management at different seedling, vegetative, flowering, and fruiting stages is important for high quality fruit production. The most critical periods for water stress in tomato are flowering and fruit enlargement stages (NRC, 1987; NRC, 1990). Furrow irrigation system is commonly used by tomato farmers. However, in most cases, it is poorly managed due to lack of experiences (Fig 5). In order to determine the optimum irrigation regime for tomato fruit production experiments have been conducted on light alluvial soil using Marglobe, in the dry season (January to May) at different levels (3, 6 and 9 cm) and irrigation intervals (4, 7 and 10 day) (NRC, 1988; NRC, 1990). The overall yield varied between 163 and 515 q/ha. Yield increased with an increase in amount of irrigation water; hence, 9 cm of water applied every 7 day increased tomato production. Currently, around Melkassa on light soil, water is applied every 3 to 5 days for the first 3 weeks after transplanting and every 7 day subsequently.

Fig5 Tomato plants growing under a) poor and b) optimum irrigated conditions

Fertilizer

Tomato plants grow stunted with small leaves and produce poor fruit yield if they are not properly nourished at vegetative flowering and fruiting stages. Application of well decomposed farmyard manure; composts and chemical fertilizers are commonly used to increase yield and quality of fresh and processing tomatoes. However, the type of fertilizers to be applied should be based on soil and plant tissue analyses for specific areas. Similarly, method of application is important for efficient use of nutrients by plant. Side dressing of NPK and foliar application of solution of macro and micronutrients are the important applications in tomato production.

Manure and compost are effective sources of nutrients for small-scale production. Manure and compost improve soil structure, soil water holding capacity and serve as source of nutrient to the crop.

Application of 600 q/ha manure could give higher marketable and total fruit yield than 300 q/ha or 900 q/ha manure; While untreated plots produced poor plants with high sun-scorched, decayed and insect-damaged fruits (IAR, 1986; IAR, 1987a).

In the absence of research recommendation on chemical fertilizers, farmers apply different levels of NP. At Melkassa, standard amount of 200 kg/ha DAP (18 N and 46 P) is used to be broadcasted at transplant and 100 kg/ha urea (46% N) is side dressed at early flowering stage. However, in the Lake Zwai area the same amount of DAP is applied at transplanting and 150 kg/ha urea as side dressed, at early flowering and fruiting stages. The farmers prefer to apply high amount of fertilizers with the expectation to produce healthy and vigorous plants and high marketable fruit yield. Since fertilizer, application is important for high quality fruit yield at reasonable amount of NP combinations should be applied at different stages in consultation with extension specialists until research recommendations are obtained for different soils.

Cultivation

Cultivation at the right stage is an important field operation to stir the soil, which has been packed in while transplanting, and to reconstruct the water canal and simultaneously removing weeds around the plants. Studying the effect of cultivation on yield and quality of

tomatoes showed that cultivated plots gave higher yield (118 to 211 q/ha) than uncultivated check (84 q/ha) (IAR, 1986). This operation must be reduced after the plants covered the ground. Early cultivation should be fairly close to the plant, but it should be followed by shallow and far away from the plants.

Crop Protection

Diseases

Disease is one of the major constraints affecting tomato plants at different growth stages and at post harvest. Diseases can reduce yield and cause complete loss of the crop in the field. Temperature and moisture especially; high relative humidity, less sunshine, high night temperature increase the disease incidence. The most common diseases in tomato production fields are septoria leaf spot (*Septoria lycopersici*), late blight (*Phytophtra infestant)*, early blight (*Alternaria solani)*, powdery mildew (*Leveillula taurica*) and viruses (Tesfaye and Habtu, 1985) as well as root-knot nematodes especially *Melidogene cognita* which is the dominant species in Rift Valley.

Late blight (*Wag)* is encouraged by rainy or humid weather. It damages leaves and branches, and causes brown dark spot on the fruit. Early blight is also encouraged in dry warm conditions. Diseases could infect fruits while they are still green. Septoria leaf spot is severe in similar conditions as early blight when plants bear fruits. The diseases defoliate the leaves and expose the fruits to sunburn which affects marketable yield and quality of fruits, to control diseases in tomato production. Nevertheless, developing disease resistant varieties and integrated disease management practices are considered to be developed by researchers for a sustainable tomato production.

For most diseases chemical and cultural control measures are recommended. Crop rotation, use of clean seed, removing all infected residuals and weed free field are also important to prevent diseases build up in the soil. At least 2-3 years rotations are needed with none related crops such as, tef, maize, beans and onion rather than continuous planting of related crops such as potatoes and hot pepper. Spraying Ridomil MZ 63.5 wp (3.5 kg/ha) at 7 days interval could be useful for the major leaf diseases (Tesfaye and Habtu, 1985). About 7-10 sprays are applied per season depending on weather conditions and the intensity of the incidence. However, it is important to contact research center for latest recommendations.

Insect pests

The major insect pests on tomato are potato tuber moth (*Phhorimaea operclella)* and African bollworm (*Helicoverpa armigera*). The tobacco white fly (*Bemisia tabaci*) is also an important pest in the Rift Valley known for its ability to transmit tomato yellow leaf curl virus. This virus can cause where yield losses of 37 % (Tsedeke and Gashawbeza, 1985). Recently red spider mite (*Tetranychus cinnabrinus*) has become a serious pest in the Rift Valley and yet no control measure has been developed.

Chemical application of Cypermethrin (10%a.i) applied at the rate of 100 g a.i/ha in about 500 to 700 liters of water every two weeks at early flowering and early fruiting stages has been recommended to control African bollworm and potato tuber moth (Tsedeke and Gashewbeza 1985). There is also variability among tomato cultivars and hybrids in their reaction to fruit worm. Recently released cultivar, *Melkasalsa*, is better in tolerance to ABW than the cultivars, which are currently in production.

Weed management

Tomato is poor weed competitor at early seedling stages. Tomato field must be cultivated or weeded frequently for good plant establishment. The critical time for weed competition is during mid growing period, 26 to 60 days after transplanting (Etagegnehu and Ahemed, 1985). In an experiment at Melkassa, the best control next to hand weeding and hoeing was applying Bentazon at the rate of 2.88 l a.i/ha can effectively control weeds above (Beyenesh and Etageghun, 1994).

Brume rape (*Orobanche/"Yemeret kitegn"*) is the common parasitic weed on tomato production in the Rift Valley Deep plowing and flooding of tomato fields for two consecutive months can reduce *Orobanche* seed in the soil (Rezene, 1985; Beyenesh and Etagegenghu, 1994). Solarization of the field with clean plastic cover for 45 days during the hottest months of the year (May) significantly reduced *Orobanche* seed bank in the soil by 97%, 91% and 92% Melkassa, Merti and Zwai respectively (Giref, 2001). Soil fumigation with Mehtyl-bromide under polyethylene cover for seven days is also effective for soil sterilization and reduces the weed incidence (Beyenesh and Etagegenghu 1994). In addition, growing trap crops

such as maize, sorghum, onion and pepper for two consecutive years also reduce *Orobanche* seed bank in the soil by about 60% (MARC, 2000). Most of these operations may not be easily applicable to the majority of the small farmers. Integrated control measures using chemicals, trap crop, improving soil fertility, bio-control, and soil treatments should be appropriates applied. However, in the absence of integrated control measures, pulling out the parasite weed before flowering is a simple operation one can easily apply.

Physiological/Nutritional Disorders

A number of physiological disorders are affecting yield and quality of tomato fruits. These disorders occur due to nutritional deficiencies, extreme temperatures, moisture stress, etc (Grimbly, 1986). The most common ones currently observed in the main production region are blossom end rot, blotchy ripening, cat face, cracking, puffiness and sunscald (Fig. 6).

Sunscald

Mostly immature fruits when exposed to the sun they become yellowish. This is common on plants with spare foliage or those plants that have lost their foliage due to leaf diseases or those cultivars susceptible to sunscald damages. The exposed spot changes to dry paper like surface, which affect the color of fresh fruit and processed products. Cultivars that are tolerant to leaf diseases and sunscald damages or that have good foliage coverage are preferred.

Misshaped

Poor pollen tube growth and poor fertilization of ovules result in misshaped or bulged fruits, which affect the quality of marketable fruit yield. This can be minimized by following standard production practices.

Blossom end rot

Small discoloration spot appear at the blossom end of tomato fruit, which is caused due to moisture fluctuations in soil and low calcium content in the fruit. In to control this disorder it is advisable to avoid the fluctuation of soil moisture and poorly drained soils, and supply plans with the necessary nutrients.

Cat face

Deformed deep cavity penetrating the fruit and result in malformation

of the fruit. This is common in large fruited cultivars. The Best solution is to find and plant tolerant cultivars.

Puffiness

It is a cavity between the outer wall and the central portion of the fruits where it becomes empty. This is caused by any conditions interfering with normal pollination, excess nitrogen or heavy rainfall. It is important to plant tomatoes under optimum growing conditions.

Cracking

There are two types of cracking. One is radiating out from the stalk and the other is in concentric order. These are common in round tomatoes. Using crack-resistant cultivars, maintaining a uniform water supply, keeping good foliage and nutrient balances, and picking fruit before full ripening can reduce the incidence of cracking. The pear or cylindrical fruits with thick skin are relatively tolerant compared to the thin-skinned round or globular fruits.

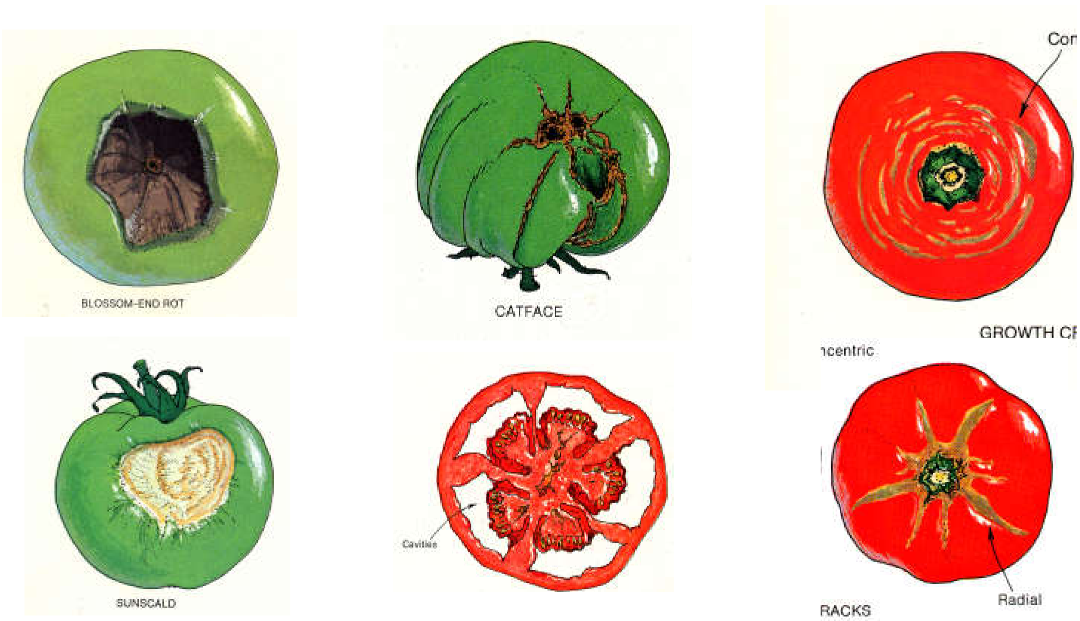


Fig 6 Symptoms of some physiological disorders

Harvesting

The stage of maturity at which tomato fruit are picked depends on:

- the purpose for which they are grown (fresh or processing);
- the distance they are transported from production to retailer or consumers; and
- availability of storage facilities.

The fruits could be harvested at different ripening stages as follows.

Mature green
When the fruits are fully green, the seed cavity filled with jelly substance, and the seeds are well developed

Turning/breaker
When the surface of the fruit, at the blossom end, turns to pink

Pink
When most of the surface of the fruit is turned to pink

Red/hard ripe
When the fruit is fully colored, but firm flesh

Over ripe
When the fruits are fully colored, but soft

Tomatoes for fresh market could better be harvested at turning stage, i.e., when fruits can be easily transported for distant market or stored for long period. For processing, fruits must be harvested when they are red ripe so that they can directly be sent to the processing plants. Depending on cultivars, fruits could be ready for harvest at about 75 to 90 days after transplanting. The duration of harvest for fresh market is about 5-7 times (30-40 days), while it is 3-5 times (15-20 days) for processing types, under Melkassa conditions. Since tomato fruit is above 90% water, careful picking, packaging and transportation is important to ensure better price.

Post-harvest Handling

The high perishable nature of tomato fruits require careful attention in harvesting and post harvest operations in order to reduce losses, meet home and export market standards and to ensure high price for producers, distributors, processors and traders. The loss is high due to moisture losses, over ripening, mechanical injury, rough handling and packaging, bruises and transportation. Firmness of pericarp tissue is a key component for long storability. Round and thin-skinned cultivars such as Marglobe, Heinz 1350 and Moneymaker are highly perishable as compared to the pear or cylindrical and thick-skinned ones such as *Melkashola, Melkasalsa*, and Roma VF.

In order to determine storability of fresh market tomato, the standard cultivar, Marglobe, fruits were harvested at three ripening stages, breaker, turning and red ripe and stored in the laboratory (27/16^{0}C day and night) and under open store (24/14^{0}C) conditions. About 50% fruit losses were noted within 6, 8, and 12 days after harvest for red, turning and breaker stages, respectively. Total losses were faster in the laboratory (7.3 days) compared to open store ambient (9.3 days) (NRC, 1988). Harvesting at breaker stages has the advantage of keeping fruit for longer period. Storage in breaker and turning stages has about 5 and 3 days storability advantages over fully red ripen fruits.

It is important that fruits be harvested at the right stages, selected, cleaned, properly graded, packed in container, and carefully transported to the final destination. Currently, especially in the Rift Valley and eastern part of the country, plastic and wooden boxes are used for harvesting and transporting. This has become important to avoid injury and reduce decay and softening of fruits that affect the attractiveness of fruit in the market.

Marketing

The fresh fruits and processed products are distributed local markets and exported to Djibouti and other markets. There are whole sellers (merchants), groceries *(kiosks),* roadside markets (*Gulits)*, which are involved in the distribution of fresh produces. The state owned marketing enterprise, ETFRUIT, is also involved in exporting and locally distributing processed products and other fresh horticultural crops. The produces in local markets are transported by donkey, carts, trucks and humans packed in wooden boxes or crates.

Frequently, small farmers who produce the bulk of tomato suffer for price fluctuations. They are forced to sell tomatoes to local merchants who have all the access to buy tomatoes at whatever price they fix. Good market for tomato is usually attributed to fresh and processing tomatoes. Quality tomatoes are:

- firm, not over ripe;
- fairly well formed;
- smooth;
- good color,; and
- free from blemishes and attractive.

Losses are high if fruits are not properly handled and properly disposed immediately. Organized tomato market systems in the main production centers region are needed in order to assist and encourage those involved in the development of the tomato industry.

Seed Production

Tomato seeds are produced under similar conditions to that of tomato fruit production. Seed production requires special care to produce standard and quality seeds. Well-managed and properly pollinated flowers give good quality seeds. However, seedless fruits due to poor pollination and low temperatures are not common in the Rift Valley. The cultivars currently produced are self-pollinated. It is important to isolate the cultivars about 50 meters distance to avoid physical contamination between cultivars during planting and harvesting. It is critical to select clean, diseases free fruits to avoid damaged, undersized, diseased and cracked, fruits. It is also important to carefully follow the seed extraction processes such as seed separation from the pulp, fermentation and dry for good quality seeds.

In an experiment at Melkassa, two commonly used fruits and vegetables juice preparation method in local groceries (juicing with blender or by hand) and duration of washing/cleaning the samples with water (right after extraction, 48 or 72 hours) were undertaken using red ripe fruits of Marglobe. The germination percent for seeds extracted by the blender was lower (28%) than hand extracted (95%) than indicate that the seeds can be easily damaged by the blender. Even though hand extraction is laborious, it produces better quality seeds and is practical for small farmers (IAR, 1986; IAR, 1987a).

In addition to the above studies, the effect of fruit fermentation period (0-9 days), and seed drying conditions (sun and shade) of hand smashed and processed (juiced) fruits on quality of seeds were further investigated on fresh market tomato (Marglobe) (Table 13). Typical colored and good quality seed were produced within three days of fermentation. However, if the fermentation period extended beyond three days the seed became off color (darker). High germination percentage (100%) was also obtained at 0 to 3 days of fermentation compared to 80 to 82% in 6 to 9 days. There was no deference between whole (hand smashed) and processed (juiced) tomatoes in seed quality.

Table 13 Effect of extraction method, fermentation period and drying condition on quality of tomato seed

Treatment	1000 seed wt.(g)			Germination (%)			Germination rate		
	1986	1987	Mean	1986	1987	Mean	1986	1987	Mean
Fermentation period									
0	2.46	3.57	3.02	99	100	100	5.89	5.35	5.62
3	2.43	3.59	3.01	99	100	100	4.69	4.69	5.49
6	2.32	3.57	2.95	79	85	82	7.06	7.06	7.20
9	2.27	3.63	2.95	81	79	86	7.59	7.73	7.66
Drying conditions									
Sun	2.38	3.56	2.97	76	91	89	6.99	6.32	6.61
Shade	2.36	3.01	2.67	92	91	92	6.55	6.06	6.31
Extraction method									
Whole fruit	2.38	3.60	2.99	91	92	92	7.0	6.07	6.54
Processed	2.36	3.56	2.96	88	90	89	6.55	6.84	6.45

Tomato seed yield varied among cultivars (90 to 125 kg/ha). Depending on varieties, the ratio of fruit to seed yield could vary from about 200 to 300: 1 and even less for some. The fruits are fermented to treat and eliminate seed surface borne diseases such as those causing bacterial canker and germination inhibiting substances. Seeds left in airtight container remain viable for 3 to 4 years. The 1000 seed weight is about 2.3 g with above 90 % germination. The current farmers' practice of using rejected fruits for seed extraction is one of the major causes to the heavy losses of fruit on the farmers' field. This must be avoided and recommended practices must be followed for sustainable and good quality produces. Detail tomato seed production has been prepared (Lemma, 1998). Tomato seed production could be more economical if combined with fruit processing component.

Conclusion

Tomato can be produced in different agro-ecologies in the country where the climate, soil and water conditions are favorable. Eight cultivars of fresh and processing types have been recommended or released with appropriate information package, mainly applicable to small producers. However, most of the cultivars have not been widely produced due to shortage of seeds. Currently many farmers are risking for growing cultivars, which are not tested under various conditions in the country. As a result, they are facing complex problems, such as diseases, insects, low yield and some times total crop failure. The establishment of a seed production and distribution system is very essential. Private investors and farmers should be encouraged and technically supported in parallel with the efforts of research centers whose primarily objectives is developing new cultivars.

Marketing tomato fruits is also an important component of the development of tomato industry. Small farmers who produce the bulk of tomato fruits suffer from high price fluctuation and poor market outlet. Along with the large scale processing plant, it is important to introduce homestead processing practices (juice, paste and ketchup) and organized marketing centers in order to absorb the surplus produces and to encourage tomato growers to exploit the diverse potential of the crop.

Since tomato is an important cash crop for small farmers and commercial enterprises, there is a need to promote the production technology (produce and seed) to potential production belts. This could be done through demonstration and popularization of the technology in potential areas where the results can easily be applied.

The research should focus on main production constraints in small-scale and large-scale commercial sectors in different production belts. Development of cultivars tolerant to diseases and insects salinity, heat complexes and seed production technologies should be the main concerns. Establishment of integrated diseases, insect pests and parasitic weeds management including improved cultural practices should be considered for different production sectors under rainfed and irrigated conditions. Determination of homestead tomato fruit processing techniques and information on cost of production and

strong collaboration with stakeholders should consider areas as indicated in the National Crops Research Strategy Document of Ethiopian Agricultural Research Organization (EARO, 2000).

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