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Genotypes x environment interaction studies on early blight disease of tomato

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Abstract

Experiments were conducted for three years to study the interaction between tomato genotypes and environment against early blight disease caused by *Alternaria solani*. Fifty one genetically diverse genotypes of tomato were screened in field conditions against early blight in Rabi season of 2006-09 at Indian Institute of Vegetable Research, Varanasi, India. Results revealed that genotype LA-3980 was resistant while, EC-520058, EC-520060, EC-520061, EC-520070, EC-521080, WIR-3928 and H-88-78-1 were highly resistant. All the resistant and highly resistant lines belong to wild species except H-88-78-1 and LA-3980. Only three genotypes, EC-520061, EC-520070 and H-88-78-1 were stable in each environment for resistance to early blight disease in tomato. Relationship of environment with resistant genotypes indicated that EC-520061, EC-520070, WIR-3928 and H-88-78-1 had low regression coefficient (b<1) and low deviation from regression (sd^2=<1) than others (b= >1and sd^2=>1) indicating stable and adaptive genotypic resistance to early blight. Hence these genotypes may be used as donor parent for development of early blight resistant/ tolerant varieties / lines.

Key words: Tomato, *Solanum lycopersicum*, early blight, *Alternaria solani*, percent disease incidence (PDI), area under disease progress curve (AUDPC)

Introduction

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crop grown worldwide. In India, among several biotic and abiotic stresses, early blight disease caused by *Alternaria solani* is second devastating malady after *Tomato leaf curl virus* (ToLCV). Symptoms of early blight disease includes stem lesions, foliage collar rot and fruit rot and in severe stages, disease lead complete defoliation (Peralta *et al.,* 2005). The yield loss in tomato has been reported 78% at disease intensity of 72% and with each 1% increase in intensity, it reduced tomato yield by 1.36% (Datar and Mayee, 1981). Management of early blight through chemicals is not much effective under the weather conditions favourable for epidemics. Moreover, spraying fungicides is not feasible because the disease always appears at fruit maturity. Growing resistant varieties is the one of the most effective and feasible alternative for early blight management. Heavy rainfall, humidity and high temperature (24-29 ^oC) favour the disease epidemics. The disease epidemic also occurs in semi arid climates where night dew takes place (Rotem and Reichert, 1964). Some tolerant/resistant cultivars like PI134417, P-1, H-7, H-22 and H-25 (Datar and Lonkar, 1985; Kalloo and Banerjee, 1993) and wild species *L. pimpinellifolium, L. hirsutum, L. glandulossum* (Datar and Mayee, 1980; Locke, 1949) are reported. The resistance of early blight is conferred by recessive and partially dominant polygenes, conferring resistance with complicated epistatic effects (Thirthamallappa and Lohitaswa, 2000). Natural epidemics of early blight are greatly influenced by environmental condition, even though severe disease appears every year in Northern India (Pandey *et al.,* 2003).

Therefore, the present investigation was carried out to identify the stable sources of resistance to early blight (EB) disease under different environmental (year) conditions.

Materials and methods

Experimental site: The study was carried out at vegetable research farm, Indian Institute of Vegetable Research (IIVR), Varanasi situated at 82.52^oE longitude and 25.10^oN latitude at an elevation of 128.93 m from mean sea level (MSL). The experimental area is located under semi-arid region with an annual mean rainfall of approximately 1113.3 mm and mean minimum/maximum (18/24 ^oC) temperature. The soil is loam with pH of 7.5 and the textural class is well drained.

Experimental material/design and management: Fifty one genetically diverse tomato genotypes, selected from the germplasm stock of cultivars (*Solanum lycopersicum*) and wild species maintained at IIVR, and field trial was conducted during main cropping season (October to March) of tomato for three consecutive years, 2006-2007, 2007-2008 and 2008-2009. The experiment was arranged in a randomized complete block design (RCBD) with three replications and each replication had 20 plants. Each genotype was planted at the spacing of 60 cm and 45 cm for row to row and plant to plant, respectively. Insecticide and fungicide were not applied during the course of the experiments. During the course of this experiment, all recommended agronomical practices were followed for raising a good crop.

Data observation and statistical analysis: Early blight disease appearance was recorded at 15 days intervals on 45, 60, 75 and 90 days after transplanting, till the crop survived. The disease severity was scored on a five-point scale (Table 1) as described by Pandey *et al.* (2003). The scored data of 15, 30, 45 and 60 days was averaged and only pooled, average PDI & AUDPC value for each year was used. The disease severity, percentage disease

Table 1. Early blight disease score on 0-5 point severity scale

Severity grade	Severity scale	Reaction	Symptom
0	0-5%	Highly resistant	Free from infection
1	5.1-12%	Resistant	One or two necrotic spots on a few lower leaves of plant.
2	12.1-25%	Moderately resistant	A few isolated spots on leaves, covering nearly 5-10% of the surface area of the plant.
3	25.1-50%	Moderately susceptible	Many spots coalesced on the leaves, covering 25% of the surface area of the plant.
4	50.1-75%	Susceptible	Irregular, blighted leaves and sunken lesions with prominent concentric rings on the stem, petiole, and fruit, covering 40-50% of the surface area.
5	>75%	Highly susceptible	Whole plant blighted; leaves and fruits starting to fall foliar part free of disease.

index (PDI), area under disease progression curve (AUDPC) were calculated by the following formula:

$$PDI = \frac{\text{Sum of all ratings x 100}}{\text{Total number of observations x maximum rating grade}}$$

$$AUDPC = \sum_{i=1}^{n-1}[(\frac{X_{i+1}+X_i}{2})*(t_2-t_1)]$$

Where X_i is the disease index expressed as a proportion at the i^{th} observation; t_i is the time (days after planting) at the observations; and n is the total number of observations.

Stability analysis: For isolation of stable genotypes against EB resistance, the data was first subjected to the analysis of variance to test the significance of genotypes x environment interaction. Analysis of variance for G x E effect, stability parameter *i.e.* regression coefficient (b) and deviation from regression (sd^2) were estimated as per model proposed by Eberhart and Russell (1966).

Characterization was undertaken for three years on the same pattern as per "Descriptors for tomato". Measurements were taken chronologically, on days to first fruiting (recorded after first flowering), plant height, branch number, fruit weight, number of fruit per plant and yield per plant were observed during harvesting of crops. Randomly 10 plants were selected from each replication of each genotype for recording plant height, numbers of primary branches, number of fruits per plant, average fruit weight and fruit yield per plant.

Results and discussion

Data presented in Table 2 indicated that out of 45 genotypes, most of the genotypes belonging to cultivated species *S. lycopersicum* except H-88-78-1 and LA-3980, were expressed as moderately susceptible to highly susceptible with PDI and AUDPC value range (40.36-1831.95 to 70.66-3240.83). However, six genotypes *viz.*, EC-520058, EC-520060 and EC-520061 (*S. habrochaites),* EC-520070 and EC-521080 (*S. pimpinellifolium*) and WIR-3928 (*S. glandulossum*) belonging to wild species were highly resistant.

In present investigation, it was observed that the genotypes as derivative of *S. habrochaites, S. pimpinellifolium and S. glandulossum,* were found highly resistant to EB which is inconsonance with the earlier findings of Loke (1949) and Gardner (1984). The highly resistant (H-88-78-1) and resistant (LA-3980) genotypes belong to *S. lycopersicum.* Limited major resistance gene has been identified for early blight in tomato cultivars *e.g.* P-1, H-7, H-22 and H-25 (Kalloo and Banerjee, 1993), ATH-1, ATH- 2, Samridhi and Vaishali (Mate *et al.,* 2005)**,** Columbia, Ace and Flora Dade (Chhabra *et al.,* 2000), NCEBR 1 (Gardener, 1987) and H-88-78-1 (Singh *et al.,* 2012) and there is limited pathogen race specificity (Pandey *et al.,* 2003). Whereas sources of genetic resistance to *A. solani* have been identified within the related wild species of tomato and were utilized in traditional breeding program (Cherani *et al.*, 2007). The highly resistant genotypes *viz.*, EC-520058, EC-520060, EC-520061, EC-520070, EC-521080, WIR-3928, H-88-78-1 and LA-3980 exhibited low PDI and AUDPC due to indeterminate growth and more number of primary branches. Johanson and Thurston (1990) observed that tomato genotypes which were indeterminate in growth causing continuous emergence of new leaves with late fruiting or late maturing exhibited high resistance to EB. In contrast, the susceptible lines, DVRT-2, Sel-18, Sel-7, Punjab Chhuhara and CO-3 showed high PDI and high AUDPC values and were early in flowering and fruiting (38, 37, 38, 35 and 33 days, respectively) with determinate growth and less number of branches (Table 2). This may be associated with early senescence of plants. Pandey *et al.* (2003) also reported that early maturing with determinate growth genotypes were more susceptible and early blight develops quickly during natural epidemics at the time of fruit set and adversely affects the yield. An analysis of variance

Table 3. Analysis of variance for 7 highly resistant tomato genotypes against early blight

Source of variations	df	Sum of squares	Mean squares	F ratio
Genotypes (G)	6	76.84	12.81	1.10
Environments (E)	2	4.56	2.28	0.18
E+ (G x E)	14	143.82	10.27	1.05
G x E	12	139.25	11.60	1.19
E (Linear)	1	4.56	4.56	0.47
G x E (Linear)	6	70.73	11.79	1.20
Pooled Deviation	7	68.53	9.79	110.07***
Pooled Error	36	3.21	0.09	

*** = Significant at $P<0.001$

Table 4. Stability analysis of seven highly resistant genotypes for EB within three environments

Genotypes	PDI Mean	ßi	S^2Di
EC-520058	5.0011	5.845	30.8609 ***
EC-520060	3.5711	7.900	35.7602 ***
EC-520061	0.0000	0.000*	-0.0927
EC-520070	0.0000	0.000*	-0.0927
H-88-78-1	0.8000	-2.324	0.2281
EC-521080	2.3778	-3.589	1.2730 ***
WIR-3928	4.2667	-0.832	-0.0610
Total		7.000	

*Significant at $P<0.05$, ***Significant at $P<0.001$, Population Mean: 2.29, Std. Err. Mean: 2.21, bi Mean: 1.00, Std. Err. bi: 3.88

Table 2. Response of tomato genotypes against early blight disease and yield components

Early blight screening			Parameters								
Reaction	Disease scale	Genotypes	PDI	AUDPC	Plant growth habit	Plant height (cm)	Branch number	Days to first fruiting	Number of fruits	Fruit weight (g)	Fruit yield/ plant (kg)
Highly resistant	0-5	EC-520058	0	0	ID	308**	14**	75**	485**	6**	2.91**
		EC-520060	0	0	ID	300**	13**	72**	494**	5*	2.47**
		EC-520061	0	0	ID	315**	15**	75**	545**	6**	3.27**
		EC-520070	0	0	ID	200**	10**	65**	894**	5*	4.47**
		H-88-78-1	3.0	3.0	ID	167**	6**	52**	85**	20**	1.70**
		EC-521080	4.4	4.4	ID	180**	9**	60**	1065**	4	4.26**
		WIR-3928	4.8	4.8	ID	175**	8**	55**	378**	10**	3.78**
Resistant	5.1-12	LA-3980	10.6	472.2	ID	158**	7**	50**	146**	23**	3.36**
Moderately Resistant	12.1-25	NIL									
Moderately Susceptible	25.1-50	H-88-78-2	40.4	1832.0	ID	95**	5**	65**	24**	180**	4.32**
		LA-4040-1	44.9	2023.6	D	93**	5**	45**	56**	45**	2.52**
		Tura Local	43.6	1971.9	ID	115**	7**	45**	68**	15**	1.02**
		Meghalaya Local	39.1	1722.4	ID	105**	6**	40**	54**	35**	1.89**
		Palam Pink	42.9	1923.2	D	62**	5**	42**	28**	128**	3.58**
		Feb-4	46.3	2096.4	D	68**	4**	42**	44**	50**	2.20**
		Flora Dade	44.6	2009.9	D	65**	5**	45**	33**	98**	3.23**
		LA-4055	46.6	2121.8	D	90**	6**	38**	47**	26**	1.22**
		Nandi	49.4	2278.2	ID	110**	7**	41**	73**	18**	1.31**
		IIHR-2195	42.3	1910.0	ID	108**	6**	39**	52**	14**	0.73**
		IIHR-2201	46.2	2090.1	ID	104**	6**	37**	47**	22**	1.03**
		Sankranti	40.6	1850.4	ID	98**	6**	42**	42**	25**	1.05**
		TLBR-3	45.2	2061.8	ID	74**	5**	34**	29**	56**	1.62**
		FLA-7421	49.3	2243.0	D	68**	4**	36**	27**	80**	2.16**
		H-88-87	36.9	1661.2	ID	108**	6**	41**	53**	15**	0.80**
		PKM-1	45.3	2070.4	D	63**	4**	46**	24**	60**	1.44**
		Roma	48.6	2241.2	D	65**	4**	40**	21**	65**	1.37**
		KT-15	43.7	1997.0	D	93**	5**	40**	44**	35**	1.54**
		Shalimar-2	46.2	2108.8	D	54**	3**	47**	15**	20**	0.30**
		Agata-30	46.0	2087.6	D	63**	4**	39**	38**	35**	1.33**
		Feb - 2	43.6	1883.9	D	53**	4**	42**	29**	58**	1.68**
		FLA-7171	46.3	2111.1	D	64**	4**	41**	27**	56**	1.51**
		TLBR-4	36.7	1716.9	D	68**	4**	45**	23**	50**	1.15**
		TLBR-2	31.9	1444.5	D	51**	4**	42**	15**	62**	0.93**
		TLBR-12	41.6	1967.5	D	60**	4**	44**	19**	65**	1.24**
		F-5070	48.6	2227.9	D	70**	5**	45**	24**	42**	1.01**
		TLBR-8	49.9	2299.2	D	62**	4**	37**	37**	55**	2.04**
		H-88-78-4	41.4	1884.2	D	72**	4**	45**	42**	40**	1.68**
		DVRT-1	45.7	2072.8	D	57**	4**	41**	21**	55**	1.16**
		Cherry Tomato	46.4	2103.5	ID	85**	5**	45**	56**	15**	0.84**
		Sun Cherry	48.8	2210.5	ID	114**	6**	40**	68**	12**	0.82**
		LA-3999	35.6	1626.4	D	67**	4**	39**	35**	28**	0.98**
Susceptible	50.1-75	H-86	52.9	2395.4	D	58**	4**	46**	29**	110**	3.05**
		Punjab Chhuhara	65.5	3021.9	D	54**	4**	35**	20**	53**	1.06**
		Agata-32	51.9	2409.6	D	65**	4**	41**	26**	42**	1.09**
		DVRT-2	57.2	2601.3	D	60**	4**	38**	21**	160**	3.36**
		Sikkim Local	50.7	2304.6	ID	100**	5**	42**	43**	15**	0.65**
		Sel-18	58.7	2674.1	D	72**	5**	37**	32**	62**	1.98**
		H-24	52.0	1230.6	D	80**	5**	48**	42**	45**	1.89**
		CO-3	70.7	3240.8	D	56**	4**	33**	22**	125**	2.75**
		Sel-7	59.6	2731.5	D	60**	4**	38**	38**	85**	3.23**
		Vaibhav	50.5	2285.2	D	75**	6**	36**	48**	65**	3.12**
		IIHR-2200	53.2	2428.8	ID	92**	6**	42**	53**	25**	1.35**
Highly Susceptible	>75	Nil									
*Significant at $P \leq 0.05$, **Significant at $P \leq 0.01$					SEM	4.99	0.28	2.25	5.57	2.32	0.098

for stability revealed significant differences for early blight disease incidence (PDI) among genotypes and environments (Table 3). The genotypes (G), environments (E), G x E and G x E (Linear) were found non-significant for the PDI when tested against pooled deviation ($P<0.01$). The G x E was partitioned into linear *i.e*., environments and G x E (Linear) and non-linear (pooled deviation) components of variation. The results are in agreement with previous reports on rice by Panwar *et al.* (2008). Mean(x), regression coefficient (bi) and deviation from regression (sd^2) of PDI of individual genotype are given in Table 4 which show relationship of environment with resistant genotypes and revealed that EC-520061, EC-520070, WIR-3928 and H-88-78-1

expressed less regression coefficient (b<1) and low deviation from regression (sd^2=<1) than others (b=>1 and sd^2=>1) indicating stable and adaptive genotypes in each environment for resistant to early blight. According to Eberheart and Russell (1966), regression coefficient less than one coupled with deviation from regression values indicate good stability.

Present study indicate that significant correlations exist between disease incidence and yield traits during field screening for early blight resistance. Weak early blight resistance was observed in the cultivated species of tomato except H-88-78-1 and LA-3980, whereas, strong resistance was detected in the tomato wild relatives *viz.*, EC-520058, EC-520060 and EC-520061 (*S. habrochaites*), EC-520070 and EC-521080 (*S. pimpinellifolium*) and WIR-3928 (*S. glandulossum*). The results of this study also imply that the genotypes EC-520061, EC-520070, WIR-3928 and H-88-78-1 showed low regression coefficient and stability in each environment for early blight resistance and could be further utilized in tomato breeding program for developing early blight resistant varieties.

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