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GENETIC ANALYSIS TO IDENTIFY SUITABLE PARENTS FOR HYBRID SEED PRODUCTION IN TOMATO (*LYCOPERSICON ESCULENTUM* MILL.)

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Abstract

Line x tester experiment was conducted to evaluate the performance of 30 hybrids along with 13 parents in tomato. Variance due to treatments, crosses and lines x testers was significant for days to fruiting, fruit weight, fruit length, fruit width, number of fruit per plant and yield per plant. The estimate of variance of *gca*, *sca*, their ratio and degree of dominance indicated preponderance of non-additive gene action for all the traits suggesting that selection might not be made in the early generations and recurrent selection with periodic intercrossing appeared to be the best method. Narrow sense heritability was low in all traits but moderate for fruit weight, while genetic advance was low to high in aforementioned traits. Contribution of lines towards the total variance was more than that of testers. Line x tester interactions contributed more in days to fruiting, number of fruit per plant and yield per plant than that of lines and testers. Based on mean performance and *gca* effects, line 88572 and UC-134 and tester Nagina were better for yield and its various components. Considering mean performance, *sca* effects and heterobeltiosis, three hybrids 88572 × Riogrande, Picdeneto × Riogrande and H-24 × Riogrande were superior for yield and recommended for further evaluation.

Introduction

Tomato (*Lycopersicon esculentum* Mill., $2n=2x=24$) of the family Solanaceae is an important kitchen crop of Pakistan and is grown on 53.1 thousand hectares with the production of 536.2 tonnes and average yield of 10.1 tonnes per hectare (Anon., 2007-08). The average yield of tomato is very low in Pakistan as compared to 27.43 tonnes per hectare in major tomato producing countries of the world (Anon., 2005). The lower yield is due to the lack of quality seed, little choice of genotypes against different stresses and inconsistency in production round the year. On average, a tomato variety yields 16-25 tonnes per hectare while the hybrid variety often produces 60-80 tonnes per hectare.

Genetic analysis provides a guide line for the assessment of relative breeding potential of the parents or identify best combiners in crops (Khattak *et al.,* 2004; Weerasingh *et al*., 2004; Sulodhani Devi *et al*., 2005) which could be utilized either to exploit heterosis in F^1 or the accumulation of fixable genes to evolve variety. Hybrid vigor in tomato was first observed by Hedric & Booth (1907). Since then a number of workers have reported heterosis in tomato (Bhatt *et al.*, 1998; Bhatt *et al.*, 2001). Kumar *et al.,* (2003) reported 60% hybrid vigor in tomato. Even though many studies have been made on combining ability, gene action and heterosis, yet the pace of work on development of tomato hybrid seed on commercial basis have been limited due to lack of superior combiners in Pakistan. As a result, import of tomato hybrid seed is a routine.

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Line × Tester technique (Kempthrone, 1957) is one of the best techniques that provides information about general and specific combining ability of the parents and at the same time it is helpful in estimating various types of gene effects. In this study efforts have been made to identify parents suitable for tomato hybrid seed production.

Materials and Methods

The present study was conducted on 13 determinate pure lines of tomato obtained from Ayub Agricultural Research Institute, AARI, Faisalabad at the experimental field of Nuclear Institute for Agricultural and Biology (NIAB), Faisalabad during 2004-05. Ten female genotypes (designated as lines) viz., CC-Haus, H-24, Pakit, Peelo, Picdeneto, Roma, Titano, T-2, UC-134 and 88572 and three male genotypes (designated as testers) viz., Nagina, Riogrande and Tibrido were crossed to generate 30 F_1 hybrids following line × tester mating design in 2004. The hybrids were evaluated along with parents following randomized complete block design (RCBD) with three replications in field during 2005. The plant-to-plant and row-to-row spacing was kept 50 cm and 150 cm respectively. Standard cultural practices and plant protection measures were adapted to raise healthy crop. Measurements were recorded on days to fruiting, fruit weight, fruit length, fruit width, number of fruit per plant and yield per plant according to "descriptors for tomato" proposed by IPGRI, Italy (Anon., 1996).

Genotype means were used for the analysis of variance (Steel & Torrie, 1980). Analysis of combining ability and other genetic parameters was performed according to Singh & Chaudhary (1999). Heritability values were categorized low (<0.3), moderate (0.3-0.6) and high (>0.6) while genetic advance low (>0.1), moderate (0.1-0.2) and high (>0.2) as given by Johnson *et al*., (1955). The distribution of crosses in relation to general combining ability (*gca*) and specific combining ability (*sca*) effects was worked out by taking combining ability effects as significant positive (high = *h*), non-significant (average = *a*) and significant negative (low = *l*). However, for days to fruiting significant positive combining ability effects were taken as low, non-significant as average and significant negative as high.

Results and Discussion

Analysis of variance based on mean square of different characters in tomato is presented in Table 1. Significant differences were observed in treatments, parents vs. crosses and line × tester interaction among all the traits. Similar views had been expressed by earlier workers (Chandha *et al.,* 2001; Dhaliwal *et al*., 2003). Lines exhibited significant variation for fruit weight and fruit length where as testers were significant for number of fruit per plant only.

The value of $\sigma^2 gca$ was less than that of $\sigma^2 sca$ in all traits; therefore non-additive type of gene action was pre-dominant. As a result the ratio of $\sigma^2 gca/\sigma^2 sca$ was also less than one and the degree of dominance $(\sigma^2 D / \sigma^2 A)^{1/2}$ was either equal to 1(for fruit weight) or greater than 1 (for rest of the traits) showed the preponderance of non-additive gene action as recorded by Chandha *et al*., (2001) and Dharmatti *et al.,* (2001). Narrow sense heritability was low in all characters but moderate for fruit weight. However value of expected genetic advance in response to selection in next generation was high for days to fruiting, fruit weight and number of fruit per plant, moderate for fruit length and low for fruit width and yield per plant. Since improvement in yield is the most important parameter for which low breeding value or additive gene action was depicted due to low heritability and genetic advance in addition to preponderance of non-additive gene action as revealed by other genetic parameters as well. Therefore selection in early generation would be ineffective and recurrent selection with periodic intercrossing is advocated.

Table 1. Analysis of variance based on mean squares and estimates of genetic component in tomato.

Source	d.f.	Days to fruiting	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	No. of fruit per plant	Yield per plant (kg)
Replication	2	8.34	25.30	0.87**	1.54**	3.32	0.01
Treatments	42	86.78**	153.52**	1.02**	0.27**	866.78**	1.45**
Parents	12	36.67**	105.86**	1.49**	0.26**	869.75**	0.90**
Parents vs Crosses	1	301.39**	692.48**	0.93**	1.47**	22.46*	2.48**
Crosses	29	100.11**	154.65**	0.82**	0.23**	894.66**	1.65**
Lines	9	142.50	277.80*	2.17**	0.35	496.28	1.66
Testers	2	67.25	86.40	0.50	0.16	3206.97*	2.24
Lines × Testers	18	82.57**	100.66**	0.19*	0.18*	836.93**	1.58**
Error	84	6.10	28.08	0.10	0.09	6.72	0.04
$\sigma^2 gca$		0.33	1.01	0.01	0.0010	1.08	0.0013
$\sigma^2 sca$		25.49	24.19	0.03	0.0279	276.73	0.5106
$\sigma^2 gca/\sigma^2 sca$		0.013	0.042	0.408	0.0360	0.004	0.003
$\sigma^2 A$		0.66	24.2	0.02	0.0020	2.16	0.0027
$\sigma^2 D$		25.49	24.2	0.03	0.0279	276.73	0.5106
$(\sigma^2 D/\sigma^2 A)^{1/2}$		6.21	1	1.22	3.74	11.32	13.75
$h^2_{(n.s)}$		0.02	0.32	0.13	0.02	0.01	0.005
$G. A$		0.23	5.7	0.11	0.01	0.26	0.008
Contribution (%) of Lines		44.17	55.75	81.64	47.56	17.22	31.24
Testers		4.63	3.85	4.22	4.87	24.72	9.37
Line x Tester		51.19	40.40	14.14	47.57	58.06	59.39

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

The contribution of lines towards the total variance was higher than that of testers for all the traits except for number of fruit per plant. Lines contributed more than line × tester interactions for fruit weight and fruit length. Line × tester contributed significantly in days to fruiting, number of fruit per plant and yield per plant; however it was almost equal to lines for fruit width. Uneven contribution of lines, testers and their interactions had also been found by different investigators (Chandha *et al*., 2001; Manivannan & Sekar, 2005).

Estimates of general combining ability effects of lines and testers have been shown in Table 2. As far as *gca* effects for days to fruiting is concerned, UC-134 surpassed its rivals by attaining value of - 4.85 followed by Pakit (-3.39), Picdeneto (-3.09), T-2 (-1.97) and 88572 (-1.86). Nagina was the best male parent with *gca* value of -1.55 for early days to fruiting. In case of fruit weight, the line UC-134 expressed its superiority with *gca* value of 12.27. None of the testers indicated significant *gca* effects for fruit weight. As regards the fruit length, the line Roma produced higher magnitude of *gca* (0.63) followed by Picdeneto (0.43), Peelo (0.31), UC-134 (0.30) and T-2 (0.22) where as male tester Riogrande showed desirable *gca* (0.14). For fruit width, only one line UC-134 could show desirable and significant *gca* value of 0.33 while neither of the tester was important for this trait. For number of fruit per plant, Picdeneto was at the top with 10.49 *gca* value followed by 88572 (8.19), H-24 (5.33), Pakit (4.66) and Roma (2.54). The tester Nagina was the best general combiner with *gca* value of 9.14 as compared to Tibrido with *gca* effect of 2.09. The line 88572 was better in yield by attaining the *gca* value of 0.58 followed by Roma (0.33), Picdeneto (0.28), Peelo (0.17) and UC-134 (0.16). Nagina was at the top with 0.31 *gca* value among testers for yield per plant.

In confirmation to the findings of Srivastava *et al*., (1998) and Dhaliwal *et al*., (2003), none of the parents was the best general combiner for all the traits. Six parents viz., 88572, UC-134, Picdeneto, Peelo and Roma among lines and Nagina among testers displayed desirable *gca* effects for yield and its various traits yet three parents viz., 88572, UC-134 and Nagina were found to be better based on mean performance and *gca* effects. Harer & Bapat (1982) and Premalatha *et al*., (2006) reported that the *per se* performance of the parents with the nature of combining ability provides the criteria to choose the parents for hybridization. These three parents may be used in multiple crossing program for the identification of superior genotypes as stated by Nadarajan & Gunasekaran (2005) with desirable trait(s) of interest. The high *gca* effects are attributed to additive gene effects or additive x additive interaction effects and represent a fixable portion of genetic variation (Sarma *et al.,* 2004).

Estimates of specific combining ability effects of the hybrids are presented in Table 3. For days to fruiting, the highest negative and significant *sca* effects were exhibited by hybrid Picdeneto × Riogrande with value of -6.82 out of ten early fruiting crosses. In case of fruit weight, CC-Haus × Tibrido showed maximum *sca* effects (8.75) followed by Titano × Tibrido (6.59). The hybrid CC-Haus × Nagina and H-24 × Tibrido gave significant *sca* effects (0.48 and 0.45 respectively) for fruit length and width. Twelve crosses displayed highly significant *sca* values for number of fruit per plant; the hybrid 88572 × Riogrande was at the top with highest *sca* value of 29.41. For yield per plant, the *sca* effect of hybrid 88572 × Riogrande was highest (1.16) followed by Picdeneto × Riogrande (0.83), H-24 × Riogrande (0.77), CC-Haus × Nagina (0.66), Pakit × Nagina (0.62), Picdeneto × Tibrido (0.57), Peelo × Riogrande (0.39), Peelo × Tibrido (0.35), T-2 × Nagina (0.34), Titano × Nagina (0.33) and Titano × Tibrido (0.27).

Table 2. General combining ability effects and mean performance (in parenthesis) of parents for different parameters in tomato.

Parents	Days to fruiting	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	No. of Fruit per plant	Yield per plant (Kg)
Lines						
CC-Haus	6.74**(151)	-6.30**(44)	-0.47**(3.2)	-0.23*(4.8)	-6.50**(64)	-0.91**(2.2)
H-24	4.50**(142)	-2.61(40)	-0.71**(3.9)	-0.04(4.5)	5.33**(80)	0.04(3.0)
Pakit	-3.39**(150)	-2.62(48)	-0.78**(4.2)	-0.14(4.3)	4.66**(115)	-0.11(3.3)
Peelo	-0.23(147)	2.55(47)	0.31**(4.9)	0.01(4.3)	-3.53**(65)	0.17*(2.5)
Picdeneto	-3.09**(150)	-3.74*(47)	0.43**(4.8)	-0.32**(4.0)	10.49**(66)	0.28**(2.6)
Roma	4.93**(152)	4.55(46)	0.63**(5.5)	0.19(3.7)	2.54*(51)	0.33**(2.0)
Titano	-0.78(148)	-5.57**(47)	0.11(4.9)	0.09(4.2)	-1.86*(63)	-0.09(2.7)
T-2	-1.97*(152)	0.23(49)	0.22*(4.6)	0.15(4.2)	-12.65**(66)	-0.45**(3.1)
UC-134	-4.85**(149)	12.26**(57)	0.30**(5.0)	0.33**(4.6)	-6.67**(57)	0.16*(3.0)
88572	-1.86*(151)	1.25(43)	-0.04(4.2)	-0.04(4.5)	8.19**(86)	0.58**(3.3)
SE(g_i)	0.82	1.77	0.11	0.10	0.86	0.07
SE(g_i-g_j) *line*	1.16	2.50	0.15	0.14	1.22	0.10
Testers						
Nagina	-1.55**(143)	-1.48(53)	-0.07	0.06(4.6)	9.14**(68)	0.31**(4.0)
Riogrande	1.45**(143)	1.86(62)	0.14*(5.6)	0.02(4.5)	-11.23**(52)	-0.20**(3.1)
Tibrido	0.10(151)	-0.38(46)	-0.07(5.7)	-0.08(4.2)	2.09**(81)	-0.11**(3.8)
SE(g_j)	0.45	0.97	0.06(5.0)	0.06	0.47	0.04
SE(g_i-g_j) *tester*	0.64	1.37	0.08	0.08	0.67	0.05

*,** = Significant at 0.05 and 0.01 levels of probability respectively, *SE*(g_i) = Standard error (*gca* effects for line), *SE*(g_i-g_j) *line* = Standard error (between *gca* effects of two lines), *SE*(g_j) = Standard error (*gca* effects for testers), *SE*(g_i-g_j) *tester* = Standard error (between *gca* effects of two testers)

Table 3. Specific combining ability effects and mean performance (in parenthesis) of hybrids for different parameters in tomato.

Hybrids	Days to fruiting	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	No. of fruit per plant	Yield per plant (Kg)
CC- Haus × Nagina	-4.56**(146)	-0.40(45)	0.48**(4.9)	-0.17(4.2)	17.00**(95)	0.66**(3.3)
CC-Haus × Riogrande	8.15**(162)	-8.33**(41)	-0.36(4.3)	-0.15(4.2)	-16.69**(35)	-0.62**(1.5)
CC-Haus × Tibrido	-3.60*(148)	8.75**(56)	-0.15(4.2)	0.32(4.7)	-0.32(108)	-0.02(3.2)
H-24 × Riogrande	5.20**(153)	-6.77*(43)	-0.02(4.1)	-0.19(4.4)	17.75**(99)	0.77**(4.4)
H-24 × Nagina	-3.79**(147)	3.30(56)	-0.23(4.1)	-0.26(4.3)	-12.84**(54)	-0.68**(2.4)
H-24 × Tibrido	-1.40(148)	3.46(54)	0.25(4.4)	0.45*(5.1)	-4.90**(86)	-0.09(3.5)
Pakit × Nagina	-0.06(140)	0.29(50)	0.21(4.3)	0.13(4.6)	13.64**(112)	0.62**(4.4)
Pakit × Riogrande	4.10**(147)	0.46(53)	-0.30(4)	-0.09(4.4)	-1.98(64)	0.06(3.1)
Pakit × Tibrido	-4.04**(138)	-0.75(50)	0.10(4.2)	-0.04(4.3)	-11.66**(76)	-0.69**(2.7)
Peelo × Nagina	-6.31**(137)	-0.37(54)	-0.04(5.1)	0.05(4.7)	-16.70**(61)	-0.74**(3.0)
Peelo × Riogrande	4.27**(151)	5.69(64)	0.09(5.5)	0.05(4.7)	6.97**(68)	0.39**(3.9)
Peelo × Tibrido	2.04(147)	-5.32(50)	-0.05(5.1)	-0.10(4.4)	9.73**(81)	0.35**(3.7)
Picdenato × Nagina	4.21**(145)	-5.96(42)	-0.11(5.2)	-0.21(4.1)	-26.05**(59)	-1.40**(2.5)
Picdenato × Riogrande	-6.82**(137)	4.52(56)	0.01(5.5)	0.01(4.3)	18.83**(115)	0.83**(4.3)
Picdenato × Tibrido	2.61(145)	1.44(51)	0.10(5.4)	0.20(4.4)	7.22**(96)	0.57**(4.0)
Roma × Nagina	1.01(150)	3.99(61)	0.10(5.6)	0.09(4.9)	-3.08*(97)	0.11(4.0)
Roma × Riogrande	-1.60(150)	4.12(64)	0.05(5.8)	0.21(4.9)	-10.21**(51)	-0.24(3.2)
Roma × Tibrido	0.59(151)	-8.11**(50)	-0.15(5.3)	-0.30(4.4)	13.29**(106)	0.13(4.0)
Titano ×Nagina	2.72(146)	2.07(49)	-0.33(4.6)	-0.08(4.4)	6.87**(90)	0.33**(4.0)
Titano × Riogrande	-4.93**(141)	-8.66**(41)	0.16(5.3)	0.26(4.9)	-9.07**(39)	-0.61**(2.3)
Titano × Tibrido	2.21(147)	6.59*(54)	0.17(5.1)	-0.18(4.4)	2.19(83)	0.27*(3.5)
T-2 x Nagina	-4.56**(137)	3.92(56)	0.00(5.1)	0.16(4.8)	12.00**(94)	0.34**(4.1)
T-2 x Riogrande	-3.13*(142)	0.31(56)	0.16(5.5)	-0.20(4.5)	-6.93**(39)	-0.16(2.5)
T-2 x Tibrido	7.69**(151)	-4.23(49)	-0.15(4.9)	0.04(4.7)	-5.08**(54)	-0.18(2.5)
UC-134 × Nagina	-1.60(137)	2.81(67)	-0.03(5.1)	0.21(5.0)	-9.89**(67)	-0.08(3.7)
UC-134 × Riogrande	4.18**(146)	-0.48(67)	0.13(5.5)	0.05(5.0)	2.52(61)	-0.14(3.1)
UC-134 × Tibrido	-2.58(138)	-2.33(63)	-0.09(5)	-0.26(4.6)	7.37**(88)	0.22(3.5)
88572 × Nagina	3.96**(146)	0.42(54)	-0.28(4.5)	0.02(4.6)	-11.54**(84)	-0.60**(3.6)
88572 × Riogrande	-0.43(144)	-0.94(56)	0.30(5.3)	0.12(4.7)	29.41**(106)	1.16**(4.8)
88572 × Tibrido	-3.53*(140)	0.51(55)	-0.02(4.8)	-0.14(4.3)	-17.85**(58)	-0.56**(3.2)
SE (s_{ij})	1.43	3.06	0.18	0.17	1.50	0.12
SE (s_{ij}-s_{kl})	2.02	4.33	0.26	0.25	2.12	0.17

*,** = Significant at 0.05 and 0.01 levels of probability respectively, *SE* (s_{ij}) = standard error (*sca* effects for crosses), *SE* (s_{ij}-s_{kl}) = standard error (between *sca* effects of two crosses)

Table 4. Heterobeltiosis percent of hybrids for different parameters in tomato.

Hybrids	Days to fruiting	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	No. of Fruit per plant	Yield per plant (Kg)
CC- Haus × Nagina	-3.53**	-15.24	-12.37**	-12.55*	30.26**	-17.20**
CC-Haus × Riogrande	6.86**	-34.52**	-25.39**	-12.90*	-45.14**	-49.78**
CC-Haus × Tibrido	-1.95	19.64*	-15.38**	-5.24	-19.99**	-40.62**
H-24 × Riogrande	6.90**	-20.25*	-26.12**	-4.62	26.77**	9.85*
H-24 × Nagina	2.96*	-9.87	-27.33**	-4.74	-36.69**	-20.57**
H-24 × Tibrido	-1.98	16.24	-12.38*	8.89	-11.05**	-16.98**
Pakit × Nagina	-6.45**	-7.08	-23.19**	0.07	-15.68**	2.50
Pakit × Riogrande	-1.68	-14.46*	-29.78**	-2.53	-46.95**	-7.17
Pakit × Tibrido	-8.93**	3.00	-16.58**	-0.39	-43.79**	-37.07**
Peelo × Nagina	-6.98**	1.37	-8.13	1.73	-14.61**	-24.62**
Peelo × Riogrande	2.23	2.27	-3.86	3.95	-4.81	19.26**
Peelo × Tibrido	-2.83*	7.59	2.20	1.70	-3.93	-1.87
Picdenato × Nagina	-3.61**	-20.86*	-7.23	-11.05*	-7.81*	-38.40**
Picdenato × Riogrande	-8.97**	-9.73	-3.22	-4.25	33.68**	37.31**
Picdenato × Tibrido	-4.34**	7.90	7.39	5.14	10.27**	7.11
Roma × Nagina	-1.63	13.27	0.30	6.50	14.14**	0.75
Roma × Riogrande	-1.38	2.98	1.23	11.40*	-3.46	3.61
Roma × Tibrido	-0.82	6.73	-2.43	5.30	7.95**	-3.38
Titano × Nagina	-1.92	-9.25	-16.92**	0.58	22.26**	-4.34
Titano × Riogrande	-5.07**	-33.86**	-6.20	10.43	-25.19**	-22.43**
Titano × Tibrido	-3.08*	16.27	2.46	5.85	-11.17**	-10.93*
T-2 × Nagina	-9.52**	5.04	-9.09	7.15	13.98**	-13.19**
T-2 × Riogrande	-6.60**	-10.12	-4.21	1.34	-41.60**	-21.51**
T-2 × Tibrido	-0.34	-0.37	-1.73	11.69	-33.46**	-32.71**
UC-134 × Nagina	-7.69**	18.60*	-8.19	11.99*	-9.25**	-8.26
UC-134 × Riogrande	-1.79	7.98	-3.39	8.28	-5.39	1.42
UC-134 × Tibrido	-8.93**	11.47	1.07	-0.58	-10.72**	-5.60
88572 × Nagina	-3.73**	0.42	-18.71**	-0.07	-12.53**	-10.60*
88572 × Riogrande	-4.65**	-10.48	-6.38	4.01	11.35**	47.20**
88572 × Tibrido	-7.58**	18.19	-4.26	-4.01	-28.03**	-14.93**
SE	2.02	4.33	0.26	0.25	2.12	0.17

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

Significant differences due to specific combining ability effects in all characters suggested that a major proportion of the variations were controlled by dominant properties of genes (Griffing, 1956). The distribution of crosses in relation to *gca* effects of parental combinations (*h* × *h, h* × *a, h* × *l, l* × *h, l* × *a, l* × *l, a* × *h, a* × *a* and *a* × *l*) showed that almost all types of *sca* effects were obtained from any kind of *gca* effects and hence performance of hybrids was independent of parents. Similar results were reported in earlier studies (Bhatt *et al*., 2004; Thakur *et al*., 2004; Hariprasanna *et al*., 2006). The crosses having one parent with high *gca* effects and other parent with low *gca* effects are expected to throw desirable transgressive segregates if the additive genetic system present in high combiner and complementary epistatic effects act in same direction (Iqbal & Khan, 2003). The situation was well reflected in promising cross Picdeneto × Riogrande for days to fruiting and 88572 × Riogrande for number of fruit and yield per plant respectively. Best crosses involved at least one parent with high *gca* effects can be used as a selection criteria for the identification of superior genotypes. Parents with high *gca* did not necessarily produced hybrid with high *sca* (Sharma *et al*., 1999), but combination of parents with average or low gca usually produced hybrids with high *sca*. In our results, the best crosses viz: CC-Haus × Tibrido for fruit weight, CC-Haus × Nagina for fruit length and H-24 × Tibrido for fruit width had *l* × *a*, *l* × *a* and *a* × *a gca* parental combinations respectively. In these hybrids, non-additive i.e. dominant and epistatic type of gene action was suggested as reported in potato (Iqbal & Khan, 2003).

Estimates of heterobeltiosis (high-parent heterosis) percent are presented in Table 4. Seventeen crosses manifested significant and desirable negative heterobeltiosis (–2.83 to –9.52%) for days to fruiting. Hybrid Peelo × Tibrido displayed minimum heterobeltiosis while T-2 × Nagina showed maximum heterobeltiosis. For fruit weight two crosses namely CCHaus × Tibrido and UC-134 × Nagina exhibited 9.64% and 18.60 % heterobeltiosis respectively. Similarly two hybrids Roma × Riogrande and UC-134 × Nagina showed 11.40% and 11.90% desirable heterobeltiosis for fruit width. None of the hybrids showed desirable high-parent heterosis for fruit length. Nine crosses exhibited desirable heterobeltiosis with range of 7.95 to 33.68% for number of fruit per plant. Cross Roma × Tibrido showed minimum and Picdeneto × Riogrande maximum desirable heterobeltiosis. Three crosses viz., 88572 × Riogrande, Picdeneto × Riogrande and H-24 × Riogrande diplayed high heterobeltiosis of 47.20, 37.31 and 9.85% with mean performance of 4.8, 4.4 and 4.3 kg respectively for yield. These hybrids were emerged from *h* × *l gca* parental combination and had higher value of mean performance and *sca* effects. Duvick (1999) reported that high degree of heterosis did not essentially correlate to *sca* effects, therefore, genotype × environment interaction might be conducted as suggested by Fox *et al.,* (1997) and Bakhsh *et al.,* (2006). It is evident that the role of male tester line Riogrande was important in exploiting of the hybrid vigor among testers.

Keeping in view mean performance, *sca* effects and heterobeltiosis, the hybrids 88572 × Riogrande, Picdeneto × Riogrande and H-24 × Riogrande may be recommended for heterosis breeding after further evaluation.

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