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Opportunities and constraints of tomato production in Eritrea

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Tomato is an important vegetable in Eritrea, grown across the entire country. Yields in Eritrea are comparatively low, due to agronomic, institutional and market constraints. We carried out a survey throughout the country based on a participatory rural appraisal, discussion groups and interviews with staff members of the Ministry of Agriculture. Results showed that farmers preferred varieties with a prolonged harvesting period and a long storage life unless other varieties are better yielding and can immediately be marketed. However, their knowledge on varieties is limited while maintaining their own seeds. Seedlings are established in nurseries and subsequently transplanted once they have reached a height of 10 to 15 cm. Spacing, staking, pruning and irrigation are important aspects of proper crop management. Flower abortion is common in some areas and the crop is affected by several diseases and pests. The harvesting takes place over a prolonged period and timing of harvest of individual fruits is based on skin colour. There are significant price differences based on size grade. Seasonality of the crop causes problems with marketing and price fluctuation. It is recommended to improve the farmer's knowledge on variety characteristics, to improve the seed systems and train the farmers in improved crop management.

Key words: Eritrea, tomato, seed systems, variety, cultural practice, pests, diseases, physiological disorders, processing, marketing.

INTRODUCTION

Tomato is one of the most popular and widely grown vegetables in the world. It is grown throughout the world, either outdoors or indoors, because of its wide adaptability and versatility.

The estimated world production of tomato is about 89.8 million Mg from an area of about 3,170,000 ha; the leading producers are China (with 25.3% of the total production), USA, Mexico and Egypt (Bose et al., 2002; Basheer, 2006). Tomato production is widely distributed in Asia, Europe, North and South America, and in North Africa. Demand for tomato products has, in recent years, risen on the international market. In 2003 the main importers were United States of America (26.5%), Germany (19.3%), United Kingdom (12.4%) and France (8.7%), which accounted together for more than 66% of the total world imports. The top ten exporters of tomato in the world in 2003 were the Netherlands (23.9%), Spain (20.5%), Mexico (20.5%), Belgium (6.5%) and Canada

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Abbreviations: 1st H, First harvest; **DAP,** di-ammonium phosphate; **FH,** final harvest; **FL,** flowering; **FR,** fruiting; **MoA,** Ministry of Agriculture; **N.R.S.,** northern red sea region; **PRA,** participatory rural appraisal; **S,** sowing; **TS,** transplanting.

Table 1. Administrative zones, and number of respondents contacted, number of group discussions held and staff of the Ministry of Agriculture (MoA) contacted during the survey.

Region	Respondents	No. of group discussions held	No. of MoA staff interviewed
Northern Red Sea	10	1	3
Gash Barka	41	2	8
Debub	44	2	6
Anseba	35	2	6
Maekel	16	1	3
Total	146	8	26

In the region Southern Red Sea, there is hardly any horticulture.

(5.5%), accounting together for 77% of the world exports.

There is a long history of horticulture production in Eritrea, starting from the first days of Italian colonization and peaking in the 1970s when Eritrea annually exported horticultural goods valued at about 4.5 million US dollars. Domestic horticultural production in 1993 was estimated at a total of 56,000 metric tonnes, with a total value of around 10.8 million US dollars. Domestic annual consumption was estimated at 14 kg per capita for fruit and 13 kg per capita for vegetables (Ministry of Agriculture, 2000).

In Eritrea horticultural crops are mainly produced by small farmers and few commercial firms. Despite the great potential for production and diversification of horticultural production (due to various combinations of topography, soil type and climate) the present production and range of cultivated crops is very limited. Banana, citrus and papaya represent the bulk of fruit production while onion, tomato, leafy vegetables, hot pepper and potato represent the bulk of the vegetable production. Tomato is placed as one of the four priority vegetable crops along with onion, potato, and pepper in Eritrea. It stands second both in terms of acreage, 1074 ha, and production, 5912.6 Mg per year (Ministry of Agriculture, 2000). Moreover, the production seems to be well distributed in all administrative zones.

In Eritrea, tomato is grown almost all over the country, mostly under irrigation (furrow, drip or spate irrigation) and sometimes under rain fed conditions. It is the most popular vegetable, used daily, mixed with sauce, soup, and salad, making the staple food more palatable.

Tomato production has a long tradition among farmers in Eritrea. Farmers like growing tomato because the crop grows fast, covers large area with little investment, has a high demand in the market, has a reasonably good yield and a good return. However, the average yield of tomato in Eritrea has remained low, 15 Mg ha^{-1} (Ministry of Agriculture, 2000) compared with 19.1 Mg ha^{-1} in Africa, 23 Mg ha^{-1} in Asia and 27.2 Mg ha^{-1} averaged over the world (Jones, 1999). This low yield level needs to be explained through a survey at ground level by identifying the status, constraints and opportunities of tomato production in Eritrea. In Eritrea, the main constraints are (Ateshim et al., 1999):

1. Agronomic constraints, including incidence of diseases and pests, and physiological disorders (blossom end rot, cracking, sunburn or scald);
2. Institutional constraints, including lack of improved varieties, lack of storage facilities, shortage of inputs such as fertilizers (manure and inorganic fertilizers), and lack of transportation; and
3. Market constraints, such as fluctuating prices.

In Eritrea, the few surveys conducted in the past, were basically very general and covered all horticultural crops. Such surveys did not identify current status, constraints and opportunities at the crop level. Therefore we carried out a survey on current production systems, constraints and opportunities of tomato using a participatory rural appraisal (PRA). The survey described and evaluated current indigenous knowledge on tomato production systems; identified production constraints; revealed the existing diversity in production methods and its potential use to improve the production systems.

Special attention was given to the varieties that farmers grow and the seed system they use, land preparation, nursery management, transplanting, spacing, staking, fertilizer application, irrigation, control of pests, diseases and weeds, physiological disorders, yield, harvesting, grading, storage, transportation, processing and marketing.

METHODOLOGY

Location

The survey was conducted in all the administrative zones of Eritrea where horticultural crops are grown, namely: Northern Red Sea, Gash Barka, Debub, Anseba and Maekel, except the Southern Red Sea zone (Figure 1) where there are only very few horticultural activities. Table 1 indicates the number of respondents addressed, number of group discussions conducted and the number of staff interviewed at each administrative zone. A total of 146 tomato producing respondents were encountered during the survey. Out of these 146 firmer respondents, 11.2% were illiterate, 30.6% could read and write, and 58.2% had formal education. Moreover, a total

of eight group discussion were conducted; one group discussion in zones Northern Red Sea and Maekel, where there are only a few tomato producers and two group discussions in the three major tomato producing zones Gash Barka, Debub and Anseba (Table 1).

Data collection

Data collection was carried out using the participatory rural appraisal (PRA) method through a questionnaire and group discussions with farmers in tomato producing areas. The survey addressed the current status of tomato production in Eritrea including: area allotted for tomato production, selection and maintenance of varieties, raising of seedlings, seedbed preparation, transplanting, spacing, fertilization, staking, pruning, pests and diseases, physiological disorders, weed control, harvesting, yield, quality of the produce, storage, processing and marketing.

PRA involved households, group discussions and staff of the Ministry of Agriculture (at headquarter, regional, and the sub-regional levels). Open end topics for discussion were used to generate a free flow of information. The group discussions were mainly used to collect qualitative data. The farmers who participated in the group discussion represented various age groups (old, medium and young) and different wealth groups (rich, moderate and poor). About 8-10 people participated in each of the group discussion sessions. Gender separation was taken into account so that women could participate in the discussion.

Household interviews were conducted to verify and quantify the data collected during group discussions. A formal, structured questionnaire was used for this purpose. The questionnaire was designed in such a way that the interview would not be boring. A check list was prepared as a guideline for the discussion with the staff members of the Ministry of Agriculture.

Data compilation and analysis

The data was compiled and organized in the form of tables and figures and interpretation included. The data obtained from household questionnaires was converted into percentages and mean values. Views of the Ministry of Agriculture staff were included to look into the intervention efforts being made by the Ministry to improve the production of tomatoes.

RESULTS AND DISCUSSION

Varieties

Generally, farmers classified tomato varieties into two major types: Marglobe (round fruits) and San-Marzano (angular fruits). Apart from such general classifications farmers lacked the appropriate know-how to identify tomato varieties, although some progressive farmers used variety names for identification. Out of the interviewed farmers 65% preferred to grow San-Marzano types and 35% preferred Marglobe types. San-Marzano varieties were preferred because:

(1) They have a longer storage life after harvesting as they contain less water. This is also important for wholesalers and retailers as they do not own cold stores.
(2) They are farmer and thus easier to transport, with less damage and less quality deterioration.
(3) They have a prolonged harvesting time; the harvesting time lasts about 1 to 2 months with intervals between picking of 3 or 4 days.
(4) They are relatively erect and their fruits do not get in contact with the wet soil, thus reducing spoilage.

Farmers who preferred to grow Marglobe (round) varieties provided the following reasons:

(1) Marglobe tomatoes have higher water content and fetch better yield per area, thus a higher return.
(2) For tomato growers close to the market there is no great risk of loss during transportation of the highly perishable Marglobe tomato.
(3) Marglobe varieties are more productive under rain fed conditions because of their short crop cycle.

Seed sources

Farmers obtain seeds from different sources:

(1) Maintenance and production of their own seeds,
(2) Exchange with other farmers, and/or
(3) Purchase at the market or from the Ministry of Agriculture.

About 50% of the respondents got their seeds from the market, 37.5% from other farmers, and 12.5% from the Ministry of Agriculture. Progressive farmers kept testing several varieties for their local conditions in terms of adaptability, disease resistance and yield. Once they selected a specific variety, this variety was kept and maintained for several years. Mostly such a variety was not shared with other farmers, rather it was kept secret (Asgedom et al., 2011). Those farmers who maintained their own seeds selected physically good looking and vigorous plants and fruits and extracted seeds from them. Normally fruits were sliced, squeezed, mixed with ash and sun dried, which was usually an exercise accomplished by women indicating the role of women in conservation of seeds.

Rotation and land preparation

Most farmers believed that land for tomato production should preferably be a land, which was fallowed, locally called *'Bedu meret'*. Farmers said 'Never plant tomato on the same land consecutively'.

Land preparation started about 2 months before the date of transplanting during which the field was ploughed. In most cases ploughing was done at first by tractor followed by two times ploughing by oxen. One month was lapsed between the first and second ploughing. Farmers believe that sufficient exposure of the land to direct sunlight helps to eliminate soil-borne diseases and

discourages weeds. Levelling is part of the first oxen ploughing. Ridging is a part of the second ploughing in which spacing between rows is also determined by guiding the oxen to make the ridges. Then ridges are divided into plots manually by hand hoeing and irrigation channels are also prepared based on the slope of the area. Farmers through experience manage to design the irrigation system and make sure that water flows to all the plots through gravity. Large commercial farms use machineries for ploughing, disking, rotivating, levelling (by 10 or 28 disc harrow) and ridging.

Seasonality

In most parts of Eritrea production of tomato is possible only once a year. Only few areas like Mai-ayni (June - September in the highland) and Forto-Sawa (April - July in the lowland) can successfully produce tomatoes twice a year. During the off-season production of tomatoes, yield levels are relatively lower than in the normal season. This is due to the rainfall which encourages the incidence of diseases and direct physical damage of the plant due to heavy rainfall and snow in some years in the highlands. In the lowlands flower drop associated with high temperature reduces the yield levels during the off-season production of tomatoes.

Nursery

Almost all tomato growers raise seedlings to produce transplants, which are used to establish the crops. In few areas, like in the Ghindae zone the crop is directly sown during the rainy season for rain-fed production. In the lowlands seedbed preparation is done in the months of July and August, whereas in the highlands it is mostly done in November.

Seedlings of tomato are established in nursery sites located at one side of the field where tomato is to be planted. Nursery sites located at the corner of the field vary in dimensions: 1 x 2 m or 1.5 x 2 m and in some cases 1 x 1 m. Beds for nurseries could be raised or sunken depending on the climate and soil type. In sandy soils and dry season sunken beds are prepared whereas in heavy soils and during rainy season raised beds are practiced. Animal manure, mainly poultry and goat manure, are highly preferred by many farmers for nurseries. Others do not use manure as they believe that manure is a source of diseases. Some farmers and commercial firms use di-ammonium phosphate (DAP) as starting fertilizer in the nurseries.

Once the plot is ready, seeds are usually broadcasted and thus randomly spread in the plots and covered by soil by strolling branches or by using hands. Some respondents, however, indicated that they plant their seedlings in rows placed 10 cm apart and seeds are then spread within the rows close to each other at a depth of 2 to 3 cm and then covered by soil. Thinning seedlings to about 2 to 3 cm between plants and weeding are common practices in both broadcasted and row-planted nurseries. Immediately after sowing, the beds are covered by locally available materials like grasses, sacks, and tree branches for shading purpose and the beds are irrigated thoroughly. Few days after emergence, 10 to 12 days after sowing, the covering material is removed and a raised shade structure is constructed using bamboos and lined using similar materials, and the structure is kept there for 1 to 2 weeks. This structure could be placed and removed depending on the weather conditions and is completely removed when the seedlings are reaching the transplanting stage. But these precautious measures are not taken everywhere: some farmers leave the seedlings grow without any protection in areas where the climate is not harsh like in Anseba. Some companies, cooperatively working farmers and firms use low tunnels to raise their seedlings mainly during the frost periods from the months of November to February.

Irrigation of the nursery site continues until transplanting. It is carried out daily in hot places like Gash Barka and Anseba and some places of the Northern Red Sea areas and every other day in cold areas like Debub and Maekel (Figure 1). Farmers believe that tomatoes do not like to be irrigated overhead, and that leaves should not come in contact with water. Farmers say that watering of seedlings from the top washes away the salts from the leaves and creates favourable conditions for disease development. Thus, seedlings are mostly watered from the side of the beds.

Cut worms, whiteflies, and root rot are the main problems farmers face at the seedling stage. Soil disinfection is not a common practice in Eritrea. Most farmers do not apply chemicals even at seedling stage and some prefer to start all over again if their seedlings are not growing properly due to pests. Farmers believe that chemically treated seedlings will not perform well in the field.

Table 2 indicates the area under cultivation and the performance in the nurseries in difference regions. On average it takes 7 days from sowing to germination, with the highest being 9 days and the lowest of 6 days. The variety used, climate and level of seed bed preparation influence the time required for germination. The percentage of germination was high in Maekel (85.5%) which is a cooler place and low in Gash Barka (77.8%) which is a hot area, with an overall mean of 82.3 %.

Transplanting

Before transplanting, seedlings are evaluated by observing the vigour, height, number of true leaves, and general appearance of the seedling. Normally vigorous seedlings with a height of 10 to 15 cm and 6 true leaves

Table 2. Area under cultivation, days from sowing to germination, percentage of germination, number of leaves at transplanting, and days from sowing to transplanting for tomato in five regions of Eritrea.

Regions	Total area (ha) of cultivation per grower	Days from sowing to germination	Percentage of germination	Number of leaves at transplanting	Days from sowing to transplanting
Northern Red Sea	1.2	6	83.0	8	27
Gash Barka	10.4	7	77.8	6	28
Debub	2.3	8	84.9	6	35
Anseba	0.9	9	80.3	5	28
Maekel	1.5	7	85.5	6	35
Mean	3.26	7*	82.3	6*	31*

In the region Southern Red Sea there is hardly any horticulture, * Figures are rounded to the nearest integer number.

and seedlings with dark green leaves are selected from the nursery for transplanting. Farmers in the Northern Red Sea region transplant seedlings when they reach the 8-leaf stage, but in Anseba farmers transplant at the 5-leaf stage (Table 2). Respondents from Anseba and Debub, the main tomato producing areas, believe that shorter seedlings with 5 - 6 leaves produce a better stand than tall seedlings with more leaves. In cooler areas like Debub and Maekel seedlings need more days to be ready for transplanting than in the hot areas of the Northern Red Sea, Gash Barka and Anseba regions. The mean number of days from sowing to transplanting was 31 days (Table 2).

Transplanting of the seedlings is done either bare rooted or with soil. This depends on the distance between the nursery and the field. If the distance is long, farmers prefer to transport seedlings with soil; otherwise bare rooted seedlings are used. In the survey 65.4% of the respondents indicated to use bare rooted seedlings, whereas 32.6% used seedlings with soil and the remaining 2% used both methods.

Two to three hours prior to transplanting, the seed bed was irrigated to facilitate the uprooting of the seedlings. A peg or sharp metal with handle is used to uplift the seedlings by penetrating the material deep into the soil below the root zone and the seedlings are lifted up together with the soil. Seedlings are then put in a tray layered with wet sacks and transported to the field. Some farmers trim the lowest tip to enhance rooting and establishing of the plant.

Planting is done by first making holes at equal distances within the rows. One person makes the holes of 3 to 4 cm wide and 6 to 8 cm deep. A second person plants the seedlings by inserting the roots into the hole and pressing the soil close to the base of the roots. The pegs used for making holes have a fixed length equal to the spacing needed between plants and thus are used for making the holes as well as measuring the distance between plants.

Seedling selection is done by the person doing the planting. Seedlings which are too tall, too short (stunted), diseased, yellow-leaved, or insect-attacked, and seedlings without terminal bud with thin stems are discarded.

Most farmers prefer to transplant their seedlings late in the afternoon rather than transplanting in the morning. Seedlings transplanted in the morning cannot withstand the heat from the sun afterwards and suffer from desiccation and scorching. Farmers say that seedlings transplanted in the afternoon have better establishment than those transplanted in the morning. Irrigation of the field can be done in two ways: 2 to 3 h prior to transplanting or immediately after transplanting. In both cases transplanted seedlings should be irrigated for the second time 12 h after the first irrigation. Farmers believe that this exercise is crucial for the establishment of the seedlings. Replacing dead seedlings will be followed, by checking up the field every three to four days and this exercise may continue up to three weeks until the desired plant stand is achieved.

Spacing

Seif and Zeineb (1988) indicated that tomato in Sudan responded more to spacing than to fertilization and cultivation. In general, from the survey results presented in Table 3, farmers in the Anseba region use the narrowest spacing within the row while farmers in Gash Barka and the Northern Red Sea region use the widest spacing within the row. Farmers in Gash Barka and the Northern Red Sea region also use wider spacing between rows whereas Anseba farmers use the narrowest between-row spacing.

Farmers in the lowlands (the Gash Barka and the Northern Red Sea regions) normally do not use staking and plants are laid in the space between the two rows, which means a wide space is required between rows. Farmers in Debub, Anseba and Maekel regions use staking and plants are kept upright, thus providing the room for more plants per unit area.

Farmers indicated that spacing between rows and

Table 3. Spacing and fertilizer rate used in tomato fields in five regions of Eritrea.

Regions	Spacing between		Fertilizer rate		
	Plants (cm)	Rows (cm)	Manure (Mg/ha)	DAP (kg/ha)	Urea (kg/ha)
Northern Red Sea	35.2	73.8	6.39	75.0	103.1
Gash Barka	34.4	78.4	1.07	115.0	91.7
Debub	28.3	56.9	4.16	128.7	150.2
Anseba	28.0	47.9	3.28	174.8	196.3
Maekel	29.5	57.0	5.25	109.5	155.0
Mean	31.1	62.8	4.03	120.6	139.3

In the region Southern Red Sea there is hardly any horticulture.

is not measured accurately and the values presented in Table 3 are estimates of spacing used by farmers. In Eritrea, ridges are made by oxen or manually by hand and thus spacing basically is determined effectively by controlling the movement of the oxen during the second ploughing, which is also a ridge making exercise. The accuracy of achieving the required spacing depends on the joined experience and skill of both the farmer and the oxen in ploughing. Thus, variation in between-row spacing could occur even at plot level. Spacing within rows is relatively accurate as it is determined by the person making the holes with pegs during transplanting.

Farmers understand the importance of spacing on growth and yield of tomato. They normally relate close spacing with high diseases incidence and difficulty in working operations inside the field like staking and harvesting whereas wider spacing is associated with wastage of land, irrigation water and fuel. Hence the importance of optimum spacing in utilizing resources (water, fuel) efficiently and for effective field operation is recognized by the farmers.

Fertilizers

The mean amount of manure used was 4.03 Mg/ha (Table 3), the highest usage of manure was in the Maekel region (5.25 Mg/ha) where manure is available from the dairy farms around the capital Asmara. The lowest usage of manure was in the Gash Barka region where more commercial farmers are located owning large areas of land and manure availability is low due to the nomadic nature of pastoralists in the region.

Farmers prefer to use poultry and goat manure over cattle manure. However, their availability is very limited especially for commercial growers. Farmers feel that manure lasts longer than inorganic fertilizers and, whenever available, they prefer to use manure over the use of artificial fertilizers. Manure is applied in the soil before first ploughing or before transplanting by spreading and incorporating during ploughing or later during ridge making. Commercial firms like Elabrid Estate apply manure and liquid farm manure by trailers towed by tractors.

The average inorganic fertilizer application for tomato is 120.6 kg/ha for DAP and 139.3 kg/ha for urea (Table 3). Farmers mentioned that due to the low availability and high price of urea in the market they were forced to use more DAP which was not the case in the past. The highest use of DAP was 174.8 kg/ha in Anseba and the lowest was in Northern Red Sea region (75.0 kg/ha). Similarly, Anseba farmers apply the highest rate of DAP (196.3 kg/ha) while the lowest was in the Gash Barka area (91.7 kg/ha). DAP is normally applied by farmers prior to transplanting at one dose by broadcasting or band application. However, urea is applied in split doses three times following the cultivation practices. Irrigation is a must just after the application of urea. These activities are indicated in Figure 1.

Farmers indicated that they could see the effect of urea immediately after the application on the vegetative growth and fruiting of tomatoes. However, they indicated that the effect of DAP was not immediately noticeable. Farmers have the opinion that urea application at early seedling stage burns the seedlings, especially if water is scarce. They therefore prefer to apply DAP or manure followed by split application of urea as indicated in Figure 1. Potassium fertilizer is not known to many of the farmers, however, big firms like the Sawa-Agro industry use potassium as a source of fertilizer with the aim of improving the quality of fruits.

Irrigation

The majority of the tomato producing farmers use furrow irrigation and only very few commercial farms use drip irrigation. Farmers in the Debub, Maekel and Northern Red Sea regions have rain-fed tomato production. Moreover, in Sheab (Northern Red Sea region) spate irrigated tomato production was encountered. Irrigation water comes from dams (3.7%), streams 6.9%), wells (72.0%), rivers (3.8%) and rainfall (13.6%). Wells are dug at about 10 to 20 m deep in most cases by machines or

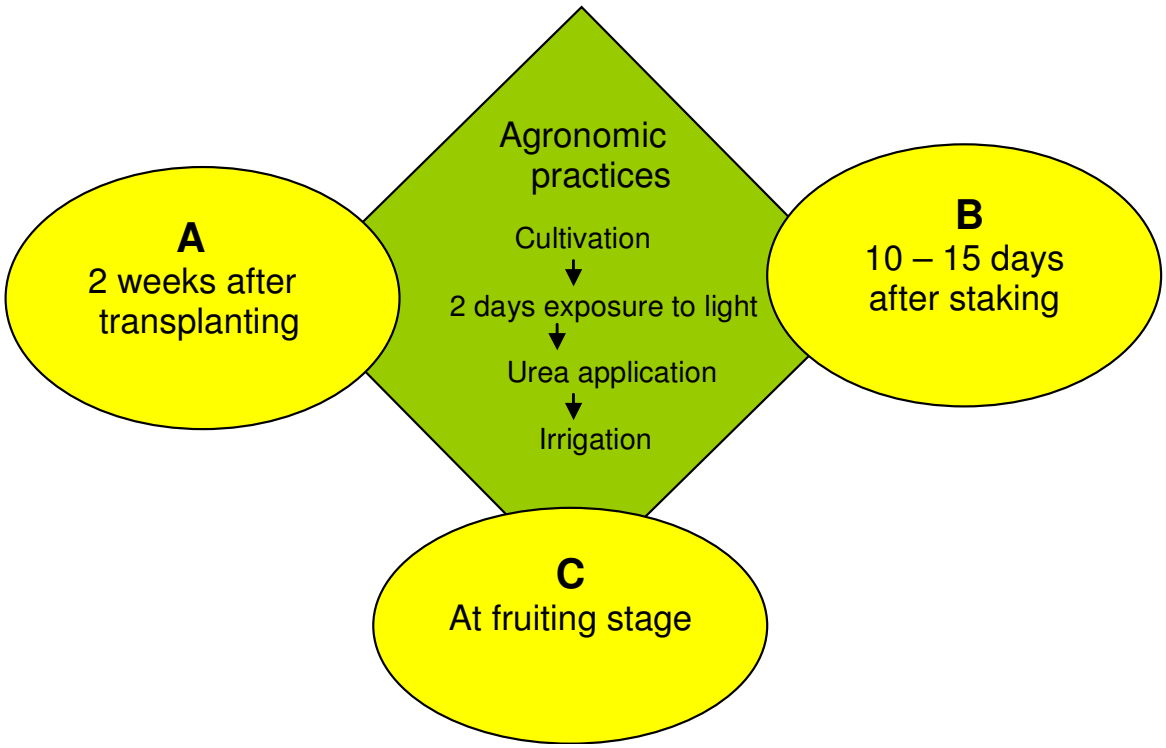

Figure 1. Schematic representation of successive package of agronomic practices (inter-cultural cultivation, urea application and irrigation) carried out at three growth stages (A, B and C) of open field tomatoes in Eritrea.

manually and the water level in most cases reaches 4 to 6 m during the normal season. However, it drops during the dry season in the months of March, May and June. Drilled wells at a depth of 50 to 60 m do exist as well but are only used among commercial farmers having sub-miscible pumps.

The irrigation interval may vary between 3 to 10 days depending on the climate. In the lowlands, where the temperature is very high (35 to 40°C) irrigation is done at intervals of 3 to 4 days. However, in the highlands, which are cooler, with temperatures ranging from 18 to 24°C, irrigation intervals may range from 7 to 10 days depending on the soil type. During the vegetative stage farmers follow a more or less regular schedule of irrigation within the season. However, in all regions farmers increase the frequency of irrigation after fruiting. Farmers say that after each harvest irrigation is crucial for higher yield and better quality. Farmers stressed that by saying 'Irrigate as much as possible after fruiting'.

Many farmers prefer to irrigate their field late in the afternoon or at night. Irrigation is very common during the night in hot areas of the lowlands mainly in medium to large scale farms. This reduces the evapotranspiration losses to a great extent. However, small scale farmers do irrigate their field early in the morning or late in the afternoon. In the highlands and middle altitude areas irrigation is done at anytime of the day. Farmers mention that they use motor pumps like Lombardini, Denaday, Zidanci, Rigorini, Caribar, IVECO, Yammer, Lister, and Mercury which work with fuel. Fuel and spare parts are important irrigation costs to the farmers.

Staking and pruning

During the growth period of tomato, staking plays an important role in improving the quality of fruits. Staking gives support to the growing plant so that it becomes straight and erect. About 54.2% of the farmers exercise staking and mounding and 45.8% use only mounding to give support to the plant. Staking is usually done about two weeks after transplanting and tying of the tomato stems continues until harvesting. Tomato plants can be supported by tying the stems at three levels, which are normally termed Kedmay miesar -> Kaley miesar -> Salsay miesar (1st, 2nd and 3rd tying of the stems). Staking materials used include bamboo and dried branches of trees. However, these staking materials are getting scarce and expensive from time to time. Although most farmers understand the importance of staking, availability of staking materials and labour costs are major limitations. For most farmers staking means the possibility of close planting but also better yield and quality fruits. Farmers who own large farms say that it is

Table 4. Mean number of days from transplanting to flowering, to reach 50% fruiting, from flowering to fruiting, to reach 50% flowering, from flowering to fruiting, to reach 50% fruiting, from fruiting to first harvest, between two harvests and from first harvest to final harvest in five regions of Eritrea.

Regions	Number of days TS-FL	Days to 50% FL from S	Days from FL-FR	Days to 50% FR from S	Days from FR-1st H	Harvest interval (days)	Days from 1st H-FH
N.R.S*	12	47	18	68	30	3	30
Gash Barka	12	46	20	66	26	4	32
Anseba	16	48	22	70	28	4	41
Debub	15	57	25	80	35	5	46
Maekel	18	54	25	78	32	4	42
Mean	15**	50**	22	72**	30**	4	38**

In the region Southern Red Sea there is hardly any horticulture, * N.R.S: Northern Red Sea region, S: sowing, TS: Transplanting, FL: Flowering, FR: Fruiting, 1st H: First harvest, FH: Final harvest, ** Figures are rounded to the nearest integer number.

not economical to use staking. Others mention that mounding during the first cultivation is enough to keep the plants relatively erect with better root establishment. In some areas, like Ala, termites are problematic as they feed on the staking materials and thus farmers cannot practice staking as use of chemicals to control termites becomes more costly.

Pruning is not a common practice among tomato growers in Eritrea and most of the farmers have no idea about it. Normally the plant is grown with many branches like a bush. In some places the first buds, locally called *'Balga'*, are pruned. Farmers believe that removal of the first bud encourages root formation and elongation of the tomato plants. But afterwards pruning is not practiced.

A few farmers in Ala (Debub), however, understood the importance of pruning, an idea passed from Italian farmers who used to cultivate tomato in the Region. The farmers were of the opinion that pruning gave large-sized and better quality fruits but were reluctant to apply it because they indicated that it is very demanding in terms of labour and the associated costs.

Physiological phases

Table 4 presents the periods required for the major physiological phases in tomato in different Regions of Eritrea. The table provides information on the number of days from transplanting to flowering, days to 50% flowering, days from flowering to fruiting, days to 50% fruiting, days from fruiting to first harvest, harvest interval and days from first harvest to the final harvest for the studied Regions of Eritrea.

The average period tomato needs from transplanting to flowering is 15 days, with 18 days taken in cooler area of Maekel Region and only 12 days in hotter areas like Gash Barka and the Northern Red Sea Region. The longest average period taken from sowing to 50% flowering was recorded in the Debub Region (57 days) while it was shortest in Gash Barka (46 days), with a mean of 50 days. The mean number of days required from flowering to fruiting is 22 days, with the lowest number of days taken in the Northern Red Sea Region (18 days) and the highest numbers in Debub and Maekel (25 days). The number of days to 50% fruiting from sowing ranges from 66 days in Gash Barka to 80 days in Debub with a mean of 72 days. Debub Region has shown the highest (35 days) average number of days needed from fruiting to 1st harvest while Gash Barka has shown the lowest number (26 days) with a mean of 30 days.

The lowest harvesting interval recorded was in the Northern Red Sea Region (3 days) while the highest was in the Debub Region (5 days), with an overall mean of 4 days. Similarly average days from 1st harvest to final harvest recorded is lowest for the Northern Red Sea Region (30 days) and highest for the Debub Region (46 days).

In general, we observed that in hotter administrative zones like the Gash Barka and Northern Red Sea Regions most of the physiological phases recorded were shorter than in the middle altitude, moderate climate Region (Anseba) and the cooler Regions of Debub and Maekel. Furthermore the physiological phases were shorter in the middle altitude, moderate climate region (Anseba) than in the cooler regions (Debub and Maekel). This is consistent with the concept of thermotime which indicates that a plant needs to pass through a certain number of degree days or heat units to accomplish a specific physiological phase.

Farmers in the relatively warm lowlands pointed out that flower abortion is a common phenomenon, especially when cloudy weather and dry winds are prevailing. Moreover, also during the hot season flowers are aborted. Failure to produce flowers due to viral diseases was recorded in Hagaz areas where tomato production is hardly possible because of this problem. Farmers believe that once the plant produces flowers then fruiting goes smoothly except in some cases where fruit size may be

affected by hot weather.

Physiological disorders

Fruit cracking, blossom end rot, puffiness and sun scald are the most common physiological disorders encountered by tomato growers in Eritrea. Fruit cracking was found to be common in Marglob types, but was hardly observed in San-Marzano types. Farmers believe that this phenomenon is due to irregular application of irrigation water and Marglob types (which normally have higher water content) are susceptible to cracking.

Blossom end rot (BER) and puffiness were documented to be common in San-Marzano types, whereas farmers are of the idea that BER is not a problem in Marglob types at all.

Sun scald was found to be a serious problem in the lowlands where the temperature is hot. Farmers introduced intercropping of maize with tomatoes in the edges of rows for shading purpose to reduce yield loss due to sun scald.

Disease, pests and weeds

The major diseases recorded were early blight, powdery mildew, rust (locally called *'himedia'*), late blight, foot rot, septoria and leaf curl virus. These diseases could cause yield losses of up to 10 to 15%. Farmers use chemicals such as Afgan, Bylaton, Euparen and Daconil with the advice of the extension agents of the Ministry of Agriculture. However, the survey proved that most farmers do not have a thorough understanding of disease types and their control measures. In the survey 21% of the interviewed farmers indicated that the major causes for yield loss are diseases. Tomato growers believe that *'Taka'*, which is a cloudy weather condition with fine dust, damages their tomato crop by drying the leaves of the plant and encouraging disease development. Small farmers spray water on their tomato plants after the occurrence of *'Taka',* however this is not possible in a large-scale operation.

Farmers indicated that insects like whiteflies and American ball worm (ABW) account for only 5% of the total yield loss and these insects are controlled by spraying chemicals like Danitol, Drusban, and Sanvex. American ball worm was perceived to be the most serious insect pest among many tomato producers. In severe cases, if proper control measures are not taken, an estimated yield loss of 20% can be encountered due to this pest in the opinion of the farmers. Farmers spray chemicals such as Roger, Savin, Drusban and Danitol to control this insect pest. Insects like leaf miner, leaf hopper and aphids also cause some damages but are considered to be less problematic.

Tomato requires a series of cultivations during the cropping season. Farmers remove weeds, mainly by hand weeding or cultivation. Pre- and post-emergence herbicides are not commonly used in Eritrea, especially not in tomato production.

Harvesting

Harvesting time in tomato is determined mainly by colour, size, shape and firmness. Additional modern characteristics used are total soluble solids (TSS) and Titrable acid (TA) contents of tomato. However, in Eritrea, the majority of the tomato growers (78.1%) use skin colour for determining the time of harvest. In practice, fruits are normally harvested at the stage when they just start turning from light green to red which is locally called the *'Gogob'* stage. Some farmers use a combination of colour, firmness as measured by fingers, and shininess to assess harvesting time.

Harvesting is done by hand by gently twisting and pulling the fruits. Then fruits are placed in locally available materials like modified Jerry cans, or cloth sheets and collected in a shaded area for grading. Harvesting continues for a month and half or two depending on the variety and takes place at 3 to 5 days intervals. Harvesting is stopped when the fruits get smaller, leaves dry out or when irrigation is no longer economical. In general, Marglob types finish quicker than San-Marzano types. Days from 1st harvest to final harvest is shorter in hot areas like Northern Red Sea and Gash Barka regions and longer in the cooler areas like Debub.

In most cases, harvesting time was during late afternoon, but in the cooler areas sometimes also during in the morning. Farmers prefer to harvest late in the afternoon and grade and put the fruits in boxes for the early market of the following day. All farmers had the opinion that tomatoes harvested during the hot period of the day have shorter shelf life than tomatoes harvested early in the morning and late in the afternoon.

Grading

Grading is a common practice among all farmers and the main criteria for grading are size, followed by colour. In most cases there are three grades:

(1) 1st grade: larger sized, healthy and with acceptable colour, locally called the '*Gogob'* stage.
(2) 2nd grade locally called *'Dekik'*: smaller fruits, healthy and brighter in colour but still marketable,
(3) 3rd grade, *'Marsho'*: unmarketable, too ripe, too green, small sized, damaged, diseased and these fruits are normally given to livestock as a feed.

Table 5. Average area of cultivation per grower and average yield in five regions of Eritrea. Note: in the region Southern Red Sea there is hardly any horticulture.

Regions	Area of cultivation per grower (ha)	Yield of tomato (Mg/ha)
Northern Red Sea	1.2	8.63
Gash Barka	10.4	14.93
Debub	2.3	10.35
Anseba	0.9	8.25
Maekel	1.5	9.55
Mean	3.26	10.34

In the region Southern Red Sea there is hardly any horticulture.

Depending on the market, the price difference between the first and second grade can be 2 to 3 Nakfa. While grading, farmers sometimes mix fruits of the 1st with some amount of the 2nd grade to benefit from the high sale price. Usually farmers may put small fruits at the base of the crate and good quality fruits at the top, an exercise locally called *'Mi-eyar'*. This practice questions the need for grading if they are going to be purposely mixed later. This happens almost everyday at every market exchange among farmers, wholesalers and retailers and it has been an accepted exercise for some years according to the farmers. But sample crates from the whole lot are checked as to whether there is too much second grade tomatoes mixed.

Acreage and yield

The average land allotted for tomato cultivation is 3.26 ha per grower, the highest being 10.4 ha in Gash Barka and the lowest 0.9 ha in Anseba (an area known for small patches of land available along the sides of Anseba river). The maximum average yield observed in Gash Barka was 14.93 t/ha (Table 5). The high yield obtained in this region yield could be due to the availability of suitable, relatively fertile land and farmers using modern cultural practices. In the Anseba region the lowest yield (8.25 t/ha) was recorded mainly due to the shortage of water and the poor topography of the area as farmers grow tomatoes in a hilly area where the top soil is eroded.

The average yield of tomatoes in Eritrea was 10.34 t/ha (Table 5) according to the survey which is very low compared to yield levels in Africa (19.1 t/ha), in Asia (23.0 t/ha) and the world average (27.2 t/ha) (Jones, 1999). But it is worth to mention that farmers did not exactly know the size of their fields and the figures could slightly be biased.

Storage and transport

Almost none of the farmers had storage facilities. They just sold the tomatoes directly to the market as soon as possible after harvest. Farmers prefer to keep the fruits on-the-plant for sometime if they feel that the market price is not attractive or if there is no market for their produce. Harvesting is done normally early in the morning or late in the afternoon, and crates are kept in a shade temporarily. Very few companies like Sawa-Agro Industry and Elaberid Estate Farm use refrigerated cold stores for tomatoes.

Farmers transport the fruits by using draft animals (46.6%), vehicles (34.3%) or both (19.1%). Farmers believe that due to unsuitable roads there is high loss of tomatoes during transportation which could reach up to 30% of the produce. Transportation cost is considered to be the most important cost of production among farmers. Some farmers stated that there were times when they gave their potentially marketable tomatoes to livestock and/or dumped their tomatoes due to high transportation costs given the low price of tomatoes.

Processing

Elaberid Estate Farm, which was established during the Italian colonial period, was the only commercial farm with processing plants for tomatoes. Since then for several years tomato pastes were sold for domestic as well as export markets. Till recent time this agro-industry was producing canned tomatoes but at the moment it is not functional due to imports of highly subsidized European canned tomatoes. Another tomato processing industry (Af-himbol Agro Industry) is planned in Gash Barka region to provide the domestic as well as the export markets with canned tomatoes and bananas. Furthermore, in Asmara there are two food processing industries which use tomatoes as a part of their inputs.

Sawa – Agro Industry located in Gash Barka region used to export dried tomatoes to Italy. Varieties Marcoro and Rio-grande with low water content were used. For this purpose harvested fruits were washed, sliced into two at the equator and sun dried for a week or two in 1 m high, stretched nets after being treated with potassium and vitamin C. However, this activity did not last long as it was difficult to maintain the quality standards required

for export.

Marketing

Farmers indicated that tomato is in high demands compared to other vegetables and thus the market for tomato is generally very good. However, the seasonal nature of tomato production is considered a bottle neck which hampers year-round availability. Tomatoes are planted at the offset of the frost period and harvested before the rainy season comes. They are therefore abundant for limited period of time and are scarce during the period between the harvest and the coming season. This creates a large price fluctuation with prices ranging from 1.8 Nakfa to 12 Nakfa/kg. Prices are high during the months of July, August till mid of September and low in October, November and December. Farmers suffer from the seasonal nature of the production because many farmers produce tomatoes in that specific time and the market is saturated with tomatoes.

On average farmers are less educated and less knowledgeable than the middlemen. The middlemen are therefore likely to have power regarding marketing of their products. Moreover, considering the lack of storage facilities and that tomato are highly perishable, farmers are easily exploited by the wholesalers and are forced to sale their products at a low price. From the survey it was evidenced that 65.5% of the farmers sell their tomatoes to the wholesalers where farmers have less bargaining power. Especially small-scale farmers were forced to bring their products directly to the wholesalers. This is mainly due to two reasons:

1. The retailers and consumers have a limited capability of buying the whole produce from the farmer at once.
2. Most of these farmers borrow the money needed for production purposes from the wholesalers. This is done with the agreement, that the farmers are obliged to bring their entire product to the wholesalers after harvest and have less bargaining power in such circumstances. Thus, a lion share of the profit margin goes to the wholesalers.

Use of village cooperatives as a marketing channel could solve the problem to some extent by empowering the farmers but most of the cooperatives formed are not active and in most areas are non-existent.

On the other hand, farmers who produce tomatoes during the off-season, that is, during the frost period as well as the dry, hot period have better bargaining power as tomato is scarce in the market at that time. Farmers producing off-season tomatoes in the Forto-Sawa area (Gash Barka) and some pocket areas in Anseba and Debub, where climatic conditions for tomato production are perfect, farmers do benefit well from the high price of tomatoes. In such conditions farmers have the upper hand in controlling the market price.

CONCLUSIONS AND RECOMMENDATIONS

Farmers have rich and in depth knowledge of tomato production in Eritrea, a knowledge which was inherited from generation to generation since the colonial Italian period. However, there are also major gaps in knowledge and there are also still major constraints in all the steps of the production chain. Similar conclusions on farmers' knowledge and gaps therein were drawn on surveys of other crops in the same region (Tsegaye and Struik, 2002; Mulugeta et al., 2007; Hirpa et al., 2010). The current survey, which covered all parts of Eritrea except one minor region, has unveiled the traditional methods of tomato production, identified the production constraints, and indicated the opportunities of the production system. The survey was of its first kind in Eritrea as many surveys in the past have merely addressed horticultural crops in general.

Farmers' knowledge of the available varieties is very limited and they merely classify them as Marglob (round) or San-Marzano (angular) fruits. However, several varieties and diversities exist within each type. Such general classification is misleading and hinders the utilization of various good performing cultivars. We also noted in other crops that farmers' understanding of the different sources of variation and of genetic diversity is sometimes limited (Kudadjie et al., 2007). Farmers need to be acquainted with different cultivars through extension services. Moreover, there is no well established seed system in Eritrea, which could assist farmers to select, maintain and use high-yielding, stable and disease-resistant varieties. More varieties have to be identified and released to farmers along with demonstration of varieties accompanied by agro-packages.

Although nursery management seems relatively unproblematic, raising of seedlings during the frost period is still a setback. Introduction of low tunnels could alleviate the problem to a great extent which can help to extend availability of tomato in the market.

There is a variation of spacing in different regions, which is influenced by the availability of staking materials, labour cost for staking, method of ridging and making of holes before transplanting. Optimum spacing could maximize productivity and quality of tomatoes.

The effects of fertilizer application method, rate and effect of specific inorganic fertilizers on productivity and quality of tomato are not well recognized by the farmers. Potassium fertilizer is not known at all by many farmers and manure availability is declining because it is scarce. Advice by the extension services on the importance of specific fertilizers like potassium might be helpful to boost productivity and quality of tomato.

Staking is limited due to shortage of staking materials. Pruning is not known to many of Eritrean tomato growers but could improve yields although this requires further study. Farmers' know-how on identification of diseases and pests, and control measures is limited, which

contributes to the low yield level. Practical training geared to the afore mentioned issues can play a paramount role in transformation of knowledge among farmers thereby improving the cultural practices.

Seasonality is one of the main problems in tomato production which results in high price fluctuations. Introduction of low tunnels and walk-in tunnels for nursery and off-season production of tomatoes could ensure year-round availability of tomatoes and stabilize their price. Revitalization of the tomato processing factories could play an additional role to this effect.

In general each step in the tomato production system needs an intervention by researchers and extension agents to improve productivity and quality through introduction of modern agro-technologies to the already existing rich traditional knowledge of farmers, finally aiming at bridging the yield gap. In that respect the tomato case of Eritrea is very similar to other cases elsewhere in Africa (cf. Richards et al., 2009; Offei et al., 2010).

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