PRODUCTIVITY OF TOMATO PROMISING HYBRIDS UNDER GREENHOUSE CONDITIONS

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Evaluation of tomato promising hybrids under greenhouse conditions comes in the first order for Plant Breeding and Conservation Program of Desert Research Center (DRC). Evaluation was carried out for eighteen hybrids of tomato at North Sinai and Ismailia locations during 2021/2022 season. Using Line × Tester analysis is a good tool for preliminary evaluation of the breeding program. The experimental design was randomized complete block design with three replicates. The results indicated that tomato hybrids mean squares in the combined data were highly significant for all traits. The interaction between locations and tomato hybrids mean squares were highly significant for all the studied traits, except plant height and number of locules per fruit. Based on the results obtained in the two locations, the most productive and adapted tomato hybrids were identified to greenhouse conditions. S812× STel (12) and S922× SR74 (13) hybrids were performed well at both locations. Yield per plant had positive correlation with all characters, except fruit firmness and TSS percentage that had a negative correlation with yield.

Keywords: tomato hybrids indeterminate, *Solanum lycopersicum*, greenhouse

INTRODUCTION

Tomato (*Solanum lycopersicum)* belongs to the family Solanaceae. It is originated from Peru-Ecuador Bolivia region of the Andes in South America. It is recognized as an important commercial and dietary vegetable crop and occupies a prominent position among vegetables, due to its export value (Singh et al., 2014). Egypt is the fifth largest producer of tomato in the world and

tomato is a very important crop in Egypt in terms of consumption and income for smallholder farmers. Tomato is very important for daily consumption, used as fresh in salad or processed in cooking also used in industries to produce ketchup, jam and salsa. In 2015, the area cultivated with tomato was estimated as 469 000 feddans, representing 32% of the total area cultivated with vegetables in Egypt (FAO, 2021)**.**

One of the most important factors in the intensification of greenhouse tomato production is the introduction of new high-yielding varieties and hybrids, which are high resistance against diseases and pests, and adapted to new technologies and unfavorable climatic conditions (Balashov, 2006 and Gavrish, 2015). The development of high yield varieties requires detail knowledge of the genetic variability present in the germplasm of the crop, the association among yield components, input requirements and culture practices (Dutta et al., 2013). Development of hybrid tomato varieties having desirable characters have proven to be an effective strategy to increase tomato production (Islam et al., 2012). The development of new tomato cultivars has intended to improve productivity, quality and adaptation for different production conditions. Sometimes, this is difficult to achieve due to reduced availability of genetic resources (Warnock, 1991).

Kumar et al. (2015) evaluated tomato lines for quantitative traits such as plant height, fruit yield, fruit weight, total soluble solids (TSS), fruit weight loss and fruit shelf-life in greenhouse as well as plants which were grown in field conditions. They found that in greenhouse conditions, the plant height was between 93.3 to 165 cm, the total fruit yield per plant was between 615 to 1730 g., fruit weight was between 34.4 to 82.0 g and number of locules per fruit was between 2.0 to 5.0. Singh et al. (2019) evaluated nine tomato hybrids under polyhouse condition in two seasons. They found that the analysis of variance revealed significant variation among the hybrids for all the characters. They revealed that hybrid Dev was performed extremely well under polyhouse condition with respect to growth and yield parameters viz., the height of plant at 90 days ranged from 161.0 to 246.9 cm. Stem diameter at 90 days was 0.75 cm and at final harvest reached 1.21 cm, percentage of fruit set was 82.45% and yield per plant was 5.50 kg. Bayomi et al. (2020) evaluated twelve tomato genotypes indeterminate in two seasons. They found that S922, S923 and S24 were the best genotypes for plant height, stem diameter and yield /plant. The genotypes S802, S811 and S812 recorded the highest mean for fruit set percentage. S700, S710, S720 and S740 genotypes had high TSS percentage. TSS percentage showed negative correlation with all characters.

Under protected environment, the natural environment is modified to the suitable conditions for optimum plant growth, which ultimately helps in the

production of tomato with suitable quality for exports and domestic consumption. It has been observed that net house grown tomatoes have potential for better performance and produce higher fruit yield than that grown in open field conditions. Tomato can be grown successfully in the off-season in net house for obtaining higher fruit yield. Occurrence of frost coupled with low temperature during the months of December and January cause death of tomato plants when grown in open field conditions, but under protected environment, the yield loss can be minimized (Cheema et al., 2013). In Egypt, for economic production of tomato under greenhouse conditions, all greenhouses' inputs must be provided locally including good hybrid seeds, especially, after project work began with one million and a half greenhouses.

In any sound breeding program, the proper choice of parents based on their combining ability is a prerequisite. Line × Tester analysis is a useful tool for preliminary evaluation of genetic stock for use in hybridization program with a view to identify good combiners. The present investigation was thus undertaken to have an idea of heterosis for fruit yield and fruit quality attributes of eighteen hybrids of tomato indeterminate under greenhouse conditions.

MATERIALS AND METHODS

The trial was set up during 2021/2022 season. Evaluation of eighteen tomato hybrids were done at two locations. The first was at Baloza research station, Desert Research Center (DRC), North Sinai Governorate and the second was at Qantara Research Station, DRC, Ismailia Governorate. Using Line × Tester analysis which is a good tool for preliminary evaluation of the breeding program. The materials used in this study consisted of six tomato indeterminate lines (S710, S740, S811, S812, S922, and S923) and three tomato indeterminate testers (SR74, SAL4 and STel) that were obtained from Plant Breeding and Conservation Program of DRC.

Each experimental plot was 33.75 m^2 (22.5 m long and 1.5 m wide). A randomized complete block design with three replicates was used. Each replicate contained 18 experimental units. Thirty days old seedlings were transplanted in a greenhouse on 10^{th} October in the two locations and the distance between plants was 50 cm in the row. Drip irrigation system was used; fertigation was carried out according to the recommendations of research stations. Routine cultural practices were done as needed similar to those used in tomato production at research stations. The data recorded for five plants from each experimental unit were plant height (cm) and stem diameter (cm) after 100 days from transplanting. While the data had recorded on ten fruits during harvest to calculate average fruit weight (g), fruit firmness (fruit firmness was measured on

the two opposite sides of the fruit using Effige penetrometer, 2 mm probe and data were recorded in LbF.), total soluble solids percentage (TSS% determined by using Hand Refractometer and expressed as percentage of the juice), also number of locules/fruit. Yield per plant (g) was recorded for five plants from each experimental unit.

Statistical Analysis

Statistical analysis was performed using analysis of variance technique by means of "MSTAT" computer software package. The treatment means were compared using least significant difference test at 5% level of significance.

RESULTS AND DISCUSSION

Analysis of variance for all traits in each location as well as the combined analysis is presented in Table (1). Test of homogeneity revealed that the error variance for the two locations were homogenous, therefore combined analysis was processed. Tomato hybrids mean squares were highly significant for all traits at both locations as well as the combined data, except number of locules per fruit and plant height in the first and second locations, respectively. Locations mean squares were highly significant for all the studied traits, except the number of locales. The interaction between locations and tomato hybrids mean squares were highly significant for all the studied traits, except plant height and number of locules/ fruit. This interaction between environmental and tomato hybrids is expected to have a significant impact on future breeding programs. These results are in line with those obtained by Alam et al. (2010), Singh et al. (2014), Kumar et al. (2015), Singh et al. (2019) and Bayomi et al. (2020).

1. Plant Height (cm)

The results presented in Table (2) clearly indicate that, significant differences were recorded among the different tomato hybrids in plant height trait at the first location. In the first location (Baloza), average plant height was 204.82 cm, while, in the second location (Qantara) it was 220.30 cm. S740× SAL4(5) and S812× SR74(10) hybrids gave the highest values of plant height (238.17 and 238.27 cm) in the first season, respectively, while S710× SR74(1) hybrid gave the lowest value (143.43 cm). Plant height is to some extent a good index of plant vigor, which may contribute towards greater productivity. Variation in plant height was also reported by Alam et al. (2010), who found that the plant height was between 115.9 and 139.5 cm. Singh et al. (2019) found that the height of plant after 90 days ranged from 161.0 cm to 246.9 cm.

Table (1). Mean squares from the combined ANOVA for tomato plant height, stem diameter, fruit weight, fruit firmness, no. of locules per fruit, TSS% and yield per plant in both locations and combined across locations.

SOV	df	Plant height (cm)	Stem diameter (cm)	Average fruit weight (g)	Fruit firmnes (s)	TSS (%)	No. of locules/ fruit	Yield/ plant (kg)
				First Location (Baloza)				
Rep.	2	65.27	0.008	116.250	0.560	0.308	0.258	0.318
Hybrids	17	2169.18**	0.023**	898.590**	5.945**	0.576ns	0.579**	3.812**
Error	34	77.23	0.006	42.730	0.153	0.252	0.184	0.219
				Second Location (Qantara)				
Rep.	2	358.91	0.004	24.65	0.016	0.037	0.097	0.045
Hybrids	17	1521.77 ns	0.081**	832.35**	3.830**	0.755**	0.486**	1.136**
Error	34	852.21	0.005	37.14	0.104	0.104	0.122	0.093
				Combined				
Location	1	6471.25**	0.724**	21508.16**	111.22**	8.670**	0.0004 ns	32.626**
Error (a)	4	212.09	0.0059	70.45	0.288	0.172	0.178	0.181
Hybrids	17	3072.22**	0.066**	1238.18**	9.006**	0.537**	1.028**	3.777**
Location × Genotype	17	618.73 ns	0.037**	492.77**	0.773**	0.794**	0.037 ns	1.171**
Error (b)	68	464.72	0.0057	39.934	0.129	0.178	0.153	0.156

ns, **: Insignificant, Significant at the 0.05 and 0.01 levels of probability, respectively

2. Stem Diameter (cm)

The grand mean of stem diameter was 1.13 and 0.97 cm in the first and second locations, respectively (Table 2). S922× STel (15), S811× SAL4 (8), S812× SR74 (10) and S922× SR74 (13) hybrids gave the highest values of stem diameter (1.93, 1.87, 1.24 and 1.24 cm) in the first location, respectively. Also, S923× SAL4 (17), S812× STel (12) and S812× SR74 (10) hybrids gave the highest values of stem diameter (1.32, 1.20 and 1.16 cm) in the second location, respectively. While S710× SAL4 (2) and S740× SR74 (4) hybrids gave the lowest values of stem diameter (0.97 and 0.75 cm) in the first and second locations, respectively. Generally, S812× SR74 (10), S812× SAL4 (11) and S812× STel (12) hybrids gave for some extent better plant height and stem diameter at the two locations.

3. Average Fruit Weight (g)

In the first location, the mean average fruit weight was 164.47 g, while in the second location it was 136.25 g (Table 2). S812× STel (12) and S922× SR74 (13) hybrids gave the highest values of average fruit weight in the first

location of 187.63 and 188.67 g, while second location they gave 160.23 and 158.87 g, respectively. Moreover, S710× SR74 (1) and S740× STel (6) hybrids gave the lowest values of average fruit weight (126.87 and 106.57 g) in the first and second locations, respectively. Kumar et al. (2015) found that in greenhouse conditions, the average fruit weight was between 34.4 to 82.0 g. The heritability estimation concerning average fruit weight was high in broad sense, while in narrow-sense it was low (Metwally et al., 1996 and Abdel-Ati et al., 2000).

4. Fruit Firmness

The grand mean of fruit firmness was 5.69 and 7.73 in the first and second locations, respectively (Table 3). S922× SR74 (13), S811× SR74 (7), S811× STel (9) and S812× SR74 (10) hybrids gave the highest values of fruit firmness (7.97, 7.80, 7.57 and 7.04) in the first location, respectively. Also, they gave the highest values of fruit firmness in the second location. While S710× SR74 (1) hybrid gave the lowest values of fruit firmness (3.67 and 5.40) in the first and second locations, respectively.

5. Total Soluble Solids Percentage (TSS%)

The grand mean of TSS percentage was 4.85 and 5.42% in the first and second locations, respectively (Table 3). S923× SAL4 (17) and S923× STel (18) hybrids gave the highest values of TSS percentage (5.53 and 6.30 %) in the first and second locations, respectively. While S812× SR74 (10) and S740× SR74 (4) hybrids gave the lowest values of TSS percentage (4.00 and 4.53%) in the first and second locations, respectively. Alam et al. (2010) reported that TSS percentage was ranged from 3.71 to 4.39.

6. Number of Locules Per Fruit

The grand mean number of locules per fruit was 3.64 and 3.65 in the first and second locations, respectively (Table 3). S922× SR74 (13) hybrid gave the highest values of the locules number per fruit (4.43 and 4.30) in the first and second locations, respectively. While S923× SAL4 (17) hybrid gave the lowest values of the number of locules per fruit (3.0 and 3.2) in the first and second locations, respectively. Kumar et al. (2015) found that in field conditions the number of locules per fruit was arranged from 2.0 to 5.0.

7. Yield Per Plant (kg)

The difference among the hybrids in yield per plant was highly significant in the two locations (Table 3). The grand mean of yield per plant was 5.38 and 4.28 kg in the first and second locations, respectively. S812× STel (12) and S922× SR74 (13) hybrids gave the highest values of yield per plant in the first (7.50 and 6.98 kg) and second (5.37 and 5.35 kg) locations, respectively. While S710× SR74 (1) and S740× STel (6) hybrids gave the lowest values of

yield per plant (3.27 and 3.42 kg) in the first and second locations, respectively. Generally, all hybrids in which yield per plant were higher than the grand mean of the two locations. Similar ranges of genetic differences for yield in different tomato hybrids had also been reported by Alam et al. (2010), Jindal et al. (2015), Kumar et al. (2015), Singh et al. (2019) and Bayomi et al. (2020). Phookan et al. (1998) found that heritability values were high for fruit set percentage and total yield/plant.

Table (2). Means of tomato plant height, stem diameter, fruit weight, fruit firmness, no. of locules per fruit, TSS% and yield per plant of eighteen tomato hybrids under greenhouse conditions in both locations and combined across locations.

Hybrid	Plant height (cm)			Stem diameter (cm)			Average fruit weight (g)		
	Baloza	**Qantara**	**Combined**	**Baloza**	**Qantara**	**Combined**	**Baloza**	**Qantara**	**Combined**
1-S710× SR74	143.43	189.87	166.65	1.10	0.82	0.96	126.87	117.33	122.10
2-S710× SAL4	178.37	227.23	202.80	0.97	0.79	0.88	149.77	119.57	134.67
3-S710× STel	167.97	158.47	163.22	1.11	0.86	0.99	144.40	110.37	127.38
4-S740× SR74	237.57	220.40	228.98	0.99	0.75	0.87	157.63	156.63	157.13
5-S740× SAL4	238.17	230.90	234.53	0.99	0.85	0.92	183.43	146.80	165.12
6-S740× STel	195.57	227.67	211.62	1.17	0.80	0.99	167.77	106.57	137.17
7-S811× SR74	186.30	221.73	204.02	1.12	0.97	1.05	179.80	127.67	153.73
8-S811× SAL4	200.17	214.83	207.50	1.87	0.93	1.06	179.23	130.73	154.98
9-S811× STel	198.37	214.97	206.67	1.21	0.88	1.05	166.07	152.97	159.52
10-S812× SR74	238.27	255.66	246.97	1.24	1.16	1.20	175.20	130.67	152.93
11-S812× SAL4	228.87	255.27	242.07	1.17	1.12	1.14	171.40	141.97	156.68
12-S812× STel	195.00	209.13	211.62	1.22	1.20	1.21	187.63	160.23	173.93
13-S922× SR74	213.33	211.83	202.07	1.24	1.07	1.15	188.67	158.87	173.77
14-S922× SAL4	213.33	241.07	227.20	1.08	1.14	1.11	166.63	139.23	152.93
15-S922× STel	224.17	208.07	216.12	1.93	0.87	1.03	159.57	132.80	146.18
16-S923× SR74	217.50	234.97	226.23	1.15	0.90	1.03	162.37	124.87	148.62
17-S923× SAL4	179.53	212.20	195.87	1.06	1.32	1.19	135.63	142.10	138.87
18-S923× STel	230.83	232.20	231.52	1.11	0.93	1.02	158.43	153.10	155.77
Average	**204.82**	**220.30**	**212.56**	**1.13**	**0.97**	**1.05**	**164.47**	**136.25**	**150.36**
L.S.D at 5%	**14.583**	**48.440**	**24.836**	**0.133**	**0.118**	**0.087**	**10.847**	**10.112**	**7.280**

Table (3). Means of tomato fruit firmness, TSS%, no. of locules per fruit, and yield per plant of eighteen tomato hybrids under greenhouse conditions in both locations and combined across locations.

Hybrid	Fruit firmness			TSS%			No. of locules/fruit			Yield/plant (kg)		
	Baloza	Qantara	Combined	Baloza	Qantara	Combined	Baloza	Qantara	Combined	Baloza	Qantara	Combined
1-S710× SR74	3.67	5.40	4.53	4.90	5.73	5.32	3.33	3.33	3.33	3.27	3.96	3.61
2-S710× SAL4	3.83	6.23	5.03	4.80	4.80	4.80	3.33	3.30	3.32	4.34	4.14	4.24
3-S710× STel	4.47	6.30	5.38	5.10	4.97	5.03	3.77	3.97	3.87	4.31	3.73	4.02
4-S740× SR74	6.13	8.10	7.12	4.93	4.53	4.73	3.50	3.60	3.55	4.17	3.64	3.91
5-S740× SAL4	6.07	5.50	7.28	5.70	5.30	5.50	4.07	4.17	4.12	4.64	3.54	4.09
6-S740× STel	5.60	7.40	6.50	5.30	4.83	5.07	3.40	3.20	3.30	5.37	3.42	4.39
7-S811× SR74	7.80	8.83	8.32	5.30	5.03	5.17	3.97	3.77	3.87	6.69	4.53	5.61
8-S811× SAL4	6.57	8.30	7.43	4.53	5.33	4.93	3.30	3.20	3.25	6.25	4.68	5.47
9-S811× STel	7.57	9.10	8.33	4.90	5.37	5.13	3.67	3.67	3.67	5.39	4.54	4.96
10-S812× SR74	7.04	8.97	8.00	4.00	4.90	4.45	3.30	3.30	3.30	6.08	4.36	5.22
11-S812× SAL4	4.73	8.20	6.47	4.43	5.80	5.12	4.43	4.10	4.27	5.08	4.33	4.71
12-S812× STel	5.10	8.57	6.83	4.30	5.90	5.10	4.20	4.40	4.30	7.50	5.37	6.44
13-S922× SR74	7.97	9.33	8.65	4.77	6.17	5.47	4.43	4.30	4.37	6.98	5.35	6.16
14-S922× SAL4	7.03	8.00	7.52	4.90	5.67	5.28	3.20	3.30	3.25	5.57	4.12	4.85
15-S922× STel	4.07	7.00	5.53	4.33	5.86	5.10	3.37	3.63	3.60	6.22	3.97	5.10
16-S923× SR74	4.03	6.50	5.27	4.73	5.43	5.08	3.97	3.87	3.92	5.36	3.64	4.50
17-S923× SAL4	5.37	7.27	6.32	5.53	5.63	5.58	3.00	3.20	3.10	3.97	4.36	4.16
18-S923× STel	5.53	7.10	6.32	4.90	6.30	5.60	3.20	3.40	3.30	5.63	5.34	5.49
Average	**5.69**	**7.73**	**6.71**	**4.85**	**5.42**	**5.14**	**3.64**	**3.65**	**3.65**	**5.38**	**4.28**	**4.83**
L.S.D at 5%	**0.650**	**0.535**	**0.413**	**0.832**	**0.534**	**0.486**	**0.712**	**0.579**	**0.450**	**0.776**	**0.507**	**0.455**

The knowledge of degree and direction of correlation among different traits of tomato are of great importance for selection of programs in the future. The results presented in Table (4) show the combination among seven important traits of tomato hybrids under greenhouse conditions at the two locations. In that context, plant height had highly significant positive correlation with fruit firmness, also positive correlation with each of average fruit weight, TSS percentage, number of locules per fruit and yield per plant. On the contrary, negative correlation was found between plant height and stem diameter. Highly significant positive correlation was observed between stem diameter and each of average fruit weight and yield per plant. On the other hand, stem diameter showed a negative correlation with each of fruit firmness and TSS percentage. Yield per plant had significant positive correlation with average fruit weight and number of locules per fruit. Negative correlation was also found between yield per plant and each of fruit firmness and TSS percentage. Ghosh et al. (1995) found that total yield had a positive correlation with fruit weight. On the other hand, Khalaf-Allah et al. (1996) found that negative correlation was detected between total yield and TSS.

Table (4). Simple correlation coefficients among the traits of combined data of tomato across the two locations.

. **Traits**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1- Plant height (cm)	1.000	-0.012 ^{ns}	0.082 ^{ns}	0.359 **	0.035 ^{ns}	0.088 ^{ns}	0.044 ^{ns}
2- Stem diameter (cm)		1.000	0.522 **	-0.133 ^{ns}	-0.181 ^{ns}	0.076 ^{ns}	0.569 **
3- Average fruit weight (g)			1.000	-0.042 ^{ns}	0.227 *	0.293 **	0.778 **
4- Fruit firmness				1.000	0.304 **	0.095 ^{ns}	-0.019 ^{ns}
5- TSS%					1.000	0.055 ^{ns}	-0.245 *
6- No. of locules/fruit						1.000	0.222 *
7- Yield per plant (kg)							1.000

CONCLUSION

This study is an important step of Plant Breeding and Conservation Program of DRC to identify the best hybrids for agriculture under greenhouse conditions in the future. S812× STel (12) and S922× SR74 (13) tomato hybrids were performed well at the two locations. Generally, all hybrids in yield per plant were higher than the grand mean of the two locations. Yield per plant had significant positive correlation with average fruit weight. However, further studies should be carried out on hybrids under greenhouse conditions in all research stations of DRC to insure better results.

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إنتاجية الهجن المبشرة من الطماطم تحت ظروف البيوت المحمية

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تقييم أداء الهجن الواعدة من الطماطم تحت ظروف الصوب المحمية يأتي في المرتبة الأولى لبرنامج تربية وصون النباتات بمركز بحوث الصحراء. تم تقييم ثمانية عشر هجين طماطم بمحطتي بحوث بالوظة والقنطرة شرق، مركز بحوث الصحراء خلال موسم ٢٠٢٢/٢٠٢١. يعتبر استخدام اختباء السلالة فى الكاشف أداة جيدة للتقييم الأولي للتراكيب الوراثية بالبرنامج. التصميم الإحصائي المستخدم هو القطاعات الكاملة العشوائية مع استخدام ثلاث مكررات. وكانت النتائج تشير إلى وجود اختلافات معنوية بين هجن الطماطم لجميع الصفات في التحليل التجميعي للبيانات. وأيضًا للتفاعل بين الهجن والمواقع لجميع الصفات ماعدا صفتي ارتفاع النبات وعدد الكرابل بكل ثمرة. واستنادًا إلى النتائج المتحصل عليها في الموقعين، تم تحديد أكثر هجن الطماطم إنتاجيةً وتكيفًا لظروف الصوب المحمية. الهجينين S922× SR74, S812× STel الأفضل إنتاجية في كلا الموقعين. وجد إرتباط موجب بين محصول النبات وجميع الصفات ماعدا صفتي صلابة الثمار ونسبة المواد الصلبة الذائبة الكلية فقد كان الارتباط بينهما سلبي.