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Determining of general combining ability for yield, quality and some other traits of tomato (*Solanum lycopersicum* L.) inbred lines

Domates (*Solanum lycopersicum* L.) saf hatların verim, kalite ve bazı özellikler bakımından genel uyum yeteneklerinin belirlenmesi

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ABSTRACT

This research was carried out to investigate the genetic structure of the 30 F_1 hybrid tomato combinations established from 15 female lines and two male testers, and to determine parents showing superior general combining ability (GCA). The 47 genotypes (30 F_1 and 17 parents) were planted in a randomized complete block design with three replications in a greenhouse at the Batı Akdeniz Agricultural Research Institute, Antalya, during the spring growing season. General combining ability was investigated for eight traits. The highest effect on GCA among lines had BH-135 for yield per plant and days to first flowering; BH-28 for early yield per plant and pH of fruit juice; BH-93 for days to first fruit ripening; G-8 for plant height and plant stem diameter at 60 days after transplantation and fruit weight. Non-additive genetic variance was predominant in controlling eight characters. Based on GCA, lines BH-4, BH-28, BH-37, BH-135, BH-53, BH-102, G-8 and Tester 2 can be recommended as potential lines for further hybrid breeding studies.

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ÖZ

Bu araştırma, 15 adet iri tipteki domates saf hattı ile 2 adet testleyici (tester) hattın, line x tester analiz yöntemine göre melezlenmesiyle oluşturulan melez (hibrit) kombinasyonlardaki genetik yapıyı incelemek ve hatların genel uyum (kombinasyon) yetenekleri belirlemek amacıyla yapılmıştır. 30 F_1 melez kombinasyon ve 17 ebeveyn, ilkbahar yetiştiricilik döneminde, Batı Akdeniz Tarımsal Araştırma Enstitüsü seralarında, tesadüf blokları deneme desenine göre üç tekerrürlü olarak denemeye alınmıştır. Hatların genel uyum yetenekleri 8 özellik için araştırılmıştır. Bitki başına toplam verimde BH-135, bitki başına erkenci verimde BH-28, dikimden % 50 çiçeklenmeye kadar geçen gün sayısında BH-135, dikimden olgunlaşmaya kadar geçen gün sayısında BH-93, ortalama meyve ağırlığında G-8, meyve suyunun pH değerinde BH-28, 60. gündeki bitki boyunda G-8 ve bitki gövde çapında G-8 nolu hatlar en iyi genel uyum veren hatlar olarak belirlenmiştir. Genellikle Tester 2 hattı Tester 1 hattına göre daha iyi uyum göstermiştir. Bütün özelliklerde eklemeli olmayan gen etkisinin daha baskın olduğu tespit edilmiştir. Bu çalışma sonucunda bütün özellikler dikkate alındığında BH-4, BH-28, BH-37, BH-135, BH-53, BH-102, G-8 nolu hatlar ile Tester 2 nolu testleyici hat ileriki ıslah çalışmaları için ümit var hatlar olarak belirlenmiştir.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is the most produced vegetable in Turkey with production of 11.8 million t in 311 000 hectares in 2012. In the world, it was produced about 164 million t from 4.7 million ha (FAOSTAT 2015). Tomato is grown both in field and greenhouse in Turkey. In greenhouse, hybrid varieties are grown as 100%. Improvement of hybrid varieties requires labor, capital and a longtime. Development of inbred lines with high combining ability and the identification of suitable combinations are the most important steps in the development of hybrid varieties (Fehr 1991). General and specific combining ability (GCA and SCA) are the most important indicators of the potential value of the pure lines in hybrid combinations. The term 'general combining ability' (GCA) is used to designate the average performance of a line in hybrid combination (Poehlman 1979). GCA effects were due to additive type of gene action and SCA effects were due to non-additive (dominant or epistatic) gene action (Poehlman 1979, Falconer 1989).

Inbred lines with high general combining ability are used at developing new hybrid varieties. Line x tester analysis provides information about GCA and SCA effects of parents and is helpful in estimating various types of gene actions (Kempthrone, 1957).Testers are hybridized with all of the lines in line x tester analysis. F_1 hybrids obtained from combinations are compared for many traits in trials with replication. Thus, the numbers of lines to be crossed in the development of new commercial hybrid varieties are reduced. This study was carried out to determine GCA of lines and gene actions on yield and yield components.

2. Materials and Methods

A total of 17 genotypes consisting 15 inbred lines and two testers of beef type tomato were crossed in a line x tester mating design (Table 1). 30 F_1 and 17 parents were grown in a randomized complete block design with three replications. Plots consisted of 10 plants in a greenhouse at the Bati Akdeniz Agricultural Research Institute, Antalya, during the spring growing season of 2009. Seeds of the genotypes were germinated and then seedlings were planted in plots as 120 x (90 x 60) cm for inter-couple rows, inter-row and inter-plant distances, respectively.

Table 1. Lines and testers used in line x tester mating design.

Lines			Testers
BH-1	BH-53	BH-94	Tester 1
BH-4	BH-59	BH-102	Tester 2
BH-28	BH-65	BH-116	
BH-37	BH-87	BH-135	
BH-43	BH-93	G-8	

The observations were recorded for the following characters: Total yield per plant (kg/plant): It was calculated by summing up the weight of fruits obtained from all pickings and dividing it by number of plants. Early yield per plant (kg/plant): It was calculated by summing up the weight of fruits obtained from first 3 harvests and dividing it by number of plants. Days to 50% flowering: It was assessed by observing the flowering date of the flowers on the first trusses in the half of 10 plants. Days from planting to ripening: The number of days taken from planting to full ripe stage. Average fruit weight (g/fruit): A random sample of 1 kg marketable fruits from second harvest was taken and average fruit weight was calculated by dividing the weight of sample with the number of fruits in the sample. Fruit juice pH: It was recorded with the help of pH meter after standardization with buffer solutions of 7.0 and 4.0 pH. Plant height (cm): The plant height was recorded at 60 days after planting. Plant stem diameter (mm): The plant stem diameter was recorded at 60 days after planting.

The data were subjected to analysis of variance according to Steel and Torrie (1980) to determine significant differences among genotypes. Combining ability studies were performed by using line x tester analysis as described by Kempthrone (1957).

3. Results and Discussion

3.1. Gene action

The recorded data on different agronomic parameters were subjected to analysis of variance to confirm the differences among tomato genotypes. Mean squares from analysis of variance for eight traits were presented in Table 2-3. The sum of squares was further portioned into lines, testers and line x tester components. Highly significant ($P \leq 0.01$) differences were displayed among line x tester interaction for all the characters except for fruit juice pH (Table 2-3).

The ratio of SCA and GCA variances was more than one for eight traits revealing the preponderance of non-additive gene action over the additive gene action. These results agreed with the results of Kryuchkov et al. (1992), Thakur and Joshi (2000), Bhatt et al. (2001), Roopa et al. (2001) for total yield, Srivastava (1998) and Dhaliwal et al. (2000) for early yield, flowering ripening and fruit weight, Farkas (1993) for plant height. On the other hand, additive gene action was more significantly found by Surjan et al. (1999) for yield, for early yield, flowering ripening and fruit weight by Chishti et al. (2008).

High dominance variance for all the character can be explained with genetic distance between 15 lines and 2 testers. Non-additive gene action effect increases hybrid vigor of specific combination crosses.

Table 2. Analysis of variance for line x tester experiment for yield and yield components in tomato.

Source	df	Total yield per plant Mean Squares	Early yield per plant Mean Squares	50% Flowering Mean Squares	Maturity Mean Squares
Replication	2	673874.9**	232.9	10.5*	1.4
Genotypes	46	1946186.9**	283954.4**	17.9**	14.5**
Parents	16	2098517.9**	255572.0**	18.4**	16.2**
P vs C	1	1966452.3**	252728.9**	0.926	27.9**
Crosses	29	1861443.5**	300690.4**	18.2**	13.0**
Lines	14	1267899.5	218742.5	7.9	17.1**
Testers	1	27987059.3**	3468424.7**	298.8**	74.7**
L x T	14	588872.0**	156371.6**	8.4**	4.6**
Error	92	132104.0	9116.2	2.1	1.0
Variance of GCA, SCA, Additive (A) and Dominance (D)					
σ^2 GCA		19072.1	2162.9	0.147	0.127
σ^2 SCA		152256.0	49085.1	2.086	1.192
σ^2 A		38144.2	4325.8	0.294	0.254
σ^2 D		152256.0	49085.1	2.086	1.192

* and ** statistically significant for p< 0.05 and p< 0.01, respectively.

Table 3. Analysis of variance for line x tester experiment for yield and yield component in tomato.

Source	df	Fruit weight Mean Squares	pH Mean Squares	Plant height Mean Squares	Plant stem diameter Mean Squares
Replication	2	313.6	0.009	40.1	3.6*
Genotypes	46	8674.7**	0.016**	413.8**	5.6**
Parents	16	19257.1**	0.019**	659.0**	8.0**
P vs C	1	44471.8**	0.104*	623.1**	1.3
Crosses	29	1601.8**	1.666*	271.3**	4.4**
Lines	14	1342.5	0.014	374.4	3.2
Testers	1	16058.7**	0.004	98.1	31.2*
L x T	14	828.5**	0.009	180.5**	3.8**
Error	92	172.7	0.007	20.1	1.1
Variance of GCA, SCA, Additive (A) and Dominance (D)					
σ^2 GCA		11.590	0.000	1.360	0.010
σ^2 SCA		218.610	0.001	53.475	0.889
σ^2 A		23.180	0.000	2.720	0.021
σ^2 D		218.610	0.001	53.475	0.889

* and ** statistically significant for p< 0.05 and p< 0.01, respectively.

3.2. GCA effects of lines and testers

GCA was found negative in 9 lines and positive in 6 lines for total yield per plant (Table 4). Highly significant positive GCA values for total yield per plant were in the lines BH-135 (816.122), BH-28 (659.456), BH-102 (485.956), G-8 (477.289), BH-53 (302.789) and BH-37 (47.456) and Tester 2 (557,644). Thus, these lines and tester can be regarded as good general combiners for this trait. Hannan et al. (2007) and Chishti et al. (2008) emphasized that lines with a high GCA should be used for development of hybrid varieties.

Table 4. General combining ability effects of parents.

Parents	Total yield per plant	Early yield per plant	50% Flowerin	Maturity
BH-1	-387.378	-284.778	-0.233	-0.622
BH-4	-5.044	111.389	1.100	-0.456
BH-28	659.456	363.389	-0.067	-0.289
BH-37	47.456	-50.611	2.100	4.044
BH-43	-147.044	-68.611	1.433	1.544
BH-53	302.789	-173.778	-1.733	2.211
BH-59	-278.211	-173.778	-0.900	1.878
BH-65	-200.378	-191.944	0.100	-1.289
BH-87	-835.544	-80.278	-1.400	-1.456
BH-93	-233.044	74.056	0.933	-2.122
BH-94	-426.044	-6.278	0.100	-0.956
BH-102	485.956	134.222	-0.233	-0.789
BH-116	-276.378	-136.778	0.767	0.378
BH-135	816.122	327.389	-1.900	-1.289
G-8	477.289	156.389	-0.067	-0.789
Tester 1	-557.644	-196.311	1.822	0.911
Tester 2	557.644	196.311	-1.822	-0.911

Negative GCA effects and the lowest total yield were recorded in the lines BH-87 (-835.544), BH-94 (-426.044), BH-1 (-87.378), BH-59 (-278.211), BH-116 (-276.378), BH-93 (-233.044), BH-65 (-200.378) and BH-43 (-147.044). These lines can be considered poor general combiners for total yield.

Lines with high GCA in terms of total yield per plant were often found to be high in early yield per plant. Highly significant positive GCA values for early yield were found for the lines BH-135 (327.389), G-8 (156.389), BH-102 (134.222), BH-4 (111.389) and BH-93 (74.06) and Tester 2 (Table 4).

The days to 50% flowering is one of the most important factors that determine early yield. Highly significant negative GCA effects were recorded in the lines BH-135 (-1.900), BH-53 (-1.733), BH-87 (-1.400) and BH-59 (- 0.900) and Tester 2 (-1.822) (Table 4). These results are in conformity with the findings of Chishti et al. (2008).

In number of days from planting to maturity, the highest and lowest GCA effect was found BH-93 (-2.122) and BH-37 (4.044), respectively. Other lines with high GCA were BH-87 (-1.456), BH-135 (-1.289) and BH-65 (-1.289) (Table 4). There were significant correlations between early yield and number of days to maturity and days to 50% flowering as reported by Zengin et al. (2011). Therefore, early yield could be estimated with the days to maturity and days to 50% flowering.

Lines BH-28, BH-102, BH-135 and G-8 were positive for early yield and were negative the number of days from planting to maturity and to 50% flowering. The use of these lines for breeding on early yield can benefical.

Line G-8 (30.520) was the highest GCA effect for fruit weight. This line was followed by lines BH-43 (15.687), BH-4 (11.520), BH-116 (6.737) and BH-28 (5.687). High significant negative GCA effects were recorded in the lines BH-94 (-27.947), BH-65 (-25.147), BH-1 (-14.147) and BH-135 (-9.447). Tester 1 showed better GCA effect according to Tester 2 for fruit weight (Table 5).

Table 5. General combining ability effects of parents.

Parents	Fruit weight	pH	Plant height	Plant stem diameter
BH-1	-14.147	0.047	-10.189	-0.633
BH-4	11.520	0.030	6.644	-0.967
BH-28	5.687	-0.120	7.478	0.700
BH-37	2.687	-0.003	-19.189	1.033
BH-43	15.687	0.030	-6.189	-0.300
BH-53	-3.897	-0.053	-2.856	1.200
BH-59	2.187	-0.037	3.144	0.200
BH-65	-25.147	0.013	-5.522	-0.633
BH-87	2.353	0.047	6.478	-1.133
BH-93	3.020	-0.003	2.311	0.533
BH-94	-27.947	0.030	-0.356	-0.633
BH-102	0.187	-0.020	-2.022	-0.467
BH-116	6.737	0.080	3.811	0.533
BH-135	-9.447	-0.020	5.644	0.533
G-8	30.520	-0.020	10.811	0.033
Tester 1	13.358	0.007	1.044	-0.589
Tester 2	-13.358	-0.007	-1.044	0.589

Line BH-28 with -0.120 value was found the highest GCA for pH trait. This line was followed by the lines BH-53 (-0.053) and BH-59 (-0.037). Line116-BH (0.080) was found the lowest general combining ability (Table 5).

Acidity influences the storability of processed tomatoes and tomato products by inhibiting the germination of thermophilic organisms. A pH above 4.5 is thus commercially undesirable as it would require increased temperature and processing time to avoid spoilage. For this reason, lines that have negative value are selected in breeding studies in terms of pH values.

High significant positive GCA values for plant height were found in the lines G-8 (10.811), BH-28 (7.478), BH-4 (6.644), BH-87 (6.478), BH-135 (5.644), BH-116 (3.811), BH-59 (3.144) and BH-93 (2.311), and Tester 1 (1.044). Therefore, these lines can be regarded as good general combiners for this trait (Table 5). Lowest GCA effect was line BH-37 (-19.189). This line can be considered poor general combiners for plant height.

GCA was found to be negative for 7 lines while it was positive for 8 lines for plant stem diameter (Table 5). Lines of the highest positive GCA effects for plant stem diameter and plant height can be used in breeding studies.for winter growing period.

As a result of this study, the lines BH-4, BH-28, BH-37, BH-135, BH-53, BH-102 and G-8, and Tester 2 are thought to be promising for further hybrid breeding studies in terms of all traits.

4. Conclusion

GCA was investigated for the eight traits including yield and yield components in tomato. GCA effects of the lines were different for the traits. The lines with high GCA, in terms of yield also need to have good fruit quality characteristics. The lines with poor quality characteristics should be eliminated. Highly significant positive GCA values were found for early yield, the number of days to 50% flowering and days to maturity for the same lines. These lines are recommended for earliness in breeding studies. Plant vigor is important indicator in cold tolerance. Thus, lines with high significant positive GCA values for plant height and plant stem diameter should be selected for cold tolerance studies. Based on GCA, the lines BH-4, BH-28, BH-37, BH-135, BH-53, BH-102 and G-8, and Tester 2 can be recommended as potential lines for further hybrid breeding studies.

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