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Participatory evaluation of tomato *(Lycopersicon esculentum Mill.)* varieties under irrigation conditions at Abergelle district, Eastern Amhara

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Summary: Participatory on-farm evaluation of improved tomato varieties ('Melka salsa', 'Roma VF' and 'Kochero') against the local tomato variety was carried out during the 2019/2020 growing season involving six farmers of Abergelle district, Eastern Amhara. The objective of the experiment was to assess the performance of different tomato varieties for the farmers, then to collect their feedback. Based on the actual and farmers' preference data, the analysis underscores the better performance of improved tomato varieties over local varieties by most yield-related attributes. Average marketable fruit yields of 'Melka salsa', 'Roma VF', 'Kochero', and the local variety were 4.62, 3.88, 3.64, and 3.10 ton ha^{-1}, respectively. The improved varieties thus had a yield advantage of 72.38%, 37.14%, and 25.72% over the local variety in that order. Among improved tomato varieties, 'Melka salsa' provided the highest fruit yield on top of owing the highest score of overall preference attributes rank. Scale-wide diffusion of 'Melka salsa' tomato variety is therefore suggested for similar and potential agro-ecologies. Biological scientists also should take farmers' preference attributes and feedback as a backup for future breeding and adaptation studies on tomato varieties.

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Key words: fruit shape, irrigation potential, late blight, preference attribute, tomato variety

Introduction

Tomato *(Lycopersicon esculentum Mill.)* is an important edible and nutritious vegetable crop, ranked 3rd next to potato and sweet potato in the world. The favorable climates for the cultivation of tomatoes are tropical, sub-tropical, and temperate agro-ecologies (FAO, 2006). In Ethiopia, beyond consumption, tomato bids better economic returns for many farmers mainly during the wet and rain seasons (Shibru, 2016). Its productivity also fluctuates as per the farmers' local context, management practices, and the variety used. The average productivity of tomatoes in Ethiopia and the Amhara region is 8.5 and 4.5 ton ha^{-1}, respectively (Meseret et al., 2012). Wag-himira, among the potential zones of the Amhara region, is one of the tomato producer areas using small irrigation schemes at the smallholder level (CSA, 2020). Considering the economic benefits stated, farmers, need to grow tomato varieties having the merits of high yield and better performance to their local environment. Despite, irrigation can evade the risks of moisture stress, it is costly compared to rain-fed farming in terms of labor, input, and equipment (Srinivasan, 2010). In this costly practice, high-yielding vegetable varieties should be produced for the efficiency of the small irrigation land that the smallholder farmers owned (Manna & Amitava, 2012).

Regional tomato production in Ethiopia is below the national average due to inadequate adaptable improved varieties. To solve this problem, researchers at dry-land agriculture research centers have adapted and recommended different improved tomato varieties ('Melka salsa, 'Roma VF' and 'Kochero') for the lowland irrigation potential areas including Wag-himra zone (Mehadi et al., 2016; Shibru, 2016; Benti et al., 2017). However, experience has shown that recommended varieties are not grown by farmers as expected since the recommendations were merely based on biological performance ignoring farmers preferences. Such preference traits are of course the building blocks for demand-driven variety adaptation and diffusion (Meseret et al., 2012; Mihiretu & Assefa, 2019; Mihiretu et al., 2019b).

The current participatory study was therefore conducted at the Abergelle district of Wag-himra zone, which has about 908.8 ha irrigation potential, to assess the farmers' preference on top of agronomic performance evaluation of the different improved tomato varieties. The study was, precisely articulated to evaluate different improved tomato verities against the locally available variety, then to select a productive and socially acceptable variety for eventual local use.

Materials and methods

Study area description

Abergelle district (***Figure 1***) is located at 13°20′N and 38°58′E latitude and longitude, respectively in Wag-himra zone of Northeast Amhara, Ethiopia (Mihiretu et al., 2019a). The district comprises about a 17.29% share of the 16240 ha irrigation potential of Wag-himra zone (WBoA, 2015). The annual temperature range of the district is between 23 °C and 43 °C, while the average annual rainfall varies between

250-750 mm (Mihiretu et al., 2021). Despite its altitude ranges between 1150-2500 meters, about 85% of the district is characterized by lowland agro-ecology *(kola)* with low and erratic annual rainfall distribution (Mihiretu et al., 2020). The district has a short rainy season, characterized by late onset (starts in early July) and early offset (ends in late August).

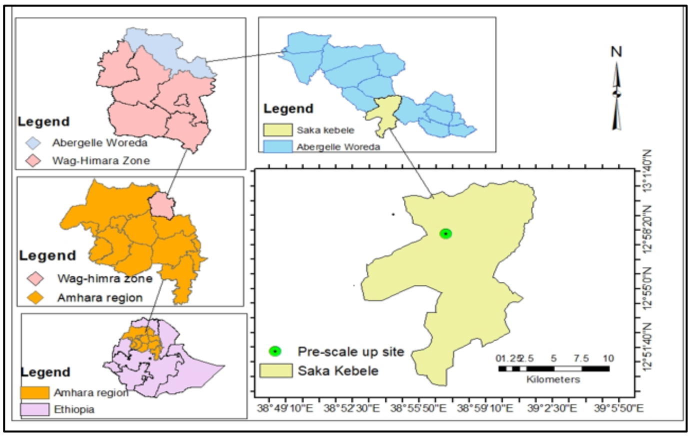

Figure 1. Study location map.

Treatments and experimental design

The study was conducted for two consecutive production years under irrigation through a participatory approach. In collaboration with experts, ten farmers (with their spouses) were selected to establish a farmers' research and extension group (FREG) for participation. The farmers and experts were given training about trial management and their roles as a participant. Sample plots from six farmers were randomly identified to host the experiment. Tomato seedlings were raised using well-prepared beds at Saka nursery site, having an area of $5m^2$ and 15cm height from the soil surface. The beds were watered at two days intervals until germination, then twice per week (Shibru, 2016). The experiment consists of four tomato varieties of which three are improved ('Kochoro', 'Melka Salsa', 'Roma VF'*)* while the remaining one is the farmers' (Abergelle local) variety. Treatments were laid out in simple plots using farmers as replications. The seedlings were warily transplanted to experimental plots having an area of 100 m^2 each. In total, 320 plants per plot were planted at 100 x 30 cm spacing of rows and plants, respectively (Mehadi et al., 2016). Package components comprising watering, weeding, fertilizer application, staking, and harvesting at the stage of mature green were carried out uniformly for all treatments (Benti et al., 2017). Furrow irrigation on weekly basis was used for watering the plots.

Data collection and analysis

The quantitative biological data such as bunch number per plant, fruit number per bunch, days to maturity, disease score, fruit weight, and marketable fruit yield were collected at the plot and farmers' level (Meseret et al., 2012; Mehadi et al., 2016; Benti et al., 2017). Descriptive statistics like mean, frequency, and percentages were employed to analyze such agronomic records. Change of yield (Eq. 1) was calculated to indicate the improved varieties' yield advantage over the local variety (Mihiretu et al., 2019). One-way ANOVA, followed by Tukey (HSD) post-statistical test was used to analyze the mean variation among and within treatments, respectively. Because the ANOVA result does not indicate the differences within treatments and their magnitude. If the assumption of equal variance is satisfied, the Tukey (HSD) post-statistical test is the most common (Kebede et al., 2021).

$$\Delta Y = \frac{Ys - Yb}{Yb} \text{ x } 100 \text{ ....}(Eq.\ 1)$$

Where, ΔY: change of yield, Ys: yield of improved variety, Yb: local variety yield

Since all treatments were under improved management (uniform), their production costs were constant hence economic data were not collected. However, to assess farmers' preferences and overall perception of the varieties, agreed parameters such as marketable fruit yield, earliness, fruit size, fruit shape, fruit taste and tolerance to disease (late blight), transportability and marketability were collected (Mehadi et al., 2016). The parameters compared each other pair-wisely to give a weighted rank, thereby constructing a weighted matrix ranking table (Mihiretu & Wubet, 2021). In the table, the varieties are compared to each other and counted to provide scores for each variety. The products (scores × weights) were then aggregated for final selection. Finally, to harmonize results from the quantitative data (actual measured) and qualitative data (farmers' preference), Spearman's (Eq. 2) rank correlation was used. For this reason that it shows the degree of coincidence between farmers' preference rank and the rank of the measured value (Mihiretu & Assefa, 2019).

$$r_s = 1 - \frac{6\sum d^2}{n\,(n^2-1)} \text{........}(Eq.\ 2)$$

Where, d: rank differences assigned for the same phenomenon, n: number of ranked phenomena

Results and discussion

Performances of yield and yield-related traits

The results of the experiment revealed that except for the number of bunches per plant, there was a statistically significant ($p \leq 0.05$) difference among tomato varieties in all yield and yield-related traits (***Table 1***). This finding is therefore in line with Mehadi et al. (2016) who stated that there was insignificant variation in the number of branches per plant among the different tomato varieties.

Besides, the number of fruits per plant was considerably different between the varieties, thus the highest fruit number per plant (28.48) was recorded from 'Melka salsa' while the lowest (17.83) was obtained from the local tomato variety ($p \leq 0.05$). Likewise, there was substantial variance among the varieties' fruit weight, hence, 'Melka salsa' had the highest fruit weight (58.24 g), followed by Roma VF (57.12 g) and 'Kochoro' (40.05 g) varieties (***Table 2***).

The most common disease, considered as the potential production constraint for tomato varieties in the study area was late blight. The experimental tomato varieties were entirely exposed and susceptible to the disease having the highest severity range, i.e., 2.02 to 4.82. The local tomato variety was thus found to be highly susceptible to the disease, whereas 'Melka salsa' was moderately resistant to other varieties. In terms of days to maturity, however, varieties 'Kochoro' followed by 'Melka salsa' were early maturing than 'Roma VF' and the local variety though there was no significant difference between the two early and late maturing varieties (***Table 3***).

Table 1. Mean performances of yield and yield related traits of different tomato varieties.

Parameters	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
Marketable fruit yield (ton ha^{-1})	Treatments	15.32	3	5.450	36.333***	0.001
	Errors	2.21	20	0.150		
	Total	17.53	23			
Number of bunches per plant	Treatments	10.29	3	3.066	1.685	0.167
	Errors	25.95	20	1.820		
	Total	36.14	23			
Days of maturity	Treatments	14915.22	3	4605.42	2089.57***	0.000
	Errors	50.84	20	2.204		
	Total	14966.06	23			
Tolerance to disease (late blight)	Treatments	12.05	3	3.510	11.396**	0.049
	Errors	1.57	20	0.308		
	Total	13.62	23			
Fruit number per bunch	Treatments	28.14	3	9.049	4.297**	0.014
	Errors	40.15	20	2.106		
	Total	68.29	23			
Fruit weight (gm)	Treatments	145.50	3	48.50	15.292***	0.002
	Errors	63.43	20	3.171		
	Total	208.93	23			

Note: ***, **, * implies the level significance at 1, 5 and 10%, respectively

Table 2. Performances of different tomato varieties for yield and yield-related traits.

Parameters	Varieties			
	Melka Salsa	**Roma VF**	**Kochoro**	**Local**
Disease (late blight) score (1-9)	2.02	4.65	3.68	4.82
Bunch number per plant	9.42	9.15	9.06	8.62
Fruit number per bunch	28.48	23.62	20.14	17.83
Days to maturity	118.4	128.6	112.8	124.2
Fruit weight (gm)	58.24	57.12	40.05	33.86
Marketable fruit yield (ton ha^{-1})	4.62	3.88	3.64	3.10
Yield advantage (%)	72.38	37.14	25.72	-

Statistically significant ($p \leq 0.05$) yield variance between tomato varieties was also observed in this study. The highest marketable yield (4.62 ton ha^{-1}) was obtained for ‘Melka salsa’ variety followed by the ‘Roma VF’ variety (3.88 ton ha^{-1}), but the lowest yield was obtained for the local variety (3.10 ton ha^{-1}). This result is in line with the finding of Manna and Amitava (2012) who underlined the existence of a positive correlation between the number of fruits per plant and the yield of the varieties. However, yields from the improved tomato varieties were better, accordingly, ‘Melka salsa’, ‘Roma VF’, and ‘Kochoro’ varieties had a yield advantage of 72.38%, 37.14%, and 25.72% over the local tomato variety, respectively. The Tukey-HSD test also showed that among varieties, ‘Melka salsa’ was the best performing tomato variety in most yield and yield-related traits at less than and/or equal to a 5% significant level (***Table 3***).

Preference traits and evaluation of different tomato varieties

Despite the improved varieties being better performed over the local variety, these varieties also need to fulfill/gain the farmers’ preferences/overall perception for sustainable adoption (Benti et al., 2017). The farmers as a group set out six weighted selection criteria to compare and rank the tomato varieties, i.e., marketable fruit yield, earliness, fruit size, fruit shape, fruit taste and tolerance to disease (late blight), transportability, and marketability. The weighted matrix ranking result exhibited that a variety with the lowest sum (∑score*weight) was farmers’ first choice, the vice-versa. Accordingly, the farmers preferred ‘Melka salsa’, ‘Roma VF’, ‘Kochoro’ and the local tomato varieties as their 1st, 2nd, 3rd, and 4th choices based on the overall preference criteria (***Table 4***). In general, the farmers specified that ‘Melka salsa’ tomato variety was selected for its higher yield, relatively better resistance to late blight, fruit size, shape, and taste. However, this result was against the finding of Mehadi et al. (2016), who indicated that the fruit size of ‘Melka salsa’ was small and even was susceptible to late blight. The difference was maybe attributed to the agro-ecological variation due to dissimilarity in experimental location and time/season. The medium-sized, oval-shaped and tasty flashed fruits of ‘Melka salsa’ tomato variety was liked by farmers for less perishability, ease of transportability, and greater market demand. The correlation between the measured ranks and the farmers’ preference ranks of different tomato varieties for tolerance to disease, earliness (days to maturity), fruit size, and marketable fruit yield revealed that 10%, 100%, 90%, and 100% coincidence, respectively (***Table 5***). According to Spearman’s correlation theory, a variety that has more than 50% degree of a coincidence for measured ranks and farmers’ ranks for the overall preference traits is accepted (Mihiretu & Assefa, 2019). As a result, the average 75% coincidence between the actual measured values and the farmers’ ranks in the current study underscores the acceptance of ‘Melka salsa’ over other competing tomato varieties in the study area.

Table 1. Post hoc analysis to identify well performing tomato varieties for yield and related traits.

Parameters	Pair of varieties	Mean Difference	Std. Error	Tukey-HSD Sig.
Marketable fruit yield (ton ha^{-1})	M – R	2.146**	0.168	0.014
	M – K	2.103***	0.168	0.006
	M – L	2.083***	0.168	0.000
	R – K	0.067	0.168	0.984
	R – L	1.667**	0.168	0.014
	K – L	1.540***	0.168	0.000
Number of bunches per plant	M – R	2.36	0.563	0.368
	M – K	1.232	0.563	0.146
	M – L	1.708**	0.563	0.018
	R – K	1.132	0.563	0.236
	R – L	1.417	0.563	0.093
	K – L	1.548	0.563	0.184
Days of maturity	M – R	42.167**	0.285	0.029
	M – K	-45.176**	0.285	0.013
	M – L	-45.176**	0.285	0.012
	R – K	-45.012**	0.285	0.023
	R – L	40.142	0.285	0.100
	K – L	42.40***	0.285	0.000
Tolerance to disease (late blight)	M – R	1.323**	0.181	0.012
	M – K	0.567	0.181	0.914
	M – L	1.467***	0.181	0.000
	R – K	0.903***	0.181	0.000
	R – L	1.007	0.181	0.902
	K – L	0.719***	0.181	0.000
Fruit number per bunch	M – R	-2.030**	0.748	0.049
	M – K	-2.400**	0.748	0.016
	M – L	.617***	0.748	0.004
	R – K	1.900***	0.748	0.006
	R – L	2.917***	0.748	0.001
	K – L	1.017**	0.748	0.038
Fruit weight (gm)	M – R	23. 050	1.360	0.150
	M – K	44.00***	1.360	0.000
	M – L	42.833***	1.360	0.000
	R – K	44.500***	1.360	0.000
	R – L	43.343***	1.360	0.000
	K – L	1.617	1.360	0.208

Note: ***, **implies significance levels at 1 and 5%, respectively; M, R, K and L stand for 'Melka Salsa', 'Roma VF', 'Kochoro' and Local tomato verities

Table 2. The farmers' preference traits and evaluation rank of different tomato varieties.

Weighted parameters		**M**	**R**	**K**	**L**
Earliness (days to maturity)	S	2.00	4.00	1.00	3.00
	W	2.00	2.00	2.00	2.00
	S×W	4.00	8.00	2.00	6.00
Marketable fruit yield	S	1.00	2.00	3.00	4.00
	W	1.00	1.00	1.00	1.00
	S×W	1.00	2.00	3.00	4.00
Tolerance to disease (late blight)	S	1.00	1.00	1.00	2.00
	W	3.00	3.00	3.00	3.00
	S×W	3.00	3.00	3.00	6.00
Fruit size	S	1.00	1.00	2.00	2.00
	W	6.00	6.00	6.00	6.00
	S×W	3.00	6.00	12.0	12.0
Fruit shape	S	1.00	1.00	1.00	2.00
	W	7.00	7.00	7.00	7.00
	S×W	7.00	7.00	7.00	14.0
Fruit taste	S	1.00	3.00	2.00	3.00
	W	4.00	4.00	4.00	4.00
	S×W	4.00	12.0	8.00	12.0
Transportability	S	1.00	2.00	3.00	1.00
	W	8.00	8.00	8.00	8.00
	S×W	8.00	16.0	24.0	8.00
Marketability	S	1.00	2.00	3.00	3.00
	W	5.00	5.00	5.00	5.00
	S×W	5.00	10.0	15.0	15.0
	∑(S*W)	35.0	64.0	74.0	77.0
	Ranks	1.00	2.00	3.00	4.00
		35.0	64.0	74.0	77.0

Note: Ranks 1, 2, 3, 4 stand for Excellent, Best, Fair, and Worst performances, respectively; S: score, W: weight; M, R, K, and L stand for 'Melka Salsa', 'Roma VF', 'Kochoro', and Local tomato verities

Table 3. Correlation between the measured ranks and the farmers' preference ranks of different tomato varieties.

Parameters	**Ranks**	**M**	**R**	**K**	**L**
Tolerance to disease (late blight)	Actual	1	3	2	4
	Farmers	1	1	1	2
	d^2	$(1-1)^2$	$(3-1)^2$	$(2-1)^2$	$(4-2)^2$
	r_s = 0.1 (10%)				
Earliness (days to maturity)	Actual	2	4	1	3
	Farmers	2	4	1	3
	d^2	$(2-2)^2$	$(4-4)^2$	$(1-1)^2$	$(3-3)^2$
	r_s = 1.0 (100%)				
Fruit size	Actual	1	2	3	4
	Farmers	1	2	3	3
	d^2	$(1-1)^2$	$(2-2)^2$	$(3-3)^2$	$(4-3)^2$
	r_s = 0.9 (90%)				
Marketable fruit yield	Actual	1	2	3	4
	Farmers	1	2	3	4
	d^2	$(1-1)^2$	$(2-2)^2$	$(3-3)^2$	$(4-4)^2$
	r_s = 1.0 (100%)				

Where, r_s = correlation coefficient, *d* = rank difference among alike phenomenon, *n* = ranked number of the phenomenon;
M, R, K, and L stands for 'Melka Salsa', 'Roma VF', 'Kochoro', and Local tomato verities

Conclusions

The overall mean marketable fruit yields of improved tomato varieties significantly out-yielded the local tomato variety under similar production practices. Among improved tomato varieties, the variety named 'Melka salsa' provided the highest fruit yield, plus the highest score of overall preference attributes rank. The farmers thus perceived the greater yield potential of 'Melka salsa' improved tomato variety, and fully promised to use the variety in the future. Scale-wide diffusion through sustainably improved tomato variety supply is therefore recommended for the study area and similar potential agro-ecologies. Furthermore, biological scientists should take the farmers' preference attributes and feedback as a backup for further breeding and adaptation studies on tomato varieties.

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