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# DEVELOPMENT OF HIGH YIELDING AND BLIGHT RESISTANT HYBRIDS OF TOMATO

**Muhammad Yussouf Saleem*, Khalid Pervaiz Akhtar, Qumer Iqbal, Muhammad Asghar and Muhammad Shoaib**

**Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan**
***Corresponding author's e-mail: mysaleem1966@gmail.com**

Blight diseases are one of the serious causes of low tomato productively in Pakistan. Two susceptible but high yielding lines Riogrande and Roma were crossed with LB2, LB3, LB4 and LB7 following line x tester mating design to generate 8 $F_1$ hybrids. All genotypes were evaluated to find high yielding and disease resistant combiners and their hybrids against check hybrid T-1359. Whole plant assay elucidated LB2, Roma x LB3 and Roma x LB4 tolerant to late blight. The same assay also expounded LB3, LB4, LB2, LB7 and Riogrande x LB2 tolerant to early blight. Non-additive gene action was observed to control each blight type, fruit length, fruit weight and 1000-seed weight except number of fruits per plant and fruit diameter. Female x male interaction affixed highest place to line x tester interaction by 48% for late blight and 84% for early blight. Riogrande, LB2 and LB7 were good general combiner for tolerance to early blight while Roma and LB3 for late blight. The perusal of high mean performance, specific combining ability effects and commercial heterosis simultaneously led to the isolation of two promising hybrids Roma x LB3, Roma x LB4 for late blight and Riogrande x LB2 for early blight. These three hybrids have been submitted in competitive multi-location field trails to adjudge their yield performance and blight response before commercialization.

**Keywords:** Hybrids, general combining ability, specific combining ability, disease resistance, yield, heterosis

## INTRODUCTION

Tomato (*Solanum lycopersicum*), an important summer vegetable crop is considered as the pillar of kitchen gardening and is always the companion of salads, various foodstuff compositions and sauces (Noureen *et al*., 2010). Although the area under tomato cultivation has been increased from 29 to 52 thousand hectare, yet the average yield has been stagnated within the tune of 9.6 to 10.7 tonne hectare$^{-1}$ during the last decade. It could not have been significantly improved compared to average yield of 34 tonne hectare$^{-1}$ of modern agricultural areas of the world (FAOSTAT, 2011; Jilani *et al*., 2013). Of several factors responsible for low productivity of tomato in Pakistan, susceptibility of extensively grown varieties to early blight (*Alternaria solani*), late blight (*Phytophthora infestans*) and lack of quality seed (hybrid varieties) are major factors. According to an estimate, early blight (EB) and late blight (LB) in epidemic form cause 49 to 91% yield losses in Pakistan (Azam and Shah, 2003; Akhtar *et al*., 2011 and 2012).

In tomato, few race-specific quantitative LB-resistance genes have been identified; *Ph-1*, a single dominant allele effective against race $T_0$ of pathogen mapped on chromosome 7; *Ph-2*, a partially dominant allele highly effective against $T_0$ but partially to race $T_1$ mapped on chromosome 10 and *Ph-3*, a single dominant allele mapped on chromosome 9 effective against isolate Pi-16 from Taiwan that overcomes *Ph*-1 and *Ph*-2 (Irzhansky and Choen, 2006). More recently, a new resistant gene (*Ph*-5) mapped on chromosome 1 has been identified which confers strong resistance to several pathogen isolates including those overcoming the previous resistance (Foolad *et al*., 2008). Early blight has been characterized as a complex quantitative trait, controlled by the additive and non-additive interaction effects of multiple genes (Nash and Gardner, 1988). In some tomato lines, the inheritance of EB resistance was reported as quantitative and recessive (Maiero *et al*., 1990), whereas in other lines as quantitative and partially dominant, with epistasis (Martin and Hepperly, 1987; Gardner, 1988). The narrow sense heritability of EB resistance has been reported low to moderate (Nash and Gardner, 1988)

To tailor with this situation, the current research work was undertaken to develop primarily high yielding and disease resistant hybrids of tomato. Such hybrids could later be released as commercial hybrids in open bidding among seed companies. The outcome of this research will boost socio-economic, health, nutrition and environmental conditions in the country.

## MATERIALS AND METHODS

Two high yielding but blight susceptible genotypes; Riogrande and Roma were crossed with four genotypes namely LB2, LB3, LB4 and LB7 with varying level of

tolerance to early and late blight as per line x tester mating design (Kempthorne, 1957; Arunachalam, 1974). The susceptible genotypes hereafter were designated as female while blight tolerant as male lines. The resultant $8F_1$ hybrids along with parent lines and commercial hybrid T-1359 were evaluated to score the level of resistance to LB and EB *visa vie* T-1359 using detached leaf and whole plant assay in controlled conditions (Akhtar *et al*., 2011 and 2012). Wild type isolate of *Alternaria solani* and *Phytophthora infestans* were obtained from naturally infected tomato plants at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad following the protocol of Akhtar *et al*. (2012). All genotypes were screened for EB and LB resistance through detached leaf and whole plant assays following protocols of Akhtar *et al*. (2011, 2012).

***Evaluation of the material in field conditions:*** Four to six inch long nursery seedlings (6 to 8 leaves) of all genotypes were transplanted at tomato breeding field of Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad in November, 2012 following randomized complete block design (RCBD) with three replications (7 plants per replicate). The experiment was set up keeping plant to plant distance of 0.5 m and bed to bed distance of 1.5 m. Crop remained in field till June, 2013 to record data on number of fruits per plant, fruit length (cm), fruit diameter (cm) and fruit yield (kg plant$^{-1}$) in addition to disease rating. Gene action and combining ability on blight response, yield and yield components were worked out as per line x tester analysis (Kempthorne, 1957; Arunachalam, 1974). Commercial heterosis was estimated according to standard procedures (Nadaranjan and Gunasekaran, 2005). Negative value of combining ability and commercial heterosis over the standard in blight response and vice versa in yield and yield components were taken desirable to select blight resistant and high yielding hybrids.

## RESULTS

Mean performance of test genotypes against commercial hybrid elucidated LB2, Roma x LB3 and Roma x LB4 tolerant to LB through whole plant assay (Table 1). The same assay also expounded LB3, LB4, LB2, LB7 and Riogrande x LB2 tolerant to EB disease. Certain parents and hybrids had varying level of resistance to LB and EB, however, this level was far better over the check T-1359. Worth of genetic variability with considerable expression of extremes; particularly in yield and yield components was observed among the entire genotypes.

Treatment mean squares were highly significant for LB and EB. Partitioning of treatment mean squares into parents, crosses and parent vs. crosses indicated highly significant importance of parents only in each assay of both early and late blight (Table 2). However, their crosses appeared significant in whole plant assays of each disease. Parents vs. crosses were very important in whole plant assay of LB whilst non-significant in whole plant assay of EB. Division of crosses into lines, testers and line x tester interaction showed highly significant differences among lines, testers

**Table 1. Mean performance of test genotypes and commercial hybrid T-1359.**

| Genotypes | Late blight | | Early blight | | Number of fruits per plant | Fruit length (cm) | Fruit diameter (cm) | Fruit yield (kg plant$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | WPA | DLA | WPA | DLA | | | | |
| Riogrande x LB2 | 52.33 de | 3.86cd | 38.33e | 5.00a | 81.33 b | 5.20 d-g | 5.60 def | 6.20 bc |
| Roma x LB2 | 54.00 cde | 3.80cd | 61.67 b | 5.00a | 82.00 b | 5.80 ab | 5.37 f | 6.53 ab |
| Riogrande x LB3 | 53.33 cde | 3.77cd | 50.00 cd | 5.00a | 62.67 cde | 4.97 fgh | 5.77 cd | 6.63 ab |
| Roma x LB3 | 30.00 f | 3.83cd | 55.00 bcd | 5.00a | 60.67 cde | 5.23 d-g | 5.67 de | 5.60 cd |
| Riogrande x LB4 | 66.67 ab | 3.73d | 56.67 bc | 5.00a | 63 cd | 5.33 c-f | 5.97 bc | 6.87 a |
| Roma x LB4 | 38.33 f | 3.86cd | 50 cd | 5.00a | 56.33 e | 5.30 def | 5.53 def | 5.17 de |
| Riogrande x LB7 | 55.00 cde | 4.00bcd | 51.67 cd | 5.00a | 61.33 cde | 5.53 bcd | 5.53 def | 5.10 de |
| Roma x LB7 | 63.33 bc | 3.73cd | 48.33 d | 5.00a | 58.33 de | 4.90 gh | 5.43 ef | 5.40 d |
| Riogrande | 61.67 bcd | 4.47ab | 88.33 a | 3.67c | 67.00 c | 5.70 bc | 4.50 g | 4.60 ef |
| Roma | 75.00 a | 4.67a | 83.33 a | 2.67d | 110.67 a | 6.13 a | 3.83 h | 5.47 d |
| LB2 | 38.33 f | 3.67d | 33.33 ef | 4.00bc | 33.67 fg | 5.27 d-g | 6.33 a | 4.63 ef |
| LB3 | 50.00 e | 3.00e | 30.00 f | 4.67ab | 39.33 f | 5.10 efg | 5.73 cd | 4.03 fg |
| LB4 | 66.67 ab | 3.67d | 31.00 ef | 5.00a | 26.00 h | 5.43 b-e | 6.13 ab | 3.57 gh |
| LB7 | 55 cde | 3.5de | 38.33 e | 5.00a | 27.33 gh | 4.60 h | 6.23 a | 3.07 h |
| T-1359 (Control) | 63.33 bc | 4.33abc | 85.00 a | 5.00a | 66.00 c | 5.70 bc | 4.50 g | 4.13 fg |
| C.V % | 11.16 | 9.01 | 9.27 | 9.47 | 6.67 | 4.12 | 2.67 | 7.26 |
| LSD 5% | 10.24 | 0.58 | 8.28 | 0.74 | 6.66 | 0.37 | 0.24 | 0.65 |
| LSD 1% | 13.81 | 0.78 | 11.17 | 1.00 | 8.99 | 0.50 | 0.33 | 0.88 |

*Values sharing similar letters do not differ significantly; WPA= Whole plant assay; DLA= Detached leaf assay

**Table 2. Mean square for analysis of variance in tomato genotypes.**

| Source of variation | D.F | Late blight | | Early blight | | Number of fruits per plant | Fruit length (cm) | Fruit diameter (cm) | Fruit yield (kg plant$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|
| | | WPA | DLA | WPA | DLA | | | | |
| Replication | 2 | 46.074 | 2.07** | 26.074 | 0.29 | 27.0088 | 0.07 | 0.09 | 0.27 |
| Treatment | 13 | 460.37** | 0.46** | 925.22** | 1.51** | 1598.27** | 0.46** | 1.34** | 3.96** |
| Parents | 5 | 502.22** | 1.17** | 2251.39** | 2.5** | 3262.27** | 0.82** | 3.27** | 2.2** |
| Parents vs. crosses | 1 | 389.38** | 0.00 | 13.0067 | 7.14** | 2327.16** | 0.08 | 0.22** | 30.07** |
| Crosses | 7 | 440.61** | 0.02 | 108.018** | 0.00 | 305.57** | 0.25** | 0.11** | 1.49** |
| Lines | 1 | 651.04** | 0.01 | 84.0038 | 0.00 | 45.0038 | 0.01 | 0.28** | 1.65** |
| Testers | 3 | 318.38** | 0.01 | 12.0015 | 0.00 | 684.004** | 0.17* | 0.13** | 1.39** |
| Lines x Testers | 3 | 492.71** | 0.05 | 212.015** | 0.00 | 13.0082 | 0.41** | 0.04 | 1.53** |
| Error | 26 | 39.023 | 0.12 | 26.0087 | 0.21 | 12.0003 | 0.05 | 0.02 | 0.16 |

*,**=Significant at 0.05 and 0.01 levels of probability, respectively; WPA=Whole plant assay; DLA=Detached leaf assay

**Table 3. Estimates of genetic components in tomato genotypes.**

| Source of variation | LB | EB | Number of fruits / plant | Fruit length (cm) | Fruit diameter (cm) | Fruit yield (kg plant$^{-1}$) |
|---|---|---|---|---|---|---|
| | WPA | WPA | | | | |
| $\sigma^2$GCA | -0.0089 | -18.21 | 38.099 | -0.04 | 0.019 | -0.0007 |
| $\sigma^2$SCA | 151.16 | 61.76 | 0.0059 | 0.12 | 0.005 | 0.0046 |
| $\sigma^2$GCA/$\sigma^2$SCA | -0.001 | -0.029 | 65.054 | -0.29 | 3.804 | -0.0015 |
| $\sigma^2$A | -1.078 | -36.042 | 77.098 | -0.07 | 0.037 | -0.0014 |
| $\sigma^2$D | 151.16 | 61.076 | 0.059 | 0.12 | 0.005 | 0.0046 |
| $\sigma^2$D / $\sigma^2$A | -85.003 | -1.0007 | 0.001 | -1.07 | 0.131 | -335.97 |
| $\sigma^2$g | 140.38 | 299.45 | 528.74 | 0.14 | 0.044 | 1.0027 |
| $\sigma^2$p | 179.61 | 326.32 | 540.78 | 0.19 | 0.046 | 1.0043 |
| $\sigma^2$e | 39.023 | 26.087 | 12.03 | 0.05 | 0.002 | 0.0016 |
| $h^2$b.s±SE | 0.78*±0.03 | 0.92*±0.02 | 0.98*±0.02 | 0.73±0.91 | 0.95*±0.61 | 0.89*±0.34 |
| G.A | 39.77 | 66.046 | 79.04 | 12.15 | 23.97 | 41.097 |
| Contribution of lines (%) | 21.11 | 11.014 | 2.012 | 0.85 | 36.05 | 15.089 |
| Contribution of testers (%) | 30.97 | 4.0081 | 95.94 | 29.25 | 49.03 | 40.007 |
| Contribution of line x testers (%) | 47.92 | 84.004 | 1.094 | 69.91 | 14.47 | 44.004 |

*, ** = Significant at 0.05 and 0.01 levels of probability, respectively; WPA= Whole plant assay

and line x tester interaction for whole plant assay of LB. For the same assay of EB, subdivision of crosses viz. lines and testers were insignificant except line x tester interaction. Crosses presented extremely low and negligible values of variability in detached leaf assays of each disease showing an array of non-significant inferences since subdivisions of crosses into lines, tester and line x tester interactions were entirely non-significant. Therefore, further analysis on detached leaf assay became useless. However, whole plant assay for each disease was further analyzed. Plants of tested genotypes were inoculated at the age of 5-6 weeks and final reading was taken after 7 days when susceptible check showed severe disease symptoms. However, observations were continued throughout the plant growing season to record its response. Worth of variation with varying significance were registered for treatments, parents, crosses, parent vs. crosses, lines, testers and line x tester interactions in yield and yield components (Table 2).

Genetic components of whole plant assay of blight showed negative and extremely low magnitude of variance of general combining ability ($\sigma^2$GCA) and additive genetic variance ($\sigma^2$A) compared with the variance of specific combining ability ($\sigma^2$SCA) and dominance variance ($\sigma^2$D) as shown in Table 3. Consequently ratio of $\sigma^2$GCA/$\sigma^2$SCA was less than unity in contrast to that of $\sigma^2$D/$\sigma^2$A (being ratio, negative sign is ignored). Relative contribution of females, males and female x male interaction scored highest place to line x tester interaction i.e., 47.92% for LB and 84.04% for EB. Of yield and yield related traits, value of variance of general combining ability ($\sigma^2$GCA) was lower than that of specific combing ability ($\sigma^2$SCA) for all traits except, number of fruits per plant and fruit diameter. Ratio of general to specific combining ability ($\sigma^2$GCA / $\sigma^2$SCA) values being <1 and ratio of dominance to additive variance ($\sigma^2$D / $\sigma^2$A) being >1 for whole plant assay of each blight, fruit length, and yield per plant suggested non-additive genetic control on the expression of these traits. However,

each ratio ($\sigma^2$GCA / $\sigma^2$SCA & $\sigma^2$D / $\sigma^2$A) proposed additive genetic control for number of fruits per plant and fruit diameter. Contribution of female and male parents and their crosses to the total variance was variable. Testers were significant for number of fruits per plant and fruit diameter while line x tester were significant for fruit length and yield per plant.

Pertaining to GCA effects of blight (Table 4), neither male and nor female carried equally important GCA effects for LB and EB. Line Roma among females and tester LB3 among males had desirable GCA effects for LB. Line Riogrande and tester LB2, LB4 and LB7 showed un-desirable positive GCA effects for LB. In case of EB, line Riogrande emerged with desired negative GCA effects among females. Of males, LB7 followed by LB2 came up with favorable negative average GCA effects. Regarding morphological traits, GCA effect of line Riogrande for number of fruit per plant was higher with average level of ranking. However, GCA effect of tester LB2 was highly significant with greater magnitude for this trait. Roma on female side and LB2 and LB4 on male side although showed positive GCA effects for fruit length yet the GCA effects of LB2 was quite desirable for the improvement of this trait. Line Riogrande and tester LB4 exhibited highly effective GCA effects for fruit diameter among all the parents. LB2 attained large amount of desirable GCA effect followed by LB3, LB4 and Riogrande which showed positive but average GCA effects for yield per plant.

Regarding SCA effects (Table 5), hybrid Riogrande x LB7 showed highest significant negative SCA effects followed by Roma x LB4 in desirable direction for LB. The other important cross combinations for this disease were Roma x LB3 and Riogrande x LB2 with desirable average SCA effects. For early blight, Riogrande x LB2 scored highly significant negative SCA effects. Three hybrids namely Riogrande x LB3, Roma x LB4 and Roma x LB7 were also better as they had negative average SCA effects. Two hybrids viz. Riogrande x LB2 and Roma x LB4 possessed desirable SCA effects for LB and EB simultaneously. These hybrids emerged out from low x average and high x average combinations of GCA of parents, respectively in LB while average x average GCA combinations of parents in EB disease. Positive but normal SCA effects were exhibited by Riogrande x LB4, Roma x LB2, Roma x LB3 and Riogrande x LB7 for number of fruit per plant. Two hybrids viz. Riogrande x LB7 followed by Roma x LB2 expressed significant and positive SCA effects for fruit length. For the same trait, hybrid Roma x LB3 and Riogrande x LB4 acquired average SCA effects. For fruit diameter, hybrid Riogrande x LB4 followed by Roma x LB3, Roma x LB7

**Table 4. General combining ability effects of parents for different parameters in tomato genotypes.**

| Parents | Late blight | Early blight | Number of fruits | Fruit length (cm) | Fruit diameter | Fruit yield |
|---|---|---|---|---|---|---|
| | WPA | WPA | per plant | | (cm) | (kg plant$^{-1}$) |
| Lines | | | | | | |
| Riogrande | 5.21** | -1.88 | 1.38 | -0.02 | 0.11* | 0.26 |
| Roma | -5.21** | 1.88 | -1.38 | 0.02 | -0.11* | -0.26 |
| S.E. (Lines) | 1.81 | 1.50 | 1.00 | 0.07 | 0.04 | 0.12 |
| Testers | | | | | | |
| LB2 | 1.54 | -0.21 | 15.96** | 0.22* | -0.13 | 0.43* |
| LB3 | -9.96** | 0.63 | -4.04** | -0.18 | 0.11 | 0.18 |
| LB4 | 0.88 | 1.46 | -6.04** | 0.03 | 0.14* | 0.08 |
| LB7 | 7.54** | -1.88 | -5.87** | -0.07 | -0.13 | -0.69 |
| S.E. (Testers) | 2.56 | 2.12 | 1.42 | 0.09 | 0.06 | 0.16** |

*, ** = Significant at 0.05 and 0.01 levels of probability, respectively; WPA= Whole plant assay

**Table 5. Specific combining ability effects of hybrids for different parameters in tomato genotypes.**

| Hybrids | Late blight | Early blight | Number of | Fruit length | Fruit diameter | Fruit yield (kg |
|---|---|---|---|---|---|---|
| | WPA | WPA | fruits /plant | (cm) | (cm) | plant$^{-1}$) |
| Riogrande x LB2 | -6.04 | -8.13* | -1.71 | -0.28* | 0.01 | -0.43 |
| Roma x LB2 | 6.04 | 8.13* | 1.71 | 0.28* | -0.01 | 0.43 |
| Riogrande x LB3 | 6.46 | -0.63 | -0.38 | -0.11 | -0.06 | 0.25 |
| Roma x LB3 | -6.46 | 0.63 | 0.38 | 0.11 | 0.06 | -0.25 |
| Riogrande x LB4 | 8.96* | 5.21 | 1.96 | 0.04 | 0.11 | 0.59* |
| Roma x LB4 | -8.96* | -5.21 | -1.96 | -0.04 | -0.11 | -0.59* |
| Riogrande x LB7 | -9.38* | 3.54 | 0.13 | 0.34* | -0.06 | -0.41 |
| Roma x LB7 | 9.38* | -3.54 | -0.13 | -0.34* | 0.06 | 0.41 |
| S.E. (Hybrids) | 3.62 | 2.99 | 2.00 | 0.13 | 0.09 | 0.23 |

*,**=Significant at 0.05 and 0.01 levels of probability, respectively; WPA=Whole plant assay DLA=Detached leaf assay

**Table 6. Estimates of commercial heterosis (%) in tomato hybrids.**

| Hybrids | Late blight | Early blight | Number of fruits | Fruit length | Fruit diameter | Fruit yield (kg |
|---|---|---|---|---|---|---|
| | WPA | WPA | per plant | (cm) | (cm) | plant$^{-1}$) |
| Riogrande x LB2 | -17.36$^{*}$ | -50.98$^{**}$ | 23.23$^{**}$ | -8.77$^{*}$ | 24.44$^{**}$ | 50.12$^{**}$ |
| Roma x LB2 | -14.73 | -27.45$^{**}$ | 24.24$^{**}$ | -5.38 | 19.26$^{**}$ | 58.19$^{**}$ |
| Riogrande x LB3 | -15.79 | -41.18 | -5.05 | -12.87$^{**}$ | 28.15$^{**}$ | 60.61$^{**}$ |
| Roma x LB3 | -52.63$^{**}$ | -35.29$^{**}$ | -8.08 | -14.63$^{**}$ | 25.93$^{**}$ | 35.59$^{**}$ |
| Riogrande x LB4 | 5.0027 | -33.33$^{**}$ | -4.55 | -6.43 | 32.59$^{**}$ | 66.26$^{**}$ |
| Roma x LB4 | -39.47$^{**}$ | -41.18$^{**}$ | -14.65$^{**}$ | -13.54$^{**}$ | 22.96$^{**}$ | 25.1$^{**}$ |
| Riogrande x LB7 | -13.15 | -39.22$^{**}$ | -7.07 | -2.92 | 22.96$^{**}$ | 23.49$^{**}$ |
| Roma x LB7 | 0.0001 | -43.14$^{**}$ | -11.62$^{*}$ | -20.07$^{**}$ | 20.74$^{**}$ | 30.75$^{**}$ |
| S.E | 5.0011 | 4.0023 | 2.084 | 0.018 | 0.012 | 0.033 |

*,**=Significant at 0.05 and 0.01 levels of probability, respectively; WPA=Whole plant assay DLA=Detached leaf assay

and Riogrande x LB2 showed desirable but average positive SCA effect. Maximum and highly significant SCA effects for yield per plant was showed by Riogrande x LB4 whereas Roma x LB2, Roma x LB7 and Riogrande x LB3 indicated positive but average level of SCA effects for this character.

***Heterosis:*** Estimates of commercial/standard heterosis have been given in Table 6. In term of resistance to LB, hybrid Roma x LB3 expressed highly significant commercial heterosis (-52.63%) followed by Roma x LB4 (-39.47%) and Riogrande x LB2 (-17.36%) over the commercial hybrid T-1359. Other attractive hybrids with average edge over the check for LB were Riogrande x LB3, Roma x LB2 and Riogrande x LB7. Regarding resistance to EB, hybrid Riogrande x LB2 indicated improvement (-50.98%) persuaded by Roma x LB7 (-43.14%), Roma x LB4 and Riogrande x LB3 (-41.18%), Riogrande x LB7 (-39.22%), Roma x LB3 (-35.29%), Riogrande x LB4 (-33.33%) and Roma x LB2 (-27.45%). $F_1$ hybrid namely Roma x LB2 and Riogrande x LB2 excelled significantly by 24.24% and 23.23% respectively over check for number of fruit per plant while none of the hybrids showed standard heterosis in fruit length. For fruit diameter, Riogrande x LB4 surpassed with 32.59% heterosis and followed by Riogrande x LB3 (28.15%), Roma x LB3 (25.93%), Riogrande x LB2 (24.44%), Roma x LB4 (22.96%), Riogrande x LB7 (22.96%), Roma x LB7 (20.74%) and Roma x LB2 (19.26%). Hybrid Riogrande x LB4 appeared as higher yielder by 66.26% followed by Riogrande x LB3 (60.61%), Roma x LB2 (58.19%), Riogrande x LB2 (50.12%), Roma x LB3 (35.59%), Roma x LB7 (30.75%), Roma x LB4 (25.1%) and Riogrande x LB7 (23.49%) compared with commercial hybrid T-1359.

## DISCUSSION

Our results revealed no agreement between tolerance/ resistance at detached leaf assay in laboratory and that of whole plant assay in field conditions. Whole plant assay was conducted throughout the plant growing season. In general field evaluation is highly useful as the data can be used to compare across plant genotypes at various time intervals during the season (Chaerani *et al*., 2007; Foolad *et al*., 2008). Parent material had varying level of resistance to LB and EB. However, this level was far better over the check T-1359. Following hybridization among the parent material, the entire first filial generation ($F_1$) got inherited the improved level of resistance visa vie T-1359, though the level of resistance was relatively lower than the respective parent. Panwar (2005) reported that significance of lines and testers referred additive gene action while that of line x tester interaction referred non-additive gene action. It is therefore inferred that females; Riogrande and Roma behaved additively for LB, fruit diameter and yield per plant. Similarly males; LB2, LB3, LB4 and LB7 acted additively for all the characters by virtue of their genotypic makeup under prevailing environment. Crosses which emerged out as a consequence of interaction of male and female alleles performed non-additively for whole plant assay of each blight, fruit length and yield per plant. Our findings are almost in favor of earlier reports (Saleem *et al*., 2011; Saleem *et al*., 2013). The magnitude and nature of GCA effects (Table 4) of lines and testers in relation to their mean performance (Table 1) was not in linear order; indeed GCA effects depended upon the intrinsic genetic makeup of the female or male parent instead of their individual per se performance as reported earlier (Saleem *et al*., 2009; Saleem *et al*., 2011) in tomato. According to Singh and Narayanam (2009), the GCA variance is primarily due to fixable additive genetic variance or additive × additive epistasis interaction and reflects high breeding value, therefore multiple crossing program involving aforementioned disease resistant and high yielding genotypes would result in generation of superior genotypes following pedigree method of selection. Expression of low GCA effects whatsoever positive or negative discloses that mean of a parent does not vary mainly from the mean performance of hybrid. In tomato this strategy has been exercised (Saleem *et al*., 2009; Saleem *et al*., 2011).

Promising specific combinations/hybrids (Table 5) did not appear best for all the disease and morphological characters. The similar situation was realized in heterosis visa vie specific combining ability. Consequently it necessitated to consider multifactor approach simultaneously to isolate the most important hybrids. The perusal of high mean performance, SCA effects and commercial heterosis enabled us to separate high yielding and LB tolerant hybrid Roma x LB3 followed by Roma x LB4. Each hybrid possessed average x average GCA combination of yield trait. Hybrid Riogrande x LB2 was tolerant to EB. It emerged from average x average GCA combination of parents for EB and average x high for yield. There were certain other hybrids viz. Riogrande x LB4, Roma x LB2, Riogrande x LB7 and Roma x LB7 though recorded 48.33 to 61.67% infection to EB but were even better than the check therefore, should be considered good and may be released as commercial hybrids for those agricultural systems where low early blight disease incidence prevails. According to Singh and Narayanam (2009), SCA is due to dominance genetic variance and all three types of epistasis (additive × additive, additive × dominance and dominance × dominance). It has relationship with heterosis therefore best high yielding specific combiner**'s** viz. Roma x LB3 and Roma x LB4 tolerant to LB and Riogrande x LB2 tolerant to EB are recommended for heterosis breeding.

***Conclusion*:** The isolation of one line (LB2) tolerant to LB and EB and three lines (LB3, LB4 and LB7) tolerant to EB exclusively in cultivated background brightens the scope of improving blight resistance in tomato. Two LB tolerant hybrids (Roma x LB3 and Roma x LB4) and one EB tolerant hybrid (Riogrande x LB2) with significantly high yield potential over the check T-1359 were developed. These three hybrids would be tested further in competitive multi-location yield trails to adjudge their yield performance and tolerance level to blight disease.

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