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Yield Stability and Quality Performance of Processing Tomato *(Lycopersicon Esculentum Mill)* Varieties in the Central Rift Valley of Ethiopia

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ABSTRACT

Six tomato varieties were evaluated at six different environments in Ethiopia, to assess their quality and yield stability to make recommendations for possible release. The experimental design used was a randomized complete block design with three replications. Data on days to 50% flowering, leaf coverage, plant height, number of fruit cluster^{-1}, average fruit weight, number of locules fruit^{-1}, fruit skin thickness and fruit yield hectare^{-1}.were collected. Differences among varieties were significant for most of the parameters except for number of fruit cluster^{-1}. The fruit size ranged from 61g to 89g and Oval Red (87g), Missouri (89g) and Mecheast 22 (87g) gave larger fruit size. Fruit pericarp thickness and total soluble solid ranged from 56 to 7.3mm and 4.13 -4.73 percent, respectively. Oval Red had significantly thicker pericarp and higher percent of total soluble solid than the rest of the varieties. Melkassa was the best yielding environment with high positive environmental index of 7.91 and 14.19 and yield level of 46.9 and 53.1 t ha^{-1} in 2013 and 2014, respectively. Oval Red exhibited superior mean (46 t ha^{-1}) for fruit yield than the grand mean (39 t ha^{-1}), non-significant regression coefficient (0.63) close to unity with insignificant deviation from regression (4.48) indicating its average stability i.e. suitable for all environments. Therefore, variety 'Oval red' was released with local name 'Galilama' for production in the Central Rift Valley area and similar agro-ecologies.

Keywords: *Tomato, Variety, Quality, Genotype by Environment Interaction, Yield Stability*

INTRODUCTION

Tomato (Lycopersicon esculentum Mill) is the major horticultural crop with an estimated global production of 164 million metric tons from 4.73 million ha of land (FAO, 2014). In Ethiopia, it is an important food ingredient in daily diet of people in almost all regions. The crop is an important cash-generating crop to small-scale farmers and provides employment in the production and processing industries. The total areas under tomato crop in the rainy season is estimated to be 5.05 thousand ha with 30.7 thousand tones of harvest (CSA, 2015). However, the productivity of the crop is very low in farmers' field in the country compared to experimental fields.

Tomato production is faced with a number of constraints which are biotic and abiotic that resulted into low yield. Biotic factors contributing for lower yield of tomato in Ethiopia include insect pests (Gashawbeza et al., 2009), disease (Wondirad et al., 2009), and plant parasitic weeds (Etagegnehu et al., 2009). Drought, heat, and poor cultural practices constitute abiotic factors for lower productivity of tomato(Lemma, 2002; Lemma et al., 2008). Tomato varieties and advanced breeding lines were introduced by the vegetable improvement program of the Ethiopian Institute of Agricultural Research (EIAR) for various purposes. These were initially screened at Melkassa center of EIAR and selected materials were tested at different locations (MARC, 2010).

Genotypes tested in different environments almost invariably showed genotypes-by-environment (GxE) interactions; that is, the relative performances of the genotypes vary from one environment to another. The advantage of selecting superior genotypes using stability analysis instead of average performance is that stable genotypes are dependable across the environments which reduce G×E interaction. Studies showed that stability analysis can result in better identification of stable genotypes, even when there are no interactions among the parameters (Fasahat et al., 2015). Stable genotype is the one possessing a constant performance irrespective of any changes in environmental conditions (Fasahat et al., 2015; Stoffella et al., 1984). The most widely used approach is based on linear regression of genotype yield on an environmental index derived from the average performance of all genotypes in each environment (Eberhart and Russell, 1966). The regression model provides two stability parameters. The first estimate is the linear regression coefficient of genotype mean on environmental index. The second estimate obtained from regression is the mean square deviation from regression for each genotype. Thus, this study was conducted to assess the extent of some promising tomato genotypes by environment interaction; yield stability and adaptability across different environments with the aim of releasing promising genotypes for production.

Material and Methods

Multi location variety trials were conducted using five tomato varieties selected from previous preliminary variety trial and one recently released tomato variety (Chali) as a standard check. The field trials were conducted in 2013 and 2014 at three locations, Melkassa, Wonji, and Ziway. The trial within a year was considered as one environment and thus totally made six environments. Seedlings were raised on seedbed and transplanted to the field 30 days after sowing. All routine management practices were applied accordingly. Randomized complete block design (RCBD) with 3 replications were employed, with plot size of 5m x 6m (30m2) at 100cm inter-rows and 30cm intra-row spacing.

Table1. *Altitude, rainfall, soil type and temperature of experiment sites*

Location	Altitude [m]	Annual Rain fall [mm]	Soil type	Temperature [^oC]	
				Min	Max
Melkassa	1550	818	Ando	14	29
Wonji	1540	831	Fluvisol	15	28
Ziway	1650	738	Ando	14	28

Maturity times were recorded based on the time from transplanting to 50% flowering. The meter rulers were used for measuring plant height from base to the tip of the main shoot. The leaf coverage of fruits was recorded at third fruit harvest. The number of fruits per cluster was counted from ten randomly selected plants. Fruit yield was recorded by harvesting the central three rows. Fruit qualities (average fruit weight, fruit shapes, fruit firmness, total soluble solid (TSS) (^{o}Brix) were assessed from fully ripe randomly selected 10 fruits from each plot.

Statistical Analysis

The combined analysis of variance for quality and vegetative performance was computed using SAS 9.22 statistical software (SAS Institute, 2010). Mean separation was done using Duncan's Multiple Range Test (DMRT). For fruit yield stability, the combined analyses of the variance across different environment was done using PROC GLM model of SAS 9.2 program with genotypes being considered as fixed effects and replication with in environments being random effect. Genotype x environment interaction was quantified using pooled analysis of variance, which partitions the total variance genotype, environment, genotype x environment interaction and pooled error. Stability parameters, regression value (bi) (predictable linear response) and deviation from regression (S2di) (unpredictable non-linear response) were worked out according to Eberhart and Russell (1966) using GENES 7.0 computer program (GENES, 2016).

Results and Discussion

Vegetative and Quality Performance

The vegetative and quality performance of processing tomato varieties at Melkassa, Ziway and Wonji over the two years period was significant at $p<0.05$ except for number of fruit cluster^{-1} (Table 2). CLN 1466P was significantly early maturing variety followed by Chali and CLN 2498A (Table 2). All tested varieties had significantly higher plant height than the check. Most of the varieties have acceptable fruit size (86 - 89g) in the local market; however none of them had significantly larger fruit size than the check, Chali. Oval Red had significantly thicker pericarp and percent total soluble solid ($_O$Brix) content than the rest. Studies have associated high consumer acceptance with high soluble solids concentration in many commodities (Kader, 1994). In addition, firmness of pericarp tissues is a key component of both processing and fresh market tomato cultivars, thicker pericarp tissues could contribute to fruit firmness (Artherton and Rudich, 1986). Tested varieties differed in number of locules fruit^{-1} Oval Red had significantly lower number of locules (2) per fruit which is the typical character of processing tomatoes (Jones, 1999).

Table2. *Average vegetative and quality performance of processing tomato varieties at three locations for two years*

Varieties	FPF	LC	PH	NFC	FST	AFW	NOL	%TSS
CLN 1466 P	31^{d}	1.3^{b}	62^{b}	4.5	5.9^{cd}	70^{b}	2.9^{a}	4.52^{ab}
Oval Red	34^{b}	3.8^{a}	68^{a}	4.5	7.3^{a}	86^{a}	2.2^{c}	4.73^{a}
Missouri	35^{a}	3.9^{a}	66^{a}	4.6	6.8^{b}	89^{a}	2.4^{b}	4.48^{ab}
Chali	32^{c}	3.6^{a}	56^{c}	4.5	6.2^{c}	86^{a}	2.5^{b}	4.13^{c}
CLN 2498 A	33^{c}	3.9^{a}	70^{a}	4.7	5.6^{d}	61^{c}	2.5^{b}	4.63^{ab}
Mecheast 22	34^{b}	3.5^{a}	67^{a}	4.6	6.8^{b}	87^{a}	2.4^{bc}	4.38^{b}
Mean	33	3.3	65	4.5	6.4	80	2.5	4.5

LC-Leaf coverage [1-5 scale, 1-very low and 5-very high leaf coverage], PH-Plant height [cm], FPF-Days to 50% flowering, AFW-Average fruit weight [g], NOL-Number of locules per fruit, FST-Fruit skin thickness [mm], NFC-Number of fruit per cluster, %TSS-total soluble solid in percent. Means followed by the same letter are not significantly different at 5% level

Yield Stability

Environment, variety and their interaction were significant (p<0.01) for fruit yield (Table 3). Mean value of total yield ranged from 33.4 to 45.7 t ha^{-1} for varieties, 23.5 to 41.2 t ha^{-1} for locations, and 36.3 to 41.6 t ha^{-1} for years (Table 4). The variation in yield among locations was relatively higher compared to those in genotypes and years. This is more due to the agronomic management difference between on station (MARC) and on farm trial (Wonji and Ziway).

The highest mean yield of 46.9 and 53.1 t ha^{-1} with high positive environmental index of 7.91 and 14.19 was recorded from Melkasaa in 2013 and 2014, respectively (Table 4). Yield level was lower than the grand mean and environmental index was negative in the rest of the environments with the exception of Ziway in 2014 which resulted in 40.9 t ha^{-1} with positive environmental index.

Table3. *Combined analysis of variance for fruit yield of six processing tomato varieties*

Source of variation	DF	Sum Square	Mean Square	F - Value
Environment (E)	5	11450.8	2290.17	31.08***
Variety (V)	5	1985.5	397.10	5.39***
E*V	25	4469.2	178.77	2.43**
Error	72	5304.8	73.68	
Total	107	23210.3		

Note: *ns=not significant, *=p< 0.05, **=p< 0.01 and ***=p<0.001*

The pooled analysis of variance revealed that mean sum of squares due to varieties were highly significant (p<0.01) indicating the presence of large amount of variability in the materials chosen for the study. The linear component of G×E interaction was also significant indicating significant rate of linear response of the genotypes to environmental changes for fruit yield of tomato (Table 5). Similar result were reported by (Al-aysh, 2013; Jyothi et al., 2012; Ortiz and Izquierdo, 1994).

The mean fruit yield per hectare across the six environments ranged from 33 t ha^{-1} (CLN 1466P) to 46 ha^{-1} (Oval Red). Based on the Eberhart and Russell's (1966) model, a b_i approximating unity along with S_2d_i near zero indicate average stability. When associated with high mean yield, genotypes have general adaptability and while those with low mean yield, are poorly adapted to all test environments. A (b_i) less than unity provides a measure of greater resistance to environmental change (above average stability), and therefore increasing specificity of adaptability to low yielding environments. In this study Oval Red and the check Chali exhibited superior mean for fruit yield than the grand mean (39 t ha^{-1}), non-significant regression coefficient (b_i=0.63 and 1.17) close to unity with non-significant S_2di (4.48 and 13.74) indicating their average stability i.e. suitable for all environments. Hence, based on the adaptability and stability parameters, mean fruit yield and overall performance, variety Oval Red was recommended for release for the Central Rift Valley and similar agro-ecologies (MoANR, 2016). The variety was released with local name 'Galilama' to recognize the former senior staff of national vegetable program Dr. Lemma Dessalegn for his significant contribution on this crop. In the local language Afan Oromo 'Galilama' means introduced by Lemma and in the same language it also mean has double advantage because the variety can also be used as fresh market tomato.

Table4. *Yield performance [t ha-1] of processing tomato varieties at three locations for two years*

Varieties	Melkassa		Wonji		Ziway		Combined mean
	2013	2014	2013	2014	2013	2014	
CLN 1466 P	40.2[bc]	57.0[a]	31.4[a]	13.9[c]	33.8[b]	24.3[cd]	33.4
Oval Red	48.6[ab]	53.0[ab]	40.1[a]	31.0[a]	49.6[a]	51.7[a]	45.7
Missouri	49.5[ab]	59.2[a]	31.9[a]	16.4[c]	36.0[ab]	38.7[abc]	38.6
Chali	59.3[a]	50.2[ab]	40.0[a]	16.7[c]	43.2[ab]	39.6[ab]	41.5
CLN 2498 A	58.8[a]	55.3[a]	37.9[a]	18.2[bc]	49.9[a]	23.6[d]	40.6
Mecheast 22	24.9[c]	44.2[b]	41.8[a]	24.7[ab]	32.7[b]	35.4[bcd]	33.9
Mean	46.9	53.1	37.2	20.1	40.9	35.5	39
Environmental index	7.9	14.19	-1.78	-18.8	1.92	-3.42	

Means followed by the same letter are not significantly different at $p<0.01$

Table5. *Pooled analysis of variance for stability over the six environments for fruit yield in six processing tomato varieties*

Source	Degree of Freedom	Sum of Squares	Mean of Sum of squares
Varieties	5	659.30	131.86**
Environment + (varieties x Environment)	30	5305.56	176.9**
Environment (linear)	1	3816.74	713.03**
varieties x Environment (linear)	5	527.27	105.45**
Pooled deviation	24	961.55	40.06*
Pooled error	72	385.40	5.35

**significantly at $p<0.05$, **significantly at $p<0.01$*

Table6. *Mean fruit yield and estimates stability parameters in six processing type tomato varieties on 3 locations in 2013 and 2014*

Varieties	Mean Yield [t ha^{-1}]	b_i	S^2d_i
CLN 1466 P	33.4	1.24[ns]	-1.00[ns]
Oval Red	45.6	0.63[ns]	4.48[ns]
Missouri	38.6	1.26[ns]	-4.27[ns]
Chali	41.5	1.17[ns]	13.74[ns]
CLN 2498 A	40.6	1.34[ns]	47.94*
Mecheast 22	33.9	0.36[ns]	41.37*
Mean	39		

*ns = not significant, *significantly at $p<0.05$*

Conclusion

Six processing tomato enotypes were evaluated across three locations for two years (six environment) to assess their quality and yield performance, fruit yield response and stability performance to make recommendations for possible release. Based on the adaptability (b_i) and stability (S_2d_i) parameter, mean fruit yield and overall performance, variety Oval Red was recommended for release for the Central Rift Valley and similar agro-ecologies with local name 'Galilama'.

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References

[1] Al-aysh, F.M., 2013. Genotype-environment interaction and phenotypic stability for fruit yield and its components of tomato in Dara'a Governorate, Syria. Res. J. Agric. Environ. Manag. 2, 371–377.

[2] Artherton, J.G., Rudich, J., 1986. The Tomato Crop. Chapman and Hall press.

[3] CSA, (Central Statistics Agency), 2015. The Federal Democratic Republic of Ethiopia. Agricultural Sample Survey. Report on Area and Production of Major Crops for Meher Season. 2014/15 (2007 E.C). Statistical Bulletin No 578.

[4] Eberhart, S.A. and, Russell, W.A., 1966. Stability Parameters for Comparing Varieties. Crop Sci. 6, 36–41.

[5] Etagegnehu, G., Taye, T., and Girefe, S., 2009. Review of Vegetable Crops Weed Research in Ethiopia, in: Abraham, T. (Ed.), Proceeding of Plant Protection Society of Ethiopia. Increasing Crop Production through Improved Plant Protection. PPSE and EIAR, Addis Ababa, Ethiopia, pp. 323–334.

[6] FAO, 2014. United Nation Food and Agriculture Organization Statistics Division. Crop Production data. Rome, Italy.

[7] Fasahat, P., Rajabi, A., Mahmoudi, S.B., Noghabi, M. and, Rad, J., 2015. An Overview on the Use of Stability Parameters in Plant Breeding. Biom Biostat Int J 2. doi:10.15406/bbij.2015.02.00043

[8] Gashawbeza, A., Bayeh, M., Mulugeta, N., Yeshitila, M., Lidet, S., Ahmed, I., and Tadele, T., 2009. Review of Research on insect and mite pests of vegetable crops in Ethiopia, in: Abraham, T. (Ed.), Proceeding of Plant Protection Society of Ethiopia. Increasing Crop Production through Improved Plant Protection. PPSE and EIAR, Addis Ababa, Ethiopia, pp. 47–67.

[9] GENES, 2016. GENES statistical software Version 6.0. For Quantitative genetics and Experimental Statistics.

[10] Jones, J.B., 1999. Tomato plant culture : in the field, greenhouse, and home garden. CRC Press LLC, New York.

[11] Jyothi, H.K., Patil, M.G., Santhosha, H.M., 2012. Studies on stability of processing-type genotypes of tomato (Solanum lycopersicum L .). J. Horti. Sci. 7, 138–141.

[12] Kader, A.A., 1994. Fruit maturity, ripening, and quality relationships. Perishables Handl. Newsl. No. 802.

[13] Lemma, D., 2002. Tomatoes: Research Experiences and Production Prospects .Research Report No. 43. Addis Ababa, Ethiopia.

[14] Lemma, D., Shimels, A., Selamawit, K., Abyote, A., 2008. Varietal development of major vegetables in the rift valley region, in: Proceedings of the First Conference of Ethiopian Horticulture Science Society 23-24 March 2006,. Addis Ababa, Ethiopia, pp. 83–89.

[15] MARC, M.A.R.C., 2010. Melkassa Agricultural Research Center Progress Report for the year 2010. Melkassa, Ethiopia.

[16] MoANR, (Ministry of Agriculture and Natural Resources), 2016. Plant Variety Release, Protection and Seed Quality Control Directorate .Crop Variety Register. Issue No. 18. Addis Ababa, Ethiopia.

[17] Ortiz, R., Izquierdo, J., 1994. Yield Stability Differences among Tomato Genotypes Grown in Latin America and the Caribbean. HortScience 29, 1175–1177.

[18] SAS Institute, 2010. SAS/STAT® 9.22 User's Guide. Cary, NC: SAS Institute Inc.

[19] Stoffella, P.J., Bryan, H.H., Howe, T.K., Scott, J.W., Locascio, S.J., Olson, S., 1984. Stability differences among fresh-market tomato genotypes. II. Fruit yield. Amer. Soc. Hort. Sci 109, 615–618.

[20] Wondirad, M., Eshetu, A., Mohammed, Y., Alemu, L., Yaynu, H., Meki, S., Fekedde, A., 2009. Review of Vegetable Disease Research in Ethiopia, in: Abreham, T. (Ed.), Proceeding of Plant Protection Society of Ethiopia. Increasing Crop Production through Improved Plant Protection. Addis Ababa, Ethiopia, pp. 203–230.

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