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Estimating Combining Ability for Earliness and Yield Contributing Traits in Bell Pepper (*Capsicum annuum* var *grossum* L.) under Protected Conditions

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A B S T R A C T

The objective of this study was to determine the effects of the general and specific combining abilities (GCA and SCA, respectively) for earliness and yield contributing traits in bell pepper (*Capsicum annuum* var *grossum* L.) and to evaluate the most promising crosses. The experimental material comprised 16 F_1 crosses, developed by crossing 8 lines with 2 testers during the year 2015. Parents (8 lines and 2 testers) and the 16 F_1 cross combinations were planted in a randomized complete block design during the year 2016 under polyhouse conditions for estimating combining ability for earliness and yield contributing traits. Combining ability studies revealed that on the basis of GCA, the parents *viz*., UHF-11, UHF-6, UHF-14 and UHF-10 were found good general combiners for majority of traits and SCA performance showed that, the cross combinations UHF-8 x California Wonder, UHF-10 x California Wonder, UHF-11 x Solan Bharpur and UHF-6 x Solan Bharpur were found best for majority of yield and yield contributing traits under protected conditions and may be utilized for development of capsicum hybrid for protected conditions in mid hills of Himachal Pradesh.

Introduction

Bell Pepper (*Capsicum annuum* var *grossum* L., 2n=24) is an important vegetable crop that is widely grown in India as well as in many other countries of the world. The cultivated area of pepper, in India, reached 46(‘000 hectare), which produced 327(‘000 MT) with an average of 7.10 (MT/ha) (Anonymous, 2016). This average is relatively low, therefore, much attention must be given to increase it by developing new cultivars or hybrids through sound breeding programs. The popularity of F_1 hybrid cultivars are due to their vigour, uniformity, disease resistance, stress tolerance and good horticultural traits including earliness and long shelf life and therefore giving constant stable high yield (Sood and Kumar, 2010). Several commercial hybrids have been developed in bell pepper coupled with good quality and high yield. With increasing popularity of F_1 hybrids it is imperative to obtain new hybrids with excellent performance. Combining ability is a prerequisite in any plant breeding programme either for varietal improvement or for evolving

a hybrid. The knowledge of general combining ability (gca) and specific combining ability (sca) helps to select the parents as well as crosses to formulate an effective breeding methodology. In India capsicum is an important off-season vegetable of western Himalayas and offers potential for boosting economy of farmers of hilly regions but all the available hybrids belong to coloured types, since no recommended hybrid is available for green capsicum, which also has good potential under protected conditions. Due to numerous factors, it is not possible to obtain higher yields of good quality fruits under open conditions and, therefore, protected cultivation offers good scope for year round and also off season production of capsicum (Spehia *et al.,* 2014). Studies on combining ability of parents are essential in choosing parents as its analysis is an important technique to understand the genetic potential of parents and their hybrids (Kamble *et al.,* 2009). From this perspective, the objective of this paper was to estimate the general combining ability (GCA), specific combining ability (SCA), to determine the most promising crosses among 16 cross combinations along with their 10 parents in a bell pepper breeding programme.

Materials and Methods

The present investigation was undertaken at the Experimental Research Farm of Department of Vegetable Science and Precision Farming Development Centre, Department of Soil Science and Water Management, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Kharif and Rainy seasons of 2015 and 2016. During 2015, seedlings of 8 lines (EC-579997, Kandaghat Sel-9, ACC-16, UHF-8, UHF-6, UHF-10, UHF-14, UHF-11) and 2 testers (Solan Bharpur and California Wonder) were transplanted in open field during May, 2015. The population of male parents (testers) was kept higher than female parents so that each tester could be crossed with each line (female line). The crosses were attempted as per Line x Tester design suggested by Kempthorne (1957). Mature fruits of crossed as well as selfed progenies were harvested and seeds were extracted manually. Seeds were dried and then stored in cool place for sowing in the subsequent year inside polyhouse. During the next year (2016), F_1 population of 16 crosses along with their 10 parents were transplanted during the month of March, 2016 in Randomized Complete Block Design (RCBD) with 3 replications under protected conditions to record the extent of combining ability for earliness and yield contributing traits. Row to row and plant to plant spacing of 60 cm x 45 cm was kept in a plot having size 1.8 m x 1.8 m. Mean temperature during the crop season (March- August) inside polyhouse varied from 15^0 C to 40^0 C, while the relative humidity varied from 53-80 per cent. The soil structure of the Experimental Research Farm is sandy loam to clay loam comprising of sand (46.09 %), silt (32.12 %) and clay (25.01 %). The pH of the soil ranged from 6.79 - 7.02. The standard cultural practices were followed as per package and practices of vegetable crops to raise the capsicum crop (Anonymous, 2014) and the characters studied were: Days to 50% flowering, days to marketable maturity, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg), fruit shape index, number of lobes per fruit, pericarp thickness (mm), plant height (cm) and harvest duration (days).

Results and Discussion

Combining ability studies guide the breeders to select appropriate parents for heterosis and recombination breeding, hence are important in crop improvement studies. The common approach of selecting the parents on the basis of *per se* performance, adaptation and genetic

variability does not necessarily lead to useful results. This is because of differential combining ability of parents which depends upon the complex interactions among the genes and cannot be judged by the *per se* performance alone (Allard, 1960). To effect improvement in polygenic traits like yield and component characters, information about the combining ability of parents and their crosses, the estimates of genetic components of variance and the type of gene action involved are of prime importance to the breeders. The analysis of variance for combining ability revealed significant differences among the parents and hybrids for all the traits under study. Further, partitioning of the sum of squares of crosses into lines (females), testers (males) and line x tester (female x male) interactions indicated that mean sum of squares due to lines and testers were significant for all the traits when tested either against mean sum of squares due to error or against variances due to line x tester interactions (Table 1).The combining ability studies evaluate the parental lines on the basis of their general combining ability (GCA) effects and the performance of these parents in specific cross combinations (SCA).

Estimates of general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of crosses for earliness

The lines or testers exhibiting significant negative or positive GCA effects were designated as good or poor general combiners, respectively. The remaining lines/testers exhibiting non-significant GCA effects were assigned as average general combiners for days to fifty percent flowering. The parents UHF-10, UHF-11, UHF-14, UHF-6 were good general combiners for days to fifty percent flowering, as these exhibited the significant GCA estimates with negative value of -5.10, -2.60, -1.94 and -1.60. Parental lines ACC-16 (2.90), UHF-8 (3.90) and Kandaghat Sel-9 (4.90) were poor parents for this trait (Table 2). Both testers showed non- significant GCA effects so assigned as average general combiners for days to fifty percent flowering.

Among the crosses UHF-8 x California Wonder (-4.06), UHF-6 x Solan Bharpur (-2.44), UHF-10 x Solan Bharpur (-2.44) and UHF-11 x California Wonder (-1.73) showed significant negative SCA effects (Table 3).These crosses involved poor x medium, good x medium, good x medium and good x medium combining parents, respectively. Four crosses were the poor specific combiners for this trait. Similar findings were also obtained by Milkova (1984), Blank and Maluf (1997), Sood and Kaul (2006), Prasath and Ponnuswami (2008) and Kamble *et al.*, (2009). In addition to early flowering, early maturity of produce is very important because a difference of few days in marketing can have a profound influence on earnings of the grower. In the present study, among the parents UHF-11 (-4.54), UHF-10 (-4.04), UHF-6 (-3.04) and UHF-14 (-1.71) were the best general combiners. Whereas ACC-16 (3.29), UHF-8 (4.63) and Kandaghat Sel-9 (6.46) showed poor general combining ability. EC-579997 was average general combiner. Tester Solan Bharpur (-0.67) was good general combiner and California Wonder (0.67) was poor combiner for this trait (Table 2).

Among the crosses, UHF-11 x Solan Bharpur (-5.00), UHF-8 x California Wonder (-4.50) and UHF-10 x California Wonder (-2.17) were the best specific combiners for days to marketable maturity (Table 3). These crosses involved good x good, poor x poor and good x poor combining parents, respectively. Three cross combination *viz.*, UHF-11 x California Wonder (5.00), UHF-8 x Solan Bharpur (4.50) and UHF-10 x Solan Bharpur (2.17) were poor specific combiners. Remaining ten crosses

exhibited non-significant SCA effects and thus were average cross combinations for this trait. Johri *et al.,* (2004) and Sood and Kaul (2006) also reported similar results for GCA and SCA effects.

Estimates of general combining ability (GCA) effects of parents and specific combining ability (SCA) effects of crosses for yield and yield contributing traits

Among the lines, UHF-6 (9.30), UHF-14 (7.85), ACC-16 (5.82), UHF-11(4.27) and UHF-10 (1.67) were found good general combiners for number of fruits per plant (Table 2). On the other hand, Kandaghat Sel-9 (-14.75) followed by EC-579997 (-14.13) were designated as poor general combiners. Only UHF-8 (-0.03) was found average general combiner for this trait. Significant positive GCA effects were observed for the tester California Wonder (0.94) and was found good general combiner, whereas Solan Bharpur (-0.94) was found poor general combiner.

Out of sixteen hybrid combinations, seven crosses *viz.,* ACC-16 x Solan Bharpur (6.02), UHF-8 x California Wonder (4.28), UHF-10 x California Wonder (3.96), UHF-11 x Solan Bharpur (3.83), UHF-14 x California Wonder (2.96), EC-579997 x Solan Bharpur (2.37) and Kandaghat Sel-9 x California Wonder (1.36) were the best combinations due to their significant positive SCA effects (Table 3) and involved the parents with good x poor, average x good, good x good, good x poor, good x good, poor x poor and poor x good GCA effects, respectively. On the other hand seven and two cross combinations were poor and average specific combinations, respectively, for this trait. These results are in conformity with Sharma and Saini (1977), Nowaczyk *et al.,* (1993), Mulge and Anand (1997), Pandey *et al.,* (2002), Johri *et al.,* (2004), Sood and Kaul (2006), Farag and Khalil (2007), Prasath and Ponnuswami (2008), Kamble *et al.,* (2009), Payakhapaab *et al.,* (2012), Khalil and Hatem (2014), Gawande *et al.,* (2015). Significant positive GCA effects among the lines were exhibited by UHF-11(11.31), UHF-10 (7.31), UHF-6 (5.41) and UHF-14 (4.38) and were indicated as good, while EC-579997 (-12.17) followed by Kandaghat Sel-9 (-10.11) and ACC-16 (-5.47) were designated as poor general combiners for this trait (Table 2). Line UHF-8 (-0.67) and testers, Solan Bharpur and California Wonder exhibited non-significant GCA effects so designated as average general combiners.

Out of sixteen hybrid combinations, seven crosses *viz.,* Kandaghat Sel-9 x Solan Bharpur (8.90), UHF-10 x California Wonder (6.97), UHF-8 x California Wonder (5.36), UHF-14 x Solan Bharpur (4.06), EC-579997 x California Wonder (3.56), UHF-6 x Solan Bharpur (1.55) and UHF-11 x Solan Bharpur (1.49) were the best combinations due to their significant positive SCA effects (Table 3) and involved the parents with poor x average, good x average, average x average, good x average, poor x average, good x average, good x average GCA effects. On the other hand seven and two cross combinations were poor and average specific combinations respectively for this trait. These results find support from Milkova (1984), Salazar and Vallejo (1990), Nowaczyk *et al.,* (1993), Gvozdenovic *et al.,* (1996), Blank and Maluf (1997), Mulge and Anand (1997), Ahmed *et al.,* (2003), Johri *et al.,* (2004), Nascimento *et al.,* (2004), Sood and Kaul (2006), Kamble *et al.,* (2009), Nascimento *et al.,* (2010), Khalil and Hatem (2014) and Gawande *et al.,* (2015). Lines UHF-6 (0.73), UHF-11 (0.64), UHF-14 (0.58), UHF-10 (0.34) and (0.06) were good general combiners for fruit yield (Kg/plant) while EC-579997 (-1.15), Kandaghat Sel-9 (-1.15) and UHF-8 (-0.06) were poor general combiners (Table 2).

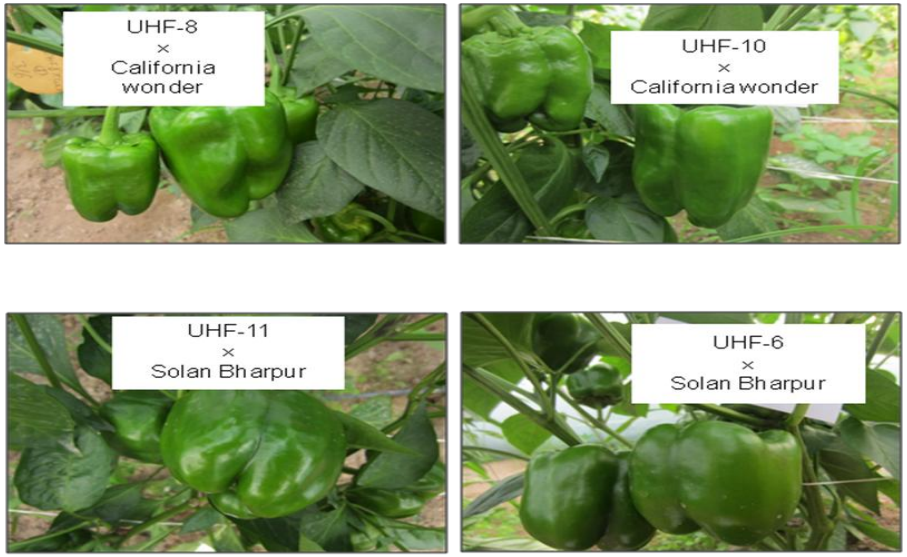

Fig 1. Top four cross combination for yield and yield contributing traits on the basis of specific combining ability effects

Table.1 Analysis of variance for line x tester analysis including parents in Capsicum

Source	Mean Sum of Squares								
	Replications	Treatments	Parents	P vs C	Crosses	Lines	Testers	Line X Tester	Error
Character									
df	2	25	9	1	15	7	1	7	50
Days to fifty percent flowering	0.36	59.42*	71.49*	118.87*	48.21*	73.24*	60.17*	27.76*	2.45
Days to marketable maturity	1.24	61.44*	33.69*	150.83*	72.13*	42.35*	2.67	45.10*	2.79
Number of fruits per plant	2.72	336.08*	430.29*	159.65*	291.31*	372.89*	1.10	86.82*	1.76
Average fruit weight (g)	1.83	276.03*	299.16*	0.41	280.52*	341.29*	158.00*	163.02*	2.96
Fruit yield per plant (kg)	0.00	1.90*	2.03*	0.86*	1.90*	1.81*	0.03*	0.59*	0.00
Fruit shape index	0.01	0.39*	0.49*	0.01*	0.36*	0.56*	0.01*	0.02*	0.01
Number of lobes per fruit	0.03	0.33*	0.27*	0.01*	0.39*	0.23*	0.73*	0.32*	0.03
Pericarp Thickness (mm)	0.01	0.97*	0.99*	4.79*	0.70*	1.05*	1.03*	0.73*	0.02
Plant height (cm)	16.32	557.65*	596.63*	1053.52*	501.20*	552.48*	4.17*	134.16*	4.16
Harvest Duration (Days)	12.36	75.23*	116.11*	103.41*	48.80*	99.71*	0.17	19.85*	2.63

*Significant at 5% level of significance

Table.2 Estimates of general combining ability (GCA) effects of parents for different traits in capsicum

Traits / Parents	DTFPF	DTMM	NOFPP	AFW (g)	FYPP (kg)	FSI	NOLPF	PT (mm)	PH (cm)	HD (Days)
Lines										
EC-579997	-0.44	-1.04	-14.13*	-12.17*	-1.15*	0.79*	-0.66*	-0.19*	-17.85*	-3.83*
Kandaghat Sel-9	4.90*	6.46*	-14.75*	-10.11*	-1.15*	-0.03	0.10*	-0.28*	-19.85*	-6.17*
ACC-16	2.90*	3.29*	5.82*	-5.47*	0.06*	-0.30*	0.09	0.59*	8.15*	-0.83
UHF-8	3.90*	4.63*	-0.03	-0.67	-0.06*	0.13*	-0.04	0.26	-1.69*	-0.50
UHF-6	-1.60*	-3.04*	9.30*	5.41*	0.73*	-0.18*	0.07	0.10*	10.48*	3.33*
UHF-10	-1.94*	-4.04*	1.67*	7.31*	0.34*	-0.13*	-0.02	-0.33*	1.98*	1.83*
UHF-14	-5.10*	-1.71*	7.85*	4.38*	0.58*	0.02	0.12*	-0.28*	10.48*	0.67
UHF-11	-2.60*	-4.54*	4.27*	11.31*	0.64*	-0.31*	0.34*	0.15*	8.31*	5.50*
Testers										
SolanBharpur	-0.40	-0.67*	-0.94*	0.30	-0.06*	-0.03	0.04*	0.13*	-1.65*	-0.04
California Wonder	0.40	0.67*	0.94*	-0.30	0.06*	0.03	-0.04*	-0.13*	1.65*	0.04
S.E.(g_i)Lines	0.63	0.61	0.54	0.67	0.02	0.04	0.05	0.05	0.83	0.62
S.E.(g_j)Testers	0.24	0.23	0.21	0.26	0.01	0.02	0.02	0.02	0.31	0.23
S.E. (g_i- g_j) Lines	0.47	0.46	0.41	0.51	0.01	0.03	0.04	0.04	0.63	0.47
S.E. (gi - g_j) Testers	0.95	0.92	0.82	1.02	0.03	0.06	0.08	0.08	1.26	0.93
C.D.$_{(0.05)}$(g_i) Lines	1.26	1.23	1.09	1.35	0.03	0.08	0.10	0.10	1.67	1.25
C.D.$_{(0.05)}$(g_j) Testers	0.48	0.46	0.41	0.51	0.01	0.03	0.04	0.04	0.62	0.46
C.D.$_{(0.05)}$ (g_i - g_j) Lines	0.95	0.92	0.83	1.02	0.02	0.06	0.08	0.08	1.27	0.94
C.D.$_{(0.05)}$ (g_i - g_j) Testers	1.90	1.85	1.65	2.05	0.05	0.13	0.16	0.15	2.53	1.87

*Significant at 5% level of significance

Where,								
DTFPF	=	**Days to 50% flowering**	**FYPP (kg)**	=	**Fruit yield per plant (kg)**	**PH (cm)**	=	**Plant height (cm)**
DTMM	=	**Days to marketable maturity**	**FSI**	=	**Fruit shape index**	**HD (Days)**	=	**Harvest Duration**
NOFPP	=	**Number of fruits per plant**	**NOLPF**	=	**Number of lobes per fruit**			
AFW (g)	=	**Average fruit weight (g)**	**PT (mm)**	=	**Pericarp Thickness (mm)**			

Table.3 Estimates of specific combining ability (SCA) effects of crosses for different traits in capsicum

Traits / Crosses	DTFPF	DTMM	NOFPP	AFW (g)	FYPP (kg)	FSI	NOLPF	PT (mm)	PH (cm)	HD (Days)
EC-579997 x SolanBharpur	0.06	0.50	2.37*	-3.56*	0.05*	0.08*	-0.15*	0.35*	5.31*	-0.46
EC-579997 x California Wonder	-0.06	-0.50	-2.37*	3.56*	-0.05*	-0.08*	0.15*	-0.35*	-5.31*	0.46
Kandaghat Sel-9 x SolanBharpur	-0.27	-1.00	-1.36*	8.90*	0.13*	-0.05	0.17*	-0.15*	-4.02*	0.87
Kandaghat Sel-9 x California Wonder	0.27	1.00	1.36*	-8.90*	-0.13*	0.05	-0.17*	0.15*	4.02*	-0.87
ACC-16 x SolanBharpur	-0.94	-0.17	6.02*	-0.12	0.33*	0.01	-0.15*	0.64*	6.31*	1.21
ACC-16 x California Wonder	0.94	0.17	-6.02*	0.12	-0.33*	-0.01	0.15*	-0.64*	-6.31*	-1.21
UHF-8 x SolanBharpur	4.06*	4.50*	-4.28*	-5.36*	-0.43*	0.02	-0.42*	-0.19*	-4.52*	0.21
UHF-8 x California Wonder	-4.06*	-4.50*	4.28*	5.36*	0.43*	-0.02	0.42*	0.19*	4.52*	-0.21
UHF-6 x SolanBharpur	-2.44*	-1.17	0.34	1.55*	0.10*	-0.01	0.22*	0.13*	0.31	0.71
UHF-6 x California Wonder	2.44*	1.17	-0.34	-1.55*	-0.10*	0.01	-0.22*	-0.13*	-0.31	-0.71
UHF-10 x SolanBharpur	-2.44*	2.17*	-3.96*	-6.97*	-0.51*	0.09*	0.15*	-0.09	-5.52*	-3.79*
UHF-10 x California Wonder	2.44*	-2.17*	3.96*	6.97*	0.51*	-0.09*	-0.15*	0.09	5.52*	3.79*
UHF-14 x SolanBharpur	0.23	0.17	-2.96*	4.06*	0.00	-0.08*	0.21*	-0.39*	-2.02*	-0.96
UHF-14 x California Wonder	-0.23	-0.17	2.96*	-4.06*	0.00	0.08*	-0.21*	0.39*	2.02*	0.96
UHF-11 x SolanBharpur	1.73*	-5.00*	3.83*	1.49*	0.33*	-0.05	-0.04	-0.29*	4.15*	2.21*
UHF-11 x California Wonder	-1.73*	5.00*	-3.83*	-1.49*	-0.33*	0.05	0.04	0.29*	-4.15*	-2.21*
S.E. (S_{ij})	0.63	0.61	0.54	0.67	0.02	0.04	0.05	0.05	0.83	0.62
S.E. ($S_{ij} - S_{kj}$) Common Line	1.64	1.60	1.43	1.76	0.04	0.11	0.14	0.13	2.18	1.61
S.E. ($S_{ij} - S_{kj}$) Common Tester	1.42	1.38	1.23	1.53	0.04	0.10	0.12	0.12	1.89	1.40
C.D.$_{0.05}$ (S_{ij})	1.26	1.23	1.09	1.35	0.03	0.08	0.10	0.10	1.67	1.25
C.D.$_{0.05}$ ($S_{ij} - S_{kj}$) Common Lines	3.30	3.22	2.86	3.54	0.09	0.22	0.28	0.27	4.38	3.24
C.D.$_{0.05}$ ($S_{ij} - S_{kj}$) Common Tester	2.86	2.77	2.48	3.07	0.07	0.19	0.24	0.23	3.80	2.81

Where,								
DTFPF	=	Days to 50% flowering	FYPP (kg)	=	Fruit yield per plant (kg)	PH (cm)	=	Plant height (cm)
DTMM	=	Days to marketable maturity	FSI	=	Fruit shape index	HD (Days)	=	Harvest Duration
NOFPP	=	Number of fruits per plant	NOLPF	=	Number of lobes per fruit			
AFW (g)	=	Average fruit weight (g)	PT (mm)	=	Pericarp Thickness (mm)			

*Significant at 5% level of significance

Testers California Wonder (0.06) and Solan Bharpur (-0.06) were good and poor general combiners, respectively.

Seven crosses had shown significant positive SCA effects for this trait being highest in UHF-10 x California Wonder (0.51) followed by UHF-8 x California Wonder (0.43), ACC-16 x Solan Bharpur (0.33), UHF-11 x Solan Bharpur (0.33), Kandaghat Sel-9 x Solan Bharpur (0.13), UHF-6 x Solan Bharpur (0.10) and EC-579997 x Solan Bharpur (0.05) involving good x good, poor x good, good x poor, good x poor, poor x poor, good x poor and good x poor general combiners, respectively. While, UHF-14 x Solan Bharpur and UHF-14 x California Wonder were average general combiners. Remaining seven crosses exhibited negative significant SCA effects and thus were poor cross combinations for this trait (Table 3). Similar results were reported earlier by Gill *et al.,* (1973), Kaul and Sharma (1988), Salazar and Vallejo (1990), Mulge (1992), Ramesh (1996), Mulge and Anand (1997), Echeverri *et al.,* (1998), Pandey *et al.,* (2002), Ahmed *et al.,* (2003), Johri *et al.,* (2004), Sood and Kaul (2006), Farag and Khalil (2007), Kamble and Mulge (2008), Kamble *et al.,* (2009), Nascimento *et al.,* (2010), Sood and Kumar (2010), Pandey *et al.,* (2012), Gawande *et al.,* (2015)**.** Two parental lines EC-579997 (0.79) and UHF-8 (0.13) were good general combiners for expression of fruit shape index as these line exhibited significant positive GCA effects whereas lines UHF-10 (-0.13), UHF-6 (-0.18), ACC-16 (-0.30) and UHF-11(-0.31) were poor general combiner for fruit shape index (Table 2). Average general combining ability was found in UHF-14 (0.02) and Kandaghat Sel-9 (-0.03). Testers Solan Bharpur (-0.03) and California Wonder (0.03) were average general combiners for this trait.

Cross combinations (Table 3) EC-579997 x Solan Bharpur (0.08), UHF-10x Solan Bharpur (0.09) and UHF-14 x California Wonder (0.08) were good specific combiners involving good x average, poor x average and average x average parents, respectively.

General combining ability effects for number of lobes per fruit revealed that three lines *viz*., UHF-11 (0.34), UHF-14 (0.12) and Kandaghat Sel-9 (0.10) had good general combining ability, whereas, EC-579997 (-0.66) was poor combiner (Table 2). The remaining four lines were designated as average general combiners. Among the testers, Solan Bharpur (0.04) was good and California Wonder was poor general combiner for number of lobes per fruit.

Significant positive SCA effects (Table 3) were exhibited by seven cross combinations (F_1) *viz*., UHF-8 x California Wonder (0.42), UHF-6 x Solan Bharpur (0.22), UHF-14 x Solan Bharpur (0.21), Kandaghat Sel-9 x Solan Bharpur (0.17), EC-579997 x California Wonder (0.15), ACC-16 x California Wonder (0.15), UHF-10 x Solan Bharpur (0.15) which involved parents with average x poor, average x good, good x good, good x good, poor x poor, average x poor and average x good GCA effects, respectively. On the other hand, seven hybrids were found poor specific cross combiners due to their significant negative SCA effects. Other two cross combinations revealed non-significant SCA effects, which indicated that these hybrid combinations were average specific combiners for number of lobes per fruit. Similar findings were obtained by Bilashini (2014).The line ACC-16 (0.59) and two others *viz*., UHF-11 (0.15) and UHF-6 (0.10) were good general combiners for expression of pericarp thickness (mm) as these line exhibited significant positive GCA effects whereas line UHF-10 (-0.33), Kandaghat Sel-9 (-0.28), UHF-14 (-0.28) and EC-579997 (-0.19) were poor general combiner (Table 2). Average general combining ability was found

in UHF-8 (0.26). Tester Solan Bharpur (0.13) and California Wonder (-0.13) were good and poor general combiners, respectively, for pericarp thickness (mm).

Among crosses, seven cross combinations showed significant positive SCA effects for pericarp thickness being highest in ACC-16 x Solan Bharpur (0.64) followed by UHF-14 x California Wonder (0.39), EC-579997 x Solan Bharpur (0.35), UHF-11 x California Wonder (0.29), UHF-8 x California Wonder (0.19), Kandaghat Sel-9 x California Wonder (0.15) and UHF-6 x Solan Bharpur (0.13) and involved the parents with good x good, poor x poor, poor x good, good x poor, average x poor, poor x poor and good x good GCA effects, respectively. On the other hand, seven and two cross combinations were poor and average specific combinations, respectively, for this trait. Similar findings were also obtained by Mulge (1992), Gong and Wang (1995), Ramesh (1996), Johri *et al.,* (2004), Farag and Khalil (2007), Kamble *et al.,* (2009), Payakhapaab *et al.,* (2012), Khalil and Hatem (2014). The parental lines UHF-14 (10.48), UHF-6 (10.48), UHF-11 (8.31), ACC-16 (8.15), UHF-10 (1.98) had shown significant positive GCA thereby indicating that they are good general combiners for plant height whereas, Kandaghat Sel-9, EC-579997 and UHF-8 were poor general combiners as they had significant negative GCA values of -19.85, -17.85 and -1.69 respectively (Table 2). Tester California Wonder was a good general combiner (1.65) and Solan Bharpur (-1.65) was a poor combiner.

Among the crosses, seven crosses showed significant positive SCA effects being maximum in ACC-16 x Solan Bharpur (6.31) followed by UHF-10 x California Wonder (5.52), EC-579997 x Solan Bharpur (5.31), UHF-8 x California Wonder (4.52), UHF-11 x Solan Bharpur (4.15), Kandaghat Sel-9 x California Wonder (4.02), UHF-14 x California Wonder (2.02) (Table 3). These all crosses involved good x poor, good x good, poor x poor, poor x good, good x poor, poor x good, good x good, general combiners respectively. Seven crosses were the poor specific combinations whereas UHF-6 x Solan Bharpur and UHF-6 x California Wonder were average combiners. Similar findings were also obtained by Joshi and Singh (1987), Blank and Maluf (1997), Mulge and Anand (1997), Ahmed *et al.,* (2003), Sood and Kaul (2006), Farag and Khalil (2007), Prasath and Ponnuswami (2008), Kamble *et al.,* (2009), Nascimento *et al.,* (2010), Payakhapaab *et al.,* (2012).

Three lines exhibited significant positive GCA effects for number of harvest duration *viz.,* UHF-11 (5.50), UHF-6 (3.33) and UHF-10 (1.83) and showed good general combining ability, while EC-579997 (-3.83) and Kandaghat Sel-9 (-6.17) were poor general combiners (Table 2). Both the testers had shown average combining ability. Significant positive specific combining ability effects were observed for two crosses *viz.,* UHF-10 × California Wonder (good × average) and UHF-11 × Solan Bharpur (good × average) whereas the cross, UHF-10 × Solan Bharpur and UHF-11× California Wonder were poor and the remaining crosses were average specific combinations for this trait. Similar results were reported earlier by Ahmed *et al.,* (2003) and Sood and Kaul (2006) for harvest duration.

The above results and discussion revealed that on the basis of GCA studies, the parents *viz.,* UHF-11, UHF-6, UHF-14 and UHF-10 were found good general combiners for earliness and yield contributing traits. Overall SCA performance showed that, the cross combinations UHF-8 x California Wonder, UHF-10 x California Wonder, UHF-11 x Solan Bharpur and UHF-6 x Solan Bharpur were found as best hybrids (Fig. 1) for

majority yield contributing traits under protected conditions.

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