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Original scientific article

DEVELOPMENT AND EVALUATION OF HYBRIDS RESISTANT TO LATE BLIGHT AND LEAF CURL VIRUS DISEASES IN TOMATO

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The current study in tomato (*Solanum lycopersicum* L.) was conducted at PAU, Ludhiana with the objective of developing hybrids possessing combined resistance to late blight and leaf curl virus diseases along with desirable horticultural characteristics. The experimental material which included 32 F_1 hybrids (developed by line × tester method), 12 parental lines (8 lines and 4 testers; including susceptible check Punjab Chhuhara) and standard check NS-524 were all planted in randomized complete block design with three replications. The values of σ^2SCA/σ^2GCA were more than unity for all the traits except average fruit weight and ascorbic acid content, indicating the predominance of non-additive gene effects. Cross combinations CLN-154 × LBR-12 and CLN-154 × LBR-21 recorded significant heterosis over better parent and check for fruit yield and other quality characteristics. Artificial and natural screening was performed for all the experimental material against late blight and leaf curl virus diseases respectively. Out of 32 hybrids, crosses namely CLN-154× LBR-12, CLN-154 × LBR-21, PVB-1 × LBR-10, PVB-4 × LBR-12 and CLN-104 × LBR-10 were identified for combined disease resistance against late blight and leaf curl virus, in relation to desirable horticultural characteristics particularly fruit yield, average fruit weight, pericarp thickness, dry matter, titrable acidity and ascorbic acid content with fair amount of heterosis. Hence, the hybrids which displayed good potential in yield with acceptable performance of qualitative traits, along with combined disease resistance could be utilized for commercial exploitation.

Key words: heterosis, Late blight, Leaf curl virus, screening, tomato

INTRODUCTION

Tomato *(Solanum lycopersicum* L.) belongs to the Solanaceae family, contains 1100 IU vitamin A and 23 mg vitamin C per 100 gm of edible portion (NATH *et al*., 2002). It is also a

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good source of organic acids, vitamins and minerals. It is most popular and valuable vegetable crop of the Solanaceae family, known as protective food universally, and is being cultivated both for processing and fresh market purposes. In tropics and subtropics, tomatoes are affected with many diseases, which include late blight caused by *Phytophthora infestans* and tomato leaf curl virus disease, a viral disease. They cause huge losses and deterioration to fruit quality, quantity as well as yield. These phyto-pathogens have huge capability to generate new forms of infestation and infection, which can cause much destruction of the crop, leading to crop failure. Many chemicals are there in literature against pathogen attacks, but mostly aren't safe to our environment, in addition, they make overall cultivation costly.

For breaking productivity barrier and for evolving high-yielding disease resistant varieties, hybridization is fruitful to a reasonable extent. GUL *et al.* (2010) concluded that in tomato, heterosis disclosure is usually seen in attributes like higher productivity, early maturity, rapid growth, faster development, increased vigour and enhanced abiotic and biotic resistance. Heterosis has also been reported in traits linked to adaptating to unfavorable conditions and yield like earliness, uniformity, plant height, disease resistance attributes and total yield. Heterosis has also been reported for traits related to quality of fruit, such as total soluble solids, pericarp thickness and content of ascorbic acid (TIWARI and LAL, 2004). Also, in tomato, heterosis has been reported by many researchers namely SHARMA *et al.* (2006); MONDAL *et al.* (2009); GARG *et al.* (2013); CHAUHAN *et al.* (2014); KAUSHIK *et al.* (2015); TAMTA and SINGH (2018); KUMAR *et al.* (2019). Heterosis is a reliable tool for enhancing yield, from 30% to 400% (SOLIEMAN *et al.* 2013). Additionally, in the form of hybrid combinations, dominant monogenic disease resistance can be exploited.

Thus, development of resistant varieties, along with effective crop management practices can lead to sustainable environment safety and reduce overall economic losses and production cost associated with fungicide spray chemicals. Several techniques are there to evaluate strains or varieties on basis of combining ability and line × tester method is one such technique, created by AL-DAEJ (2018). It can analyze relatively greater number of lines at one time, compared to partial diallel and diallel techniques. This technique also proposes whether the breeder should go for selection in improved generations to identify advanced, improved genotypes under homozygous conditions or for development of F_1 hybrids commercially. So, the main objective of this investigation was to develop hybrids possessing combined resistance against late blight and leaf curl virus diseases, along with desirable horticultural traits.

MATERIALS AND METHODS

The present study was performed at the Department of Vegetable Science, Punjab Agricultural University Ludhiana, India during 2018-19 and 2019-20. The material for the current investigation consisted of eight leaf curl virus tolerant/resistant lines viz. Punjab Varkha Bahar-1 (PVB-1), CLN-154-22-5-0 (CLN-154), CLN-138-6-7-0 (CLN-138), CLN-3241-H-27 (CLN-3241), CLN-104-48-1-0 (CLN-104), CLN-76-9-13-0 (CLN-76), CLN-37-8-1 (CLN-37) and Punjab Varkha Bahar-4 (PVB-4). All lines were procured from AVRDC, Taiwan except PVB-1 and PVB-4 which were from PAU, Ludhiana. Four testers viz. LBR-10, LBR-12, LBR-21and Punjab Chhuhara were used in the study, out of which three were procured from AVRDC,

Taiwan and Punjab Chhuhara was from PAU, Ludhiana. The crossing in line x tester scheme generates 32 F_1 hybrids. Thus, the experimental material consisting of 32 F_1 hybrids, 14 parental lines (including susceptible check, Punjab Chhuhara) and commercial check, NS-524 (a hybrid from Namdhari Seeds Pvt. Ltd., India) were evaluated in Randomized Block Design. Three replications per treatment were transplanted and there were ten plants per entry per replication.

Observations recorded

The data were taken from the five randomly chosen plants, except the ones planted at borders for average fruit weight (g), total fruit yield (kg/plant), number of locules per fruit, pericarp thickness (mm), fruit shape index (P/E ratio). The random sample of 100g dried red fruits from each replication was taken in account to calculate dry matter content (%) (by dividing the dried fruit weight with fresh weight then multiplying with 100). The fresh fruits were utilized for the estimation of TSS (°Brix), lycopene content (mg/100g of fresh weight), titrable acidity (mg/100ml of juice) and ascorbic acid (mg/100ml of juice) by following the method suggested by BALA *et al.* (2019).

Artificial Screening for late blight

Artificial screening was performed through detached-leaf assay technique.

Young but detached leaves of all the 45 genotypes were completely washed with tap-water, air-dried and placed in plastic trays lined with moist blotting paper, with the adaxial surface facing upwards. The leaves were sprayed with sporangial suspension of 4.5 x 10^4 sporangia/ml concentrations using an atomizer (GILL *et al.* 1999). The inoculated trays were capped with polythene bag and water was sprayed inside the bag to ensure high relative humidity and they were incubated in a growth room at a temperature of 18±2°C. Further, these were subjected to fluorescent light for 12h. Individual leaf rating for each genotype was taken on 0-5 scale described by THIND *et al*. (1989) and mean percentage disease index (PDI) was determined to generate severity index of the disease.

PDI=∑[number of plants with rating × rating score] / maximum rating score × number of samples observed×100

Screening against leaf curl virus

The natural screening was done during the autumn season (September-October) when insect vector i.e. whitefly pressure becomes very high in Punjab conditions. To ensure even dissemination of virus inoculums, susceptible lines of var. Punjab Chhuhara were sown after every ten rows of testing material. ToLCV disease incidence (%) and severity were both recorded according to severity scale. The data was noted at fortnightly time intervals by using severity scale from 0-5 given by MUNIYAPPA *et al.* (2000).

Statistical analysis

The whole data were all arranged and then subjected to SPAR-1 software for statistical analysis includes ANOVA for experimental design, ANOVA for combining ability Heterosis estimation over better parent and check that was performed as per suggested by AL-DAEJ (2018)

RESULTS AND DISCUSSION

Heterosis for yield traits

The results of ANOVA are tabulated in Table 1.

Table 1. Analysis of variance for combining ability for different horticultural and biochemical traits

Source of variation	d.f	Average fruit wt. (g)	Total fruit yield (Kg/plant)	Number of locules per fruit	Pericarp thickness (mm)	Fruit shape index	Dry matter (%)	Total soluble solids (^{0}Brix)	Lycopene content (mg/100g fresh weight)	Titrable acidity (mg/100ml of juice)	Ascorbic acid content (mg/100ml of juice)
Lines	7	1724.67**	0.70**	0.57**	2.70**	0.03**	0.47	0.67**	4.23**	0.07**	2.43**
Testers	3	1085.17**	2.33**	4.78**	1.37*	0.13**	3.25**	1.68**	3.79**	0.11**	0.51
Lines × Testers	21	286.04**	0.90**	0.99**	0.77*	0.05**	2.25**	0.73**	1.37**	0.02**	0.84
Error	62	121.83	0.16	0.18	0.40	0.00	0.31	0.08	0.30	0.01	0.76
Components of genetic variance											
σ^2GCA		62.16	0.03	0.09	0.07	0.00	-0.02	0.02	0.15	0.00	0.04
σ^2SCA		54.74	0.25	0.27	0.12	0.02	0.65	0.22	0.36	0.00	0.03
σ^2SCA/GCA		0.88	8.33	3.00	1.71	10.00	-32.5	11.00	2.40	1.00	0.75

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

The mean squares due to replications were identified as non-significant for all characters under study. However, the mean squares due to parents and hybrids were found significant, except for ascorbic acid content. This significance pointed towards persistence of significant genotypic variation among hybrids and parents. The mean squares due to lines were found significant for average fruit weight, pericarp thickness, fruit shape index, dry matter and total soluble solids. Also, mean squares due to testers were significant for all the characters except total fruit yield, lycopene content and ascorbic acid content. The mean squares due to lines v/s testers were found significant in case of total fruit yield, number of locules per fruit, lycopene content, titrable acidity and ascorbic acid content, while mean square due to parents v/s hybrids were recorded significant for average fruit weight, pericarp thickness, total soluble solids, lycopene content and titrable acidity.

Analysis of variance for combining ability is given in Table 1. The values of σ^2SCA/σ^2GCA were recorded greater than unity for all the traits except average fruit weight and ascorbic acid content. This clearly referred towards the predominance of non-additive gene. For traits such as average fruit weight and ascorbic acid content, more prominent role of additive gene was observed. In case of titrable acidity, non-additive and additive gene effects are equally present, as its σ^2SCA/σ^2GCA valueis unity. Also, negative GCA variance was recorded for dry matter, which could be taken similar to null value.

The results showing mean performance of parents and check are tabulated in Table 2, while that of hybrids in Table 3.In case of lines, average fruit weight ranged from 58.08 (CLN-154) to 85.70 g (PVB-4) with PVB-4 possessing the maximum average fruit weight. In case of testers, average fruit weight ranged from 65.00 g (LBR-12) to 89.33 g (LBR-10) with LBR-10 possessing the maximum average fruit weight. Among lines, lines PVB-4, PVB-1 and CLN-138 displayed significant results in case of average fruit weight viz. 85.70 g, 85.33 g and 84.17 g (Table 2). Among testers, LBR-10 and LBR-21 showed remarkable weights of 89.33 g and 83.17

g. In Table 3, it is clearly evident that Cross PVB-1 × LBR-12 (45.57%) exhibited the maximum heterosis, both over better parent and check, followed by CLN-138 × LBR-21 (28.12%), PVB-4 × LBR-21 (25.05%) and PVB-1 × LBR-21 (24.90%) with average fruit weight of 124.22 g, 107.83 g, 107.17 g and 106.58 g respectively. TAMTA and SINGH (2018) also discovered significant heterosis over better parent, in terms of average fruit weight under crosses 'AC824 × Sweet72' (69.93%), 'CLN-2237 × Sweet72' (63.47%) and 'CLN-2070 × Sweet72' (63.77%).

Total fruit yield deserves primary importance under any hybridization programme. In case of lines, total fruit yield ranged from 1.94 (CLN-3241) to 2.37 kg/plant (PVB-4) with PVB-4 possessing the best mean plant yield. In case of testers, yield ranged from 0.37 (Punjab Chhuhara) to 0.81 kg/plant (LBR-21). Lines PVB-4, CLN-104-48-1-0 and CLN-76 displayed significant fruit yield of 2.37, 2.13 and 2.10 kg/plant respectively (Table 2). The crosses PVB-1 × LBR-10 (24.49%), CLN-154 × LBR-12 (23.67%) and CLN-154 × LBR-21 (21.74%) exhibited significantly positive heterosis value over better parent with mean fruit yield of 2.42 kg/plant, 2.56 kg/plant and 2.52 kg/plant respectively. The crosses CLN-154 × LBR-12 (29.29%) and PVB-4 × LBR-12 (29.29%), CLN-154 × LBR-21 (27.27%) and CLN-104 × LBR-10(25.25%) displayed significant heterosis over standard check NS-524 with mean fruit yield of 2.56 kg/plant, 2.56 kg/plant, 2.52 kg/plant and 2.48 kg/plant respectively (Table 3). KHAN and JINDAL (2016) reported nine heterotic hybrids for higher yield over better parent and commercial check. TAMTA and SINGH (2018) also identified hybrids from 'CLN-2237 × Sweet-72', 'CLN-2237 × Punjab Chhuhara', and 'PT-2007-09 × Punjab Chhuhara' with 149.23, 36.44, and 28.91% higher heterosis, as compared to better parent, respectively, for total fruit yield. SALIM *et al* (2019) also identified hybrids G-5, G-13, G-16, G-17, G-18, and G-20 with 25.72, 19.93, 39.21, 36.48, 53.78 and 50.32% respective heterosis percentage over the better parent, in case of total fruit yield per plant.

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Table 2. Mean performance of parents and check for different horticultural and biochemical traits

Parents	Average fruit wt. (g)	Total fruit yield (Kg/ plant)	Number of locules per fruit	Pericarp thickness (mm)	Fruit shape index	Dry matter (%)	Total soluble solids (^{0}Brix)	Lycopene content (mg/ 100g fresh weight)	Titrable acidity (mg/ 100ml of juice)	Ascorbic acid content (mg/ 100ml of juice)
Lines										
PVB-1	85.33	1.95	3.33	5.43	1.01	4.89	4.20	3.49	0.51	18.83
CLN-154	58.08	2.07	2.56	4.30	1.01	6.57	4.22	4.02	0.50	19.60
CLN-138	84.17	2.05	2.89	4.26	0.95	6.25	3.62	3.28	0.58	18.70
CLN-3241	69.00	1.94	2.44	4.23	0.97	7.84	4.20	3.14	0.65	19.20
CLN-104	68.50	2.13	3.00	3.90	0.89	6.97	4.13	3.79	0.40	18.13
CLN-76	72.50	2.10	2.33	4.47	1.03	5.87	4.22	3.02	0.46	19.33
CLN-37	71.27	1.98	2.67	6.08	1.13	4.95	3.49	3.31	0.55	19.07
PVB-4	85.70	2.37	2.67	5.94	1.01	4.54	4.33	3.99	0.48	18.81
Testers										
LBR-10	89.33	0.75	3.80	4.29	0.84	4.84	4.00	3.46	0.72	18.74
LBR-12	65.00	0.54	3.44	5.50	0.88	6.27	3.45	2.89	0.72	18.13
LBR-21	83.17	0.81	3.22	4.51	0.77	5.87	4.98	2.73	0.58	18.93
Punjab Chhuhara (Check)	72.33	0.37	2.22	3.87	1.38	5.99	4.22	2.53	0.56	17.57
NS-524	74.17	1.98	3.93	5.45	1.04	4.25	3.87	3.65	0.51	17.93
Grand Mean	75.27	1.62	2.96	4.79	0.99	5.78	4.07	3.33	0.56	18.69
CD (5%)	11.28	0.40	0.50	0.64	0.06	0.65	0.40	0.56	0.10	0.97
CD (1%)	14.90	0.53	0.66	0.84	0.08	0.86	0.53	0.74	0.14	1.29

Locule number per fruit directly refers to fruit firmness index. Lesser the loculenumber, more will be the firmness index of fruit. In case of lines, locule number per plant ranged from 2.33 (CLN-76) to 3.33 (PVB-1). In case of testers, it ranged from 2.22 (Punjab Chhuhara) to 3.80 (LBR-10) with line Punjab Chhuhara exhibiting the least locule number per fruit among parents. Lines CLN-76 and CLN-3241 and tester Punjab Chhuhara displayed least locule number values viz. 2.33, 2.44 and 2.22 respectively (Table 2). The cross combination CLN-104 × LBR-12(-41.92%) exhibited best negative heterosis (Table 3) over better parent, followed by PVB-4 × LBR-21 (-37.95%), CLN-3241 × LBR-10(-26.93%) and CLN-76 × LBR-12(-25.85%) with mean locule number of 2.00, 2.00, 2.78 and 2.55 respectively. Cross combinations CLN-104 × LBR-12, CLN-76 × Punjab Chhuhara and PVB-4 × LBR-21 possessed significantly negative percentage (-49.11%) of heterosis over check NS-524. KHAN and JINDAL (2016) identified cross combination 2-1 x 115-1-8-1 which showed -33.33% and -35.06% heterosis over the better parent and check NS-524, respectively. Similarly, SALIM *et al* (2019) also identified nine hybrids producing significantly negative heterosis over better parent, ranging from -18.16 to -51.37%. More than 35 per cent negative heterosis was possessed by five hybrids namely G-8 (-51.37%), G-16 (-46.02%), G-18 (-46.04%), G-17 (-40.03%) and G-15 (-36.28%).

Table 3. Mean performance of hybrids for different characters

Hybrids	Average fruit wt. (g)	Total fruit yield (Kg/plant)	Number of locules per fruit	Pericarp thickness (mm)	Fruit shape index	Dry matter (%)	Total soluble solids (^{0}Brix)	Lycopene content (mg/100g)	Titrable acidity (mg/100ml)	Ascorbic acid content (mg/100)
PVB-1 × LBR-10	89.10	2.42	3.56	4.94	0.86	5.61	3.64	3.85	0.65	19.37
PVB-1 × LBR-12	124.22	0.89	3.00	6.74	0.93	5.75	4.33	4.28	0.58	18.00
PVB-1 × LBR-21	106.58	0.99	2.99	5.78	0.87	6.94	4.73	4.08	0.77	18.73
PVB-1 × Punjab Chhuhara	84.11	1.12	2.33	5.31	1.13	5.43	3.70	3.50	0.45	18.43
CLN-154 × LBR-10	96.22	1.14	3.22	5.39	0.99	6.47	4.07	5.08	0.83	18.83
CLN-154 × LBR-12	80.47	2.56	2.67	4.10	1.09	6.17	4.53	5.30	0.65	18.53
CLN-154 × LBR-21	93.67	2.52	2.78	5.01	0.96	5.53	4.15	4.35	0.63	18.47
CLN-154 × Punjab Chhuhara	77.50	1.12	2.56	4.41	1.19	4.55	3.02	2.81	0.66	18.60
CLN-138 × LBR-10	94.00	1.79	4.11	5.69	0.83	5.39	4.00	5.63	0.75	17.30
CLN-138 × LBR-12	83.67	1.47	3.22	6.61	1.14	5.20	3.11	4.69	0.73	18.50
CLN-138 × LBR-21	107.83	1.32	3.00	5.44	0.95	8.25	5.75	5.73	0.67	17.70
CLN-138 × PunjaChhuhara	93.40	1.83	2.67	5.31	0.88	4.89	4.03	3.12	0.69	17.42
CLN-3241 × LBR-10	71.83	1.05	2.78	4.59	0.87	5.93	4.31	4.71	0.75	19.47
CLN-3241 × LBR-12	67.17	1.60	2.89	4.12	0.87	5.29	3.45	4.27	0.65	19.13
CLN-3241 × LBR-21	65.23	1.91	3.53	4.45	0.98	5.51	4.07	4.02	0.61	19.08
CLN-3241 × Punjab Chhuhara	50.17	1.31	2.11	5.03	1.06	5.58	4.18	5.51	0.52	18.53
CLN-104 × LBR-10	81.50	2.48	3.56	4.74	0.88	6.79	4.53	5.21	0.75	17.87
CLN-104 × LBR-12	74.33	2.29	2.00	5.15	1.06	7.13	4.07	4.09	0.56	17.33
CLN-104 × LBR-21	76.80	1.64	3.10	4.57	1.03	5.51	3.93	3.56	0.68	18.92
CLN-104 × Punjab Chhuhara	78.07	1.81	2.33	4.35	1.19	5.07	4.13	3.07	0.77	18.07
CLN-76 × LBR-10	70.27	1.75	3.60	4.71	0.92	5.53	3.50	3.11	0.72	19.29
CLN-76 × LBR-12	75.67	1.63	2.55	5.82	0.90	6.02	3.49	3.23	0.47	18.80
CLN-76 × LBR-21	72.77	1.69	4.11	5.52	0.90	5.41	3.59	3.33	0.64	18.49
CLN-76 × Punjab Chhuhara	70.33	0.79	2.00	4.53	1.06	5.90	3.45	3.18	0.55	18.47
CLN-37 × LBR-10	74.10	1.82	4.00	5.18	1.04	5.07	3.63	3.25	0.57	19.54
CLN-37 × LBR-12	85.63	2.27	3.67	5.74	0.99	5.31	3.83	3.48	0.52	18.63

Table 3. continued

Hybrids	Average fruit wt. (g)	Total fruit yield (Kg/plant)	Number of locules per fruit	Pericarp thickness (mm)	Fruit shape index	Dry matter (%)	Total soluble solids	Lycopene content (mg/100g)	Titrable acidity (mg/100ml)	Ascorbic acid content (mg/100)
CLN-37 × LBR-21	95.33	0.81	3.11	4.98	0.85	6.63	4.25	3.19	0.42	17.90
CLN-37 × Punjab Chhuhara	65.33	0.61	2.11	4.99	1.02	6.26	3.78	2.94	0.40	18.70
PVB-4 × LBR-10	78.67	1.40	3.67	5.14	0.86	7.48	3.77	4.07	0.85	17.33
PVB-4 × LBR-12	76.07	2.56	3.86	5.45	0.67	5.24	3.47	3.31	0.64	18.45
PVB-4 × LBR-21	107.17	1.34	2.00	6.18	1.26	6.19	4.12	4.36	0.50	18.47
PVB-4 × Punjab Chhuhara	75.23	0.87	3.67	5.41	1.15	5.48	3.67	3.29	0.61	17.96
NS-524 (check)	74.17	1.98	3.93	5.45	1.04	4.25	3.87	3.65	0.51	17.93
CD (5%)	11.28	0.40	0.50	0.64	0.06	0.65	0.40	0.56	0.10	0.97
CD (1%)	14.90	0.53	0.66	0.84	0.08	0.86	0.53	0.74	0.14	1.29

Thickness of pericarp is an added bonus for post-harvest storage and distant transportation. In case of lines, the range of pericarp thickness was observed from 3.90 mm (CLN-104) to 6.08 mm (CLN-37). In case of testers, it ranged from 3.87 mm (Punjab Chhuhara) to 5.50 mm (LBR-12). In this study, lines CLN-37 and PVB-4 displayed remarkable pericarp thickness of 6.08 and 5.94 mm respectively (Table 2). The cross CLN-138 × LBR-10 (32.79% and 5.69 mm) was identified with maximum positive heterosis (Table 3) over better parent, followed by CLN-154 × LBR-10 (25.27% and 5.39 mm) and CLN-138 × Punjab Chhuhara (24.55% and 5.31 mm). However, the best heterotic crosses over check were PVB-1 × LBR-12 (23.67% and 6.74 mm), PVB-4 × LBR-21 (13.39% and 6.18 mm) and CLN-76 × LBR-12 (6.79% and 5.82 mm). KUMAR *et al* (2019) also identified the cross 'DT-2 × Azad-T5' exhibiting significantly positive heterobeltiosis (56.82%) in case of pericarp thickness.

In case of lines, the range of fruit shape index (P/E ratio) ranged from 0.89 (CLN-104; flat-round shaped) to 1.13 (CLN-37; oval shaped). In case of testers, it ranged from 0.77 (LBR-21; flat round shaped) and 1.38 (Punjab Chhuhara; pear shaped). In case of fruit shape index, lines CLN-37 and CLN-76 displayed oval and round fruit shape with significant mean values viz. 1.13 and 1.03, respectively (Table 2). The cross PVB-4 × LBR-21 (24.83%) displayed maximum positively significant heterosis over better parent followed by CLN-138 × LBR-12 (20.35%) and CLN-104 × LBR-12 (17.84%), exhibiting mean values of 1.26, 1.14 and 1.06, all possessing oval-shaped fruit while the cross PVB-4 × LBR-21 (21.15%) exhibited maximum heterosis percentage over standard check NS-524, followed by CLN-154 × Punjab Chhuhara and CLN-104 × Punjab Chhuhara (14.42%). Overall, 59.38% hybrids exhibited mean values less than unity, thus, possessing flat/oblate shape and rest 40.62% reflected oval shape (Table 3). KAUSHIK *et al.* (2015) also identified the cross combinations '102-1-6-1 × 115-1-8-1' for polar diameter (32.07%), and '115-1-8-1 × 55-26-1-1' for equatorial diameter (19.07%) exhibiting positive heterosis over standard check.

Heterosis for quality traits

In case of lines, dry matter (%) ranged from 4.54% (PVB-4) to 7.84% (CLN-3241). In case of testers, per cent dry matter ranged from 4.84% (LBR-10) to 6.27% (LBR-12). Lines CLN-3241, CLN-104 and CLN-154 displayed significant mean dry matter values of 7.84%, 6.97% and 6.57% (Table 2). The cross PVB-4 × LBR-10(54.72%) exhibited maximum heterosis over better parent (Table 3) followed by CLN-138 × LBR-21(32.02%) and PVB-1 × LBR-21(18.28%) with mean dry matter percentage of 7.48%, 8.25% and 6.94%. The cross CLN-138 × LBR-21 (94.12%) exhibited maximum positive heterosis over check NS-524, followed by PVB-4 × LBR-10(76.00%), CLN-104 × LBR-12 (67.76%) and PVB-1 × LBR-21 (63.29%) with mean dry matter percentage of 8.25%, 7.48%, 7.13% and 6.94%. KAUSHIK *et al* (2015) also identified the cross combination 'Punjab Chhuhara × 58-18-1-1' possessing significant heterosis over standard check (43.88%) for dry matter content.

TSS, for the purpose of processing, should be >4.5%. According to BERRY and UDDIN (1991), a rise in 1% of solids leads to 20% rise in recovering tomato's processed product. In case of lines, the range of TSS (total soluble solids) was observed from 3.49 (CLN-37) to 4.22 °Brix (CLN-154 and CLN-76). In case of testers, TSS was in the range of 3.45 (LBR-12) to 4.98 °Brix (LBR-21), therefore displaying tester LBR-21 with maximum TSS value among all the parents. Line PVB-4, CLN-154 and CLN-76 displayed significant TSS values of 4.33, 4.22 and 4.22 °Brix respectively. Testers LBR-21 and Punjab Chhuhara possessed TSS of 4.98 and 4.22 °Brix (Table 2). Cross CLN-138 × LBR-21(15.53% and 5.75 °Brix) exhibited significant positive heterosis over better parent followed by CLN-37 × LBR-12(9.84% and 3.83 °Brix) and CLN-104 × LBR-10(9.68% and 4.53 °Brix)whereas the cross CLN-138 × LBR-21 (48.58% and 5.75 °Brix)followed by PVB -1 × LBR-21(22.22% and 4.73 °Brix) and CLN-154 × LBR-12(17.05% and 4.53 °Brix) exhibited significantly positive heterosis (Table 3) over check. KAUSHIK *et al.* (2015) also identified '102-1-6-1× 58-18-1-1' cross combination possessing significant heterosis over check (19.32%) for TSS content.

High lycopene imparts darker red colour to tomato, which is desirable both for table and processing purpose. In addition to immense nutrition value, lycopene possesses maximum antioxidant properties amongst all the carotenoids (RAI *et al* 2004). In case of lines, lycopene content ranged from 3.02 (CLN-76) to 4.02 mg (CLN-154). In case of testers, it ranged from 2.53 (Punjab Chhuhara) to 3.46 mg (LBR-10). Lines CLN-154, PVB-4 and CLN-104 exhibited appreciable mean values viz. 4.02, 3.99 and 3.79 mg/100g fresh weight (Table 2). Cross CLN-3241 × Punjab Chhuhara (75.66% and 5.51 mg) followed by CLN-138 × LBR-21 (74.42% and 5.73 mg) and CLN-138 × LBR-10(62.78% and 5.63 mg) exhibited significant positive heterosis over better parent. The cross combination CLN-138 × LBR-21(56.99% and 5.73 mg) followed by CLN-138 × LBR-10(54.25% and 5.63 mg) and CLN-3241 × Punjab Chhuhara (50.96% and 5.51 mg) exhibited significantly positive heterosis over check NS-524 (Table 3). KUMAR *et al.* (2019) also recorded the cross combination 'NDTVR60 × Floradade' exhibiting significantly positive heterobeltiosis (60.22%) for lycopene content.

According to BERRY and UDDIN (1991), pH <4.5 and acidity >0.35mg/100ml juice are essential in avoiding spoilage by *B. coagulans* and also for reducing the time for processing.In case of lines, titrable acidity ranged from 0.40 (CLN-104) to 0.65 mg/100ml (Table 2) of juice (CLN-3241). In case of testers, it ranged from 0.56 (Punjab Chhuhara) to 0.72 mg/100ml of juice

(LBR-10 and LBR-12). Cross combination CLN-104 × Punjab Chhuhara(39.52% and 0.77 mg) followed by PVB-1 × LBR-21 (34.68% and 0.77 mg) and CLN-138 × Punjab Chhuhara(20.81% and 0.69 mg)exhibited maximum significant heterosis over better parent. Cross PVB-4 × LBR-10(66.67% and 0.85 mg) followed by CLN-154 × LBR-10(62.75% and 0.83 mg), PVB-1 × LBR-21and CLN-104 × Punjab Chhuhara (50.98% and 0.77 mg) possessed maximum positive heterosis over check NS-524 (Table 3). ACHARYA *et al.* (2018) also recorded the hybrids 'CLN-2777C × Utkal Urbash' and 'CLN-2498D × Utkal Kumari' with significant heterosis over better parent. KUMAR *et al* (2019) also identified the hybrid combination 'NDTVR60 × Floradade' possessing highest, positive heterosis over better parent (31.37%) for titrable acidity.

Table 4a. Best heterotic hybrids for various characters over better parent and check

Average fruit wt. (g)		Total fruit yield (Kg/plant)		Number of locules per fruit		Pericarp thickness (mm)		Fruit shape index	
Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over	
Better parent	NS-524	Better parent	NS-524	Better parent	NS-524	Better parent	NS-524	Better parent	NS-524
PVB-1 × LBR-12 (45.57**)	PVB-1 × LBR-12 (67.48**)	PVB-1 × LBR-10 (24.49**)	CLN-154 × LBR-12 (29.29**)	CLN-104 × LBR-12 (-41.92**)	CLN-104 × LBR-12 (-49.11**)	CLN-138 × LBR-10 (32.79**)	PVB-1 × LBR-12 (23.67**)	PVB-4 × LBR-21 (24.83**)	PVB-4 × LBR-21 (21.15**)
CLN-138 × LBR-21 (28.12**)	CLN-138 × LBR-21 (45.38**)	CLN-154 × LBR-12 (23.67**)	PVB-4 × LBR-12 (29.29**)	PVB-4 × LBR-21 (-37.95**)	PVB-4 × LBR-21 (-49.11**)	CLN-154 × LBR-10 (25.27**)	PVB-4 × LBR-21 (13.39**)	CLN-138 × LBR-12 (20.35**)	CLN-154 × Punjab Chhuhara (14.42**)
PVB-4 × LBR-21 (25.05**)	PVB-4 × LBR-21 (44.49**)	CLN-154 × LBR-21 (21.74**)	CLN-154 × LBR-21 (27.27**)	CLN-3241 × LBR-10 (-26.93**)	CLN-76 × Punjab Chhuhara (-49.11**)	CLN-138 × Punjab Chhuhara (24.55**)	CLN-76 × LBR-12 (6.79*)	CLN-104 × LBR-12 (17.84**)	CLN-104 × Punjab Chhuhara (14.42**)
PVB-1 × LBR-21 (24.90**)	PVB-1 × LBR-21 (43.70**)	CLN-104 × LBR-10 (16.61**)	CLN-104 × LBR-10 (25.25**)	CLN-76 × LBR-12 (-25.85**)	CLN-3241 × Punjab Chhuhara (-46.31**)	PVB-1 × LBR-12 (22.41**)	PVB-1 × LBR-21 (6.06*)	CLN-104 × LBR-21 (14.49**)	PVB-4 × Punjab Chhuhara (10.58*)
CLN-154 × LBR-12 (23.79**)	CLN-154 × LBR-10 (29.73**)	CLN-37 × LBR-12 (14.29**)	PVB-1 × LBR-10 (22.22**)	CLN-3241 × LBR-12 (-16.07**)	CLN-37 × Punjab Chhuhara (-46.31**)	CLN-76 × LBR-21 (22.32*)		CLN-154 × LBR-12 (8.22**)	CLN-138 × LBR-12 (9.62**)
CLN-37 × LBR-12 (20.16**)	CLN-37 × LBR-21 (28.53**)	PVB-4 × LBR-12 (8.16**)	CLN-37 × LBR-12 (14.65**)	CLN-76 × Punjab Chhuhara (-14.29*)	PVB-1 × Punjab Chhuhara (-40.71**)	CLN-138 × LBR-21 (20.62**)			PVB-1 × Punjab Chhuhara (8.65*)
CLN-37× LBR-21 (14.63**)	CLN-138 × LBR-10 (26.74**)			CLN-154 × LBR-21 (-13.86**)	CLN-76 × LBR-12 (-35.11*)	CLN-138 × LBR-12 (20.17**)			CLN-154 × LBR-12 (4.81*)

Table 4b.Best heterotic hybrids for various characters over better parent and check

Dry matter (%)		TSS (^{0}Brix)		Lycopene content (mg/100g of fresh weight)		Titrable acidity (mg/100ml of juice)		Ascorbic acid content (mg/100ml of juice)	
Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over		Percentage increase/ decrease over	
Better parent	NS-524	Better parent	NS-524	Better parent	NS-524	Better parent	NS-524	Better parent	NS-524
PVB-4 × LBR-10 (54.72**)	CLN-138 × LBR-21 (94.12**)	CLN-138 × LBR-21 (15.53**)	CLN-138 × LBR-21 (48.58**)	CLN-138 × LBR-10 (62.78**)	CLN-138 × LBR-21 (56.99**)	CLN-104 × Punjab Chhuhara (39.52**)	PVB-4 × LBR-10 (66.67**)	PVB-1 × LBR-10 (2.83**)	CLN-37 × LBR-10 (8.98**)
CLN-138 × LBR-21 (32.02**)	PVB-4 × LBR-10 (76.00**)	CLN-37 × LBR-12 (9.84**)	PVB-1 × LBR-21 (22.22**)	CLN-3241 × Punjab Chhuhara (75.66**)	CLN-138 × LBR-10 (54.25**)	PVB-1 × LBR-21 (34.68**)	CLN-154 × LBR-10 (62.75**)	CLN-37 × LBR-10 (2.50*)	CLN-3241 × LBR-10 (8.59**)
PVB-1 × LBR-21 (18.28**)	CLN-104 × LBR-12 (67.76**)	CLN-104 × LBR-10 (9.68**)	CLN-154 × LBR-12 (17.05**)	CLN-138 × LBR-21 (74.42**)	CLN-3241 × Punjab Chhuhara (50.96**)	CLN-138 × Punjab Chhuhara (20.81**)	PVB-1 × LBR-21 (50.98**)		PVB-1 × LBR-10 (8.03**)
PVB-1 × LBR-10 (14.58**)	PVB-1 × LBR-21 (63.29**)	CLN-154 × LBR-12 (7.42**)	CLN-104 × LBR-10 (17.05**)	CLN-138 × LBR-12 (42.84**)	CLN-154 × LBR-12 (45.21**)	CLN-154 × Punjab Chhuhara (19.16**)	CLN-104 × Punjab Chhuhara (50.98**)		CLN-76 × LBR-10 (7.59**)
CLN-37 × LBR-21 (13.00**)	CLN-104 × LBR-10 (59.76**)		PVB-1 × LBR-12 (11.89**)	CLN-104 × LBR-10 (37.68**)	CLN-104 × LBR-10 (42.74**)	CLN-104 × LBR-21 (18.50**)	CLN-138 × LBR-10 (47.06**)		CLN-3241 × LBR-12 (6.69**)
PVB-4 × LBR-21 (5.51*)	CLN-37 × LBR-21 (56.00**)		CLN-3241 × LBR-10 (11.37**)	CLN-3241 × LBR-12 (36.24**)	CLN-3241 × LBR-10 (29.04**)	PVB-4 × LBR-10 (18.06**)	CLN-104 × LBR-10 (47.06**)		CLN-3241 × LBR-21 (6.41**)
	CLN-154 × LBR-10 (52.24**)		CLN-37 × LBR-21 (9.82**)	CLN-3241 × LBR-10 (36.16**)	CLN-138 × LBR-12 (28.49**)	CLN-138 × LBR-21 (16.76**)	CLN-138 × LBR-12 (43.14**)		CLN-104 × LBR-21 (5.52**)

Ascorbic acid (Vitamin C) holds an essential constituency in nutritional status of tomato. In case of lines, ascorbic acid was observed in the range of 18.13 (CLN-104) to 19.60 mg/100ml of juice (CLN-154), with line CLN-154 exhibiting the maximum mean value. In case of testers, it ranged from 17.57 (Punjab Chhuhara) to 18.93 mg/100ml of juice (LBR-21) (Table 2). Two crosses, out of thirty two, possessed significantly positive heterosis over better parent, namely PVB-1 × LBR-10 (2.83% and 19.37 mg) and CLN-37 × LBR-10(2.50% and 19.54 mg)

however,cross CLN-37 × LBR-10 (8.98% and 19.54 mg) followed by CLN-3241 × LBR-10(8.59% and 19.47 mg), PVB-1 × LBR-10(8.03% and 19.37 mg) and CLN-76 × LBR-10(7.59% and 19.29 mg) displayed maximum positive heterosis over the check (Table 3). KUMAR *et al.* (2019) also recorded 'Sel-7 × Floradade' (25.12%) for ascorbic acid, possessing significant heterosis over better parent, for further exploitation.

Screening of hybrids against late blight and leaf curl virus

Under artificial screening of late blight (Table 5), eleven hybrids namely PVB-1 × LBR-10 (30.00% incidence and 18.00% PDI), PVB-1 × LBR-21 (35.00% incidence and 18.00% PDI), CLN-154 × LBR-12 (20.00% incidence and 15.00% PDI), CLN-154 ×LBR-21 (30.00% incidence and 18.00% PDI), CLN-138 × LBR-10 (15.00% incidence and 16.67 % PDI), CLN-138 × LBR-12 (48.00% incidence and 16.00% PDI), CLN-3241 × LBR-12 (20.00% incidence and 15.00% PDI), CLN-3241 × LBR-21 (30.00% incidence and 18.00% PDI), CLN-104 × LBR-10 (20.00% incidence and 15.33% PDI), CLN-76 × LBR-12 (32.50% incidence and 16.87% PDI) and PVB-4 × LBR-12 (20.00% incidence and 12.67% PDI) were found resistant, as in these hybrids, symptoms appeared after 72 hours. Rest of the ten cross combinations displayed moderately susceptible response to *P. infestans* attack with PDI in the range of 20.00-40.00%. Similarly, FOOLAD *et al.* (2015) screened 72 genotypes from two species having varying degree of late blight resistance and disease susceptibility for determining resistance using detached-leaf assay in two replicated experiments. Significant ($P<0.001$), positive correlations between experiments (mean $r = 0.72$) and replications (mean $r = 0.75$) indicated consistency of detached-leaflet investigations.

For screening against leaf curl virus (Table 5), eighteen cross combinations namely PVB-1 × LBR-10, PVB-1 × LBR-12, PVB-1 × LBR-21, CLN-154 × LBR-10, CLN-154 × LBR-12, CLN-154 × LBR-21, CLN-138 × LBR-10, CLN-138 × LBR-21, CLN-3241 × LBR-12, CLN-3241 × LBR-21, CLN-104 × LBR-10, CLN-104 × LBR-12, CLN-76 × LBR-12, CLN-37 × LBR-10, CLN-37 × LBR-12, PVB-4 × LBR-10, PVB-4 × LBR-12 and PVB-4 × LBR-21 were recorded resistant with no appearance of symptoms and 0.00% incidence. Ten cross combinations displayed mild symptoms of leaf curl virus infection. VIJETH *et al.* (2018) also evaluated 45 F_1 hybrids and ten parents for ToLCV resistance and for horticultural characters. Twenty F_1 hybrids and seven parents were symptom-less till fruit maturation, under conditions of natural infection.

Resistance hybridization programme is dependent on different factors viz. successful recognition of genetic origin of resistance and accurate result assessment (PICO *et al.*, 1998). Artificial disease screening, along with field screening gives the benefit of selecting resistant hybrids in a particular crop disease. In this study, the cross combinations namely CLN-154 × LBR-12, CLN-154 × LBR-21, CLN-104 × LBR-10, PVB-1 × LBR-10 and PVB-4 × LBR-12 were identified as best cross combinations in terms of both late blight and leaf curl virus resistance, vis-à-vis desirable horticultural characters i.e. average fruit weight, total fruit yield, dry matter, pericarp thickness and TSS with heterosis of decent quantity (Table 6).

Table 5. Screening of tomato genotypes for late blight and leaf curl virus

Genotype	Artificial screening against late blight			Natural screening against leaf curl virus		
	Per cent Incidence	Per cent Disease Index	Response	No. of plants infected/ planted	Per cent incidence	Response
PVB-1	68.33	56.67	S	0/30	0.00	R
CLN-154	55.00	65.00	HS	0/30	0.00	R
CLN-138	60.00	66.67	HS	0/30	0.00	R
CLN-3241	65.00	86.67	HS	0/30	0.00	R
CLN-104	70.00	56.33	S	0/30	0.00	R
CLN-76	55.00	52.00	S	0/30	0.00	R
CLN-37	80.00	81.33	HS	0/30	0.00	R
PVB-4	72.33	73.33	HS	0/30	0.00	R
LBR-10	15.00	4.00	HR	18/30	60.00	SI
LBR-12	20.00	6.67	HR	21/30	70.00	SI
LBR-21	25.00	7.33	HR	18/30	60.00	SI
Punjab Chhuhara	100.00	96.00	HS	30/30	100.00	VSI
PVB-1 × LBR-10	30.00	18.00	R	0/30	0.00	R
PVB-1 × LBR-12	60.00	36.00	MS	0/30	0.00	R
PVB-1 × LBR-21	35.00	18.00	R	0/30	0.00	R
PVB-1 × Punjab Chhuhara	65.00	78.00	HS	9/30	30.00	MI
CLN-154 × LBR-10	70.00	28.00	MS	0/30	0.00	R
CLN-154 × LBR-12	20.00	15.00	R	0/30	0.00	R
CLN-154 × LBR-21	30.00	18.00	R	0/30	0.00	R
CLN-154 × Punjab Chhuhara	60.00	86.67	HS	9/30	30.00	MI
CLN-138 × LBR-10	15.00	16.67	R	0/30	0.00	R
CLN-138 × LBR-12	48.00	16.00	R	3/30	10.00	MI
CLN-138 × LBR-21	45.00	28.50	MS	0/30	0.00	R
CLN-138× Punjab Chhuhara	55.33	57.00	S	15/30	50.00	MoI
CLN-3241 × LBR-10	38.00	34.00	MS	6/30	20.00	MI
CLN-3241 × LBR-12	20.00	15.00	R	0/30	0.00	R
CLN-3241 × LBR-21	30.00	18.00	R	0/30	0.00	R
CLN-3241 × Punjab Chhuhara	60.00	83.67	HS	12/30	40.00	MoI
CLN-104 × LBR-10	20.00	15.33	R	0/30	0.00	R
CLN-104 × LBR-12	35.00	38.33	MS	0/30	0.00	R
CLN-104 × LBR-21	52.67	55.00	S	6/30	20.00	MI
CLN-104 × Punjab Chhuhara	70.00	73.33	HS	12/30	40.00	MoI
CLN-76 × LBR-10	50.00	54.00	S	6/30	20.00	MI
CLN-76 × LBR-12	32.50	16.87	R	0/30	0.00	R
CLN-76 × LBR-21	35.00	38.50	MS	6/30	20.00	MI
CLN-76 × Punjab Chhuhara	80.00	86.67	HS	12/30	40.00	MoI
CLN-37 × LBR-10	42.00	37.50	MS	0/30	0.00	R
CLN-37 × LBR-12	55.00	58.00	S	0/30	0.00	R
CLN-37 × LBR-21	40.00	33.33	MS	6/30	20.00	MI
CLN-37 × Punjab Chhuhara	75.00	62.50	HS	15/30	50.00	MoI
PVB-4 × LBR-10	53.33	35.00	MS	0/30	0.00	R
PVB-4 × LBR-12	20.00	12.67	R	0/30	0.00	R
PVB-4 × LBR-21	42.00	27.50	MS	0/30	0.00	R
PVB-4 × Punjab Chhuhara	70.00	76.00	HS	6/30	20.00	MI
NS 524 (check)	65.00	52.00	S	9/30	30.00	MI

Where, 0-10 PDI - Highly resistant (HR), 10-20 PDI - Resistant (R), 20-40 PDI - Moderately susceptible (MS), 40-60 PDI - Susceptible (S), >60 PDI - Highly susceptible (HS)

R- Resistant, MI- Mild Infection, MoI- Moderate Infection, SI- Severe Infection, VSI- Very severe infection

Table 6. Promising crosses possessing resistance to late blight and leaf curl virus with desirable horticultural traits

Crosses possessing combined resistance	Average fruit wt. (g)	Total fruit yield (Kg/plant)	Number of locules per fruit	Pericarp thickness (mm)	Fruit shape index
CLN-154 × LBR-12	80.47	2.56	2.67	4.10	1.09
CLN-154 × LBR-21	93.67	2.52	2.78	5.01	0.96
PVB-1 × LBR-10	89.10	2.42	3.56	4.94	0.86
PVB-4 × LBR-12	76.07	2.56	3.86	5.45	0.67
CLN-104 × LBR-10	81.50	2.48	3.56	4.74	0.88
Crosses possessing combined resistance	Dry matter (%)	Total soluble solids (^{0}Brix)	Lycopene content (mg/100g fresh weight)	Titrable acidity (mg/100ml of juice)	Ascorbic acid content (mg/100ml of juice)
CLN-154 × LBR-12	6.17	4.53	5.30	0.65	18.53
CLN-154 × LBR-21	5.53	4.15	4.35	0.63	18.47
PVB-1 × LBR-10	5.61	3.64	3.95	0.65	19.37
PVB-4 × LBR-12	5.24	3.47	3.31	0.64	18.45
CLN-104 × LBR-10	6.79	4.53	5.21	0.75	17.87

CONCLUSION

The significant mean square due to line, testers and line × tester clearly pointed towards role of non-additive and additive gene effects in the inheritance of all the considered characters. Ratio of σ^2SCA/σ^2GCA was observed more than unity for almost all the characters, except average fruit weight and ascorbic acid, which points out towards predominance of non-additive gene effects, for majority of studied traits. Based on combined analysis, it is concluded that crosses namely CLN-154 × LBR-12, CLN-154 × LBR-21, CLN-104 × LBR-10, PVB-1 × LBR-10 and PVB-4 × LBR-12 were identified for combined disease resistance against late blight and leaf curl virus, vis-à-vis desirable horticultural characters particularly fruit yield, mean fruit weight, pericarp thickness, dry matter, titratable acidity and ascorbic acid content with heterosis of decent quantity. Henceforth, the hybrids which displayed combined resistance against both the diseases, along with higher yield potential, and improved qualitative traits, along with desirable and market acceptable horticultural traits, can surely be utilized for commercial purpose.

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RAZVOJ I OCENA HIBRIDA PARADAJZA OTPORNIH NA PLAMENJAČU I VIRUSNU KOVRDŽAVOST LISTA

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Izvod

Ovaj rad na paradajzu (*Solanum licopersicum* L.) je sproveden u Pendžab Univerzitetu, Ludijana sa ciljem da se razviju hibridi koji poseduju kombinovanu otpornost na bolesti plamenjače i virusne uvijenosti listova, zajedno sa poželjnim hortikulturnim karakteristikama. Eksperimentalni materijal koji je uključivao 32 F1 hibrida (razvijen metodom linija × tester), 12 roditeljskih linija (8 linija i 4 testera; uključujući osetljiv standard Punjab Chhuhara) i standard NS-524 su svi posađeni u randomiziranom kompletnom blok dizajnu sa tri ponavljanja. Vrednosti σ^2SCA/σ^2GCA su bile više od jedinice za sve osobine osim prosečne težine ploda i sadržaja askorbinske kiseline, što ukazuje na preovlađivanje neaditivnih efekata gena. Kombinacije ukrštanja CLN-154 × LBR-12 i CLN-154 × LBR-21 su zabeležile značajan heterozis u odnosu na boljeg roditelja i standard za prinos ploda i druge parametre kvaliteta. Urađen je veštački i prirodni skrining za sav eksperimentalni materijal na bolesti plamenjače i virusne uvijenosti listova. Od 32 hibrida, identifikovana su ukrštanja za kombinovanu otpornost na obe bolesti, i to: CLN-154× LBR-12, CLN-154 × LBR-21, PVB-1 × LBR-10, PVB-4 × LBR-12 i CLN-104 × LBR-10, zajedno sa poželjnim hortikulturne osobinama, kao što su prinos ploda, prosečna masa ploda, debljina perikarpa, suva materija, titrabilna kiselost i sadržaj askorbinske kiseline sa dosta heterozisa. Dakle, hibridi koji su pokazali dobar potencijal za prinos sa prihvatljivim performansama kvalitativnih osobina, uz kombinovanu otpornost na bolesti, mogli bi se koristiti za komercijalnu eksploataciju.

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