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Combining ability and gene action studies over environments in bacterial wilt resistant tomato genotypes

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Abstract : Tomato cultivation in many potential pockets of India has suffered a serious set-back due to bacterial wilt disease (*Ralstonia solanacearum*). Being soil borne only the genetic resistance in the cultivars/hybrids is of practical significance. In the current study, 28 hybrids (developed by crossing 7 bacterial wilt resistant determinate lines with 4 indeterminate resistant testers) along with their parents were evaluated 2009 and 2010. Appreciable diversity in the experimental material existed as revealed by significant differences due to lines, testers and line x tester interactions in pooled environment for most of the traits. On the basis of general combining ability of the parents, it was concluded that the lines 7-2 and BWR-5 and the testers 16-B and CLN1314G were found to be the best general combiners for marketable fruit yield and most of the component traits. The hybrids BWR-5 x 16-B 17-2 x CLN1314G and 7-2 x Palam Pride were observed consistently good specific combinations over both the environments. Non-additive gene action was observed for the traits marketable yield per plant, days to 50 per cent flowering, pericarp thickness, plant height, harvest duration and TSS over environments. However, for the traits days to first harvest, gross yield per plant, total number of fruits per plant, marketable fruits per plant, fruit weight and locules per fruit, additive gene action was in preponderance.

Keywords: Bacterial wilt, combining ability, gene action, *Solanum lycopersicum*, tomato.

Introduction

Tomato (*Solanum lycopersicum* L.) is world's the largest vegetable crop after potato and sweet potato and also tops the list of processed vegetables (Choudhury 1996). Its production has increased tremendously due to its multifarious uses like raw for salad, cooked as vegetable and processed in many forms as soup, sauces, ketchups, preserves, paste and puree (Tiwari and Choudhury 1986). Tomatoes from Himachal Pradesh fetch higher premium in northern plains during raining season. Over the last two decades the area and production of tomato in Himachal Pradesh has increased manifolds and presently it is being grown in about 9,600 hectares with a production of 3,36,300 tonnes (Anonymous 2009-10).

Tomato cultivation in many potential pockets of India has suffered a serious set-back due to bacterial wilt disease (*Ralstonia solanacearum*). Being soil borne in nature only the genetic resistance to the disease in the cultivars/hybrids is of practical significance. Hybrids are preferred over pure lines varieties in tomato on account of their superiority in marketable fruit yield, component traits and fruit quality. The success of any breeding programme lies in the choice of appropriate parents and the breeding method. The combining ability analysis facilitates the partitioning of genotypic variation of crosses into variation due to general combining ability (main effects) and specific combining ability (interactions), which are the measures of additive and non-additive gene actions, respectively. The common approach of choosing the parents on the basis of performance, adaptation and genetic variability does not necessarily lead to useful results. This is because of the differential ability of the parents, which depends upon the complex interactions among the genes and cannot be judged by *per se* performance alone (Allard 1960). The parents which perform well in the cross combinations are of great importance to the breeders. Thus, the investigation of the general and specific combining ability analysis is very useful in the selection of parents and the formulation of an appropriate crossing plan. Among the various methods to estimate combining ability, top cross (inbred x variety) or line x tester method (Kempthorne 1957) is very useful in screening the parental lines by attempting less number of crosses.

Materials and Methods

The experimental material comprising 28 F_1s (developed in 'line x tester' mating design by crossing 7 determinate

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lines *viz.,* 1-2 (L_1), CLN2116B(L_2), BL333-3(L_3), BWR-5(L_4), 17-2(L_5), 15-2(L_6), 7-2(L_7) with 4 indeterminate testers *viz.,* Palam Pride(T_1), 12-1(T_2), 16-B(T_3) and CLN1314G(T_4) alongwith parents were transplanted in bacterial wilt sick plots consecutively for two years (7th April, 2009 and 2nd March, 2010) in Randomized Block Design (RBD) with three replications at the Vegetable Research Farm (32°6' N latitude, 76°3' E longitude and 1290.8 m altitude), Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. All the lines and testers were resistant to bacterial wilt disease. Each entry was grown in a single row of 3.15 m length. The plants were spaced at 75 cm row to row and 45 cm plant to plant. Two susceptible checks, Solan Gola and Roma were transplanted as every 11th row to ensure uniform presence of the inoculum of bacterial wilt disease in the experimental fields. All the recommended package of practices were followed to raise the healthy crop. The data were recorded for the characters *viz.*, bacterial wilt disease incidence, days to 50% flowering, days to first harvest, gross yield per plant, marketable yield per plant (kg), total number of fruits per plant, marketable fruits per plant, fruit weight (g), fruit shape index, pericarp thickness (mm), locules per fruit, plant height, harvest duration and TSS in each entry and replication. Statistical analysis was carried by using the following model suggested by Kempthorne (1957)

Results and Discussion

Keeping in view the bulk of data, the results of major findings have been discussed for pooled analysis over both years of study only.

Analysis of variance for combining ability

To concise the paper, the results have been discussed for pooled environment only. The line x tester analysis revealed significant differences due to lines, testers and line x tester interactions in pooled environment for most of the traits, when tested against error mean squares, indicating appreciable diversity in the experimental material (Table 1). The interactions of lines, testers and line x tester with environment exhibited significant differences for days to 50 per cent flowering, gross yield per plant, marketable yield per plant and total and marketable fruits per plant and non-significant for fruit shape index, pericarp thickness, plant height and harvest duration. Variable interactions were significant for the traits days to first harvest (tester x environment and line x tester x environment), fruit weight (line x environment and tester x environment) and locules per fruit and TSS (tester x environment). This shows the importance of testing parents as well as hybrids across environments especially for the traits expressing significant interaction with environment.

General combining ability (GCA) effects

For marketable fruit yield per plant and component traits, the lines 7-2(L_7) and BWR-5(L_4) and the testers 16-B (T_3) and CLN1314G (T_4) were found to be the best general combiners. L_7 was good general combiner for gross yield per plant, total number of fruits per plant, marketable fruits per plant, marketable yield per plant and plant height in pooled environment (Table 2). The line L_4 had good GCA for gross yield per plant, fruit weight, marketable yield per plant and locules per fruit in pooled environments. Similarly, the tester T_3 was

Table 1: Analysis of variance for combining ability in pooled over environments:

Source of variation →	Crosses	Lines (L)	Testers (T)	Line x Tester	Env. (E)	Rep/ Loc.	LxE	TxE	LxTxE	Error (E_P)
Characters df →	27	6	3	18	1	4	6	3	18	108
Days to 50% flowering	18.10*	24.41*	44.98@*	11.52*	4160.10*	48.60*	27.65*	39.78@*	9.46*	5.27
Days to first harvest	23.66*	29.26*	79.88@*	12.42	2079.01*	50.99*	9.54	48.00*	21.18*	9.61
Gross yield per plant	0.57*	1.13@*	2.02@*	0.14*	14.34*	1.52*	0.25*	0.33*	0.21*	0.022
Marketable yield per plant	0.51*	0.86*	1.13@*	0.29*	19.63*	0.91*	0.26*	0.36@*	0.10*	0.012
Total number of fruits per plant	441.60*	640.92@*	1731.26@*	160.22*	4120.26*	1091.66*	149.76*	212.51*	115.00*	11.64
Marketable fruits per plant	338.31*	349.35*	1651.78@*	115.72*	6958.59*	600.39	65.85*	138.91@*	41.21*	7.17
Fruit weight	941.68*	1531.09@*	4389.74@*	170.53*	68.46	131.15*	88.09*	200.29@*	36.54	24.30
Fruit shape index	0.04*	0.036@*	0.25@*	0.004	0.03*	0.004	0.01	0.01	0.002	0.003
Pericarp thickness	0.51*	0.61*	0.24	0.52*	0.01	1.32*	0.13	0.20	0.15	0.19
Locules per fruit	1.96*	4.14@*	7.61@*	0.29*	0.71*	3.78*	0.05	0.44@*	0.11	0.08
Plant height	317.06*	460.86*	564.62@*	227.88*	1189.92*	53.42	65.96	93.78	34.79	67.18
Harvest duration	-	93.68*	110.42*	167.91*	70.73	75.36*	4.48	2.41	3.98	22.52
TSS	0.29*	0.88@*	0.03	0.13	0.02	0.024	0.08	0.65@*	0.034	0.09

* Significant at 5% level of significance when tested against MSS due to error

@ Significant at 5% level of significance when tested against MSS due to line x tester/ line x tester x environment interactions

Table 2: Estimates of GCA effects of lines and testers in pooled over environments

	lines/testers → Characters ↓	L_1	L_2	L_3	L_4	L_5	L_6	L_7	CD-lines (5%)	T_1	T_2	T_3	T_4	CD-Testers (5%)
1.	Days to 50% flowering	1.49*	-0.38	0.54	-0.30	0.66	-1.67*	-0.34	1.31	-0.60	1.55*	-0.55	-0.40	0.99
2.	Days to first harvest	-1.32*	-0.65	1.73*	1.02	0.31	-1.02	-0.07	1.77	-0.79	2.07*	-0.60	-0.67	1.35
3.	Gross yield per plant	-0.26*	-0.01	-0.13*	0.36*	0.11*	-0.19*	0.13*	0.08	-0.30*	0.01	0.07*	0.22*	0.06
4.	Marketable yield per plant	-0.23*	-0.04*	0.02	0.27*	0.05*	-0.24*	0.18*	0.06	-0.22*	-0.02	0.15*	0.09*	0.04
5.	Total number of fruits per plant	-7.27*	1.41	-1.38	-0.69	-2.84*	1.08	9.69*	1.94	-5.30*	2.47*	7.95*	-5.12*	1.47
6.	Marketable fruits per plant	-4.64*	0.66	0.78	-1.67*	-2.75*	0.24	7.37*	1.53	-5.25*	2.48*	7.73*	-4.96*	1.15
7.	Fruit weight	0.83	-2.02*	-1.55	12.80*	7.14*	-11.1*	-6.09*	2.82	2.16*	-6.29*	-9.35*	13.49*	2.14
8.	Fruit shape index	0.05*	0.00	-0.03*	-0.05*	0.05*	-0.01	0.00	0.04	-0.03*	0.05*	0.08*	-0.09*	0.24
9.	Pericarp thickness	-0.10	-0.19*	0.29*	0.00	0.06	-0.13	0.06	0.25	-	-	-	-	-
10.	Locules per fruit	-0.23*	0.07	-0.17*	0.91*	-0.23*	-0.08	-0.26*	0.16	0.37*	-0.35*	-0.38*	0.37*	0.12
11.	Plant height(cm)	-7.02*	2.71	4.41*	-0.01	-0.84	-4.00*	4.75*	4.70	-3.68*	4.69*	0.96	-1.97	3.55
12.	Harvest duration	2.55*	0.80	0.14	-4.24*	0.35	-0.86	1.26	2.72	1.39	-1.95*	2.03*	-1.47*	2.06
13.	TSS	-0.03	0.24*	0.13*	-0.25*	-0.23*	0.16*	-0.02	0.18	-	-	-	-	-

*Significant at 5% level of significance

L_1= 1-2 L_2=CLN2116B L_3 = BL333-3 L_4= BWR-5 L_5=17-2 L_6= 15-2 L_7= 7-2

T_1= Palam Pride T_2= 12-1 T_3= 16-B T_4= CLN1314G

found to be good general combiner for a number of traits *viz.*, total number of fruits per plant, marketable yield per plant, marketable fruits per plant, fruit shape index, gross yield per plant and harvest duration in pooled environment while T_4 for gross yield per plant, fruit weight, locules per fruit and marketable yield per plant in pooled environment. Although the line L_6 was a good general combiner for days to 50 per cent flowering but was a poor combiner for marketable yield per plant. The lines L_7 (7-2) and L_4 (BWR-5) and the testers T_3 (16-B) and T_4 (CLNI314G) besides being good general combiners for marketable yield and component traits were average combiners for the traits associated with earliness and hence, deserve to be included in crossing programme so as to develop promising pure lines/ inbreds. Different parental lines and testers expressing significant positive and negative and also non-significant GCA effects in respect of yield and component traits in tomato have also been reported earlier by Rattan *et al.* (2007), Sharma *et al.*(2007) and Saidi *et al.* (2008).

Specific combining ability (SCA) effects

For marketable yield per plant, desirable SCA effects were recorded in 8 cross combinations in pooled environment (Table 3). The hybrids L_4 x T_3, L_5 x T_4 and L_7 x T_1 were observed consistently good combinations over both the environments. The cross combination L_4 x T_3 (BWR-5 x 16-B) also revealed significant desirable SCA effects in component traits *viz.,* gross yield per plant, total number of fruits per plant, marketable fruits per plant, pericarp thickness, plant height and harvest duration in pooled environment. Majority of the cross combinations exhibiting desirable SCA effects, had atleast one of the parents as either good or average general combiners. In some of the crosses, significant SCA effects were observed but they had both the parents as poor general combiners. These cross combinations were L_3 x T_1 for gross yield per plant, L_1 x T_4 for total number of fruits per plant, L_6 x T_3 for fruit weight and L_1 x T_3 for locules per fruit in pooled environment. Sometimes, due to specific interaction effects (most likely complimentary), poor x poor crosses may prove better than good x good and good x poor combinations. The better performance of the cross having poor x poor general combiners as parents suggests that high magnitude of non-additive component was responsible for the superiority of the pertinent cross combination. Similar views have also been expressed by earlier researchers, Chadha *et al.* (2002), Rattan *et al.* (2007), Sharma *et al.* (2007), Chishti *et al.* (2008) and Saidi *et al.* (2008).

Genetic components of variances

Based on pooled environment analysis, the estimates of s^2 SCA were higher for the traits days to 50 per cent flowering, marketable yield per plant, pericarp thickness, plant height, harvest duration and TSS, whereas, s^2GCA (average) were higher for the traits days to first harvest, gross yield per plant, total number of fruits per plant, marketable fruits per plant, fruit weight and locules per fruit (Table 4). The estimates of s^2 SCA were equal to the s^2GCA (average) for the trait fruit shape index. Except for the trait TSS, there was complete correspondence between s^2 SCA and s^2 D (non-additive

Table 3: Estimates of SCA effects of crosses in pooled over environments

Characters → Crosses ↓	Days to 50 per cent flowering	Gross yield per plant	Marketable yield per plant	Total number of fruits per plant	Marketable fruits per plant	Fruit weight	Pericarp thickness	Locules per fruit	Plant height	Harvest duration
L_1 x T_1	-0.78	0.01	0.02	1.33	0.28	-1.35	0.06	-0.41*	-7.22*	4.45*
L_1 x T_2	-1.76	-0.04	-0.09*	-0.20	-0.75	0.66	-0.09	-0.18	5.87	1.28
L_1 x T_3	1.17	-0.05	0.06	-5.13*	-1.09	2.75	-0.17	0.46*	5.50	-3.70
L_1 x T_4	1.36	0.08	0.01	4.00*	1.57	-2.05	0.21	0.13	-4.14	-2.03
L_2 x T_1	-0.40	-0.20*	-0.42*	-9.37*	-8.92*	0.07	-0.03	0.15	4.02	-6.47*
L_2 x T_2	0.62	0.06	0.28*	5.35*	5.41*	0.59	-0.01	-0.08	-3.33	0.86
L_2 x T_3	1.71	0.33*	0.18*	8.16*	4.85*	-1.24	-0.14	0.07	3.06	3.22
L_2 x T_4	-1.93*	-0.18*	-0.03	-4.14*	-1.35	0.59	0.18	-0.15	-3.75	2.39
L_3 x T_1	-0.99	0.12*	0.10*	-1.19	-0.53	3.84	0.38*	0.02	-4.00	0.86
L_3 x T_2	-0.80	-0.07	-0.20*	-1.27	-4.10*	0.21	-0.40*	0.10	6.60	-2.97
L_3 x T_3	-0.70	-0.05	0.16*	2.24	4.60*	0.42	-0.01	-0.06	-11.41*	-2.11
L_3 x T_4	2.49*	0.00	-0.07	0.22	0.03	-4.47*	0.03	-0.06	8.82*	4.22*
L_4 x T_1	0.51	-0.07	-0.02	-3.96*	-1.60	5.36*	-0.37*	0.28*	-2.08	-1.26
L_4 x T_2	1.04	0.00	0.04	-0.31	-0.58	1.37	0.29	0.12	-3.07	0.90
L_4 x T_3	-1.37	0.16*	0.26*	5.86*	3.94*	-2.38	0.45*	-0.42*	7.59*	2.76
L_4 x T_4	-0.18	-0.10	-0.28*	-1.58	-1.76	-4.35*	-0.37*	0.03	-2.45	-2.40
L_5 x T_1	0.39	-0.09	0.08	0.55	-0.07	5.43*	0.33	0.04	2.68	-2.51
L_5 x T_2	0.91	0.19*	-0.02	2.76*	1.00	-3.93	0.18	-0.05	-2.25	-2.85
L_5 x T_3	0.01	-0.22*	-0.27*	-3.20*	-3.09*	-5.50*	-0.39*	-0.09	-4.70	2.68
L_5 x T_4	-1.30	0.12*	0.20*	-0.12	2.16	4.00*	-0.12	0.10	4.27	2.68
L_6 x T_1	-0.61	0.10	0.00	4.66*	3.21*	-6.75*	-0.34	0.00	0.59	4.70*
L_6 x T_2	-0.09	-0.10	-0.05	-3.35*	-1.87	4.11*	0.11	-0.11	-4.75	1.53
L_6 x T_3	0.17	-0.05	-0.01	-5.02*	-3.95*	7.36*	0.29	0.05	1.43	-3.78
L_6 x T_4	0.53	0.05	0.06	3.71*	2.61*	-4.72*	-0.06	0.05	2.74	-2.45
L_7 x T_1	1.89*	0.13*	0.24*	7.99*	7.64*	-6.60*	-0.03	-0.09	6.01	0.24
L_7 x T_2	0.08	-0.05	0.04	-2.98*	0.89	-2.99	-0.07	0.20	0.94	1.24
L_7 x T_3	-0.99	-0.12*	-0.38*	-2.91*	-5.26*	-1.40	-0.04	-0.02	-1.47	0.93
L_7 x T_4	-0.97	0.03	0.10*	-2.09	-3.26*	10.99*	0.14	-0.10	-5.48	-2.40
CD (5%)	2.64	0.18	0.12	3.97	3.08	5.65	0.50	0.32	9.39	5.44

gene action) and s^2GCA (average) and s^2 A (additive gene action). As per pooled environment analysis, the per cent contribution of lines was higher for the traits gross yield per plant, locules per fruit and TSS. Testers contributed more for the traits days to first harvest, total number of fruits per plant, marketable fruits per plant, fruit weight and fruit shape index whereas, per cent contribution of interaction (crosses) was higher for the traits days to 50 per cent flowering, marketable yield per plant, pericarp thickness, plant height and harvest duration. A complete correspondence was noticed between per cent contribution of interaction (crosses) and non-additive gene action (s^2D) in the traits days to 50 per cent flowering, marketable yield per plant,

Table 4: Estimation of genetic components of variances and proportional (%) contribution of lines, testers and their interactions in pooled over environments

	Characters	σ^2 GCA lines	σ^2 GCA testers	σ^2 GCA average	σ^2 GCA (lines x env.)	σ^2 GCA (testers x env.)	σ^2 SCA crosses	σ^2 SCA (crosses x env.)	σ^2A	σ^2 D	% Contribution		
											lines	testers	Interaction
1.	Days to first 50% flowering	-0.22	0.08	-0.03	1.52	1.44	0.68	1.40	-0.06	1.04	29.97	27.62	42.41
2.	Days to first harvest	1.19	0.97	1.05	-0.97	1.28	-2.92	3.86	2.09	0.47	27.49	37.52	35.00
3.	Gross yield/plant	0.04	0.04	0.04	0.00	0.01	-0.02	0.06	0.08	0.02	44.13	39.44	16.43
4.	Marketable yield / plant	0.02	0.01	0.02	0.01	0.01	0.06	0.03	0.03	0.05	37.42	24.58	38.00
5.	Total number of fruits/plant	18.58	35.08	29.08	2.90	4.64	15.07	34.55	58.17	24.81	32.25	43.56	24.19
6.	Marketable fruits per plant	8.71	34.25	24.96	2.05	4.65	24.84	11.35	49.92	18.09	22.95	54.25	22.80
7.	Fruit weight	54.54	96.56	81.28	4.30	7.80	44.66	4.08	162.56	24.37	36.13	51.80	12.07
8.	Fruit shape index	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	21.15	73.08	6.15
9.	Pericarp thickness	0.00	-0.01	-0.001	0.00	0.00	0.12	0.01	-0.01	0.05	26.92	5.12	67.86
10.	Locules per fruit	0.16	0.17	0.17	0.00	0.02	0.06	0.01	0.33	0.03	47.00	43.15	9.83
11.	Plant height	8.41	6.61	7.27	25.98	28.09	64.36	107.95	14.53	26.78	32.30	19.79	47.91
12.	Harvest duration	1.43	2.23	1.94	0.04	-0.08	2.39	6.18	3.88	8.87	26.19	19.92	53.89
13.	TSS	0.03	0.00	0.01	0.00	0.00	0.03	0.02	0.02	0.01	68.40	0.99	30.69

pericarp thickness, plant height and harvest duration.

The results of the gene action studies of the present investigation reaffirm the importance of hybrids in tomato. However, additive gene action (s^2A) was higher for the traits days to first harvest, gross yield per plant, total and marketable fruits per plant, fruit weight, fruit shape index, locules per fruit and TSS, which could be exploited by developing superior pure lines/inbreds through hybridization and biparental mating followed by selection.

References

Allard RW (1960) *Principles of Plant Breeding*. John Wiley and Sons, Inc. New York, London. p 485.

Anonymous (2009-10) Area and Production of Vegetables in Himachal Pradesh Directorate of Agriculture (H.P.), Shimla-5.

Chadha S, Vidyasagar and Kumar J (2002) Combining ability and gene action studies for some fruit characters in bacterial wilt resistant tomato lines. South Indian Hort 50(1-3): 65-71.

Chishti SAS, Khan AA, Bushra S and Khan IA (2008) Analysis of combining ability for yield, yield components and quality characters in tomato (*Lycopersicon esculentum* Mill.). J Agric Res 46(4): 325-332.

Choudhury B (1996) *Vegetables*. National Book Trust of India, New Delhi. p 214.

Kempthorne O (1957) *An introduction to Genetic Statistics*. John Wiley and Sons, New York. pp 458-471.

Rattan P, Vidyasagar and Kumar S (2007) Line x tester analysis for combining ability studies involving bacterial wilt resistant genotypes of tomato (*Lycopersicon esculentum* Mill.). Haryana J Hort Sci 36(1-2): 158-161.

Saidi M, Warade SD and Prabu T (2008) Combining ability estimates for yield and its contributing traits in tomato (*Lycopersicon esculentum*). International J Agric and Biol 10(2): 236-240.

Sharma P, Vidyasagar and Bhardwaj N (2007) Combining ability in bacterial wilt resistant genotypes of tomato. Environ and Ecol 25(1): 196-200.

Tiwari RN and Choudhury B (1986) Solanaceous Crops, Tomato. In: *Vegetable Crops in India* (TK Bose and MG Som eds), Naya Prokash, Calcutta. pp 248-290.