INNSPUB

International Journal of Agronomy and Agricultural Research (IJAAR)
ISSN: 2223-7054 (Print) 2225-3610 (Online)
http://www.innspub.net
Vol. 12, No. 4, p. 70-77, 2018

RESEARCH PAPER OPEN ACCESS

Participatory tomato (*Lycopersicum esculentum* Mill) variety evaluation and selection for yield and quality in Wolaita Zone, Southern Ethiopia

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Article published on April 27, 2018

Key words: Tomato, Fruit yield, Quality, Selection, Variety

Abstract

The experiment was conducted under field conditions at Humbo, Wolaita zone in 2015 to 2016 using 10 tomato varieties with the objectives to identify and select the best performing tomato varieties in terms of yield, quality and to promote tomato production technologies and productivity using RCBD with three replications. Combined ANOVA revealed that there was statistically significant difference among varieties in all traits recorded. The highest marketable fresh fruit yield (37560kg/ha) was recorded by variety 'Melkashola' while the lowest (21595kg/ha) was recorded by 'Chali' indicating the marketable yield range of 15,965kg/ha due to variety difference in performance. Similarly, the highest total fresh fruit yield (39,599kg/ha) and that of the lowest (23949kg/ha) was recorded by varieties "Melkashola' and 'Chali', respectively, having total yield range of (15,650Kg/ha). The result depicted that Eshete, Fetan and Melkashola were among the top three varieties selected for fresh fruit yield. On other fruit quality and yield related traits such as fruit diameter and average fruit weight, varieties Metadel, Eshete and Bishola were superior. The varieties Cochoro and Fetan were observed to be the best varieties in TSS with highest value 6.25^{o}Brix which could be the best for processing. Correlation coefficient analysis indicated that plant height was highly strongly and positively correlated with marketable fresh fruit yield (0.79) and total fresh fruit yield (0.77). Fruit diameter and average fruit weight were highly positively correlated (0.94) whereas total soluble solid was negatively correlated with almost all other growth and yield traits.The farmer' preferences based on fruit size, color and field performance also revealed that varieties Eshete, Melkashola, Fetan, Melkaselsa and Metadel were better selected candidates for yield and quality. Therefore, varieties such as Eshete, Fetan and Melkashola could be recommended for fresh local and national markets while Cochoro would be selected for processing among the tested varieties.

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Introduction

Ethiopia is endowed with wide varieties of agroecological conditions that allow growing various horticultural crops in general and vegetables in particular. The geographical location of the country again can be mentioned as an opportunity to grow vegetables even for export markets as well (EIA, 2012; Bezabih *et al.*, 2015).

Crop yield is basically affected by plant genetic and environmental factors including soil fertility. Therefore, crop production is concerned with the exploitation of plant morphological (or structural) and plant physiological (or functional) responses with a soil and atmospheric environment to produce a high yield per unit area of land (Isah, 2014).

Tomato productivity at a given location depends on the potential of the genotype used and timely availability of resources. Crop variety is one of the vital factors that influence yield. Tomato yield and quality have been reported to be under genetic control and hence do vary widely with cultivars (Oko-Ibom and Asiegbu, 2007). The use of appropriate variety may result in better growth and higher yield (Alemayehu *et al.*, 2010; Isah, 2014).

A limited number of improved varieties and other agronomic packages have been recommended resulting in improvement of production and productivity of tomato in Ethiopia. But Still the national average yield of tomato in Ethiopia is 7.6 ton/ha (CSA, 2013; Abu and Teddy, 2013) which is incomparable with the average yield of other countries such as China, USA, Turkey, India, Egypt, Italy and Spain with average yield of 22.67, 80.61, 35.81, 18.61, 40.00 and 76.35 ton/ha in that order (FAO, 2009).

The sector is now growing rapidly and contributing a lot for national economy for the last five years. Yet major part of the production is in a scattered small scale farmer's level that needs great effort to improve its production, quality and post harvest loss in general. So far, variety development has been conducted mainly in central rift valley areas in the dry season and limited information is available regarding performance of the released tomato varieties in different agro-ecologies in Ethiopia (EIA, 2012; Abu and Teddy, 2013; Bezabih *et al.*, 2015).

However, production and productivity of vegetable crops in general and tomatoes in particular are challenged by many factors among which low/poor variety development and limited number of varieties for production is the major one. Diversifying of crop variety for particular production system is one of the best options for boosting production and productivity due fact that genetic potential varies with varieties for yield, nutrient use efficiency, disease and other stress resistance. Therefore, evaluation of genotypes for particular agroecological area is essential to give valid recommendation. Hence, the current research is designed to alleviate the existing gap in production, productivity and quality improvement for farmers and commercial producers at Humbo, Wolaita zone with the following objective: To identify and select the best performing tomato varieties in terms of yield, quality and farmers' preference.

Materials and methods

Study site/area

The field experiment was conducted during 2015 and 2016 at Abela site, Humbo Woreda in wolaita Zone of Southern Ethiopia. Humbo is located at 6°40'46"N latitude and 37°46'56"E longitude with an altitude of 1450 m.a.s.l. The area has bimodal rainfall distribution with mean annual rainfall of 500 mm. Area has hot warm climate with mean minimum and maximum air temperature of 24°C and 34°C, respectively. The soil of area was classified as sandy loam in texture.

Treatments and experimental design

Ten recently released tomato varieties were collected from Melkasa Agricultural Research Center and used as treatments and arranged in the following order: 1. Chali 2. Miya 3. Bishola 4. Metadel 5. Cochoro 6. Fetan 7. Eshete 8. Melkaselsa 9. ARP-Tomato 10. Melkashola. The experimental treatments were laid out in Randomized Complete Block (RCB) Design with three replications. Field planting was done using plant spacing of 100cm x 40 cm between rows and plants, respectively, in 2015 and 2016.

Each plot had 4 rows and 10 plants per row. The total plot area was 4.0m x 4.0m =16.0m^2. All cultural practices were done using recommended agronomic practices by Melkasa agricultural research center during field management.

Data Collected

From the total of four rows in a plot, data was collected from sample representative plants from two central rows and excluding the boarder plants of central rows.

Plant height [cm]- The height of the plant to the tip of the longest branch from the surface level was measured for selected 8 sample plants.

Cluster number per plant- The number of cluster of 8 sample plants per plot was counted and their average was recorded.

Number of fruits per cluster- The number of fruits per cluster for 8 sample plants per plot was counted and recorded.

Fruit size (diameter) (mm)- 10 fruits from the selected sample plants were collected and their size was measured using calipers during 2nd and 3rd harvesting time.

Average fruit weight [g]- 10 fruits from the harvestable plot were selected and their weight was measured during 2nd and 3rd harvesting time.

Fruit wall thickness [mm]- Pericarp (fruit flesh) thickness of selected 10 representative fruits were recorded during 2nd harvesting using digital caliper.

Marketable fruit yield [kg/ha]- Yield of the entire plot excluding the border plants and rows was collected and their marketability was judged by the farmers subjective decision and data was recorded.

Unmarketable fruit yield [Kg/ha]- Similar to marketable yield, unmarketable ones were separated from those marketable by subjective judgment and data was recorded (Under size, defected, bird attacked, sun scald, diseased etc... were considered to be unmarketable).

Total Fruit yield [kg/ha]- The sum total of marketable and unmarketable ones was recorded.

Total Soluble Solids [^{o}Brix]– TSS from sample fruits from each plot was determined.

Fruit color- Color preference based on farmers' subjective interest on the basis of local market demand was determined and ranked.

Statistical Analysis

Analysis of variance- The data collected for each trait was subjected to Analysis of Variance (ANOVA) using SAS software (9.2 version) and least significant difference (LSD) was used to separate the means that showed significant difference at five percent probability levels. Again simple pearson correlation coefficient was used to study character correlation.

Results

Under field condition plant height (cm), average fruit weight(g), number of cluster per plant, fruit number per cluster, fruit diameter(mm), fruit flesh thickness(mm), marketable fresh fruit yield(kg/ha), unmarketable fresh fruit yield (kg/ha) and total fresh fruit yield (kg/ha), total soluble solids (^{o}Brix), and fruit color were measured.

Table 1. Combined ANOVA of traits studied for 10 tomato varieties at Humbo Abela, Wolaita zone, 2015 & 2016.

SV	Df	Ph	FD	Fwt	FNC	NCP	Tic	Myld	UMyld	Tyld	TSS
Rep	2	154.33*	25.39	53.16	0.37	7.15	0.31	351687393	627125	326310909	4.74
Trt	9	478.73**	324.73**	1900.74**	0.69*	4.55*	0.44*	66957368*	4677082*	56426660*	0.68*
Error	18	35.33	26.06	351.99	0.24	1.72	0.13	63973233	2246102	58116936	0.60
CV(%)		8.65	9.25	27.50	12.3	16.62	5.82	28.4	43.27	24.1	14.89

*=Significant (at 5% probability); ** = highly significant (at 1% probability); Sv=Source of variation, df=degree of freedom, Trt=Treatment, Rep=Replication, CV(%)=Coefficient of variation in percent, Ph=Plant height(cm), FD=fruit diameter(mm), Fwt=Average fruit weight(g), FNC= fruit number/cluster, NCP=number of clusters/plant, Tic= Fruit flesh(pericarp) thickness(mm), Myld=Marketable yield(Kg/ha), UMyld= Unmarketable yield(kg/ha), Tyld= Total yield(kg/ha), TSS=Total soluble solids(^{o}Brix).

Analysis of variances for quantitative traits

The two years combined ANOVA result indicated significant difference among varieties in all tested parameters (Table 1). Plant height showed statistically highly significant difference among varieties. The highest plant height (98.73cm) was recorded by variety *Eshete* followed by variety *Melkashola* (79.84cm) whereas the lowest plant height (55.89cm) was recorded by variety *Fetan* followed by variety *Chali* (56.10cm) having range of 42.63cm (Table 2). In terms of fruit quality, average fruit size (diameter) and average fruit weight revealed statistically highly significant difference among varieties. On average the highest fruit diameter (71.19mm) was recorded by variety *Eshete* followed by *Bishola* (65.18mm) whereas the lowest fruit diameter (36.73mm) was recorded by variety *Melkaselsa*. As far as average fruit weight is concerned, the highest (98.17g) and the lowest (28.00g) was recorded by varieties *Bishola* and *Melkaselsa*, respectively showing range of 70.17g. Fruit flesh thickness was also highest (6.68, 6.63, 6.26mm) for varieties *Eshete, Chali* and *Miya* in their respective order whereas the lowest value (5.38) was recorded by variety *Melkaselsa* (Table 2). Average of two years fruit number per cluster and number of cluster per plant had shown statistically significant difference among the tested genotypes/varieties. Thus, variety *Melkaselsa* and *Melkashola* were found to be the best in fruit number per cluster with 4.83 and 4.70, respectively and again with 10.88 and 9.08 in number of cluster per plant, respectively. The lowest value in fruit number per cluster (3.43) was recorded by variety *Cochoro* and *Fetan* while the lowest in number of cluster per plant (6.82) was recorded by variety *Fetan*. The range of fruit number per cluster and number of cluster per plant was 1.40 and 4.06, respectively (Table 2).

Fresh marketable fruit yield revealed significant difference among treatments. Thus, the combined mean highest values in marketable fruit yield (37,560kg/ha) was recorded by variety *Melkashola* followed by *Melkaselsa* (31,590kg/ha) whereas the lowest (21,595kg/ha) was recorded by *Chali* having marketable yield range of 15,965kg/ha (Table 2). Moreover, unmarketable fresh fruit yield showed statistically significant difference among treatments. The highest unmarketable yield (5262kg/ha) was recorded by *Bishola* and the lowest (1495kg/ha) was recorded by *Melkaselsa* and followed by *Melkashola* (2039 kg/ha) (Table 2). As far as total fresh fruit yield was concerned, it illustrated significant difference among treatments (Table 1). The three highest values in total fresh fruit yield (39,599kg/ha, 34,981kg/ha, and 34,939kg/ha) were recorded by varieties *Melkashola, Fetan* and *Eshete* in the given order whereas the lowest total yield (23949kg/ha) was recorded by *Chali* (Table 2; Fig.1).

Similarly, total soluble solids (TSS) has shown significant difference among tested varieties. The best scores obtained include 6.25°Brix and 5.78°Brix by variety *Cochoro* and *Fetan*, respectively. The lowest yield in TSS (4.89°Brix and 4.57°Brix) was recorded by varieties *ARP-Tomato* and *Melkashola*, respectively (Table 2).

Table 2. Mean value of traits studied for 10 tomato varieties at Humbo Abela, Wolaita zone, in 2015 & 2016.

Trt	Ph	FD	.Fwt	FN/C	NC/P	Tick	Myld	UMyld	TYld	TSS
1	56.10d	49.24cd	54.67bcd	3.63c	7.48bc	6.63ab	21595b	2355bc	23949b	5.39ab
2	65.56cd	46.34d	43.17cd	3.97bc	7.48bc	6.26abc	27130ab	2715abc	29845ab	5.35ab
3	74.11bc	65.18ab	98.17a	3.97bc	6.88bc	5.94cd	23890ab	5262a	29152ab	5.23ab
4	64.98cd	62.99ab	94.67a	3.77c	7.68bc	5.77cd	24300ab	4550ab	28850ab	4.94ab
5	63.25d	57.17bc	75.67ab	3.43c	7.08bc	6.08abc	25276ab	4160ab	29436ab	6.12a
6	60.42d	58.65b	78.17ab	3.43c	7.62bc	5.93cd	30394ab	4587ab	34981ab	5.63ab
7	98.73a	71.19a	97.00ab	4.1abc	6.82c	6.68a	31318ab	3621abc	34939ab	4.99ab
8	64.62cd	36.73e	28.00d	4.83a	10.88a	5.38d	31590ab	1495c	33085ab	5.31ab
9	59.54d	58.01bc	70.83abc	3.77c	7.95bc	6.07bc	28566ab	3850abc	32415ab	4.66b
10	79.84b	46.17d	42.00cd	4.7ab	9.08ab	6.07bc	37560a	2039bc	39599a	4.53b
LSD	10.20	8.76	32.18	0.83	2.25	0.61	13720	2571	13077	1.33
mean	68.72	55.18	68.23	3.96	7.89	6.08	28161.74	3463.38	36625.12	5.20
Range	42.63	34.46	70.17	1.40	4.06	1.30	15965	3767	15650	1.59

Note: means with the same letter are statistically non-significant. Sv=Source of variation, df=degree of freedom, Trt=Treatment, Rep=Replication, Ph=Plant height(cm), FD=fruit diameter(mm), Fwt=Average fruit weight(g), FNC= fruit number/cluster, NCP=number of clusters/plant, Tic= Fruit flesh(pericarp) thickness(mm), Myld=Marketable yield(Kg/ha), UMyld= Unmarketable yield(kg/ha), Tyld= Total yield(kg/ha), TSS=Total soluble solids(°Brix); Lsd = Least significant difference.

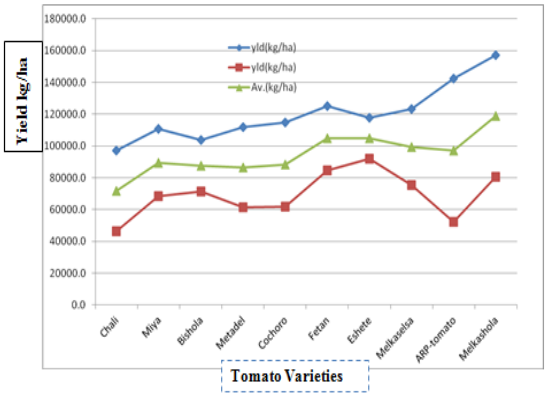

Fig. 1. Graphical representation of ten tomato varieties tested at Humbo, Wolaita, 2015 & 2016.

Character correlation study

Simple character correlation coefficient analysis indicated that plant height was highly strongly and positively correlated with marketable fresh fruit yield (0.79) and total fresh fruit yield (0.77). Fruit diameter and average fruit weight were highly positively correlated (0.94) whereas fruit diameter and average fruit weight were negatively correlated with number of fruits per clusters and cluster number per plant. Though it was non-significantly, analysis revealed that total soluble solid was negatively correlated with almost all other growth and yield traits except fruit wall thickness and unmarketable yield (Table 3).

Table 3. Estimate of correlation coefficients of traits studied for ten tomato varieties at Humbo, Wolaita in 2015 & 2016.

Traits	FD	Fwt	FN/C	NC/P	Tic	MYld	UMyd	TYd	TSS
Ph	0.15	0.07	0.56	0.03	0.18	0.79**	0.11	0.77**	-0.4
FD	-	0.94**	-0.50	-0.73**	0.41	0.03	0.44	0.08	-0.09
Fwt		-	-0.58	-0.71*	0.32	0.02	0.39	0.07	-0.18
FN/C			-	0.76	-0.34	0.47	-0.43	0.40	-0.60
NC/P				-	-0.60	0.17	-0.42	0.11	-0.29
Tic					-	-0.34	-0.03	-0.33	0.08
MYld						-	0.29	0.99**	-0.19
UMyd							-	0.39	0.23
TYd								-	-0.15

Ph=Plant height (cm), FD=fruit diameter (mm), Fwt=Average fruit weight (g), FN/C= fruit number/cluster, NC/P=number of clusters/plant, Tic= Fruit flesh(pericarp) thickness(mm), Myld=Marketable yield(Kg/ha), UMyld= Unmarketable yield(kg/ha), Tyld= Total yield(kg/ha), TSS=Total soluble solids(°Brix).

Producers preference on basis of some qualitative traits

Field evaluation of the fruits was done during peak harvest period. The evaluation was done by farmers research groups, about 20 neighboring farmers (about 10 female &10 male), two Kebele DAs and two TAs. The cumulative relative ranking result indicated that varieties *Eshete, Melkashola, Metadel, Fetan* and *Melkaselsa* were better preferred by community on the basis of fruit colour, size, and general appearance (Table 4).

Table 4. Farmers preference (ranking) of the varieties on the basis of fruit color, size and appearance evaluation, 2015 & 2016.

Varieties	Summary of evaluation ranking by farmer groups			
	Group 1	Group2	Group3	Relative ranking
1. Chali	4	3	4	3.6
2. Miya	2	2	3	2.3
3. Bishola	4	2	3	3.0
4.. Metadel	1	2	1	1.3
5 .Cochoro	2	3	2	2.3
6. Fetan	1	2	1	1.3
7. Eshete	1	1	1	1.0
8. Melkaselsa	1	2	1	1.3
9. ARP-Tomato	2	1	2	1.6
10.Melkashola.	1	1	1	1.0

Discussion

The highly significant difference among varieties in plant height with the highest plant height (98.73cm) by variety *Eshete* whereas the lowest plant height (55.89cm) by variety *Fetan* having range of 42.63 cm due to the difference in genotypes was observed. This result was in agreement with the finding of Isah (2014) who reported the variation in plant height in four tomato varieties tested in two locations in Nigeria. In same manner, Gebisa *et al.*, 2017 reported plant height range of 39.34cm to 96.67cm with the longest *Eshete* and the shortest *Chali*.

As of fruit quality, average fruit size (diameter), average fruit weight and fruit wall thickness revealed statistically highly significant difference among varieties. Among genotypes tested *Eshete* and *Bishola* were among the superior varieties where as *Melkaselsa* inferior in most cases. The variation in the traits concerned was attributed to the differences in genetic potential and their environment response to varieties. The current finding goes in line with the finding reported by (Hossain *et al.*, 2014). They observed fruit diameter range (4.79-3.74 cm) and average fruit weight range (72.33-39.67g) using different tomato varieties.

The variety *Melkaselsa* was superior in both fruit number per cluster (4.83) and cluster number per plant(10.88) whereas the lowest was recorded by variety *Fetan* showing the range of variation 1.40 and 4.06 in fruit number and cluster number, respectively was observed due to variation in genotypes. Consistent with the current investigation, similar conclusion was reported by Alemayehu *et al.* (2010) and Isah (2014). In concordance with the current result, Gebisa *et al.*, (2017) reported the variation in mean clusters number per plant of 7 to 16 while fruit number per cluster of 1.67 to 3.33 in different varieties tested in 2012/1013.

The maximum (37,560kg/ha) and minimum (21,595kg/ha) marketable fresh fruit yield was depicted by varieties *Melkashola* and *Chali*, respectively, with range of 15,965kg/ha because of the varietal difference that in turn might be attributed to their genetic potential.

In similar manner, unmarketable fruit yield was statistically different which revealed the total variation of 3,767kg/ha having the least unmarketable yield value recorded by variety *Melkaselsa*. The total fresh fruit yield envisaged potential variation among varieties. The top three selected varieties include *Melkashola, Fetan* and *Eshete* whereas the lowest was *Chali*. The total fresh fruit yield range of 15,650kg/ha was observed due variation in genotypes. This indicated the huge potential in yield variation due to varieties. This result was in line with the finding reported by Desalegn *et al.*, (2016). They found maen marketable yield range 11.61 to 22.95 ton/ha in six tomato varieties. Moreover, Gebisa *et al.*, (2017) reported fruit yield range between 18557 and 30863 kg/ha with superior tested varieties of *Melkashola* and *Bishola*. In consistent with the result, other researchers such as Abu and Teddy (2013) and Lemma (2002) noticed more or less the same finding. Hence, it is very important to diversify the genotypes for different localities to utilize their genetic potential so as to improve productivity in tomato production.

Similar to yield and growth, total soluble solids (TSS) showed significant difference among genotypes with the highest value of 6.25°Brix by variety *Cochoro* and the lowest 4.57°Brix by variety *Melkashola*. This showed the TSS range of 1.68°Brix variation due to differences their inherent genetic potential. Again the investigation confirmed that varieties superior for fresh yield were inferior for TSS in most cases that calls for critical evaluation for specific and dual purposes.

Correlation studies provide information that selecting one character will result in progress for all positively correlated characters. So, Plant height with total yield and marketable yield; fruit diameter with fruit weight were highly significantly correlated that implies their possibility of simultaneous improvement. In contrary to this, TSS is negatively correlated with most characters which depicted their antagonistic effects for simultaneous breeding. Similar result was reported by (Souza *et al.*, 2012) where the association of TSS with other traits was negative which indicates that these traits could not be improved simultaneously.

Correlation studies in tomato breeding programs are useful when highly heritable traits are associated with an important trait like yield (Souza *et al*., 2012). Many of the characters are correlated because of mutual association, positive or negative, with other characters (Wali and Kabura, 2014).

Conclusions

The research result substantiated significant variation in growth, yield and yield components among the tested ten tomato varieties in the study area. Thus some of best varieties selected among the tested genotypes for fresh fruit yield include variety *Eshete, Melkashola* and *Fetan*. Character correlation study also indicated that some growth, yield and yield component characters are positively correlated and hence could be improved simultaneously. But TSS was negatively correlated with most of the characters studied. Further farmers field observation and stakeholders participation contributed for promotion of tomato production in the area.

Conflict of interest

Authors have no conflict of interest in financial or things directly or indirectly related to it.

Acknowledgements

The authors like to thank Wolaita Sodo University College of Agriculture and Melkassa Agricultural Research Center for their valuable contribution in both facilitation and financial support.

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