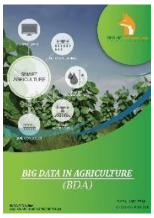
ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2682-7786 (Online)
CODEN: BDAIDR

Big Data in Agriculture (BDA)

DOI: http://doi.org/10.26480/bda.01.2022.28.31



RESEARCH ARTICLE

STUDY ON COMBINING ABILITY FOR YIELD AND YIELD CONTRIBUTING TRAITS IN WATER STRESS TOLERANT GENOTYPES OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

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ARTICLE DETAILS

Article History:

Received 10 August 2022
Accepted 20 September 2022
Available online 22 September 2022

ABSTRACT

The experiment was conducted to develop tomato hybrids by identifying parental lines with estimation of good combining ability effects and their variances through line x tester analysis of 44 genotypes including 32 F_1 cross combinations using 12 parents after selfing (8 lines and 4 testers). The genotypes were evaluated for the yield and contributing traits. The analysis of variance (ANOVA) showed highly significant difference for all the characters suggesting the presence of genetic variability among the studied materials. The variance values of general combining ability (GCA) were lower than the specific combining ability (SCA) for all the traits except plant height. This indicates that these traits were under the control of non-additive (non-fixable) gene effects and could be exploited by heterosis breeding. The lines L_1, L_2, L_3, L_5, and testers T_2, and T_4 showed a desirable significant negative GCA effect for days to first flowering and days to maturity. The line L_5 showed a positive significant GCA effect for most of the traits except fruit per cluster and L_4 for plant height, cluster per plant, fruit per cluster, fruit per plant, fruit diameter, and yield per plant. Based on GCA effects across ten traits L_4 and L_5 were identified as the most promising parental lines for inclusion in hybridization programs. Outstanding crosses based on SCA effects across ten traits were L_6XT_1, L_2XT_3, L_7XT_2, and L_4XT_4. These crosses could be considered the most promising specific combiner for most traits which can be used to develop elite tomato varieties.

KEYWORDS

General Combining Ability, Specific Combining Ability, Yield Contributing Traits, HYV Tomato

1. Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop grown throughout the world because of its wider adaptability, high yield potential, and suitability for a variety of uses in fresh as well as processed food industries (FAOSTAT, 2013). Due to changing climate, demand for developing high-yielding OP and/or hybrids remains a key and continuous activity in creating variation in a breeding program. By adopting an appropriate breeding procedure, a considerable scope in enhancing yield in tomato is possible. Combining ability studies offer consistent evidence in selecting parents for hybrid combination by revealing the nature and magnitude of gene actions involved in the expression of quantitative traits (Agarwal et al., 2017). General combining ability (GCA) expresses the additive genetic effects and specific combining ability (SCA) non-additive genetic effects refer to a deviation from the foreseen behavior due to the general combining abilities of the parents (Sprague and Tatum, 1942).

Since introducing the concept of combining ability in 1942, it has been widely adopted in plant breeding to compare the performances of lines in hybrid combinations (Fasahat et al., 2016). However, developing hybrids for better yield and quality traits identification of good specific and general combiners are required. In inheritance patterns, the nature of gene activity is revealed by combining traits of the parent (GCA) and hybrids (SCA) (Ishaq and Raziuddin, 2016). A group of researchers identified tomato lines with good general combining ability, which were suitable for breeding high-yield tomato genotypes (Saleem et al., 2013). Several workers like observed positive GCA values in the yield variables of tomato genotypes, with the highest yields (López et al., 2012; Gabriel et al., 2013; Kumar et al., 2013). Considering the above-mentioned circumstances, the present study was undertaken to select elite tomato lines to develop hybrids for growing in an open field, by identifying parental lines with good combining ability through line x tester crosses.

2. Materials and Methods

2.1 Experimental Site

The experiment was set up in the research field of the Genetics and Plant Breeding Department, Sher-e-Bangla Agricultural University, Dhaka during the winter season of 2016-2017 and 2017-2018.

2.2 Collection of Genotypes, Designing the Experiment and Management

In the first year 2016-2017, twelve diverse SAU-identified water stress-tolerant genotypes of tomato were used for making crosses following the Line x Tester design. The parental genotypes (eight lines and four testers) and their thirty-two F_1 generations were evaluated during the Robi season of 2017-2018. Thirty days old seedlings were transplanted into the main

Quick Response Code	Access this article online	
	Website: www.bigdatainagriculture.com.my	**DOI:** 10.26480/bda.01.2022.28.31

Cite The Article: Sayda Rehana, Md. Harun-Or-Rashid, Naheed Zeba, Mohammad Zahir Ullah, Nabila Narzis, Asmaul Husna and Abu Bakar Siddique (2022). Study on Combining Ability for Yield and Yield Contributing Traits in Water Stress Tolerant Genotypes of Tomato (*Solanum Lycopersicum* L.). *Big Data in Agriculture, 4(1): 28-31.*

plot on 20 November each year. The experiment was arranged in RCBD design with three replications having a plot size of 4.0 sq. m providing a spacing of 60 × 40 cm on a 1 m wide bed.

2.3 Data Collection and Analysis

Data were recorded on days to first flowering, days to maturity, plant height at last harvest (cm), cluster per plant, fruits per cluster, fruits per plant, individual fruit weight (g), yield per plant (kg), fruit length (mm), fruit diameter (mm). The analysis of variance was carried out as per the methods described (Panse and Sukhatme, 1985). The mean values of all the traits studied were used for combining ability analysis as per the method suggested (Kempthorne, 1957; Arunachalam, 1974). The data obtained for different characters have been statistically analyzed with the computer-based software OPSTAT and Microsoft excel 2007 (Sheoran et al., 1998).

3. Results and Discussion

Analysis of variance (Table 1) for combining ability revealed that variance due to line effect was highly significant for days to first flowering, plant height (cm), cluster per plant, fruit per cluster, and fruits per plant. Mean squares due to testers were significant for plant height (cm) and fruit per cluster indicating a wide diversity between the parental materials used in this study. While the variance due to line x tester effects was highly significant for all traits under study, representing specific combining ability and suggesting the manifestation of parental genetic variability in their crosses or the possibility of better selection of cross combinations among 32 F1 hybrids for these traits.

Table 1: ANOVA For Combining Ability of Yield and Contributing Traits in Tomato

Parameters	df	D FF	DM	PH (cm)	CPP	FPC	FPP	FL (mm)	FD (mm)	IFW (g)	YPP (kg)
Replication	2	0.08	0.01	0.01	0.04	0.03	4.88	0.83	0.002	1.48	0.01
Genotypes	43	55.94**	52.98**	1281.03**	10.49**	2.22**	434.67**	70.23**	91.75**	212.68**	0.45**
Line effect	7	75.98**	61.40*	2188.41**	20.75**	3.30**	1236.42**	37.06	56.77	172.97	0.55
Tester effect	3	32.02	16.42	3393.03**	14.39*	6.23**	342.05*	43.95	32.24	227.82	0.26
Line X Tester effect	21	12.33**	24.48**	140.06**	4.32**	1.00**	115.54**	62.07**	70.50**	107.28**	0.34**
Error	86	0.03	0.02	0.01	0.01	0.01	0.71	0.75	0.001	0.88	0.002

*, ** Significant at 0.05 and 0.01 probability levels, respectively.

df: degree of freedom, DFF: days to first flowering, DM: days to maturity, PH (cm): plant height (cm), CPP: cluster per plant, FPC: fruit per cluster, FL: fruit length, FD: fruit diameter, IFW: individual fruit weight, and YPP: yield per plant

Variance due to GCA was lower than that due to SCA for the entire trait studied and the ratios between GCA/SCA were lower than unity except for plant height (cm) (table 2). This indicates that these traits were under the control of non-additive ((dominance and epistasis) gene effects and could be exploited by heterosis breeding. On the other hand, as the additive gene effects are easily fixed and exploitable, the improvements of the characters with predominate additive effects viz., plant height can be done by single plant selection of superior segregating populations in early generations. These results are confirmed (Hannan et al., 2007; Kryuchkov et al., 1992; Thakur and Joshi, 2000; Bhatt et al., 2001; Roopa et al., 2001).

Table 2: Yield Contributing Traits Analysis of Variance For In A Line X Tester Cross

Source of variation	DFF	DM	PH (cm)	CPP	FPC	FPP	FL (mm)	FD (mm)	IFW (g)	YPP (kg)
σ2gca	4.04	0.84	169.59	-0.23	-0.08	-2.15	-4.14	-2.40	6.33	-0.03
σ2sca	12.32	24.47	140.05	4.31	0.99	115.07	61.57	70.50	106.70	0.34
σ2gca/ σ2sca	0.328	0.034	1.211	-0.053	-0.081	-0.019	-0.067	-0.034	0.059	-0.088

Legend: σ^2gca = GCA variance, σ^2sca = SCA variance, σ^2gca/ σ^2sca = GCA variance/SCA variance,

The lines L_1, L_2, L_3, L_5, and testers T_2, and T_4 showed a desirable significant negative GCA effect for days to first flowering and days to maturity indicating could be considered as good combiners for developing early tomato genotypes (table 3). While the other lines L_4, L_7, L_8, and testers T_1, T_3 exhibited a positive significant GCA effect, indicating a sheer tendency towards delayed flowering dates and maturity (Kumar et al., 2013; Reddy et al., 2013; Hatem and Khalil, 2014; Shalaby, 2012). The line L_5 showed a positive significant GCA effect for most of the traits except fruit per cluster and L_4 for plant height, cluster per plant, fruit per cluster, fruit per plant, fruit diameter, and yield per plant.

Table 3: General Combining Ability (GCA) Effects of Lines and Testers for Different Traits in Tomato

GCA	DFF	DM	PH	CPP	FPC	FPP	FL (mm)	FD (mm)	IFW (g)	YPP (kg)
Lines										
L_1	-1.45**	-2.13**	-11.90**	-1.58**	0.26**	-6.37**	0.57	0.51**	-2.38**	-0.28**
L_2	-2.98**	-2.62**	-8.97**	-1.53**	-0.32**	-8.38**	2.04**	1.19**	-2.37**	-0.33**
L_3	-2.83**	-1.07**	18.09**	1.00**	-0.15**	3.48**	-3.23**	-2.67**	-2.27**	0.05**
L_4	0.84**	0.63**	1.85**	1.19**	0.46**	8.92**	-0.67*	0.04*	-0.30	0.31**
L_5	-5.05**	-4.82**	6.91**	0.53**	0.40**	5.86**	0.36	0.91**	2.09**	0.25**
L_6	0.82**	-0.82**	-8.60**	0.90**	-0.24**	2.28**	-4.27**	-5.72**	-5.42**	-0.09**
L_7	5.51**	5.98**	8.45**	0.07*	-0.60**	-3.63**	6.41**	8.19**	14.40**	0.28**
L_8	5.13**	4.84**	-5.84**	-0.58**	0.19**	-2.17**	-1.22**	-2.45**	-3.75**	-0.19**
GCA Standard Error	0.06	0.05	0.04	0.03	0.03	0.32	0.33	0.01	0.36	0.02
Testers										
T_1	0.39**	0.38**	0.37**	-0.45**	-0.26	-3.81	2.71**	3.30**	5.08**	0.004
T_2	-0.96**	-0.84**	20.50**	0.32**	-0.11	0.67	-1.80**	-1.71**	-2.39**	-0.03**
T_3	1.74**	0.77**	-4.81**	0.23**	0.27	2.42	-0.99**	-1.87**	-4.14**	-0.08**
T_4	-1.17**	-0.32**	-16.05**	-0.11**	0.10	0.72	0.08	0.28**	1.44**	0.11**
GCA Standard Error	0.04	0.03	0.02	0.02	0.02	0.21	0.22	0.01	0.23	0.01

** and * significant at 1% and 5% level, respectively

The results in table 4 for SCA effects reflected that cross L_6XT_1 showed the most expected desirable traits studied except fruit per cluster. The crosses L_2XT_3, and L_7XT_2 performed all desirable traits except fruit per cluster and fruit length (Sharma et al., 1999). Besides cross L_4XT_4 showed expected desirable traits except for days to maturity, plant height, and fruit per cluster. Similar results were reported (Mondal et al., 2009; Shalaby, 2012; Shatran et al., 1996; Chisti et al., 2007; Saleem et al., 2009).

Table 4: Specific Combining Ability (SCA) Effects of Hybrids For Different Traits in Tomato

Designation	DFF	DM	PH	CPP	FPC	FPP	FL (mm)	FD (mm)	IFW (g)	YPP (kg)
L_1XT_1	-1.45**	-2.36**	4.77**	-0.43**	-0.37	-2.79**	-1.69**	-1.28**	-0.46	-0.12**
L_1XT_2	2.08**	-1.14**	4.56**	2.12**	-0.43	7.50**	2.39**	4.36**	-0.90	0.20**
L_1XT_3	1.18**	5.25**	-0.05	-0.99**	0.41	-2.64**	3.70**	-0.46**	2.52**	0.05
L_1XT_4	-1.81**	-1.76**	-9.29**	-0.70**	0.39	-2.08**	-4.40**	-2.61**	-1.16	-0.13**
L_2XT_1	-0.53**	1.11**	3.65**	0.72**	0.62	6.65**	-0.61	-4.12**	-1.36*	0.18**
L_2XT_2	1.71**	2.25**	-8.57**	-1.14**	0.46	-2.89**	-0.98	0.68**	5.77**	0.03
L_2XT_3	-3.19**	-4.28**	6.84**	1.15**	0.08	5.58**	1.33*	2.74**	0.44	0.22**
L_2XT_4	2.02**	0.92*	-1.92**	-0.74*	-1.16	-9.34*	0.26	0.69**	-4.84*	-0.43*
L_3XT_1	2.08**	2.57**	-5.30**	-0.80**	0.11	-2.78**	1.91**	1.53**	-0.68	-0.09
L_3XT_2	-0.34**	-0.11	-5.41**	0.73**	0.22	4.92**	-3.81**	-2.59**	6.12**	0.37**
L_3XT_3	-1.22**	-0.63**	9.67**	0.30**	-0.32	-0.53	1.51**	2.60**	-2.28**	-0.09**
L_3XT_4	-0.52**	-1.83**	1.04**	-0.23**	-0.01	-1.61**	0.40	-1.55**	-3.17**	-0.20**
L_4XT_1	2.29**	2.86**	0.73**	-0.98	0.80	0.33	-2.73**	-2.96**	-3.55**	-0.08**
L_4XT_2	-0.19	1.09**	0.90**	-0.84**	-0.50	-7.63**	-2.15**	0.11**	0.03	-0.30**
L_4XT_3	-0.09	0.59**	0.91**	1.24**	-0.69	1.27*	-4.95**	-7.00**	-7.56**	-0.32**
L_4XT_4	-2.01**	-4.54	-2.54**	0.58**	0.39	6.03**	9.84**	9.85**	11.09**	0.69**
L_5XT_1	-2.57**	0.32**	-9.02	-1.42**	-0.30	-9.05**	2.13**	4.03**	7.16**	-0.14**
L_5XT_2	-0.31**	-0.27**	10.66**	-0.11	-0.36	-3.55**	-1.18*	-4.13**	-3.79**	-0.25**
L_5XT_3	-1.02**	-4.17**	-3.85**	0.10	0.28	3.07**	-8.01**	-6.99**	-7.84**	-0.19**
L_5XT_4	3.90**	4.11**	2.21**	1.42**	0.38	9.53**	7.05**	7.10**	4.48**	0.58**
L_6XT_1	-1.57**	-0.48**	7.28**	1.21**	0.22	6.79**	3.15**	4.94**	2.35**	0.34**
L_6XT_2	-1.28**	-2.46**	-3.54**	-1.57**	0.07	-6.38**	2.55**	-0.41**	-1.23*	-0.24**
L_6XT_3	3.02**	1.13**	-3.55	0.52**	-0.28	0.86	-1.15*	-0.13**	0.88	0.05
L_6XT_4	-0.16	1.81**	-0.19**	-0.16**	-0.02	-1.27*	-4.55**	-4.40**	-2.00**	-0.15**
L_7XT_1	1.58**	-2.69**	-5.85	0.03	-0.17	-0.86	0.06	-1.45**	-8.24**	-0.31**
L_7XT_2	-1.06**	-1.25**	4.00**	0.70**	0.65	7.49**	0.97	1.79**	2.00**	0.41**
L_7XT_3	0.42**	1.93**	-8.70**	-0.43**	0.05	-1.26*	3.98**	3.85**	5.96**	0.19**
L_7XT_4	-0.95**	2.01**	10.55**	-0.30**	-0.53	-5.37	-5.01**	-4.19**	0.28	-0.30**
L_8XT_1	0.17	-1.34**	3.74**	1.68**	-0.91	1.70**	-2.21**	-0.69**	4.79**	0.21**
L_8XT_2	-0.59**	1.89**	-2.60**	0.11	-0.12	0.53	2.20**	0.19**	-7.99**	-0.23**
L_8XT_3	0.90**	0.17*	-1.29**	-1.90**	0.47	-6.34**	3.59**	5.39**	7.89**	0.08**
L_8XT_4	-0.47**	-0.73**	0.14*	0.12*	0.56	4.11**	-3.58**	-4.89**	-4.69**	-0.06*
SCA Standard Error		0.08	0.06	0.06	0.05	0.56	0.57	0.02	0.62	0.03

** and * significant at 1% and 5% level, respectively

4. Conclusion

The variance values of general combining ability (GCA) were lower than the specific combining ability (SCA) for all the traits except for plant height (cm). The crosses revealed significant high SCA effects that could be more worthwhile in a hybrid breeding program after intensive investigation. Outstanding crosses based on SCA effects across ten traits were $L_6 X T_1$, $L_2 X T_3$, $L_7 X T_2$, and $L_4 X T_4$. These crosses could be considered the most promising specific combiner for most of the traits. Choice of parents based on combining ability in hybrid breeding is a sound scheme. From this study, effects of parent or general combining ability (GCA) in a crossing program has been observed of major importance, helps to estimate the genetic potentiality of crosses. Specific combining ability is associated with interaction effects, which may be due to dominance and epistatic components of variation that are non-fixable in nature. Hereafter, combining ability could be exploited in the development of hybrid varieties.

Acknowledgment

The authors would like to thank Sher-e-Bangla Agricultural University for providing land and other experimental facilities for this study, and also thank extended to the University Grants Commission (UGC), and the Government of Bangladesh for providing fellowship to pursue this piece of research work.

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