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Participatory tomato (*Lycopersicon esculentum* Mill) variety selection and evaluation for production in Eastern Amhara regional state

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Abstract
A field experiment was conducted at Kobo and Mersa under irrigation with the objectives of evaluating the adaptability and yield potential of different tomato varieties and asses farmers' perceptions. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and used six released tomato varieties. The result showed that there was variation in yield and yield components of tomato varieties. The highest number of fruit clusters per plant (15.7) and marketable yield (45.8 ha^{-1}) was recorded from variety Oval red whereas highest fruit per plant (70.5) and fruit length (5.9 cm) was recorded from the variety Mersa. From the six tested tomato varieties Oval red was first ranked by its yield advantage over other tomato varieties and its shape has good market value by farmers' selection. Variety Mersa was selected by farmer's due to its disease resistance (powdery mildew) and good market value. Therefore, Oval Red and Mersa tomato varieties were recommended for Mersa and Kobo areas under irrigation.

Keywords: Farmers' perception, tomato, variety

Introduction
Tomato (*Lycopersicon esculentum* Mill.) is one of the most widely consumed vegetable crops in the world. Globally, among horticultural products tomato ranks third for volumes of production after potato and sweet potato and first in terms of processing volumes (FAO 2019) [14]. By virtue of its high yields per hectare and its processing potential, it is one of the strategic commodities prioritized by the government of Ethiopia for agro-industry development in the country (Brasesco *et al*., 2019) [6].

It is originated in Mexico, and spread throughout the world following the Spanish colonization of the Americas (Wikipedia, 2016) [27]. In Ethiopia, there is no exact information as to when tomato was first introduced; however, the crop is cultivated in different major growing areas of the country. According to (CSA 2019) [7] in the year of 2018/19 of Meher season the total production of tomatoes in Ethiopia was about 23,583.75 tons harvested from 4,322.31 hectares of land and in Amhara region, about 7,422.5 tons from 894.3 hectares of land and its productivity was 5.12 and 8.3 ton ha^{-1} in Ethiopia and Amhara region respectively, which was very low compared to other countries.

It is a nutritionally well-balanced food that contains a substantial amount of vitamin A and vitamin C, thus it plays an important role towards ensuring food security and nutrition. It is generally cultivated in tropical, subtropical, and temperate climates, including Ethiopia's mid and lowland areas (Brasesco *et al*., 2019) [6]. Tomato is an essential ingredient in the diet of the Ethiopian population and it is consumed in large quantities in many traditional dishes such as soups, sauces, stews, and salads (FAO, 2019) [14]. Tomato has medicinal values and being used for blood purification and curing digestive ailments (Kaushik *et al*., 2011) [17].

Tomato is produced in the state and private horticultural enterprises, commercial farms, and small farmers scattered in different parts of Ethiopia. It is produced mainly as a source of food and income both under rain-fed as well as irrigated conditions. Tomato is among the most important vegetable crops in Ethiopia. Therefore, developing superior-yielding varieties through appropriate breeding work is required to satisfy ever increasing demand of domestic and export markets for this crop.

Kobo and Mersa areas are naturally suitable for vegetable production due to favorable agro ecology and availability of irrigation water. It is mainly for commercial vegetable production in three rounds per year. Even though the areas have high potential in vegetable production and their economic role is huge, farmers are unlikely to extract the opportunity due to a lack of better tomato varieties and other constraints.

Participatory variety selection (PVS) is a breeding approach that brings breeders, social scientists, farmers, and extension personnel together in a field setting in order to prioritize and target traits of importance. It also helps to identify and assess traits that are important to small-scale farmers and is especially successful in assessing "subjective traits" such as taste, aroma, appearance, texture, storage quality, and culinary qualities, which are difficult to measure quantitatively (Bellon 2002) [4]. Understanding farmers' preferences across different agro-ecologies is an important first step for breeding programs who seek to develop acceptable varieties by farmers. The breeding program should work directly with farmers in variety selection, jointly evaluating new varieties along with farmers existing local varieties (Danial *et al*. 2007) [8].

The production and productivity not only depend on cultural practices and areas of cultivation but on high-yielding varieties, which have good adaptability to the growing areas. Hence, evaluation of tomato varieties is extremely important to see the performance of varieties for their adaptability and agronomic performance like growth and yield traits to identify the potential variety. Therefore, this study was executed to evaluate the adaptability and yield potential of different improved tomato varieties in the study area through participatory variety selection and to ensure their acceptability by farmers.

Materials and Methods

Description of Study Areas

The study was conducted at Kobo sub-center research field, and at Mersa on farmers' field from December to April 2017 under irrigation. The testing site at Kobo is located at 12˚ 08'21''N latitude and 39˚38' 21" E longitude with an altitude of 1470 M.A.S.L. The soil type is clay-loam in texture. The long-term (10-year) mean annual rainfall is 668mm with a maximum and minimum temperature of 31°C and 15 °C, respectively (SARC, 2009) [25]. The testing site at Mersa is located at 11^0 40'N latitude and $39^0$39.5'E longitude with an altitude of 1600m.a.s.l. The soil type is clay-loam in texture The long-term (10-year) mean annual rainfall is 848mm with maximum and minimum temperature is 30 °C and 11.6 °C, respectively (EAMSC, 2019) [9].

Description of Test Varieties

Six open-pollinated tomato varieties (Mersa, Cochoro, Miya, Bishola, Oval red, and ARP Td2,) were used for the study. Variety Mersa was used as a standard check. The varieties were released by Sirinka and Melkasa Agricultural Research Centers (Table 1).

Table 1: Description of the experimental materials

Variety name	Year of release	Altitude (m)	Rainfall (mm)	Days to maturity	Yield ha^{-1} (research field)	Breeder/Maintainer
Mersa	2006	800-2000	1400	100-120	27.6	SARC
Cochoro	2007	800-2000	1400	100-120	45	MARC
Miya	2007	500-2000	1200	82	47.1	MARC
Bishola	2005	500-1800	1200	85-90	34	MARC
ARP Td2	2012	800-2000	1400	100-120	37.2	MARC
Oval red	2015	800-2000	1400	100-110	50	MARC

Where: SARC: Sirinka Agricultural Research Center, MARC: Melkasa Agricultural Research Center. Source: Directory of released crop varieties, Ministry of Agriculture, Addis Ababa.

Experimental Treatments, Design, and Management

Six improved and released tomato varieties collected from Sirinka and Melkasa Agricultural Research Centers were evaluated for their performance at two on stations and four farmers' fields both at Kobo and Mersa. The treatments were laid out in Randomized Complete Block Design (RCBD) with three replications. Treatments were assigned to the experimental plot randomly. The size of the experimental plots was 4 m x 3 cm (12 m^2) with a net plot area of 2 m x 2.4 m (4.8 m^2). A free space of 1 m and 1.5 m between plots within blocks and between blocks was kept for cultural practices. Seedlings were planted at the spacing of 30 x 100 cm between plants in the row and between rows, respectively, as indicated by Naika (2005) [21].

Seeds were sown in rows of 15 cm spacing on well-prepared raised ground nursery beds having the size of 1 m x 5 m at Kobo trial station. Sown seeds were covered lightly with fine soil and then with 2-3 cm thick grass mulch. Watering was done daily until germination and then with three days interval. Transplanting of seedlings on the experimental field was done at the 3-5 true leave stage when seedlings attained the height of about 15-25 cm. The experimental field was well prepared ahead of seedling transplanting using tractor and human labor. On each experimental plot, 40 seedlings were planted at the spacing of 30 x 100 cm between plants and rows respectively.

Watering was done using furrow irrigation at three days intervals. The whole amount of DAP (200 kg ha^{-1}) recommended to the area was applied during transplanting while the recommended rate of urea (150 kg ha^{-1}) was applied into two equal splits. The first half of urea was applied at the time of planting while the remaining half was applied 21 days after transplanting of seedlings. Experimental plots were kept free from weeds manually and other cultural practices such as disease and insect pest control were performed as per the recommendation for tomato production (EARO, 2004) [11]. The first harvest was started after three months of planting and the final harvest was done after four months of planting. Variety Mersa harvested five times whereas the other varieties harvested three times.

Farmers' selection and participatory evaluation of the varieties

During the experiment, two groups of tomato growers having 21 members (7 women and 14 men) each were selected from the two study areas (Kobo and Mersa) with the help of development agents. Training was given to the farmers to create general awareness about the experiment. In addition to farmers, researchers (breeders, pathologists, and socio-economists) have participated. Group discussions and debates were made to seriously observe and clear contradictory ideas on issues like farmers' preferences, criteria for evaluation, and characteristics of good tomato varieties. Evaluation criteria were set by farmers prior to evaluation as vegetative performance, maturity, number of fruits per plant, fruit size, fruit shape, transportability, market preference, and resistance to disease. According to the participant farmers, good tomato verities should have the following characteristics: vigorous, free from disease, with a higher number of fruits per plant, firm and medium fruit size with oval shape.

Data Collection and Analysis

Data on growth parameters, yield, and yield components consisting of plant height (cm), number of primary branches, days to 50% flowering, number of fruit clusters per plant, marketable fruit yield ha^{-1}, average fruit length (cm), average fruit equatorial diameter (cm), disease severity score and farmers' preference were recorded.

Plant height: Heights of five randomly selected plants from the ground level to the apex grown in the net plot area using rules were measured at the maturity stage.

Number of primary branches per plant: The primary branches of five randomly selected plants in the net plot area were counted at the maturity stage.

Days to 50% flowering: The number of days elapsed from the date of transplanting up to the date when 50% of the plants in plot flowered was recorded and used for analysis.

Number of fruit clusters per plant: The number of fruit clusters in five randomly selected plants in the plot was counted at 50% flowering.

Fruit length: The length of five randomly selected fruits at each harvest was measured using a caliper.

Fruit equatorial diameter: The central diameter of five randomly selected fruits at each harvest was measured using a caliper and the mean values were taken for analysis.

Marketable fruit yield (T-ha^{-1}): Fruits free from any visible damages (diseased, insect pest, physiologically and mechanically) were considered as marketable fruit yield.
Analysis of variance (ANOVA) was done for the measured variables using SAS version 9.4 statistical software (SAS Institute, 2009) [25]. Means were compared by using the least significance difference (LSD) test at a 5% probability level. The varieties were evaluated by the farmers' criteria and analyzed using pairwise and matrix ranking (Boef and Thijssen, 2007) [5].

Results and Discussion

Yield and yield components of tomato varieties for the individual locations indicated (Tables 2 and 3). In both locations, the varieties significantly differ in all considered parameters, and the highest marketable yield was obtained from the Oval red variety. Variety by location interaction showed non-significant differences in all considered traits except the disease severity which was different across the locations. Combined over the locations, all considered traits were highly significantly affected by the varieties (Table 4).

Table 2: Effects of tomato varieties on yield and yield components at Kobo in 2017

Variety	PH(cm)	NPB	50% FD	NFCPP	NFPP	FL(cm)	FED(cm)	Mkt Y T-ha^{-1}	DSEV%
Mersa	85.4^{a}	5.7^{c}	59.3^{a}	7.4^{c}	70.1^{a}	5.7^{a}	2.8^{d}	19.8^{d}	1.7^{e}
Bishola	64.9^{b}	7.2^{ab}	47^{b}	8.6b^{c}	18.1^{d}	4.1^{c}	5.1^{a}	26.5^{c}	6.9^{d}
Oval red	58.9^{c}	7.7^{a}	47^{b}	14.9^{a}	39.5^{b}	5.2^{b}	4.2^{b}	45a	14.2^{c}
Miya	47.6^{d}	6.2^{bc}	47^{b}	14.2^{a}	29.5^{c}	3.4^{d}	3.6^{c}	32.6^{b}	21.6^{b}
Cochoro	45.3^{d}	5.6^{c}	47.3^{b}	10.8^{b}	17.8^{d}	4.3^{c}	4.2^{b}	29.3^{c}	31.3^{a}
ARP T d2	41.3^{e}	5.5^{c}	48^{b}	8.6b^{c}	15.9^{d}	4.3^{c}	4.3^{b}	21.1^{d}	31.8^{a}
LSD (5%)	3.8	1.3	2.4	2.6	3.9	0.3	0.5	3.1	1.4
CV (%)	3.6	11.7	2.7	13.1	6.9	3.5	6.5	5.9	4.4

Where, PH (plant height), NPB (Number of primary branches), 50% FD (50% flowering date), NFCPP (number of fruit clusters per plant), NFPP (number of fruits per plant, FL (fruit length), FED (fruit equatorial diameter), Mkt Y T-ha^{-1} (marketable yield ton per hectare) and DSEV (disease severity percentage).

Table 3: Effects of tomato varieties on yield and yield components at Mersa in 2017

Variety	PH(cm)	NPB	50% FD	NFCPP	NFPP	FL(cm)	FED(cm)	Mkt Y T-ha^{-1}	DSEV%
Mersa	86.2^{a}	6.9^{c}	57.7^{a}	8.8^{c}	70.9^{a}	6.2^{a}	3.2^{d}	21.3^{d}	2.2^{e}
Bishola	65.8^{b}	8.4^{ab}	45.7^{b}	10b^{c}	18.9^{d}	4.7^{c}	5.4^{a}	28^{c}	9.1^{d}
Oval red	59.8^{c}	8.9^{a}	47^{b}	16.4^{a}	40.3^{b}	5.8^{b}	4.6^{b}	46.5^{a}	17.8^{c}
Miya	48.4^{d}	7.4^{bc}	47^{b}	15.6^{a}	30.3^{c}	3.9^{d}	3.9^{c}	34^{b}	27.4^{b}
Cochoro	46.1^{d}	6.8^{c}	46.7^{b}	12.3^{b}	18.7^{d}	4.9^{c}	4.5^{b}	30.7^{c}	34.5^{a}
ARP Td2	42.1^{e}	6.7^{c}	46^{b}	10bc	16.8^{d}	4.9^{c}	4.7^{b}	22.6^{d}	34.9^{a}
LSD (5%)	3.8	1.3	3.9	2.6	3.9	0.3	0.5	3.1	1.2
CV (%)	3.6	9.8	4.4	11.5	6.7	3.1	5.9	5.6	3.1

Where, PH (plant height), NPB (Number of primary branches), 50% FD (50% flowering date), NFCPP (number of fruit clusters per plant), NFPP (number of fruits per plant, FL (fruit length), FED (fruit equatorial diameter), Mkt Y T-ha^{-1} (marketable yield ton per hectare) and DSEV (disease severity percentage)

The combined data over the locations indicated that the highest value of plant height (85.8 cm) was recorded from variety Mersa, whereas the shortest plant height (41.7 cm) from variety ARP Td2 (Table 4). This might be due to different genetic makeup of tomato varieties. This finding was in agreement with other scholars (Khah *et al.* 2006; Fayaz *et al*. 2007; Eshteshabul *et al.* 2010; Kaushik *et al.* 2011; Meseret *et al*. 2012) [18, 15, 10, 17, 19] obtained tomato with plant height in the range of 36.8-126.5 cm. The result indicated a variety of Mersa might need stalking compared to the other tomato varieties.

The highest number of primary branches (8.3) was recorded from variety Oval red, however, non-significant difference from variety Bishola, and the least (6.1) was recorded from variety ARP Td2 (Table 4). The difference might be due to genetic differences of the tomato varieties and the environmental conditions of the experimental areas. Many authors (Mohanty and Prusti 2001; Fayaz *et al*. 2007) [20, 15] reported that the number of primary branches per plant between ranged from 3.1 to 12.63. Shushay *et al*. (2013) [24] reported that the number of branches per plant is an important parameter that indicates the yielding capacity of the tomato variety.

The longest day of 50% flowering, from the period between transplanting and flowering (58.5) was recorded from the variety Mersa and the shortest day (46.3) was recorded from the variety Bishola (Table 4). The analysis indicated that except variety Mersa, the other varieties were not statistically different from each other. This result is in agreement with other authors. Abrar *et al.* (2011) [2] and Falak *et al.* (2011) [12] indicated that the period from transplanting to flowering of tomato varieties ranged between 40 and 49 days. According to Parvej (2010) [23], days to 50% flowering is one of the important phonological parameters and determinant factors for the growth and productivity of tomato plants. Moreover, the difference in 50% flowering days can also be attributed to the genetic makeup of genotypes as observed by Abdelmageed *et al.* (2003) [1]. The highest number of fruit clusters per plant (15.7) was recorded from variety Oval red and followed by varieties Miya (14.9) and Cochoro (11.6) whereas the least (8.1) was recorded from the variety Mersa (Table 4). This might be due to genetic make-up differences of the tomato varieties which were also indicated by the research results of Mohanty *et al*. (2001) [20]. According to Pandey *et al*. (2006) [19], number of fruit clusters per plant is the most important yield attributes in tomato production.

The maximum number of fruits per plant was obtained from the variety Mersa (70.5), while the minimum was recorded from variety ARP Td2 (16.4) (Table 4). Even if the maximum number of fruits per plant was recorded from Mersa variety, the least marketable yield was also obtained from the same variety which might be due to the least fruit equatorial diameter (3 cm) of the variety. Several authors (Eshteshabul *et al.* 2010; Turhan *et al.* 2011; Abrar *et al.* 2011; Falak *et al.* 2011) [10, 26, 2, 12] reported that the mean number of fruits per plant lay between 4.46 and 98.30. The higher the number of fruits per cluster the more fruit yield is expected, although fruit size also determines the yield estimation (Pandey, 2006) [19].

The combined mean of maximum fruit length (5.9 cm) was recorded from the variety Mersa; whereas the least (3.7 cm) was recorded from the variety Miya. The result is in line with Meneberu *et al.* (2011) who reported that the average fruit length of tomatoes is ranging from 3.35 to 5.14 cm and fruit length was an important parameter for variety selection and customer preference. The highest fruit equatorial diameter (5.2 cm) was recorded from the variety Bishola; whereas the lowest (3 cm) was recorded from the variety Mersa (Table 4). Several studies (Kacjanmarsic *et al.* 2005; Eshteshabul *et al.* 2010; Abrar *et al*. 2011; Kaushik *et al.* 2011) [16, 10, 2, 17] showed that the equatorial diameter of tomato fruits lay between 3.2 and 10.67 cm. The size, length, and width of tomato fruits are influenced by the genetic makeup of the varieties (Atherton and Rudich, 1986) [3]. The combined mean of maximum marketable yield (45.8 T-ha^{-1}) was recorded from the variety Oval red which emerged as the best-performing variety while the least (20.5 t ha^{-1}) was recorded from variety Mersa (Table 4). Marketable fruit yield is the major determinant variable for the selection of a particular tomato variety, as it directly affects commercialization and thus income generation of the farmers (Pandey, 2006) [22]. Meseret *et al.* (2012) [19] who reported the marketable fruit yield ranging from 7.21-43.8 T-ha^{-1} in their study.

Disease severity percentage was highly significantly (p<0.0001) affected by the varieties and interaction effects of variety and location. The maximum powdery mildew disease severity score was recorded from varieties of ARP Td2 (31.8-34.9%), Cochoro (31.3-34.5%), and Miya (21.6-27.4%) whereas moderate severity was recorded from Oval red (14.2-17.8%) and Bishola (6.9-9.1%) varieties, and the least disease severity percentage (1.7-2.2%) was recorded on variety Mersa (Table 5).

Table 4: Combined mean values of tomato varieties at Kobo and Mersa in 2017.

Variety	PH (cm)	NPB	50% FD	NFCPP	NFPP	FL (cm)	FED (cm)	Mkt Y T-ha^{-1}
Mersa	85.8^{a}	6.3^{b}	58.5^{a}	8.1^{c}	70.5^{a}	5.9^{a}	3d	20.5^{e}
Bishola	65.4^{b}	7.8^{a}	46.3^{b}	9.3^{c}	18.5^{d}	4.4^{d}	5.2^{a}	27.3^{d}
Oval red	59.4^{c}	8.3^{a}	47^{b}	15.7^{a}	39.9^{b}	5.5^{b}	4.4^{b}	45.8^{a}
Miya	47.9^{d}	6.8^{b}	47^{b}	14.9^{a}	29.9^{c}	3.7^{e}	3.8^{c}	33.3^{b}
Cochoro	45.7^{d}	6.2 ^{b}	47^{b}	11.6^{b}	18.2^{d}	4.6^{c}	4.3^{b}	30^{c}
ARP T d2	41.7^{e}	6.1^{b}	47^{b}	9.3^{c}	16.4^{d}	4.6^{c}	4.5^{b}	21.9^{e}
LSD (5%)	2.4	0.8	2.1	1.6	2.5	0.2	0.3	1.9
CV (%)	3.4	10.2	3.5	11.7	6.5	3.1	5.9	5.5

Where, PH (plant height), NPB (Number of primary branches), 50% FD (50% flowering date), NFCPP (number of fruit clusters per plant), NFPP (number of fruits per plant, FL (fruit length), FED (fruit equatorial diameter), Mkt Y T-ha^{-1} (marketable yield ton per hectare) and DSEV (disease severity percentage).

Regarding Farmers' perception on the performance of tomato varieties, the majority of participant farmers in the study areas have a good interest in growing tomatoes. The evaluated varieties performed well as compared to the local varieties. The tested varieties showed similar performance in the two study areas. After discussion and debates, farmers ranked the varieties based on their preference (Table 6). Matrix ranking results showed that the overall mean of the ranks for all performance in the study areas indicated that the Oval red variety was first ranked in relation to fruit yield, fruit size, and fruit appearance. Variety Mersa was ranked first in relation to disease resistance. This means farmers have a better preference towards these varieties as compared to others (Table 7).

Farmers were also given a chance to compare each variety to the other ones with regards to the values based on identified criteria. Pair-wise ranking was used as a tool to summarize farmers' preference toward the varieties (Boef and Thijssen, 2007) [5]. The result showed that Mersa was the most preferred variety followed by Oval Red, Cochoro, ARP Td2, and Miya (Table 8). Farmers indicated that Oval Red and Mersa were selected due to their higher yield potential and moderately resistance to powdery mildew.

Table 5: Interaction effects location and tomato varieties on disease severity percentage

Location	Variety	DSEV%
Kobo	Mersa	1.7^{i}
	Bishola	6.9^{h}
	Oval	14.2^{f}
	Red Miya	21.6^{d}
	Cochoro	31.3^{b}
	ARP Td2	31.8^{b}
Mersa	Mersa	2.2^{i}
	Bishola	9.1^{g}
	Oval	17.8^{e}
	red Miya	27.4^{c}
	Cochoro	34.5^{a}
	ARP Td2	34.9^{a}
LSD (5%)		1.17
CV (%)		3.6

Where, DSEV % (disease severity percentage)

Table 6: Pairwise and weighting parameters

	FY	FS	DR	FA	FH	Weight	Rank
FY	X	FS	Y	Y	Y	3	1
FS		X	FS	FS	DR	2	2
DR			X	DR	DR	3	1
AF				X	FA	1	3
FH					X	0	4

Where, FY=Fruit Yield, FS=Fruit Size, DR=Disease Resistance, FA=Fruit Appearance; FH=Fruit Height

Table 7: Total score given to varieties based on each criteria set by farmers

	FY (1)	DR (1)	FS (2)	FA (3)	FH (4)
Mersa	16 (2)	19 (1)	18 (2)	20 (2)	19 (2)
Cochoro	24 (5)	21 (3)	28 (5)	30 (5)	22 (3)
ARP Td2	18 (3)	24 (5)	26 (4)	23 (3)	24 (4)
Oval red	15 (1)	19 (2)	14 (1)	16 (1)	18 (1)
Miya	23 (4)	22 (4)	25 (3)	25 (4)	26 (5)
Bishola	25 (6)	26 (6)	30 (6)	31 (6)	33 (6)

Table 8: Final ranking result for varieties (weight of criteria × rank of the varieties)

	FY-1	DR-1	FS-2	FA-3	FH-4	Total	Rank
Mersa	2	1	4	6	8	22	1
Cochoro	5	3	10	15	12	45	5
ARP Td2	3	5	8	9	16	41	3
Oval red	1	2	2	3	4	11	2
Miya	4	4	6	12	20	42	4
Bishola	6	6	12	18	24	66	6

Conclusion and Recommendation

The tomato varieties performed differently in growth, yield, and yield components. The marketable fruit yield of the tomato varieties varied from 20.5-45.8 T-ha^{-1}. However, the maximum yield marketable fruit yield was recorded from Oval Red followed by Miya and Cochoro varieties whereas the least marketable fruit yield was recorded from variety Mersa less disease pressure. This makes very interesting for a breeder to work on crossing of high yielding with disease-resistant varieties. Therefore, based on yield performance and disease resistance Oval Red and Mersa varies can be further promoted for commercial production under irrigation at Kobo and Mersa areas.

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