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Assessment of the Stability and Adaptability of Some Newly Promising Tomato (*Solanum lycopersicum* L.) Lines Under Different Environmental Conditions

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ABSTRACT

Present study was designed to evaluate the performance of newly developed tomato advance genotypes and to investigate their yield stability across a range of environments over two consecutive years. Ten genotypes (8 new promising lines and two check *cvs* were grown at five different environments. in a randomized complete block design with three replications to determine the Phenotypic and genotypic stability. These Egyptian environments were Kaha, 2015 (Kalubia Governorate); Kaha, 2016 (Kalubia Governorate); El Tal El Kabier, 2015 (Ismailia Governorate); El Tal El Kabier, 2016 (Ismailia Governorate) and Dokki, 2016 (Giza Governorate). Combined results showed that line Z_5 produced significantly high mean values for each of earliness, fruit firmness and fruit yield than other studied genotypes, ranked first over all sites in both years and exhibited average stability and it can be recommended for favorable environments. It was concluded that both promising lines G_3 and Z_3 exhibited high stability of yield and both total soluble solids and fruit firmness where the regression coefficient (b_i) was near unity with low deviation from the regression (non-significant, S^2d_i). Therefore, both genotypes G_3 and Z_3 were found to be the most stable genotypes for all the environments and strongly recommended for planting at multi location trials. A_2, Super strain-B, Z_{42} and G_5 are considered as genotype with low stability. G_5 appeared to be more productive under unfavorable environments for plant height, days to flowering, fruit firmness, fruit length, fruit diameter, No. locules/fruit, fruit weight and fruit yield.

Keywords: Tomato, stability, adaptability, Fruit quality and total yield.

INTRODUCTION

Tomato (Solanum lycopersicum L.) belongs to the Solanaceae family and self pollination annual crop. Tomato is a very important vegetable cultivated and consumed in most parts of the world, from home gardens, greenhouses and open field to large commercial farms due to its wider adaptability to various agro-climatic conditions (Agyeman, 2014). In Egypt, total area cultivated by this crop was estimated by 515225 faddens with a total production of 8571050 tons with an average of 16.636 tons/fadden[*] .The ultimate goal of plant breeders in a crop improvement program is the development of the genotypes, which can be adapted to a wide range of diversified environments. Consequently, according to Allard and Bradshow, (1964) for develop a high yielding genotype and consistency, high attention should be given to the importance of stable performance for the genotypes under different environments and their interactions which had important. G x E interaction usually tested the adaptation of a genotype (G) over different environments (E). Bhnan (2008) evaluated five selected lines in F7 generation with three check cvs, and found that some lines were superior to the check cvs for plant height, total yield, fruit weight, fruit firmness and TSS. To test the stability of genotypes under different environments, Eberhart and Russell (1966) suggested a model and distinct a stable variety as having unit regression over the environments (b_i=1.00) and minimum variation from regression (S^2di= 0). Consequently, a variety with a high mean yield over the environments, unit regression coefficient (b_i=1) and variation from regression as small as possible (S^2di = 0), will be a superior choice as a stable variety. The interaction between genotype and environment is one of the effective factors to study of stability and it was studied by many researchers on the various genotypes of tomato (Ortiz and Izquierdo, 1994; Mandal *et al*., 2000; Shalinim 2009; Hosamani, 2010;Panthee *et al*., 2012 ;Al-Aysh, 2013 and Mohamed *et al*., 2013). The yield stability in different places can be due to cultivar performance that derived from a specific collection of genes (G), the characteristic that associated factors of the environment in which it is grown (E), and the interaction between genotype and location which are usually conducted in various years and locations to satisfactorily stand for spatiotemporal variation. Therefore, stability studies (Genotype x environment interaction) are therefore of great importance to identify superior genotypes that perform well across a wide range of environments and to detect specific adaptability of genotypes over favorable or unfavorable environments.

The aim of this study was conducted to evaluate the performance of newly developed tomato advance genotypes and to investigate their yield stability across a range of environments over two consecutive years. The information generated by such studies will be helpful for breeders to develop tomato genotypes which could produce higher and more stable yields over diversified environments.

MATERIALS AND METHODS

Ten genotypes of tomato (8 new promising lines, *i.e*., A_1, A_2, G_2, G_3, G_5, Z_3, Z_5 and Z_{42} were derived from a previous breeding program by (Zakher, 2005 and 2010) and two check *cvs* i.e., Peto86, and Super strain-B; as shown in Table ii) were included in the yield trial to study the performance of ten genotype x environment interactions over five different environments. These environments, in Egypt, were E_1: Kalubia Governorate (Kaha), 2015; E_2: Kalubia Governorate (Kaha), 2016; E_3: Ismailia Governorate (El Tal El Kabier), 2015; E_4: Ismailia Governorate (El Tal El Kabier), 2016 and E_5: Giza Governorate (Dokki), 2016. The experimental layout in each of the five environments was a randomized complete block design with 3-replications

[*] **Department of Agricultural Economics and statistics, Ministry of Agriculture and Land Reclamation, A.R. Egypt October, 2013.**

for each experiment. Seeds of each genotype were sown in the nursery on 25th of January / 2015 and the transplanting took place on 16th and 18th of March at E_1 and E_3 respectively, also in the 2nd year, 2016 the transplanting took place on15th, 16th and 17th of March at E_2, E_4 and E_5, respectively. Three rows (5 m long × 1.25 m wide with spacing of 40 cm between plants) in each plot. The drip irrigation system was followed in all environments and the normal agricultural practices of tomato were applied.

The mean air temperature data of test locations during 2015 and 2016 seasons as shown in table i.

Table i. Monthly mean air temperature data of the test locations during the 2015 and 2016 seasons.*

Location Monthes	Kaha2015 Mean Air Temperature [°C]	Kaha2016 Mean Air Temperature [°C]	Ismailia2015 Mean Air Temperature [°C]	Ismailia2016 Mean Air Temperature [°C]	Dokki2016 Mean Air Temperature [°C]
March	15.0	16.5	20.8	16.5	19.8
April	17.3	21.5	23.4	20.8	24.5
May	24.6	23.9	28.2	23.5	25.9
June	25.8	27.6	29.4	27.6	29.9

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Table ii. Pedigree of the studied tomato genotypes

No. Code	Genotypes	From	Origin
A1	F_8 4-60-7-2/11	Selected line from segregation generations of the commercial Rocky F_1 hybrid of Seed Co Import-Export – France	Egypt
A2	F_8 27-5-33-12/11	Selected line from segregation generations of the commercial Rocky F_1 hybrid of Seed Co Import-Export – France	Egypt
G2	F_8 1-2-71-16/11	Selected line from segregation generations of the commercial Dora F_1 hybrid of Amsa – Seed, U.S.A.	Egypt
G3	F_8 3-22-5-7/11	Selected line from segregation generations of the commercial Dora F_1 hybrid of Amsa – Seed, U.S.A.	Egypt
G5	F_8 3-22-7-7/11	Selected line from segregation generations of the commercial Dora F_1 hybrid of Amsa – Seed, U.S.A.	Egypt
Z3	F_8 3-3-25-26/11	Selected line from segregation generations of the commercial Peto $pride_2$ F_1hybrid of Peto seed, U.S.A	Egypt
Z5	F_8 8-1-1-7/11	Selected line from segregation generations of the commercial Peto $pride_2$ F_1hybrid of Peto seed, U.S.A	Egypt
Z42	F_8 8-4-8-26/11	Selected line from segregation generations of the commercial Peto $pride_2$ F_1hybrid of Peto seed, U.S.A	Egypt
Check	Peto-86	Peto Seed Com. USA	USA
cvs	Super strain-B	Sun seed Com. Parma, Idaho, USA	USA

Observations were recorded for plant height (cm), number of days to 50% flowering, acidity of fruits juice % (using a pH meter), average fruit weight(g), length (cm) and diameter (cm), No of locules/fruit, fruit firmness (kg/cm^2), total soluble solids % using of the refractometer; (A.O.A.C., 19٩0) and total yield (g/plant).

Data were subjected and statistically analyzed. Combined analysis of variance was performed across the five environments to detect the genotype by environment interaction effects as described by Steel et al., 1997.

Stability analysis for the characteristics studied was performed according to the model of Eberhart and Russell (1966) as follows:

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij}$$

Where: Y_{ij}: is the mean yield of the ith genotype at the j environments (i = 1, 2, 3. . v and j = 1, 2 … n),

μ: is the mean of ith genotype across all environments and

β_i : is the regression coefficient of the measured response of the ith genotype to several environments.

$$bi = \Sigma_j Y_{ij} I_j / \Sigma_j I_j^2$$

I_j: is the environmental index obtained as the mean of all genotypes at the jth environment minus the grand mean.

$$[I_j = (\Sigma_i Y_{ij} / v) - (\Sigma_i \Sigma_j Y_{ij} / vn)], \ \Sigma_j I_j = 0$$

Also, δ_{ij}: is the deviation from the regression of the ith genotype at the jth environment.

$$S^2 d_i = [\Sigma_j \delta^2_{ij} / (n-2)] - s^2 e / r$$

RESULTS AND DISCUSSION

Combined analysis of variance over all environments displayed significant to highly significant differences between genotypes, environment and genotype x environment interaction relative to all studied traits (Table 1) which indicated a wide range of variability among the genotypes performance. The G x E interaction when tested by collective error it was significant for all the factors, indicating that the majority of interaction was linear in nature and forecast over the environments was possible (Ortiz and Izquierdo, 1994; Mandal *et al*., 2000; Shalinim, 2009; Hosamani, 2010; Panthee et *al*., 2012; Al-Aysh, 2013 and Mohamed *et al*., 2013).

Table 1. Combined analysis of variance for studied traits of 10 tomato genotypes evaluated at five different environments

Source of variance	d.f.	Plant height (cm)	Number of days to 50% flowering	Acidity of fruits juice (%)	Total soluble solids (%)	Fruit firmness (kg/cm^2)
Genotypes(G)	9	758.48**	209.58**	0.1143*	2.453*	0.5279**
Environments(E)	4	8550.8**	47.183**	2.484**	12.70**	1.3075**
Replications in environments	10	0.8666	0.58	0.0008	0.2311	0.0178
G × E	36	173.05**	9.9574**	0.0471**	1.0484**	0.1159**
Error	90	0.5407	0.3281	0.0007	0.0975	0.0165

***, ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Table 1.Cont.

Source of variance	d.f.	Fruit length (cm)	Fruit diameter (cm)	No. of locules/ fruit	Fruit weight (gm)	Yield/ plant (gm)
Genotypes(G)	9	2.5042**	2.3424**	10.0333**	6276.9**	8217216.9**
Environments(E))	4	0.9159**	1.6171**	1.3833*	718.2**	486743.0**
Replications in environments	10	0.0134	0.0117	0.1	33.23	1931
G × E	36	0.2079**	0.3066**	0.4722**	181.53**	22622.91**
Error	90	0.0068	0.0085	0.1444	23.14	4175.86

***, ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Significant differences were observed for a number of days to 50% from flowering among the genotypes (Table 2). A_2 genotype had the shortest days to flowering over all environments. Combined results for days to flowering showed that both A_2 and Z_5 produced significantly early mean combined over flowering (28.5 and 30.1 days, respectively) than other genotypes and ranked first (no significant differences between them) over all sites in both years. Other high earliness genotypes were G_2, A_1 and Peto-86 which flowered after 31.8, 32.1 and 32.3 days, respectively (no significant differences between them) with 2.4, 2.1 and 1.9 days, respectively earlier than the grand mean of all environments and ranked as second earliness group. On the other hand, no significant differences were observed between the line Z_{42} and grand mean of all studied environments. All genotypes reached the 50% flowering earlier in E_4 (Ismailia 2016) except G_3, G_5 and Super strain-B. Each of Z_5, G_2 and A_1 favorable genotypes with respect to yield reached the 50% flowering by about 4, 3 and 2 days, respectively earlier than grand mean. Genotype G_3, G_5, Z_3 and the check cultivar Super strain-B remained late across all studied environments. The highest site mean earliness (32.2 days) was recorded at (E_4) Ismailia, 2016 followed by (E_3) Ismailia 2015 (34 days); (E_1) Kaha, 2015 (34.3 days); (E_5) Dokki (35.1 days) and (E_2) Kaha, 2016 which exhibited 35.3 days with no significant differences between them and grand mean (Table 2).There were negligible differences among genotypes with respect to days to flowering between environments but these differences caused Environmets x Genotypes interaction ($P < 0.05$). As a result of genetic differences among genotypes, the new lines had different day to flowering period.

Table 2. Overall days to flowering performance of tomato genotypes evaluated at five different environments.

Genotypes	Environments					Grand mean
	Kaha2015 (E_1)	Kaha2016 (E_2)	Ismailia 2015 (E_3)	Ismailia 2016 (E_4)	Dokki2016 (E_5)	
A1	31.6	32.6	33.3	30.6	32.6	32.1
A2	27.3	28.3	29.0	28.3	29.6	28.5
G2	33.3	34.3	30.6	29.3	31.6	31.8
G3	35.6	36.6	39.3	38.0	39.3	37.8
G5	36.6	37.6	35.6	35.6	35.6	36.2
Z3	36.6	36.6	40.0	32.0	39.3	36.9
Z5	31.0	31.3	28.0	29.6	30.6	30.1
Z42	38.3	39.6	32.3	30.3	39.6	36.0
Peto-86	32.3	33.6	31.3	30.6	33.6	32.3
Super strain-B	40.6	42.6	40.3	37.6	39.6	40.1
Mean	34.3	35.3	34.0	32.2	35.1	34.2
LSD at 0.05	0.85	0.67	0.71	0.82	0.71	1.92
LSD at 0.01	1.17	0.92	0.98	1.12	0.98	2.59

Results for fruit firmness (Table 2) showed that Z_5, Z_3, G_3, A_2 and G_5 produced significantly high mean combined over firmness (2.78, 2.75, 2.69, 2.68 and 2.58kg/cm^2), without any significant differences between them, than other genotypes and ranked first over all environments. Other high yielding genotypes were A_1, G_2 and Z_{42} which produced 2.55, 2.44 and 2.41kg/cm^2, respectively, and ranked as a second group (also, without any significant differences between them). Both check cultivars, *i.e*., Peto-86 and Super strain-B remained poor in performances across all studied environments. The highest site mean value (2.79 kg/cm^2) was recorded at (E_4) Ismailia, 2016 followed by (E_3) Ismailia, 2015; (E_5) Dokki; (E_2) Kaha, 2016; and in descending order; while the lowest site mean yield was recorded with (E_1) Kaha, 2015 without any significant differences with E_2 (Table 2a).

Regarding to yield, the combined results (Table 2b) showed that Z_5 produced significantly high mean combined over yield (3167.8 g/plant) than other genotypes and ranked first over all sites in the both years. Other high yielding genotypes were G_2, G_3 and A_1 which produced 2670.9, 2371.1 and 2057.3 g/plant, respectively yield and ranked as the second, third and fourth. No significant differences were observed between Z_3 (1859.2 g/plant) and grand mean (1823.69 g/plant) over all sites. Genotype G_5 and Z_{42} in addition to both check cvs, i.e., Peto-86 and Super strain-B remained poor in performances across all studied environments. The highest site mean yield (1976 g/plant) was recorded at (E_1) Kaha, 2015 followed by (E_4) Ismailia, 2016 (1926.3 g/plant); (E_3) Ismailia, 2015 (1812.1 g/plant) and (E_2) Kaha, 2016 (1728.6 g/plant) in descending order; while the lowest site mean yield (1675.3 g/plant) was recorded with (E_5)Dokki (Table 2b).

Table 2a. Over all firmness (kg/cm^2) performance of tomato genotypes evaluated at five different environments.

Genotypes	Environments					Grand mean
	Kaha 2015 (E_1)	Kaha 2016 (E_2)	Ismailia 2015 (E_3)	Ismailia 2016 (E_4)	Dokki 2016 (E_5)	
A1	2.32	2.43	2.92	2.83	2.25	2.55
A2	2.79	2.78	2.75	2.75	2.33	2.68
G2	2.31	2.43	2.5	2.58	2.42	2.44
G3	2.36	2.27	3.00	3.00	2.83	2.69
G5	2.42	2.50	2.65	2.67	2.67	2.58
Z3	2.63	2.80	3.00	3.00	2.33	2.75
Z5	2.68	2.32	3.17	3.17	2.58	2.78
Z42	1.92	2.00	2.67	2.83	2.67	2.41
Peto-86	1.92	2.13	2.25	2.58	2.33	2.24
Super strain-B	2.08	2.16	2.45	2.58	2.25	2.30
Mean	2.34	2.38	2.73	2.79	2.46	2.545
LSD at 0.05	0.20	0.08	0.19	0.17	0.16	0.22
LSD at 0.01	0.28	0.12	0.26	0.24	0.22	0.30

Highly significant of the environments linear response was observed for all studied traits (Table 3). Consequently, the regression coefficient (b_i) and deviation from regression (S^2d_i) pooled over the five environments were calculated for each genotype and presented in Table 4. On the other hand, the variation in both linear trend and non linear trend relative to most traits were significant, where it was corroborated by Kulkarni *et al*., (2000). Eberhart and Russell (1966) confirmed that a need for considering both the linear and non-linear trend in order to evaluate yield and other parameters of stability of genotypes as well as both the linear regression coefficient and deviation from the regression for phenotypic stability.

Table 2b. Overall total yield (g/plant) performance of tomato genotypes evaluated at five different environments.

Genotypes	Kaha 2015 (E_1)	Kaha 2016 (E_2)	Ismailia 2015 (E_3)	Ismailia 2016 (E_4)	Dokki 2016 (E_5)	Grand mean
	Environments					
A1	2166.6	1966.6	2130.0	2163.3	1860.0	2057.3
A2	1800.0	1566.6	1631.6	1700.3	1510.0	1641.7
G2	2900.0	2640.0	2594.3	2663.6	2556.6	2670.9
G3	2570.0	2275.0	2326.6	2470.6	2213.3	2371.1
G5	1150.0	940.0	1043.3	1126.6	910.0	1034.0
Z3	1973.3	1780.0	1873.3	1969.6	1700.0	1859.2
Z5	3600.0	2968.3	3074.0	3380.0	2816.6	3167.8
Z42	1183.3	986.6	985.0	1136.0	1023.3	1062.8
Peto-86	1150.0	1036.6	1226.6	1339.3	1050.0	1160.5
Super strain-B	1266.6	1126.6	1236.6	1313.3	1113.3	1211.3
Mean	1976.0	1728.6	1812.1	1926.3	1675.3	1823.69
LSD at 0.05	50.54	29.02	62.9	166.4	23.77	75.36
LSD at 0.01	69.24	39.75	86.18	230.7	46.26	101.49

The mean squares due to E + (G x E) interaction was highly significant so, genotypes interacted considerably with the five environmental conditions. A major portion of these interactions may be attributed to E (linear) component. Significance of Pooled deviation mean squares for plant height, days to flowering, acidity of fruits juice, total soluble solids, each of firmness, length and diameter of fruits as well as both fruit weight and yield revealing deviation mean squares for individual genotypes (Table 3). Such genotypes i.e., A_1, A_2, G_3, G_5, Z_3, Z_5, Z_{42} and Super strain-B for both length and weight of fruit; A_1, G_2 and Peto-86 for yield seemed to be not consistent in its performance over all environments.

Table 3. Stability analysis of variance for all studied traits of 10 tomato genotypes evaluated under five different environmental conditions.

Source of variance	d.f.	Plant height (cm)	Number of days to 50% from flowering	Acidity of fruits juice (%)	Total soluble solids (%)	Fruit firmness (kg/ cm^2)
G	9	252.82	69.86**	0.038**	0.484	0.17٦**
E + (G x E)	40	336.94**	4.56**	0.09٧**	0.738**	0.078**
E (linear)	1	11401.1**	62.91**	3.312**	16.94**	1.743**
G x E (linear)	9	115.76**	5.8365*	0.007	0.159	0.05٣
Pooled deviation	30	34.493**	2.23٢**	0.01٧**	0.37٢**	0.031**
A1	3	6.896	0.722	0.02٤	0.564	0.02٢
A2	3	52.341	0.954	0.00٥	0.659	0.050
G2	3	33.313	1.863	0.007	0.213	0.00٣
G3	3	36.465	3.488	0.03١	0.149	0.03٦
G5	3	86.154	0.761	0.02٣	0.14٨	0.007
Z3	3	8.385	6.647	0.01٨	0.386	0.056
Z5	3	48.148	1.794	0.03٩	0.11٣	0.03٦
Z42	3	20.685	4.336	0.001	1.01٧	0.06٦
Peto-86	3	42.981	0.297	0.00٣	0.10٧	0.029
Super strain-B	3	9.560	1.45٧	0.01٧	0.358	0.001
pooled error	100	0.1911	0.1178	0.0002	0.03٧	0.006

***, ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

The data on the three stability parameters including mean performance (x_i), regression coefficient (b_i) and deviation from the regression (S^2d_i) have been shown in the Table 4 relative to various factors. The regression coefficient (b_i) for fruit weight and number of locules/ fruit was significant in the genotype A_2 and G_3 whereas genotype Z_{42} showed approximately a unit regression. Also, tomato genotype Z_{42} exhibited significant deviation from regression (S^2d_i) for fruit weight. However, it showed no significant deviation from regression for some studied traits, *i.e.*, total soluble solids, fruit firmness, number of locules/fruit and yield. Therefore, it is difficult to generalize stability for all genotypes relative to all observations because the genotypes used in this study did not exhibit a uniform stability and response pattern for different observations. Eberhart and Russell (1966) indicated that if the observations were associated with high performance of yield so properly the selection of genotype only for yield will be effective. Based on observed results genotype G_3 and Z_3 exhibited high stability of yield , both total soluble solids and fruit firmness where the regression coefficient (b_i) was near unity with low deviation from the regression (non-significant, S^2d).

Table 3.Cont.

Source of variance	d.f.	Fruit length (cm)	Fruit diameter (cm)	No. of locules/ fruit	Fruit weight (g)	Yield/ (g) plant
G	9	0.835**	0.781**	3.344**	2092.32**	2739072.3**
E + (G x E)	40	0.093**	0.146**	0.188**	78.400**	23011.6**
E-(linear)	1	1.221**	2.156**	1.844**	957.64**	648990.7**
G x E(linear)	9	0.197**	0.142	0.499**	159.75**	18813.5**
Pooled deviation	30	0.024**	0.080**	0.039	24.68**	3405.1**
A1	3	0.024	0.062	0.026	47.63	3787.5
A2	3	0.024	0.040	0.006	3.27٥	555.3
G2	3	0.005	0.352	0.10٣	5.7٢	8644.7
G3	3	0.016	0.056	0.02٦	8.07	732.3
G5	3	0.012	0.037	0.026	37.32	249.١
Z3	3	0.018	0.033	0.01٩	0.97	709.6
Z5	3	0.076	0.009	0.073	72.06	3525.6
Z24	3	0.016	0.182	0.05٤	50.94	2939.١
Peto-86	3	0.024	0.018	0.039	6.4١	11327.٢
Super strain-B	3	0.025	0.010	0.01٩	14.49	1580.7
pooled error	100	0.0023	0.0029	0.047	8.051	1317.1٣

**** highly significant at 0.01 level of probability.**

Therefore, both genotypes G_3 and Z_3 were superior to other and strongly recommended for planting at multi location trials at the studied regions. Based on Eberhart and Russell, 1966, (method of analysis of stability), generally, when the yield of cultivars is more than total average, the regression coefficient equal to one and there is minimum deviation from the regression line that means there is stability in the cultivar. However, the genotype G_3 followed by Z_3 presented a high performance in yield production (2371.1 and 1859.2 g/plant, respectively), low deviation from the regression line (non-significant S^2d_i) and the regression coefficient (b_i) nearby 1, so that both promising lines were superior among genotypes in terms of yield stability and recommendable for all environments.

From Table 4 the genotypes can be divided in to four categories as follows:

i) Genotypes with high mean, b_i=1 and no significant difference in S^2d_i are suitable for general adaptation, so that they can be recommendable for all environmental conditions and they are considered as stable genotypes where both genotypes G_3 and Z_3 were included.

ii) Genotypes with high mean, b_i>1 with no significant difference in S^2d_i are considered as genotype with average stability where genotype Z_5 was included and it can be recommended for favorable environments.

iii) Genotypes with low mean, b_i< 1 with no significant difference in S^2d_i are considered as genotype with low stability where genotypes A_2, Super strain-B, Z_{24} and G_5 in descending order, were included.

iv) Genotypes with a few b_i values with significant difference in S^2d_i are considered as genotype with poor stability. Based on results in some genotypes, the yield production was high as in genotypes Z_5 and G_2, but there was a high variance by various environments which is why those genotypes have average stability. The genotypes with high yield and average yield stability are recommendable for favorable environments. Based on results genotypes G_3, Z_3 and Z_5 produced high value of yield but the stability of them was varied. The tomato genotypes G_3 and Z_3 not only exhibited a high fruits yield over the population mean, but also the regression coefficient (b_i) and deviation from regression (S^2d_i) was minimum so that both genotypes G_3 and Z_3 were stable than other genotypes. The genotype Z_5 indicated moderate stability. Thus, it is concluded that the tomato genotypesG_3 and Z_3 are ideally adaptable and stable and could be recommended for multi location of Egypt.

Accordingly, again, it is evident that stability analysis showed a wide variation among genotypes; some genotypes exhibited wide adaptation, while other showed specific adaptation either to favorable or unfavorable environments. In Table 4, the high yielding genotype G_3 produced the highest mean yield (2371.1 g/plant) over all environments and had a regression coefficient (b_i) close to unity (1.133) and deviation from regression (S^2d) not significantly from zero followed by Z_3, A_2, Super strain-B, Z_{42} and G_5. Generally, genotypes which show low G×E interaction variance, high mean yield potential over environments and below deviation from the expected response within a target environment are Preferred genotypes (Lin and Binns 1988). This indicated its high yielding performance based on wide adaptation and stability of performance over all environments.

Table 4. Estimates of stability for some studied traits of 10 tomato genotypes grown under different environments.

Genotypes	Plant height (cm)			Number of days to 50% from flowering			Acidity of fruits juice (%)		
	x	b_i	S^2d_i	X	b_i	S^2d_i	X	b_i	S^2d_i
A1	70.7	0.685	4.9**	32.2	0.590	0.432**	3.63	0.843	0.017**
A2	56.0	0.504**	39.1**	28.5	0.159	0.606**	3.52	1.155	0.003**
G2	69.7	1.343	24.8**	31.8	1.295	1.288**	3.44	0.959	0.005**
G3	71.3	1.531**	27.2**	37.8	0.134	2.506**	3.47	0.987	0.022**
G5	61.5	0.822	64.4**	36.2	0.381	0.461**	3.64	0.961	0.016**
Z3	64.1	1.193	6.1**	36.9	1.770	4.876**	3.52	1.203	0.013**
Z5	75.7	0.871	35.9**	30.1	0.544	1.236**	3.64	1.170	0.028**
Z42	76.3	1.024	15.3**	36.1	3.21**	3.142**	3.56	0.966	0.001**
Peto-86	60.8	0.808	32.1**	32.3	1.012	0.113	3.50	1.034	0.001**
Super strain-B	59.3	1.215	6.9**	40.2	1.173	0.983**	3.70	0.718	0.012**
Significantly test	$LSD_{0.05}$= 7.584	Seb= 0.173	t at 0.05 = 2.04 t at 0.01 = 2.75	$LSD_{0.05}$= 1.929	Seb=0.595	t at 0.05 = 2.04 t at 0.01 = 2.75	$LSD_{0.05}$= 0.166	Seb= 0.223	t at 0.05 = 2.04 t at 0.01 = 2.75

**** highly significant 0.01 level of probability.**

Although four genotypes (Z_5, G_2, G_3 and A_1) had a superior yield performance on average, the yield performance of Z_5 and G_2 genotypes showed great variation between environments (Table 2b). Yield performance of plants is controlled by the genetic capacity of a plant, environment and their interaction,… etc. (Fehr, 1993). High and stable yield performances are the main objectives in plant breeding programs. To be widely accepted, a genotype must show good performance across a range of environments (Zayed *et al.*, 2005). Genotypes respond to changes in environmental conditions such as temperature, soil type, moisture, ,… etc. (Fehr, 1993). G_3 and Z_3 genotypes must be more stable against environmental condition than those of Z_5, G_2 and A_1 genotypes; hence G_3 and Z_3 genotypes can be considered for further investigation with respect to production for new variety development.

Table 4. Cont.

Genotypes	Total soluble solids (%)			Fruit firmness (kg/cm²)			Fruit length (cm)			Fruit diameter (cm)		
	x	b_i	S^2d_i	x	b_i	S^2d_i	x	b_i	S^2d_i	x	b_i	S^2d_i
A1	5.038	0.696	-0.619	2.55	1.327	-0.85	5.604	1.394	0.015**	5.253	0.334	0.044**
A2	5.333	0.645	-0.548	2.68	0.107**	-0.82	4.987	0.945	0.015**	5.42	0.334*	0.027**
G2	4.393	0.687	-0.883	2.44	0.446	-0.86	5.27	1.638	0.001	5.953	1.899	0.260**
G3	4.886	0.787	-0.930	2.69	1.502	-0.83	5.257	0.066	0.009**	5.533	0.713	0.039**
G5	5.026	0.915	-0.932	2.58	0.427	-0.86	5.22	0.005	0.006**	5.493	0.237	0.024**
Z3	4.464	1.315	-0.753	2.75	0.910	-0.82	5.93	0.058	0.011**	5.293	0.510	0.022**
Z5	4.808	1.338	-0.958	2.78	1.613	-0.83	5.947	2.460	0.054**	5.687	1.397	0.004*
Z42	5.226	1.509	-0.280	2.41	1.736	-0.81	4.96	0.451	0.010**	5.26	1.073	0.134**
Peto-86	4.893	1.043	-0.962	2.24	0.945	-0.84	4.973	1.772	0.015**	4.5	1.624	0.011**
Super strain-B	4.584	1.059	-0.774	2.31	0.983	-0.86	5.913	3.098	0.016**	4.993	2.351	0.004*
Significantly test	$LSD_{0.05}$= 0.787	Seb= 0.468	$t,_{0.05}$=2.04	$LSD_{0.05}$ = 0.225	Seb= 0.418	$t,_{0.05}$=2.04	$LSD_{0.05}$= 0.200	Seb= 0.444	$t,_{0.05}$=2.04 $t,_{0.01}$=2.75	$LSD_{0.05}$= 0.365	Seb= 0.609	$t,_{0.05}$=2.04 $t,_{0.01}$=2.75

	$t,_{0.01}$=2.7 5	$t,_{0.01}$=2.7 5	

***, ** significant and highly significant at 0.05 and 0.01 levels of probability, respectively.**

Again, genotypes with "b_i" value less than 1.0 and higher S^2d_i than zero are said to be specifically adapted to poor or unfavorable environments, while, genotypes having high "b_i" value are specifically adapted to favorable or high yielding environments (Finlay and Wilkinson, 1963 and Eberhart and Russell, 1966). A_2 produced higher yield than check *cvs.* Super strain-B over a range of environments showed below regression coefficient (b_i<1) and non-significant deviation from the regression (S^2d_i), indicated specific adaptability of this genotype to harsh (unfavorable) environments. It is evident that this genotype could be used as stress tolerant genotypes under stressed environments (poor yielding or unfavorable environments). Each of the genotypes A_1 (for fruit firmness, fruit length and fruit weight); A_2 (for Acidity, No. locules/fruit, and fruit weight); both G_2 and Super strain-B (for plant height, days to flowering, fruit length, diameter, and weight), G_3 (for plant height, fruit firmness, No. loculess/fruit, and fruit weight); Z_3 (for plant height, days to flowering, Acidity and total soluble solid), Z_5 (for Acidity, total soluble solid, firmness, fruit length, diameter and fruit yield); Z_{42} (for days to flowering, total soluble solid, and fruit firmness) and Peto-86 (for both length and diameter of fruit) with above average regression coefficient (b_i>1), it indicated that these genotypes could produce the higher Values of the parenthetically traits at favorable environments with fertile soil, adequate water and other inputs.

On the other hand, regression coefficient was less than 1 (b_i<1) for 10 genotypes at least two to eight studied traits, such as A_1 for plant height, days to flowering, Acidity, total soluble solid, fruit diameter, and No. locules/fruit and also;A_2 for plant height, days to flowering, total soluble solid, firmness, fruit diameter and fruit yield; G_2 for total soluble solid, firmness, No. locules/fruit and fruit yield; G_3 for days to flowering, total soluble solid, fruit length and fruit diameter; G_5 for plant height, days to flowering, fruit firmness, fruit length and diameter, No. locules/fruit, fruit weight and fruit yield; Z_3 for fruit length, fruit diameter, No. locules/fruit and fruit weight; Z_5 for plant height, days to flowering, No. locules/fruit and fruit weight; Z_{42} for both fruit length and fruit yield; Peto-86 for plant height, fruit weight and fruit yield and Super strain-B for Acidity, No. locules/fruit and fruit yield.

Table 4. Cont.

Genotypes	No. of locules/fruit			Fruit weight (gm)			Yield /plant (gm)		
	x	**b_i**	**S^2d_i**	**X**	**b_i**	**S^2d_i**	**X**	**b_i**	**S^2d_i**
A1	3.9	0.240	-1.97	64.213	1.814	39.9**	2057.3	0.995	2395.5**
A2	4.4	2.530**	-1.99	67.933	2.913**	-4.4	1641.7	0.876	-836.65
G2	4.4	0.120	-1.92	103.4	1.236	-1.9	2670.9	0.846	7252.7**
G3	3.8	5.060**	-1.97	92.333	2.821**	0.3	2371.1	1.133	-659.72
G5	3.9	0.240	-1.97	110.33	0.549	29.6**	1034	0.838	-1142.88
Z3	3.0	0.421	-1.98	94.622	0.196**	-6.7	1859.2	0.919	-682.32
Z5	4.3	0.120	-1.94	130.757	0.382	64.3**	3167.8	2.461**	2133.66
Z42	4.2	0.903	-1.95	92.533	1.118	43.2**	1062.8	0.614	1547.13
Peto-86	2.2	1.024	-1.96	71.356	0.627	-1.3	1160.5	0.680	9935.20**
Super strain-B	5.2	0.421**	-1.98	95.78	1.267**	6.7	1211.3	0.634	188.78
Significantly test	$LSD_{0.05}$= 0.255	Seb= 0.460	t at 0.05 = 2.04 t at 0.01 = 2.75	$LSD_{0.05}$= 6.417	Seb= 0.508	t at 0.05 = 2.04 t at 0.01 = 2.75	$LSD_{0.05}$= 75.36	Seb= 0.229	t at 0.05 = 2.04 t at 0.01 = 2.75

**** highly significant 0.01 level of probability.**

These genotypes appeared to be more productive under unfavorable environments. Zayed et al. (2005) reported some genotypes to consider as standard cultivars for cultivation under less favorable conditions. The different genotypes used in this study did not exhibit uniform stability and responsiveness appeared to be specific for specific characters within a single genotype. On the other hand, the value of "bi" approached nearly unity in some genotypes for some traits, indicating an average response to the fluctuating environmental conditions prevailed the different locations across years.

CONCLUSION

The results of this study indicated that the genotypes G3 and Z3 genotypes most stable genotypes, gave the maximum total yield per plant overall the five studied environments and were adapted to environments for most traits. Also, the genotypes G5 and Z42 considered promising lines for their performances and found to be suited to low yielding environments and could be used as stress tolerant genotypes under stressed environments (poor yielding or unfavorable environments). Generally, in conclusion, based on yield and yield its component values in this experiment conducted for two years less than five environments ecological condition, most of the new lines can be considered promising genotypes for cultivar development. Although G5 and Z42new lines had statistically similar earliness and yield performance on average of the environments, they showed great variation across the locations and years. Hence, these two lines need further breeding studies to increase stability. Therefore G3 and Z3 genotypes should be used in location trials in order to develop a new variety for seed production.

REFERENCES

Agyeman K., I. M. Osei, J. N. Berchie, M. K. Osei, M. B. Mochiah, J. N. Lamptey, O. Kingsley and G. A. Bolfrey (2014). Effect of poultry manure and different combinations of inorganic fertilizers on growth and yield of four tomato varieties in Ghana. Agric. Sci. 2(4):27-34.

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. of Agric. and Envir.Management. 2(11): 371-377(online at http://www. apexjournal. org)

Allard, R.W., and A.D. Bradshaw.(1964).Implications of genotype-environmental interactions in applied plant breeding. Crop Science 4: 503–508.

A.O.A.C. (1990). Official Method of Analysis. 15th Ed., Association of Official Analytical Chemists, Inc., USA.

Bhnan, E. Y. (2008). Development of some new tomato lines for fresh market by selection. Egypt. J. of Appl. Sci. 23 (4A) 168-178.

Eberhart, S. A., and W. A. Russell. (1966). Stability parameters for comparing crop varieties. *Crop Science*, 6: 36–40.

Fehr, W.R., (1993). Principles of Cultivar Development. I. Theory and Technique. Macmillan Comp Inc, Ames, Iowa, USA, 536 P.

Finlay, K.W., and G.N. Wilkinson. (1963). The analysis of adaptation in aplant-breeding programme. Aust. J. Agric. Res. 14: 742-754.

Hosamani, R.M. (2010).Biometrical and transformation studies in tomato (Solanum lycopersicumL.). Ph.D. Thesis. Department of Horticulture, College of Agriculture, University of Agricultural Sciences, Dharwad, India.

Kulkarni N., D. G. Nirmala, and G. Sarojini.(2000). G x Einteraction for quality traits in mutants of SambaMahsuri. Oryza, 37(1): 72-74.

Lin, C.S., and M.R. Binns. (1988). a method of analyzing cultivar x location x year experiments: a new stability parameter. Theor. Appl. Genet., 76: 425-430.

Mandal, A.R., B.K. Senapati., and T.K. Maity (2000).Genotype-environment interaction, stability and adaptability of tomato (*Lycopersicon esculentum*Mill.). Vegetable Sci., 27(2): 155-157.

Mohamed A.G., A. M. Ahmed., and R.M. Galal. (2013). Genotypic and Phenotypic Stability for New Lines of Tomato (Solanum Lycopersicum L) Assiut Journal of Agricultural Sciences. V.44, No.2 (June 2013) p. 105-123

Ortiz1,R., and J. Izquierdo . (1994). Yield Stability Differences among Tomato Genotypes Grown in Latin America and the Caribbean. Hortscience 29(10):1175–1177.

Panthee, D.R., C. Cao, S. J. Debenport, G.R. Rodriguez, J.A. Labate, L.D. Robertson, A.P., Breksa, E.V.D. Knaap., and B.B.M. Gardner. (2012). Magnitude of genotype xenvironment interactions affecting tomato fruit quality. Hort. Sci., 47(6): 721-726.

Shalini, M. (2009).Studies on heterosis and combining ability in tomato (Solanum lycopersicumL.). Ph.D. Thesis. Department of Horticulture, College of Agriculture, University of Agricultural Sciences, Dharwad, India.

Steel, R. G. D., J. H. Torrie., and D. Dickey. (1997). Principles and Procedures of Statistics: A Biometrical Approach, Third Edition, New York: McGraw-Hill, Inc.

Zakher, A.G. (2005). Comparative studies on advanced segregated generations of some tomato hybrids. Ph.D. Thesis, Fac. Agric., Ain Shams University, Egypt.

Zakher, A.G. (2010). Developing fresh market tomato lines by selection Egypt. J.Plant Breed.14(1): 321-332.

Zayed, G. A., Fawzeya. A. Helal., and S.T. Farag.(2005). The genetic performance of some continuously variable characteristics of pea under different locations.Annals Agric. Sci., Moshtohor, 43(1).

الثبات والاقلمة لبعض السلالات الجديدة من الطماطم تحت ظروف بيئية مختلفة

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أجريت هذه الدراسة تحت خمس بيئات مناخية مختلفة تشمل محافظات (الجيزة والقليوبية والاسماعيلية) خلال المواسم الصيفية المبكرة ٢٠١٥ و٢٠١٦ فى تصميم قطاعات كاملة العشوائية فى ثلاث مكررات لتقدير معايير الثبات الوراثى والمظهرى لبعض السلالات المبشرة من الطماطم مع بعض الأصناف المنتشرة فى الزراعة المصرية تحت هذه البيئات المناخية المختلفة . أظهرت النتائج وجود إختلافات عالية المعنوية بين التراكيب الوراثية وبين البيئات وكذلك التفاعل بينهما لجميع الصفات تحت الدراسة. أظهر تحليل التباين المشترك للصفات التي تم دراستها وجود إختلافات عالية المعنوية بين التراكيب الوراثية والبيئات لكل الصفات المدروسة وهذا يشير إلى أن أداء التركيب الوراثى يختلف إختلافاً كبيراً عبر البيئات المختلفة ، وعلاوة على ذلك فإن التفاعل بين التراكيب الوراثية والبيئات (دالة خطية) كان معنوياً أو عالى المعنوية لجميع الصفات المدروسة .* من دراسة التباين المشترك لصفات الازهار والمحصول وكذلك صفة صلابة الثمار على مستوى كل البيئات تحت الدراسة تبين ان السلالة Z_5 تفوقت فى هذه الصفات حيث اعطت اعلى محصول من ثمار الطماطم مع اعلى قيم لصفة صلابه الثماربالاضافة الى التبكير فى الازهار وهى من السلالات متوسطة الثبات الوراثى ويمكن التوصية بزراعتها تحت الظروف الملائمة للمحصول* أظهرت قيم الثبات (S^2d_i و b_i) بالنسبة لصفة محصول الثمار أن التراكيب الوراثية تختلف فى قيمتها من حيث b_i كذلك تختلف فى قيمتها من حيث S^2_d ويمكن ملاحظة أن معامل الإنحدار b_i للسلالات G3وZ3 كان غير معنوياً عن الواحد كما كانت قيمة الإنحراف عن الإنحدار S^2_dغير معنوية عن الصفر وهذا يشير إلى أن هذه التراكيب تعتبر ثابتة للزراعة فى مدى واسع من الظروف المناخية بالنسبة لصفة المحصول وقد أعطت هذه السلالات محصول أعلى عن بقية السلالات مما يجعلها سلالات مبشرة. فى حين السلالة G_5 يمكن ان تؤدى سلوكا عاليا فى صفات التبكير والصلابة وطول وقطر الثمرة وعدد حجرات الثمرة ووزن الثمرة وكذلك مصول الثمار تحت ظروف غير المناسبة ولذا يمكن زراعتها تحت ظروف غير المناسبة اى تحت اى اجهاد بيئى محدد (باجراء مزيد من التجارب الفسيولوجية).* أظهرت قيم الثبات (S^2d_i و b_i) ان كلا من A_2 ، Super strain B ، Z_{42} ، G_5 تعتبر تراكيب ضعيفة الثبات فى حين السلالة G_5 يمكن ان تؤدى سلوكا عاليا فى صفات التبكير والصلابة وطول وقطر الثمرة وعدد حجرات الثمرة ووزن الثمرة وكذلك مصول الثمار تحت ظروف غير المناسبة ولذا يمكن زراعتها تحت ظروف غير المناسبة اى تحت اى اجهاد بيئى محدد (باجراء مزيد من التجارب الفسيولوجية).