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Original scientific article

ASSESSMENT OF COMBINING ABILITY COMPRISING *alc*, *nor* AND *rin* MUTANT ALLELES OF TOMATO UNDER MAIN AND LATE PLANTING SEASONS

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Seventy four genotypes of the tomato (14 lines, four testers of ripening mutant and their 56 F_1 crosses developed in line × tester mating fashion) were appraised under main (E_1) and late (E_2) planting season at Department of Vegetable Science, Punjab Agricultural University, Ludhiana, Punjab, India. To find out few general and specific combiners, if some, which might be utilized in furthermore breeding programmes to prolong the fruit harvesting span of tomato in the Punjab conditions. The findings hinted in general, the particular parent or hybrid could not be used to assess all examined characters with same efficiency. In main (E_1) season line, FL-556 was found best general combiner for average fruit weight, locules number, pericarp thickness, P/E ratio, dry matter and lycopene content; PAU 114 for average fruit weight, lesser locules, pericarp thickness, TSS and dry matter. During late (E_2) planting season line, Punjab Ratta found with good GCA values for average fruit weight, lesser locules number, pericarp thickness and TSS content; Roma for average fruit weight, locules number, pericarp thickness and P/E ratio. Similarly tester, *alc*-IIHR-2050 for pollen viability, minimum days from transplanting to first harvest, harvesting span, average fruit weight, pericarp thickness and P/E ratio in main (E_1) season while, for pollen viability, average fruit weight, pericarp thickness and P/E ratio in late (E_2) season. The received results furthermore illustrated the best combinations that possessed significant values of SCA which effectively combine to develop a cross with good performance. In main (E_1) season from combinations, F_1 hybrid SMZ-867 × *rin*-Rutgers were registered with best specific combiner for pollen viability, average fruit weight, lesser locules number, Pericarp thickness and P/E ratio;

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PAU 2381 × *nor*-RM-1 for harvesting span, average fruit weight, pericarp thickness, total fruit yield and lycopene content. Likewise, in late (E_2) season cross, SMZ-867 × *nor*-RM-1 for pollen viability, minimum days from transplanting to first harvest, harvesting span and fruit yield; LT-44 × *alc*-IIHR-2050 for pollen viability, average fruit weight, lesser locules and pericarp thickness.

Keywords: combining ability, harvesting span, ripening mutants, testers, tomato

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is globally considered as 'Protective Food' because of it is plentiful source of vitamins, organic acids and minerals. Tomatoes are consumed as raw in salad, sandwiches etc. and in processed products like puree, sauce, chutney, soup, ketchup etc. (BALI *et al.,* 2021). It is a good appetizer and soup considered to be best remedy for constipation.

India ranks second in tomato production after China. In 2020, total production in India was 20.57 million tonnes from 0.88 million hectares area (ANONYMOUS, 2020a), whereas in Punjab, corresponding statistics were 256.87 thousand tonnes from 10.27 thousand hectares (ANONYMOUS, 2020a). Tomato is one of the popular vegetable at national as well as state level. It is third most important vegetable crop after potato and onion in India, while second in the world after potato. In Punjab, as concerns to area, it holds fourth position after potato, peas and chilli and productivity is about 250.02 q/hectare (ANONYMOUS, 2020b).

In Punjab, main season tomato crop is raised from mid-November to Early-December and fruit availability period is after mid-April to mid-May. Tomato production during this period is very high causes an oversupply of fruits which gives low prices to growers. After mid-May shortage occurs which ultimately gives a higher market price. At many times the occurrence of heavy frost in December-January causing more loss in the main-season crop results in forcing growers to replant the crop in the late season. A few ripening mutant alleles have been identified which interfere with the ripening related processes of tomato fruit which are slow ripening alcobaca (*alc*), non-ripening (*nor*), ripening inhibitor (*rin*), colourless non-ripening (*Cnr*), never ripe (*Nr*) and Green ripe (*Gr*) (ROBINSON and TOMES, 1968; OSEI *et al*., 2017; WANG *et al*., 2020). These mutants are beneficial for extending harvesting span of tomato in Punjab conditions by slowdown of ripening related process of fruits on plant itself (GARG *et al.,* 2013).

Besides, to prolong the harvesting span, another crop probably planted during first two weeks of March. Even though, the quality attributes of fruits like TSS content, titratable acidity, P^H, TSS/Acid ratio etc. are improved under late season conditions as compared to the main season, but there is reduction in productivity because of insufficient vegetative growth as well as lower fruit set percentage under the higher temperature conditions (GARG *et al*. 2013).

The selection of supreme parents for the use in a breeding programme is the most crucial decision for any plant breeder. Relative information on general (GCA) and specific (SCA) combining abilities is mandatory in any plant breeding programme during selection of right parents for the F_1 hybrids development. SPRAGUE and TATUM (1942) described GCA means the average performance of parental lines in hybrid cross combinations whereas, SCA used in the identification of certain hybrid combination perform worse or better than expectation which already made on the basis of mean performance of parental lines participated. The higher magnitude of SCA effects pointed towards non additive gene effect. Combining ability is most effective breeding tool, which provides precious information on the genetic capability for the selection of desirable parents based on their hybrids performance (KUMAR *et al.*, 2015).

To evolve new varieties by using ripening mutants having a prolonged availability period along with high yield potential, hybridization is effective for a considerable extent. Selection of superior parents by *per se* performance is a not sound procedure sometimes, *per se* performance of superior lines may poor yield recombinants in the following segregating generations (ALLARD, 1960). Therefore, parental lines should be selected on the basis of their combining ability. Furthermore, assessment of the breeding potential of different parental lines by genetic analysis gives a guideline for utilization of parents either in F_1 hybrids for the exploitation of heterosis or to accumulate fixable genes for evolving a new varieties. Therefore, it is necessary to find out estimates of combining ability of the desirable parental genotypes to be participated in the breeding programme to ensure an effective transmission of desirable genes in resulting progenies. There are numerous methods for the screening of strains or varieties in term of combining ability and the line × tester analysis in one of such method, suggested by KEMPTHORNE (1957), it is based on combining ability variance or component of genetic variance and effects. This helps to assess relatively more number of lines or germplasms at a time as compared to partial diallel or diallel methods. Keeping these all points in view, the present research work was planned to identify the gene effects governing yield and other quality attributes under both main and late planting season and to find out some best general and specific combiners which could be utilized in upcoming breeding programme of tomato to extend the fruit harvesting span i.e. availability period in Punjab conditions.

MATERIALS AND METHODS

Location

The present research programme was conducted from October 2019 to June 2021 at Vegetable Research Farm, Department of Vegetable Science, Punjab Agricultural University Ludhiana, India at 30° 55' north latitude, 75° 54' east longitude with an altitude of 247 m from MSL.

Soil and climate

The soil texture of the research field was sandy loam with medium level of fertility. The climatic condition of Ludhiana is sub-tropical with humid and hot summer and dry and cold winters. The minimum and maximum temperature shows remarkable variations during winters and summers. The curving of actual minimum, maximum and mean temperature recorded on monthly frequency during crop season is represented in figure 1.

Experimental material

The research material was consisted of 14 genetically diverse lines and 4 testers of ripening mutants and their 56 F_1 cross breds developed using line × tester mating design (KEMPTHORNE, 1957) during February-March, 2020

Evaluation of research material

All 74 genotypes (18 parental lines and 56 F_1 hybrids) were appraised in randomized Complete Block Design (RCBD) in two different seasons (Figure 1) with 3 replications as given:

Season	Sowing date	Transplanting date
Main (E_1)	October 30, 2020	November 27, 2020
Late (E_2)	January 19, 2021	March 1, 2021

The details of parental lines utilized in the experiment were shown in Table 1

Table 1. Details of parental lines utilized in the experiment

Plant material	Source	Growth habit	Fruit shape
Lines (Female parents)			
1. SMZ-867	PAU	Determinate	Oval
2. CLN 1621L	AVRDC	Determinate	Round
3. PAU 114	PAU	Determinate	Oval
4. FL-556	PAU	Determinate	Oval
5. PAU 2381	PAU	Determinate	Round
6. LT-44	PAU	Determinate	Oval
7. Punjab Ratta	PAU	Determinate	Oval
8. Roma	USA	Determinate	Flat
9. LT-42	PAU	Determinate	Oval
10. LST-17	PAU	Determinate	Round
11. LST-6	PAU	Determinate	Oval
12. Leader	USA	Determinate	Oval
13. Malintka	USA	Determinate	Round
14. Spectrum	USA	Determinate	Oval
Testers (Male parents)			
1. *alc*-IIHR-2050	IIHR	Semi-determinate	Flat
2. *nor*-RM-1	PAU	Determinate	Round
3. *rin*-Rutgers	USA	Determinate	Oval
4. Olive Green#	PAU	Determinate	Round

Gene unidentified in tester ‘Olive Green’, PAU – Punjab Agricultural University, Ludhiana, India,USA – United States of America, IIHR – Indian Institute of Horticultural Research, Bangalore, India, AVRDC – Asian Vegetable Research and Development Center, Taiwan

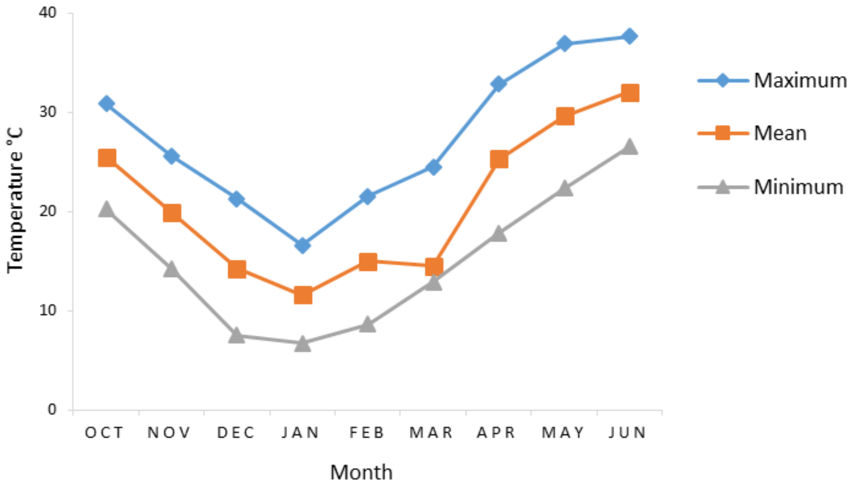

Fig. 1. Minimum, maximum and mean temperature recorded on monthly frequency during crop season.

Observations recorded

Five random plants of each treatment, with exception of border plants in each replication were selected to record observations of the following characters:

1. Pollen Viability (%): Fresh pollen grains from fully developed flowers having mature anthers were stained with 2% solution of acetocarmine in the slide for around 15 minutes and each slide examined with the help of compound microscope. The unstained and stained pollen grains were separately counted to determine pollen viability (%).

2. Days from Transplanting to the First Harvest: The number of days from transplanting to the picking of first ripened fruits were calculated for five random competitive selected plants. The final fruit colour at fully ripened stage was pink in *alc* and *rin* homozygotes, yellow in the *nor* homozygote, green in Olive Green and red of varied intensity in 14 other genotypes.

3. Harvesting Span (Days): It was determined by counting number of days between first harvesting and last harvesting. The average of five plants in every entry taken as harvesting span.

4. Average Fruit Weight (g): Marketable sized fruits of around one kg were taken randomly from the second harvesting and then, average weight was computed by dividing sample weight with the total number of fruits per sample.

5. Number of Locules per Fruit: Transverse section of every randomly selected fruit was taken, then average of the five fruits in each entry was considered as locule numbers per fruit.

6. Pericarp Thickness (mm): Five fruits selected by random basis dissected transversely and pericarp thickness at two different places were measured by using ‘digital Vernier Calliper’ and expressed as average value over five random fruits.

7. Polar/Equatorial (P/E) ratio: P/E ratio was computed by dividing average length of fruits with average width of five randomly selected tomatoes from every replication.

8. Total Fruit Yield (kg plant^{-1}): It was determined by dividing total fruits weight received from the all pickings with total number of harvested plants.

*9. Total Soluble Solids (°Brix)***:** The ten fruits were harvested from each treatment at red-ripe fruit maturity stage and then the TSS content were recorded through hand refractometer at room temperature.

10. Dry Matter (%): 50 grams well-sliced sample from fresh tomato fruits was added in pre-weighed Petridish and later, placed in the oven at 65±2 °C temperature for drying and stable weight was taken as final dry weight. Dry matter content (%) was determined as:

$$\text{DM (\%)} = \frac{\text{Final sample weight (Dry)}}{\text{Original sample weight (Fresh)}} \times 100$$

11. Lycopene (mg/100 gm of fresh weight): Pigment was extracted by using 2 grams sample from fully ripe fruits with 10 ml acetone as a 2ml until colourless and transparent residue was left. Solution of acetone was subjected for evaporation to dryness. Then, volume of 25 ml was prepared by addition of the petroleum ether. Finally, optical density (OD) was noted at 505 nm through Spectrophotometer (SL177) and petroleum ether was used as a blank. The lycopene content was determined as:

$$\text{Lycopene} = \frac{\text{Final volume}}{2 \times \text{gm of sample used}} \times 100$$

12. Titratable Acidity (mg /100 ml fruit juice): Tomato fruit juice of volume 2 ml was added in conical flask and afterwards, titrated with 0.1N sodium hydroxide using indicator as phenolphthalein solution. Pink colour of solution was sign of end point. Acidity content (mg /100ml of fruit juice) was calculated as:

$$\text{Acidity} = \frac{0.0064 \times A \times 100}{B}$$

Where, A = ml of 0.1N NaOH consumed, B = ml of fruit juice taken

Statistical analysis: To find out differences between parents, hybrids as well as parent vs. hybrids, whole data received for every traits were subjected for analysis through the Randomized Block Design (RBD). Analysis for combining ability effects was performed only then, if significant differences were observed between the hybrids. Analysis for the combining ability effect for plant attributes was carried out by using model proposed by KEMPTHORNE (1957).

RESULTS AND DISCUSSION

Analysis of variance for the combining ability for various characters of research material determined in main and late planting season are tabulated in Table 2. The findings, in general, indicated that estimated variance for effects of general (σ^2GCA) and specific (σ^2SCA) combining ability displayed relatively higher estimates for the all studied characters. Further, it was noticed for most of studied traits that the non-additive gene effect were recorded predominantly for their significant contributions to genetic variability than the resulting from additive gene actions, hence the estimates of σ^2SCA showed greater values than these of σ^2GCA for most of examined characters. The estimated variance of general combining ability (σ^2GCA), presented in the Table 2 possessed greater values than variance due to specific combining ability (σ^2SCA) in the cases of average fruit weight in main (E_1) and late (E_2) season and for locules per fruit, pericarp thickness, TSS content and dry matter in late (E_2) season. On the contrary, SCA variances (σ^2SCA), except average fruit weight in both seasons and locules per fruit, pericarp thickness, TSS, dry matter and lycopene content in late season were noticed to have greater estimates than the general combining ability. Regarding P/E ratio in main (E_1) and late (E_2) season and titratable acidity in late season both σ^2GCA and σ^2SCA contributed equally. The GCA variance (σ^2GCA) were found with negative estimate for lycopene content in late (E_2) season therefore, it could be considered similar to zero.

Table 2. Analysis of variance for combining ability for different characters in main (E_1) and late (E_2) season

Source of variation	d.f	Pollen Viability (%)		Days from Transplanting to the First Harvest		Harvesting Span (Days)		Average Fruit Weight (g)	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Lines	13	227.70	291.38	22.68	28.51	33.36	56.39	1580.98**	999.29**
Testers	3	909.48	400.86	213.12**	17.34	176.87**	24.71	10700.18**	8617.92**
Lines × Testers	39	368.73**	285.28**	28.43**	20.92**	34.39**	35.50**	341.10**	339.89**
Error	146	17.01	12.45	8.86	5.34	3.23	3.00	2.44	68.90
Components of genetic variance									
σ^2GCA		7.40	2.25	3.32	0.08	2.62	0.19	214.80	165.51
σ^2SCA		117.10	90.80	6.35	5.19	10.32	10.89	112.78	93.47
σ^2SCA/GCA		15.82	40.32	1.91	67.45	3.94	58.25	0.53	0.56

Source of variation	d.f	Number of Locules per Fruit		Pericarp Thickness (mm)		Polar/Equatorial (P/E) ratio		Total Fruit Yield (kg plant^{-1})	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Lines	13	2.52**	1.54**	6.54**	4.17**	0.34**	0.16**	0.84*	0.21
Testers	3	1.00*	0.22	34.08**	35.56**	0.21**	0.31**	1.53**	0.64
Lines × Testers	39	0.32**	0.133**	2.20**	1.33**	0.02**	0.02**	0.34**	0.25*
Error	146	0.05	0.07	0.06	0.47	0.00	0.00	0.03	0.15
Components of genetic variance									
σ^2GCA		0.05	0.03	0.67	0.69	0.01	0.01	0.03	0.01
σ^2SCA		0.10	0.02	0.72	0.28	0.01	0.01	0.10	0.03
σ^2SCA/GCA		1.83	0.61	1.07	0.41	1.00	1.00	3.32	4.57

Source of variation	d.f	Total Soluble Solids ($^\circ$Brix)		Dry Matter (%)		Lycopene (mg/100 gm of fresh weight)		Titratable Acidity (mg /100 ml fruit juice)	
		E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Lines	13	3.31*	0.19	2.03	0.82	2.7	0.64	0.06	0.03
Testers	3	24.96**	8.94**	20.77**	23.49**	3.35	0.45	0.08	0.16**
Lines × Testers	39	1.64**	0.34**	1.71**	0.89*	2.18**	0.69*	0.03**	0.02*
Error	146	0.04	0.16	0.07	0.56	0.27	0.42	0.01	0.02
Components of genetic variance									
σ^2GCA		0.36	0.42	0.03	-0.01	0.00	0.00	0.36	0.42
σ^2SCA		0.55	0.14	0.63	0.08	0.01	0.00	0.55	0.14
σ^2SCA/GCA		1.52	0.33	20.39	-16.00	3.50	1.00	1.52	0.33

*,** significant at 5% and 1% level, respectively

From the estimates of combining abilities, outcomes in the table 2 and 3 exhibited that the lines FL-556, PAU 114 and PAU 2381 were reported as good general combiners for most of the traits in main (E_1) season. Line, FL-556 was found to be best general combiner for average fruit weight (4.73), locules number (-0.17), pericarp thickness (0.52), P/E ratio (0.04), dry matter (0.27) and lycopene content (0.47). Line, PAU 114 was found as good combiner for average fruit weight (7.62), lesser locules (-0.18), pericarp thickness (0.93), TSS (0.24) and dry matter (0.54). Line, PAU 2381 showed significant and best GCA effects for harvesting span (1.96), average fruit weight (9.24), pericarp thickness (0.16), total fruit yield (0.16) and lycopene content (1.18). Similarly in late (E_2) season, lines Punjab Ratta, Roma and LST-6 resulted as good general combiners in most of characters. Line, Punjab Ratta showed significant GCA values for average fruit weight (6.26), lesser locules number (-0.17), pericarp thickness (0.64) and TSS content (0.26). Line, Roma in case of avg. fruit weight (6.89), locules number (-0.17), pericarp thickness (0.40) and P/E ratio (0.31). Similarly line, LST-6 showed desirable GCA values for pollen viability (7.94), days from transplanting to first harvest (-1.37), harvesting span (2.47) and less locules number (-0.20). Among testers, *alc*-IIHR-2050 was the best general combiner in main as well as late season. In main (E_1) season for pollen viability (6.45), minimum days from transplanting to first harvest (-3.16), harvesting span (2.74), average fruit weight (12.70), pericarp thickness (0.57) and P/E ratio (0.10) while, for pollen viability (3.20), average fruit weight (6.86), pericarp thickness (0.53) and P/E ratio (0.12) in late (E_2) season.

Table 3. General combining ability (GCA) effects of parents for different characters in main (E_1) and late (E_2) season

Genotype	Pollen Viability (%)		Days from Transplanting to the First Harvest		Harvesting Span (Days)		Average Fruit Weight (g)		Number of Locules per Fruit		Pericarp Thickness (mm)	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Lines												
SMZ-867	1.75	-6.62**	0.98	-1.16	-2.01**	1.87**	-12.56**	-7.65**	-0.18**	-0.19*	-0.11	-0.01
CLN 1621L	-2.91*	2.16*	2.08*	-1.17	0.96	0.74	3.93**	-1.98	0.58**	0.60**	-1.15**	-0.60**
PAU 114	0.51	4.09**	-1.19	-0.57	-1.54**	-2.78**	7.62**	-7.79**	-0.18**	-0.19*	0.93**	0.01
FL-556	-6.56**	0.99	0.05	0.46	-0.82	2.09**	4.73**	2.35	-0.17**	-0.17*	0.52**	0.10
PAU 2381	-4.06**	-0.09	-0.02	2.56**	1.96**	-1.50**	9.24**	9.89**	-0.09	0.09	0.16*	0.52*
LT-44	-4.08**	0.59	-1.84	-0.56	1.78**	1.94**	25.17**	14.85**	1.42**	1.01**	-0.28**	0.23
Punjab Ratta	-3.57**	-8.62**	-3.07**	-1.05	0.81	0.92	3.76**	6.26**	-0.26**	-0.17*	0.68**	0.64**
Roma	2.00	0.33	0.63	2.21**	-0.66	-3.88**	5.54**	6.89**	-0.12	-0.17*	-0.16*	0.40*
LT-42	5.91**	-2.06*	1.15	-0.08	1.24*	-1.21*	0.27	5.22**	-0.08	-0.15	0.61**	0.51*
LST-17	1.86	2.71**	-0.79	-0.76	-0.99	0.17	-8.99**	-5.06**	-0.09	-0.05	-0.24**	-0.30
LST-6	0.48	7.94**	0.50	-1.37*	0.53	2.47**	-16.19**	-5.02**	-0.22**	-0.20*	-0.42**	-0.12
Leader	-0.12	-8.17**	-0.57	3.14**	0.91	-2.78**	-8.58**	1.16	-0.09	-0.1	0.48**	0.61**
Malintka	-0.34	1.11	1.13	-1.19	-3.74**	2.69**	-16.49**	-21.53**	-0.26**	-0.15	-1.67**	-1.51**
Spectrum	9.84**	5.64**	0.95	-0.06	1.56**	-0.73	2.55**	2.38	-0.26**	-0.15	-0.65**	-0.47*
CD (5%)	2.35	2.01	1.70	1.32	1.03	0.99	0.69	3.21	0.12	0.15	0.14	0.39
CD (1%)	3.11	2.66	2.24	1.74	1.35	1.31	0.98	4.56	0.16	0.20	0.18	0.52
Testers												
alc-IIHR-2050	6.45**	3.20**	-3.16**	0.38	2.74**	-1.04**	12.70**	6.86**	0.08*	0.00	0.57**	0.53**
nor-RM-1	0.18	-3.95**	0.21	0.64	-0.95**	0.45	12.74**	7.99**	-0.14**	-0.07	0.82**	0.78**
rin-Rutgers	-2.50**	-0.74	0.82	-0.79*	0.26	0.69*	-20.37**	-20.54**	0.18**	-0.10*	-0.22**	-0.02
Olive Green	-4.13**	1.50**	2.13**	-0.24	-2.05**	-0.09	-5.07**	1.67	-0.12**	-0.03	-1.18**	-1.29**
CD (5%)	**1.25**	**1.08**	**0.91**	**0.70**	**0.55**	**0.53**	**0.37**	**1.71**	**0.07**	**0.08**	**0.07**	**0.21**
CD (1%)	**1.65**	**1.42**	**1.20**	**0.93**	**0.72**	**0.70**	**0.52**	**2.43**	**0.09**	**0.11**	**0.10**	**0.28**

*,** significant at 5% and 1% level, respectively

Genotype	Polar/Equatorial (P/E) ratio		Total Fruit Yield (kg plant^{-1})		Total Soluble Solids (˚Brix)		Dry Matter (%)		Lycopene (mg/100 gm of fresh weight)		Titratable Acidity (mg /100 ml fruit juice)	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
Lines												
SMZ-867	0.11**	0.11**	0.19**	-0.07	0.94**	-0.08	0.95**	-0.33	-0.18	0.10	0.04	0.06**
CLN 1621L	-0.23**	-0.18**	0.26**	0.17*	0.45**	-0.17	0.04	-0.55*	-0.55**	0.29	0.05	0.02
PAU 114	0.01	0.01	0.06	-0.07	0.24**	-0.11	0.54**	0.13	0.10	-0.03	-0.04	0.04
FL-556	0.04*	-0.02	-0.28**	0.01	0.01	-0.07	0.27**	-0.03	0.47**	0.22	0.03	-0.02
PAU 2381	0.01	-0.02	0.16**	0.21*	-0.96**	-0.1	-0.26**	0.01	1.18**	-0.09	-0.11**	-0.04
LT-44	-0.20**	-0.11**	0.26**	0.29**	-0.26**	-0.07	-0.47**	-0.19	-0.25	0.32	-0.10**	-0.06**
Punjab Ratta	-0.01	-0.02	0.11**	-0.14	-0.20**	0.26*	0.06	0.29	-0.54**	-0.07	0.01	0.02
Roma	0.47**	0.31**	0.22**	-0.04	-0.07	0.15	-0.36**	0.09	0.45**	-0.11	0.01	0.03
LT-42	0.02	0.00	0.24**	0.02	-0.68**	0.08	-0.32**	-0.22	-0.49**	0.32	-0.06	-0.07**
LST-17	-0.13**	-0.09**	-0.18**	-0.05	-0.02	0.05	-0.54**	0.35	0.10	-0.01	-0.05	-0.01
LST-6	-0.14**	0.04	0.10*	-0.04	0.93**	0.05	0.32**	0.14	0.11	0.00	0.16**	0.01
Leader	0.00	0.07**	-0.44**	-0.18*	-0.27**	0.11	-0.13	0.13	0.12	-0.23	-0.01	-0.01
Malintka	-0.09**	-0.08**	-0.48**	-0.05	0.02	0.07	-0.11	0.33	-0.25	-0.26	0.06	0.11**
Spectrum	0.11**	-0.03	-0.22**	-0.07	-0.13*	-0.16	0.03	-0.14	-0.28	-0.46*	0.01	-0.07**
CD (5%)	0.03	0.04	0.07	0.16	0.11	0.23	0.15	0.43	0.30	0.37	0.06	0.04
CD (1%)	0.04	0.05	0.10	0.23	0.15	0.31	0.19	0.56	0.39	0.49	0.07	0.05
Testers												
alc-IIHR-2050	0.10**	0.12**	0.00	0.01	-0.59**	-0.27**	-0.55**	-0.44**	-0.30**	-0.04	-0.02	0.01
nor-RM-1	-0.03**	-0.03*	0.27**	0.05	-0.25**	-0.12	-0.07	-0.29*	-0.36**	0.01	0.06**	0.03
rin-Rutgers	-0.02*	-0.02	-0.10**	-0.02	-0.29**	-0.29**	-0.40**	-0.38**	-0.13	-0.11	0.00	0.05
Olive Green	-0.06**	-0.08**	-0.10**	-0.12*	1.13**	0.68**	1.01**	1.12**	0.05	0.14	-0.04*	-0.09
CD (5%)	**0.01**	**0.02**	**0.04**	**0.09**	**0.06**	**0.12**	**0.08**	**0.23**	**0.16**	**0.20**	**0.03**	**0.15**
CD (1%)	**0.02**	**0.03**	**0.06**	**0.12**	**0.08**	**0.16**	**0.10**	**0.30**	**0.21**	**0.26**	**0.04**	**0.20**

*,** significant at 5% and 1% level, respectively

The superior hybrid crosses that reflected highest significant values of SCA (T), which intends that the both parents of particular hybrid can combine effectively to develop cross combination with a higher general performance in main season were reported in those of cross, SMZ-867 × *rin*-Rutgers for pollen viability (18.74), average fruit weight (7.53), lesser locules number (-0.27), Pericarp thickness (0.58) and P/E ratio (0.14). Cross, PAU 2381 × *nor*-RM-1 reflected significant SCA for harvesting span (4.87), average fruit weight (12.41), pericarp thickness (0.89), total fruit yield (0.47) and lycopene content (0.93). Hybrid, Punjab Ratta × *nor*-RM-1 was recorded as good specific combiner for pollen viability (7.43), harvesting span (3.75), average fruit weight (2.23), pericarp thickness (0.37) and P/E ratio (0.10). In late (E_2) season crosses, SMZ-867 × *nor*-RM-1, LT-44 × *alc*-IIHR-2050 and PAU 2381 × *nor*-RM-1 were identified as good specific combiners. Cross combination SMZ-867 × *nor*-RM-1 was found to be best specific combiner for pollen viability (9.79), minimum days from transplanting to first harvest (-3.91), harvesting span (5.29) and total fruit yield (0.46). Hybrid, LT-44 × *alc*-IIHR-2050 considered as good combiner for pollen viability (11.02), average fruit weight (17.71), lesser locules (-0.35) and pericarp thickness (0.80). Cross PAU 2381 × *nor*-RM-1 exhibited significant SCA in case of pollen viability (6.85), average fruit weight (16.06) and pericarp thickness (1.08).

Table 4. Specific combining ability (SCA) effects of hybrids for different traits in main (E_1) and late (E_2) season

Hybrids	Pollen Viability (%)		Days from Transplanting to the First Harvest		Harvesting Span (Days)		Average Fruit Weight (g)		Number of Locules per Fruit		Pericarp Thickness (mm)	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
SMZ-867 × *alc*-IIHR-2050	-10.75**	-7.63**	0.68	1.89	-2.12*	-1.56	-1.86*	-10.66*	-0.16	0.05	0.41**	-0.35
SMZ-867 × *nor*-RM-1	2.58	9.79**	2.57	-3.91**	2.77**	5.29**	-12.04**	-3.37	0.39**	0.06	-0.35*	-0.37
SMZ-867 × *rin*-Rutgers	18.74**	-1.56	0.50	3.19*	0.42	-5.35**	7.53**	-5.55	-0.27*	-0.12	0.58**	-0.78
SMZ-867 × Olive Green	-10.57**	-0.60	-3.74*	-1.16	-1.07	1.62	6.38**	19.58**	0.04	0.01	-0.66**	1.50**
CLN 1621L × *alc*-IIHR-2050	10.10**	-5.01*	3.91*	0.84	-1.42	1.91	14.83**	7.43	0.76**	0.14	-0.11	0.67
CLN 1621L × *nor*-RM-1	-1.10	5.74**	0.27	-0.76	-3.54**	1.69	-10.52**	-7.90	-0.20	-0.2	-1.06	-0.62
CLN 1621L × *rin*-Rutgers	-3.35	0.19	-2.47	1.47	1.06	-1.89	3.06**	7.77	-0.18	0.37*	0.32*	-0.45
CLN 1621L × Olive Green	-5.65*	-0.92	-1.71	-1.55	3.90**	-1.71	-7.37**	-7.30	-0.38**	-0.31*	0.85**	0.40
PAU 114 × *alc*-IIHR-2050	-5.38*	-14.68**	-2.16	1.77	4.08**	-1.64	20.15**	-3.55	-0.16	0.05	1.13**	-0.37
PAU 114 × *nor*-RM-1	4.22	-4.60*	-2.4	-3.96**	0.17	-0.60	-1.57	-7.35	0.06	0.06	0.72**	0.12
PAU 114 × *rin*-Rutgers	-12.90**	18.06**	2.00	-1.46	-1.11	4.43**	-9.88**	-2.50	0.07	-0.12	-0.69**	0.24
PAU 114 × Olive Green	14.06**	1.22	2.56	3.65**	-3.14**	-2.20*	-8.70**	13.41**	0.04	0.01	-1.17**	0.01
FL-556 × *alc*-IIHR-2050	-12.72**	-8.91**	-2.79	-2.27	3.50**	1.96	-3.47**	2.80	-0.16	0.04	-0.57**	0.42
FL-556 × *nor*-RM-1	9.42**	4.70*	-2.90	4.94**	-3.89**	-1.13	4.69**	4.44	0.05	0.11	1.20**	-0.05
FL-556 × *rin*-Rutgers	-8.56**	-7.37**	2.63	-1.09	0.57	1.23	2.03*	-3.72	0.07	-0.14	0.19	-0.18
FL-556 × Olive Green	11.86**	11.58**	3.06	-1.58	-0.19	-2.06*	-3.25**	-3.52	0.04	-0.01	-0.82**	-0.19
PAU 2381 × *alc*-IIHR-2050	-3.95	-11.96**	-0.66	1.97	-1.35	-4.06**	9.30**	-12.50*	-0.24	-0.22	-0.37**	-0.68
PAU 2381 × *nor*-RM-1	-2.82	6.85**	-2.50	-0.03	4.87**	-2.95**	12.41**	16.06**	0.31*	0.15	0.89**	1.08**
PAU 2381 × *rin*-Rutgers	-7.26**	0.58	2.76	-1.66	-2.94**	5.82**	-11.24**	4.80	-0.02	0.01	-0.29*	0.18
PAU 2381 × Olive Green	14.03**	4.53*	0.39	-0.28	-0.57	1.19	-10.47**	-8.36	-0.05	0.07	-0.22	-0.58
LT-44 × *alc*-IIHR-2050	2.73	11.02**	-0.17	-1.72	-0.17	0.84	8.60**	17.71**	0.41**	-0.35*	0.54**	0.80*
LT-44 × *nor*-RM-1	10.27**	-7.70**	1.79	3.96**	-2.22*	-5.18**	-7.01**	-20.82**	-1.16	-0.61**	-1.35**	-1.44**
LT-44 × *rin*-Rutgers	-10.25**	3.76	-5.29**	-0.08	3.51**	-0.82	17.06**	11.61*	0.98**	0.62**	0.59**	0.72
LT-44 × Olive Green	-2.75	-7.08**	3.67*	-2.17	-1.12	5.15**	-18.65**	-8.50	-0.23	0.34*	0.22	-0.08
Punjab Ratta × *alc*-IIHR-2050	-7.83**	-7.10**	0.59	-2.02	1.8	5.39**	2.64**	4.71	-0.08	-0.03	0.19	0.17
Punjab Ratta × *nor*-RM-1	7.43**	0.52	-0.98	1.86	3.75**	-0.30	2.23*	2.30	0.14	0.11	0.37**	0.55
Punjab Ratta × *rin*-Rutgers	0.79	-1.29	4.21*	-0.71	-3.86**	-2.20*	-0.10	-2.78	-0.18	-0.07	-0.04	-0.23
Punjab Ratta × Olive Green	-0.39	7.87**	-3.83*	0.87	-1.69	-2.90**	-4.77**	-4.22	0.12	-0.01	-0.51**	-0.49
Roma × *alc*-IIHR-2050	-12.20**	17.69**	-4.31*	0.79	2.80**	0.86	-6.34**	-3.05	-0.21	-0.03	-1.50**	-0.69
Roma × *nor*-RM-1	-3.53	-5.96**	3.86*	-1.61	-0.72	0.77	10.48**	7.55	0.14	0.17	0.24	-0.30
Roma × *rin*-Rutgers	5.49*	-10.17**	-0.96	2.02	-0.99	-1.87	-0.13	5.00	0.02	-0.14	0.50**	0.78
Roma × Olive Green	10.25**	-1.55	1.41	-1.2	-1.09	0.24	-4.01**	-9.50*	0.05	-0.01	0.76**	0.21
LT-42 × *alc*-IIHR-2050	-0.58	0.54	1.51	-0.72	0.83	3.73**	-2.97**	-6.17	-0.09	-0.05	0.19	-0.90*
LT-42 × *nor*-RM-1	-3.05	-3.25	1.14	-0.12	-4.72**	-3.36**	3.45**	-7.41	-0.04	0.09	-0.15	0.41
LT-42 × *rin*-Rutgers	-0.36	-7.72**	-1.81	3.38*	-1.06	-3.14**	-5.92**	12.61**	-0.03	-0.02	-0.11	0.42
LT-42 × Olive Green	4.00	10.43**	-0.84	-0.54	4.95**	2.77**	5.43**	0.98	0.16	-0.02	0.07	0.07
LST-17 × *alc*-IIHR-2050	8.87**	2.04	-2.82	3.82**	1.53	0.41	-3.42**	8.12	0.09	0.39*	0.32*	0.13
LST-17 × *nor*-RM-1	-14.13**	-7.81**	-0.26	-1.51	-2.39*	-1.01	1.73	-0.23	-0.03	-0.08	0.24	0.37
LST-17 × *rin*-Rutgers	13.02**	20.31**	0.86	-0.08	-0.06	-1.59	-0.19	-8.46	-0.02	-0.19	-0.86**	-0.22
LST-17 × Olive Green	-7.75**	-14.53**	2.22	-2.23	0.91	2.19*	1.87*	0.56	-0.05	-0.12	0.31*	-0.28
LST-6 × *alc*-IIHR-2050	8.85**	8.14**	2.09	-0.03	-4.52**	-0.42	-8.56**	10.28*	0.05	0.00	0.07	0.23
LST-6 × *nor*-RM-1	4.45	-0.71	-0.35	-2.63	1.5	2.49*	-5.06**	-6.48	0.10	0.07	-0.14	0.05
LST-6 × *rin*-Rutgers	-13.53**	1.08	-2.36	-1.73	4.76**	-0.09	4.52**	-3.36	-0.22	-0.1	0.29*	0.01
LST-6 × Olive Green	0.23	-8.50**	0.61	4.39**	-1.74	-1.98	9.10**	-0.44	0.08	0.03	-0.22	-0.28
Leader × *alc*-IIHR-2050	10.72**	-5.08*	1.49	-1.82	0.5	0.76	-7.30**	-1.80	-0.08	0.04	0.29*	1.01*
Leader × *nor*-RM-1	-17.35**	0.47	-5.48**	3.46*	5.12**	2.67**	-5.67**	18.12**	-0.03	0.04	-0.70**	0.62
Leader × *rin*-Rutgers	17.94**	-3.61	2.31	-3.18*	-6.96**	1.43	8.46**	-12.29*	0.15	0.00	1.22**	-0.62
Leader × Olive Green	-11.30**	8.22**	1.67	1.54	1.35	-4.86**	4.51**	-4.03	-0.05	-0.07	-0.81**	-1.01*
Malintka × *alc*-IIHR-2050	12.67**	14.77**	3.86*	-0.75	-5.05**	-3.91**	-9.98**	-5.25	-0.08	0.02	-1.24**	-0.36
Malintka × *nor*-RM-1	7.20**	-4.21*	3.76*	-2.41	-1.77	4.40**	-4.18**	-5.70	0.14	0.02	0.13	-0.32
Malintka × *rin*-Rutgers	-10.78**	-9.36**	-4.19*	1.02	5.36**	-0.97	3.83**	-5.89	-0.18	-0.09	0.26	-0.17
Malintka × Olive Green	-9.09**	-1.20	-3.43*	2.14	1.46	0.47	10.34**	16.84**	0.12	0.04	0.86**	0.85*
Spectrum × *alc*-IIHR-2050	-0.52	6.17**	-1.22	-1.75	-0.42	-4.29**	-11.63**	-8.06	-0.08	-0.05	0.66**	-0.08
Spectrum × *nor*-RM-1	-3.58	6.19**	1.47	2.72	1.07	-2.78**	11.06**	10.80*	0.14	0.02	-0.05	-0.11
Spectrum × *rin*-Rutgers	11.04**	-2.89	1.80	-1.11	1.32	4.98**	-19.03**	2.75	-0.18	-0.02	-1.97**	0.32
Spectrum × Olive Green	-6.94**	-9.47**	-2.04	0.14	-1.97	2.09*	19.59**	-5.49	0.12	0.04	1.35**	-0.13
CD (5%)	**4.71**	**4.03**	**3.40**	**2.64**	**2.05**	**1.98**	**1.78**	**9.47**	**0.25**	**0.30**	**0.27**	**0.78**
CD (1%)	**6.21**	**5.32**	**4.49**	**3.48**	**2.70**	**2.61**	**2.35**	**12.51**	**0.33**	**0.40**	**0.36**	**1.04**

Table 4. Specific combining ability (SCA) effects of hybrids for different traits in main (E_1) and late (E_2) season (contd..)

Hybrids	Polar/Equatorial (P/E) ratio		Total Fruit Yield (kg plant^{-1})		Total Soluble Solids (°Brix)		Dry Matter (%)		Lycopene (mg/100 gm of fresh weight)		Titratable Acidity (mg /100 ml fruit juice)	
	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2	E_1	E_2
SMZ-867 × *alc*-IIHR-2050	-0.09*	-0.09*	0.27*	-0.37	-0.10	0.08	-0.43**	-0.39	-0.49	-0.11	-0.03	-0.12*
SMZ-867 × *nor*-RM-1	0.02	-0.03	-0.37**	0.46*	1.09**	0.16	1.39**	-0.21	-0.18	0.40	0.06	0.10
SMZ-867 × *rin*-Rutgers	0.14**	0.08	-0.20	0.15	-0.72**	0.63**	-0.28	1.17**	0.55	-0.06	-0.14*	-0.01
SMZ-867 × Olive Green	-0.07	0.04	0.30**	-0.24	-0.28*	-0.87**	-0.68**	-0.57	0.12	-0.30	0.11	0.04
CLN 1621L × *alc*-IIHR-2050	-0.06	-0.16**	0.55**	0.22	-0.04	-0.03	-0.67**	-0.13	-0.15	-0.32	-0.03	0.01
CLN 1621L × *nor*-RM-1	0.03	0.11**	-0.34**	-0.18	-0.26*	-0.28	-0.27	-0.27	0.12	0.18	-0.04	0.01
CLN 1621L × *rin*-Rutgers	0.03	0.01	-0.27*	-0.03	0.20	0.16	1.05**	0.87*	-0.33	0.26	0.17**	-0.05
CLN 1621L × Olive Green	0.00	0.05	0.06	-0.01	0.09	0.15	-0.11	-0.47	0.36	-0.13	-0.09	0.03
PAU 114 × *alc*-IIHR-2050	-0.04	-0.12**	0.11	-0.07	0.03	-0.16	0.60**	-0.08	-0.11	0.02	0.11	0.14*
PAU 114 × *nor*-RM-1	0.02	0.11**	0.23*	-0.02	-0.23	0.46	-0.35*	0.18	0.26	0.00	-0.14*	0.00
PAU 114 × *rin*-Rutgers	0.02	0.07	-0.71**	-0.12	0.16	-0.40	0.23	-0.12	-0.18	-0.2	0.00	-0.17**
PAU 114 × Olive Green	0.01	-0.06	0.38**	0.21	0.05	0.09	-0.49**	0.02	0.03	0.18	0.02	0.03
FL-556 × *alc*-IIHR-2050	0.02	0.09*	-0.21*	0.41	0.19	0.54*	0.06	0.58	0.46	0.09	0.03	-0.14*
FL-556 × *nor*-RM-1	0.03	-0.02	-0.23*	-0.28	-0.23	-0.21	-1.21**	-0.04	0.77*	-0.27	0.00	0.08
FL-556 × *rin*-Rutgers	0.02	-0.06	0.32**	0.01	0.17	-0.44	0.64**	-0.77	0.17	0.46	-0.05	0.07
FL-556 × Olive Green	-0.07	-0.01	0.12	-0.14	-0.13	0.12	0.50**	0.23	-1.40**	-0.29	0.02	-0.01
PAU 2381 × *alc*-IIHR-2050	0.12**	0.06	-0.02	0.14	-0.39**	-0.21	0.20	-0.17	0.14	0.62	0.00	0.01
PAU 2381 × *nor*-RM-1	0.04	-0.02	0.47**	-0.33	-1.09**	0.31	-0.31*	0.54	0.93**	0.15	-0.01	-0.01
PAU 2381 × *rin*-Rutgers	-0.08*	0.01	-0.23*	0.21	0.36**	0.08	-0.57**	-0.51	-1.55**	-0.24	0.08	-0.06
PAU 2381 × Olive Green	-0.07	-0.05	-0.23*	-0.02	1.12**	-0.19	0.68**	0.13	0.47	-0.53	-0.08	0.06
LT-44 × *alc*-IIHR-2050	-0.04	0.02	-0.32**	0.13	-1.89**	0.00	-0.18	-0.16	1.62**	-0.24	-0.04	-0.04
LT-44 × *nor*-RM-1	0.04	-0.01	-0.01	0.03	0.77**	-0.01	0.45**	0.50	-0.57	0.24	0.12*	0.11
LT-44 × *rin*-Rutgers	-0.04	-0.07	0.60**	0.14	0.41**	0.02	-0.42**	0.55	-0.94**	-0.01	-0.06	0.02
LT-44 × Olive Green	0.04	0.06	-0.28**	-0.3	0.71**	-0.02	0.15	-0.89*	-0.12	0.01	-0.02	-0.09
Punjab Ratta × *alc*-IIHR-2050	-0.08*	0.03	-0.20	0.14	0.77**	-0.12	0.79**	-0.18	-0.61*	0.25	0.09	-0.02
Punjab Ratta × *nor*-RM-1	0.10**	0.04	-0.08	-0.29	-1.35**	0.33	-0.60**	0.01	-0.33	-0.89*	-0.05	-0.07
Punjab Ratta × *rin*-Rutgers	0.02	-0.03	0.09	-0.1	0.33**	-0.27	-0.30*	-0.24	0.39	-0.52	-0.11	-0.03
Punjab Ratta × Olive Green	-0.03	-0.04	0.19	0.24	0.25*	0.06	0.11	0.41	0.56	1.15**	0.08	0.12*
Roma × *alc*-IIHR-2050	0.21**	0.13**	-0.39**	-0.08	0.09	-0.01	-0.71**	0.01	0.60*	-0.13	0.01	0.10
Roma × *nor*-RM-1	-0.13**	0.06	0.39**	0.48*	0.36**	-0.03	0.46**	-0.08	-0.15	0.36	-0.03	-0.10
Roma × *rin*-Rutgers	-0.06	-0.27**	0.30**	-0.33	-0.51**	0.04	-0.05	0.07	0.87**	-0.38	-0.10	-0.01
Roma × Olive Green	-0.02	0.08	-0.30**	-0.07	0.07	0.00	0.30*	-0.01	-0.33	0.16	0.12*	0.00
LT-42 × *alc*-IIHR-2050	0.06	0.01	0.18	-0.42	0.16	-0.18	-0.15	-0.21	-0.09	-0.14	0.05	0.09
LT-42 × *nor*-RM-1	0.03	-0.08	-0.08	0.39	-0.05	0.11	-0.43**	0.13	-1.15**	-0.27	-0.03	-0.09
LT-42 × *rin*-Rutgers	-0.02	0.09*	0.00	0.31	-0.01	-0.13	-0.89**	-1.14**	0.97**	0.36	0.04	0.04
LT-42 × Olive Green	-0.07	-0.02	-0.1	-0.28	-0.10	0.20	1.47**	1.21**	0.26	0.05	-0.06	-0.04
LST-17 × *alc*-IIHR-2050	-0.01	-0.11**	0.44**	-0.24	-0.13	-0.28	0.26	-0.08	-0.24	-0.12	0.01	-0.02
LST-17 × *nor*-RM-1	0.00	0.01	-0.24*	-0.10	0.23	0.14	-0.28	-0.03	0.48	-0.18	-0.06	0.07
LST-17 × *rin*-Rutgers	-0.06	0.02	0.17	0.30	-0.53**	-0.09	-0.33*	-0.12	-0.46	0.18	0.07	0.00
LST-17 × Olive Green	0.07	0.07	-0.36**	0.05	0.44**	0.23	0.35*	0.22	0.22	0.65	-0.02	-0.05
LST-6 × *alc*-IIHR-2050	-0.13**	0.13**	-0.06	-0.19	0.47**	-0.15	0.17	-0.44	1.24**	-0.13	-0.14*	0.00
LST-6 × *nor*-RM-1	-0.12**	-0.08	-0.11	-0.11	0.79**	-0.30	0.82**	-0.09	-0.67*	0.95*	0.33**	-0.01
LST-6 × *rin*-Rutgers	0.17**	0.02	0.05	0.10	-1.13**	0.14	-0.83**	0.21	-0.64*	-0.41	-0.03	0.01
LST-6 × Olive Green	0.08*	-0.07	0.12	0.21	-0.12	0.30	-0.15	0.33	0.06	-0.41	-0.16**	0.00
Leader × *alc*-IIHR-2050	0.08*	0.05	-0.37**	0.15	0.37**	0.66**	0.37*	0.39	-0.99**	-0.02	-0.02	0.03
Leader × *nor*-RM-1	0.02	-0.04	0.40**	-0.13	-0.14	-0.49*	-0.36*	-0.34	-0.62*	0.32	0.01	-0.19**
Leader × *rin*-Rutgers	-0.07	0.06	0.05	-0.21	-0.07	0.18	0.38*	0.42	0.28	-0.33	0.05	0.20**
Leader × Olive Green	-0.02	-0.07	-0.08	0.19	-0.17	-0.36	-0.39*	-0.46	1.33**	0.03	-0.03	-0.05
Malintka × *alc*-IIHR-2050	-0.01	-0.03	0.34**	0.54*	0.27*	0.16	-0.2	0.68	-0.89**	0.45	-0.04	0.06
Malintka × *nor*-RM-1	-0.05	-0.07	-0.24*	-0.27	0.23	-0.29	0.44**	0.02	0.83**	0.06	-0.05	-0.06
Malintka × *rin*-Rutgers	-0.01	0.05	-0.26*	-0.34	-0.28*	0.22	-0.28	-0.02	-0.41	-0.16	0.00	-0.05
Malintka × Olive Green	0.06	0.04	0.16	0.07	-0.22	-0.09	0.04	-0.68	0.47	-0.35	0.08	0.05

Spectrum × *alc*-IIHR-2050	-0.01	-0.01	-0.35**	-0.36	0.21	-0.31	-0.12	0.18	-0.48	-0.23	0.01	-0.09
Spectrum × *nor*-RM-1	-0.02	0.02	0.21*	0.35	-0.12	0.08	0.26	-0.34	0.26	-0.52	-0.13*	0.15**
Spectrum × *rin*-Rutgers	-0.05	0.00	0.11	-0.08	1.62**	-0.15	1.65**	-0.38	1.27**	1.04**	0.09	0.04
Spectrum × Olive Green	0.08*	-0.01	0.03	0.09	-1.71**	0.38	-1.79**	0.54	-1.05**	-0.28	0.03	-0.10
CD (5%)	**0.07**	**0.08**	**0.20**	**0.44**	**0.23**	**0.46**	**0.29**	**0.86**	**0.59**	**0.74**	**0.11**	**0.11**
CD (1%)	**0.09**	**0.10**	**0.27**	**0.59**	**0.30**	**0.61**	**0.39**	**1.13**	**0.78**	**0.98**	**0.15**	**0.14**

*,** significant at 5% and 1% level, respectively

The aforesaid findings of combining ability effects hinted that the both additive as well as non-additive gene actions were essential in controlling the inheritance of all studied traits. The calculated effects of specific combining ability (σ^2SCA) possessed higher estimates than the GCA effects for most of studied characters. Thus, F_1 cross combinations can be perform greater, in many aspects, than their respective parents or the commercial cultivars. Such finding support the experiment of ARORA *et al*. (2022) for pericarp thickness, number of locules, fruit weight, TSS, polar diameter and total fruit yield.

The findings illustrated that, the assessed general combining ability variance (σ^2GCA) estimates were found higher than those SCA variance (σ^2SCA) for average fruit weight in E_1 and E_2 and for locules per fruit, pericarp thickness and TSS content and dry matter in E_2; alluding that additive gene effects were accumulated more firmly for the inheritance. In contrast, specific combining ability variance (σ^2SCA) for characters viz. pollen viability (%), days from transplanting to the first harvest, harvesting span and total fruit yield in both main as well as late season and for locules per fruit, pericarp thickness, TSS, dry matter and titratable acidity in main season were noticed to have high values than the general combining effects. Such results suggest that non-additive genes played prominent role than the additive genes for expression of these traits. In case of P/E ratio in main and late season and titratable acidity in late season both additive and non-additive gene effects were reflected, as GCA and SCA variance observed equally. CHEEMA *et al*. (2014) and ARORA *et al.* (2022) also observed predominance of both non-additive and additive gene action for the expression of the studied traits.

Preponderance of additive as well as non-additive genes effect were involved in the inheritance of all concerned traits but non-additive gene action were more prominent in the basic mechanism for controlling expression of most of characters. Present results perfectly agree with those findings reported by ARORA *et al.* (2022) for locule number, fruit shape index (P/E ratio) and TSS content, since them observed greater role of non-additive genes for expression for respective traits. This research also complementary to the study of EL-GABRY *et al.* (2014), who recorded ratio of the dominance to the additive variance greater than one pointing the predominant non-additive gene effects.

CONCLUSION

This research study be utilized to pick out the parents to be participated in the hybrid combinations to foretell the best hybrid crosses. Parents with best GCA don't consecutively develop superior hybrid with excellent SCA in the all combinations. A certain lines and testers or hybrid crosses may not be used for evaluation of all the traits with equal productivity. Hence, parental selection must done after meticulous appraisal of the GCA and SCA effects. Results signified that cross, PAU 2381 × *nor*-RM-1 in both season; SMZ-867 × *rin*-Rutgers, Punjab Ratta × *nor*-RM-1 in main season and hybrids, SMZ-867 × *nor*-RM-1, LT-44 × *alc*-IIHR-2050 in late season were found to be best specific combiners for most of the traits.

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OCENA KOMBINACIONE SPOSOBNOSTI KOJA OBUHVATA *alc, nor* I *rin* MUTANTNE ALELE PARADAJZA U GLAVNOJ I SEZONI KASNE SETVE

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Izvod

Sedamdeset četiri genotipa paradajza (14 linija, četiri testera mutanta zrenja i njihovih 56 F1 ukrštanja razvijenih ukrštanjem linija × tester) procenjena su u glavnoj (E1) i sezoni kasne setve (E2) na Odeljenju za nauku o povrću, Pendžab Poljoprivredni Univerzitet, Ludhiana, Pendžab, Indija. Da saznamo nekoliko opštih i specifičnih kombinatora, ako ih ima, koji bi se mogli koristiti u daljim programima oplemenjivanja da bi se produžio period berbe paradajza u uslovima Pendžaba. Rezultati su generalno nagoveštavali da se određeni roditelj ili hibrid ne može koristiti za procenu svih ispitivanih karaktera sa istom efikasnošću. U liniji glavne (E1) sezone, FL-556 je pronađen kao najbolji opšti kombinator za prosečnu masu ploda, debljinu perikarpa, P/E odnos, sadržaj suve materije i likopena; PAU 114 za prosečnu težinu ploda, debljinu perikarpa, TSS i suvu materiju. Tokom kasne (E2) sadnje, Punjab Ratta je imao dobre GCA vrednosti za prosečnu težinu ploda, debljinu perikarpa i sadržaj TSS; Romi za prosečnu masu ploda, debljinu perikarpa i P/E odnos. Slično, tester, *alc*-IIHR-2050 za održivost polena, minimalne dane od presađivanja do prve berbe, period berbe, prosečnu težinu ploda, debljinu perikarpa i P/E odnos u glavnoj (E1) sezoni, dok, za održivost polena, prosečnu težinu ploda, debljina perikarpa i P/E odnos u kasnoj setvi (E2). Dobijeni rezultati su dalje ilustrovali najbolje kombinacije koje su posedovale značajne vrednosti SCA koje se efikasno kombinuju da bi razvile ukrštanje sa dobrim performansama. U glavnoj (E1) sezoni iz kombinacija registrovani su F1 hibrid SMZ-867 × rin-Rutgers sa najboljim specifičnim kombinatorom za vitalnost polena, prosečnu masu ploda, debljinu perikarpa i P/E odnos; PAU 2381 × nor-RM-1 za raspon berbe, prosečnu masu ploda, debljinu perikarpa, ukupan prinos ploda i sadržaj likopena. Slično, u ukrštanjima u kasnoj (E2) setvi, SMZ-867 × nor-RM-1 za održivost polena, minimalne dane od presađivanja do prve berbe, raspon berbe i prinos ploda; LT-44 × alc-IIHR-2050 za vitalnost polena, prosečnu težinu ploda i debljinu perikarpa.

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