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Heterotic expression for fruit yield and component traits in intervarietal hybrids of okra [*Abelmsochus esculentus* (L.) Moench]

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Abstract

Heterosis studies were conducted using 9 lines and 3 testers in a line × tester mating design at Vegetable Research Farm, CSK HPKV, Palampur (H.P.) during rainy season 2021. The results revealed HPO-1 × P-8, Kashi Vibhuti × Hisar Unnat, Palam Round × Hisar Unnat and VRO-4 × Hisar Unnat found as promising cross-combinations over better parent for fruit yield. Whereas Palam Round × Hisar Unnat, Kashi Vibhuti × Hisar Unnat and VRO-4 × Hisar Unnat were the top ranking cross-combinations exhibiting significant heterosis over Samrat (standard check 1) and Shakti (standard check 2). Palam Round × Hisar Unnat was identified as best cross-combination as it exhibited significant positive heterosis over both SC1 and SC2 for fruit yield per plant. It also displayed significant positive heterosis over SC1 for nodes per plant, plant height, average fruit weight and fruits per plant and over SC2 for average fruit weight. Hybrid vigour is available for commercial production of okra hybrid and that isolation of pure lines from the progenies of heterotic F_1's is a possible way to enhance the fruit yield.

Key words: Heterobeltiosis, Standard heterosis, Okra and Productivity

Okra (*Abelmoschus esculentus* L.) also known as Lady's finger or Bhindi belongs to family Malvaceae, native to Africa is one of the most valuable warm season vegetable crops grown in India having highest chromosome number among vegetables (2n=130). It is grown in many tropical and subtropical parts of the world. India is the largest producer of okra in the world and it is cultivated extensively round the year for its immature fruits (Javed *et al*. 2009). Tender fruits are used as vegetables or in culinary preparations as sliced or dried pieces. Mature fruits and stem containing crude fibre and are used in paper industry. It is more beneficial than leafy vegetables as it contains low calorie food provide 30 calories per 100g and is rich source of dietary fibre, minerals and vitamins (A, C, K), folic acid, riboflavin and its pods are rich source of mucilage substance that help in smooth peristalsis of digested food (Sood *et al*. 2016). Because of high mucilage content, it is used for thickening gravies and soups. Okra contains highest amount of iodine which prevents goitre disease and often recommended by nutritionists because it controls cholesterol level and used in weight reduction programmes. Its nutritive value is higher than tomatoes, eggplant and most of the cucurbits except bitter gourd (Nonnecke 1989). The okra plant requires warm temperature and is unable to withstand low temperature for long or tolerate any threat of frost. Optimum minimum temperature for growth ranges between 21 to 30^{0}C and maximum temperature ranges between 18^{0}C to 35^{0}C, respectively (Abd-EI Kader *et al*. 2010). Okra is an annual crop that requires warm temperature and found in almost every market all over Africa (Schippers 2000).

Exploitation of heterosis in okra has been recognized as a practical tool in providing the breeders a means of improving yield and other related traits. Emasculation and pollination events are easier due to large flower and monoadelphous stamens. The highest percentage of fruit setting shows the likelihood of exploitation of hybrid vigour. For developing promising hybrids, the choice of parents is a matter of great concern to the plant breeder (Inamullah *et al*. 2006). The present research was, therefore, undertaken to study the heterotic expression for fruit yield and component traits.

Materials and Methods

The experimental material involved 27 F_1's developed by crossing nine diverse genotypes of okra viz., 9801, Punjab Suhawani, Kashi Vibhuti, Kashi Pragati, Kashi Satdhari, Palam 5 ridged, Palam Round, VRO-4 and HPO-1 as female parents and three horticulturally superior testers namely Hisar Unnat, Palam Komal and P-8 in line × tester mating design given by Kempthorne (1957). 27 F_1 hybrids along with twelve parents and two standard checks, Samrat (SC1) and Shakti (SC2) hybrids of Nunhems were grown in Randomized Block Design with three replications in rainy season 2021 at Vegetable Research Farm, CSK HPKV, Palampur (H.P.). The material was planted with inter and intra row spacing of 45cm and 30 cm, respectively. The observations were recorded on five randomly taken plants in each replication. The traits studied were days to 50% flowering, days to first picking, nodes per plant, internodal length (cm), plant height (cm), fruit length (cm), fruit diameter (cm), average fruit weight (g), fruits per plant and fruit yield per plant (g). Heterosis over better parent and standard checks were calculated as percent increase or decrease in F_1 hybrids as per the formulae given by Singh and Chaudhary (1977).

Results and Discussion

The analysis of variance for the experimental design given in Table 1 revealed significant differences among genotype for all the traits studied except nodes per plant and analysis of variance for line × tester design presented in Table 2. The data indicated significant differences among parent, female and male

Table 1. Analysis of variance for the Randomized Block Design for different traits in okra

Source of variation		Mean squares		
		Replication	Genotype	Error
Trait	df	2	40	80
Days to 50 % flowering		23.569*	12.898*	3.086
Days to first picking		18.829*	21.694*	3.596
Nodes per plant		4.178	5.334	0.884
Internodal length (cm)		7.911*	6.208*	0.684
Plant height (cm)		900.778*	1713.12*	87.780
Fruit length (cm)		0.680*	1.581*	0.158
Fruit diameter (cm)		0.0118*	0.0185*	0.0024
Average fruit weight (g)		6.542*	7.688*	1.334
Fruits per plant		3.934*	6.100*	1.002
Fruit yield per plant(g)		670.829*	2537.85*	149.487

* Significant at 5% level

Table 2. Analysis of variance for line × tester mating design for different traits in okra

Source of variation	Mean squares							
Trait	Replication	Parent	Female	Male	Female *vs.* Male	Hybrid	Parent *vs.* Hybrid	Error
df	2	11	8	2	1	26	1	76
Days to 50% flowering	19.342*	10.939*	11.287*	3.444	23.148*	13.992*	1.163	3.149
Days to first picking	14.316*	15.583*	12.648*	33.778*	2.676	26.255*	0.086	3.492
Nodes per plant	3.138*	4.733*	5.762*	2.953*	0.054	5.074*	3.291	0.858
Internodal length (cm)	7.792*	5.667*	4.463*	5.812*	15.014*	3.499*	94.863*	0.700
Plant height (cm)	1004.422*	1459.002*	857.006*	2014.633*	5163.708*	1115.891	1028.488*	88.215
Fruit length (cm)	0.677*	1.904*	1.551*	1.267*	6.007*	1.516*	1.337*	0.165
Fruit diameter (cm)	0.012*	0.028*	0.025*	0.039*	0.029*	0.016*	0.025*	0.002
Average fruit weight (g)	6.551*	7.065*	6.961*	5.858*	10.316*	7.857*	15.083*	1.392
Fruits per plant	2.877	7.518*	8.696*	5.817*	1.500	5.330*	4.925*	0.977
Fruit yield per plant (g)	537.106*	2741.169*	3062.044*	2820.507*	15.501	2664.458*	437.842	145.641

* Significant at 5% level

for all the traits except non-significant differences among males for days to 50% flowering. Hybrid exhibited significant differences for all the traits except plant height. Significant differences recorded among female *vs*. male for days to 50% flowering, internodal length, plant height, fruit length, fruit diameter and average fruit weight. Parent *vs*. hybrid exhibited significant differences for internodal length, plant height, fruit length, fruit diameter, average fruit weight and fruits per plant.

A perusal of data presented in Table 3-7 indicated that Kashi Pragati × P-8 recorded maximum negative significant heterobeltiosis while 9801 × P-8 exhibited maximum negative significant standard heterosis over standard check 1 and standard check 2. Out of 27 cross-combinations; 8, 11 and 11 crosses exhibited desirable heterosis over better parent, standard check 1 and standard check 2, respectively for days to 50% flowering. Significant and negative heterosis for this trait have also been reported earlier by Kachhadia *et al*. (2011), Medagam *et al*. (2012), Jagan *et al*. (2013), Javia (2013), Shaikh (2014), Neetu (2015), Babubhai (2017), Manubhai (2017), Kulkarni *et al*. (2018), Patel *et al*. (2020), Rajani *et al*. (2021) and Singh (2021). For days to first picking, maximum negative significant heterobeltiosis were exhibited by Kashi Pragati ×

Table 3. Estimates of heterosis for days to 50% flowering and days to first picking

Trait	Days to 50% flowering			Days to first picking		
Cross	Better parent	Standard heterosis 1	Standard heterosis 2	Better parent	Standard heterosis 1	Standard heterosis 2
9801 × Hisar Unnat	0.00	0.00	0.00	-5.06	-6.83*	-5.06
9801× Palam Komal	-8.39*	-9.03*	-9.03*	-9.64*	-6.83*	-5.06
9801 × P-8	-11.43*	-13.89*	-13.89*	-6.67*	-13.04*	-11.39*
Punjab Suhawani × Hisar Unnat	-4.86	-4.86	-4.86	-9.49*	-11.18*	-9.49*
Punjab Suhawani × Palam Komal	-9.09*	-9.72*	-9.72*	-6.63*	-3.73	-1.90
Punjab Suhawani × P-8	-2.82	-4.17	-4.17	3.27	-1.86	0.00
Kashi Vibhuti × Hisar Unnat	0.69	0.69	0.69	1.90	0.00	1.90
Kashi Vibhuti × Palam Komal	-0.70	-1.39	-1.39	-4.82	-1.86	0.00
Kashi Vibhuti × P-8	-6.52*	-10.42*	-10.42*	-3.85	-6.83*	-5.06
Kashi Pragati × Hisar Unnat	-11.03*	-10.42*	-10.42*	-14.97*	-11.80*	-10.13*
Kashi Pragati × Palam Komal	-0.69	0.00	0.00	-8.38*	-4.97	-3.16
Kashi Pragati × P-8	-11.72*	-11.11*	-11.11*	-8.38*	-4.97	-3.16
Kashi Satdhari × Hisar Unnat	-9.03*	-9.03*	-9.03*	-1.27	-3.11	-1.27
Kashi Satdhari × Palam Komal	0.00	-0.69	-0.69	6.63*	9.94*	12.03*
Kashi Satdhari × P-8	-5.80	-9.72*	-9.72*	2.04	-6.83*	-5.06
Palam 5 ridged× Hisar Unnat	-2.08	-2.08	-2.08	0.00	-1.86	0.00
Palam 5 ridged× Palam Komal	-2.80	-3.47	-3.47	-6.63*	-3.73	-1.90
Palam 5 ridged× P-8	-2.90	-6.94*	-6.94 *	2.00	-4.97	-3.16
Palam Round× Hisar Unnat	2.78	2.78	2.78	12.03*	9.94*	12.03*
Palam Round× Palam Komal	0.70	0.00	0.00	-1.81	1.24	3.16
Palam Round× P-8	0.00	-4.17	-4.17	1.28	-1.86	0.00
VRO-4 × Hisar Unnat	-2.78	-2.78	-2.78	-1.90	-3.73	-1.90
VRO-4 × Palam Komal	-5.59	-6.25*	-6.25*	-7.83*	-4.97	-3.16
VRO-4 × P-8	5.80	1.39	1.39	10.46*	4.97	6.96*
HPO-1 × Hisar Unnat	-5.56	-5.56	-5.56	-4.97	-4.97	-3.16
HPO-1 × Palam Komal	-7.69*	-8.33*	-8.33*	-11.45*	-8.70*	-6.96*
HPO-1 × P-8	-0.72	-4.86	-4.86	-6.83*	-6.83*	-5.06
S.E. ± (d)	1.45	1.45	1.45	1.53	1.53	1.53

* Significant at 5% level

Standard heterosis 1: over standard check (Samrat); Standard heterosis 2: over standard check (Shakti)

Hisar Unnat while 9801 × P-8 showed maximum negative significant heterosis over standard check 1 and standard check 2. As many as 11, 9 and 4 crosses exhibited significant negative heterosis over BP, SC1 and SC2, respectively. Similar results were also observed by Jagan *et al*. (2013), Neetu (2015), Vani (2015), Babubhai (2017), Manubhai (2017), Kulkarni *et al*. (2018), Makdoomi *et al*. (2018), Vekariya *et al*. (2019), Patel *et al*. (2020), Rajani *et al*. (2021).

For nodes per plant, Palam Round × Hisar Unnat exhibited maximum positive significant heterosis over better parent and standard check 1. Over BP, 1 cross-combination while over SC1, 2 crosses exhibited significant positive heterosis. None of the cross-combination showed significant value over SC2 but highest positive non-significant heterosis displayed by Palam Round × Hisar Unnat. Kachhadia *et al*. (2011), Javia (2013), Neetu (2015), Vani (2015), Babubhai (2017), Makdoomi *et al*. (2018) and Singh (2021) also reported significant positive heterosis for this trait.

For internodal length, two cross-combinations *viz*., Palam 5 ridged × P-8 and HPO-1 × Palam Komal exhibited significant negative heterobeltiosis whereas two crosses viz., HPO-1 × Palam Komal and Palam 5 ridged × P-8 displayed significant negative heterosis over both SC1 and SC2. These results are in agreement

Table 4. Estimates of heterosis for nodes per plant and internodal length

Trait	Nodes per plant			Internodal length (cm)		
Cross	Better parent	Standard heterosis 1	Standard heterosis 2	Better parent	Standard heterosis 1	Standard heterosis 2
9801 × Hisar Unnat	-11.11*	-2.37	-11.33*	5.79	17.57*	13.05
9801× Palam Komal	-16.25*	-8.01	-16.46*	30.68*	7.64	3.50
9801 × P-8	-0.83	8.93*	-1.08	-12.36	-7.25	-10.81
Punjab Suhawani × Hisar Unnat	-6.14	-5.28	-13.98*	-2.99	7.81	3.67
Punjab Suhawani × Palam Komal	-15.19*	-16.58*	-24.23*	18.45*	4.64	0.62
Punjab Suhawani × P-8	-6.11	-7.65	-16.13*	3.44	9.47	5.27
Kashi Vibhuti × Hisar Unnat	0.36	1.28	-8.02*	2.36	13.76	9.39
Kashi Vibhuti × Palam Komal	-14.28*	-16.21*	-23.90*	24.42*	15.25*	10.82
Kashi Vibhuti × P-8	-3.63	-12.93*	-20.93*	12.82	19.39*	14.80*
Kashi Pragati × Hisar Unnat	-10.65*	-9.84*	-18.11*	4.30	15.91*	11.46
Kashi Pragati × Palam Komal	-3.84	-6.01	-14.64*	5.36	11.00	6.73
Kashi Pragati × P-8	6.16	-2.73	-11.66*	1.56	7.48	3.35
Kashi Satdhari × Hisar Unnat	-8.66*	-7.83	-16.29*	4.99	16.68*	12.20
Kashi Satdhari × Palam Komal	-12.04*	-14.03*	-21.92*	28.31*	11.55	7.26
Kashi Satdhari × P-8	-1.51	-10.66*	-18.86*	2.18	8.14	3.98
Palam 5 ridged× Hisar Unnat	-5.23	-4.37	-13.15*	4.70	16.35*	11.88
Palam 5 ridged× Palam Komal	-5.52	-7.65	-16.13*	11.62	-8.06	-11.6
Palam 5 ridged× P-8	3.90	-2.91	-11.83*	-26.81*	-22.54*	-25.52*
Palam Round× Hisar Unnat	9.69*	15.08*	4.52	-6.42	4.00	0.00
Palam Round× Palam Komal	-14.53*	-10.33*	-18.56*	46.60*	20.75*	16.11*
Palam Round× P-8	-15.28*	-11.11*	-19.27*	16.38*	23.17*	18.43*
VRO-4 × Hisar Unnat	1.44	2.37	-7.03	1.99	13.34	8.99
VRO-4 × Palam Komal	-6.45	-8.56*	-16.96*	43.93*	18.55*	13.99
VRO-4 × P-8	-4.42	-7.10	-15.63*	0.69	6.56	2.47
HPO-1 × Hisar Unnat	-7.22	-6.38	-14.97*	7.83	19.83*	15.23*
HPO-1 × Palam Komal	1.75	-0.55	-9.68*	-16.69*	-23.53*	-26.47*
HPO-1 × P-8	-1.61	-11.11*	-19.27*	7.41	13.67	9.31
S.E. ± (d)	0.76	0.76	0.76	0.68	0.68	0.68

* Significant at 5% level; Standard heterosis 1: over standard check (Samrat); Standard heterosis 2: over standard check (Shakti)

with the findings of Kachhadia *et al*. (2011), Medagam *et al*. (2012), Javia (2013), Neetu (2015), More *et al*. (2017), Kulkarni *et al*. (2018), Makdoomi *et al*. (2018), Vekariya *et al*. (2019), Patel *et al*. (2020) and Rajani *et al*. (2021). For plant height, highest positive significant heterosis over better parent exhibited by VRO-4 × Palam Komal while over standard check 1 by Palam Round × Hisar Unnat. None of the cross-combination exhibited positive significant heterosis over SC2 but highest positive non-significant heterosis displayed by Palam Round × Hisar Unnat. As many as 6 crosses each over BP and SC1 exhibited significant positive heterosis. These results are in broad conformity to the findings of Kachhadia *et al*. (2011), Shaikh (2014), Neetu (2015), Babubhai (2017), More *et al*. (2017), Makdoomi *et al*. (2018), Vekariya *et al*. (2019), Patel *et al.* (2020) and Singh (2021).

For fruit length, VRO-4 × Hisar Unnat exhibited significant positive heterosis over better parent whereas Punjab Suhawani × P-8 displayed maximum positive significant heterosis over both standard check 1 and standard check 2. Over BP, SC1 and SC2; 1, 4 and 1 cross-combination showed significant positive heterosis, respectively. The results are in line with those of Kachhadia *et al*. (2011), Javia (2013), Shaikh

Table 5. Estimates of heterosis for plant height and fruit length

Trait	Plant height (cm)			Fruit length (cm)		
Cross	Better parent	Standard heterosis 1	Standard heterosis 2	Better parent	Standard heterosis 1	Standard heterosis 2
9801 × Hisar Unnat	2.67	14.68*	0.72	-6.27*	-1.63	-5.85*
9801× Palam Komal	22.71*	-1.14	-13.18*	-18.27*	-10.73*	-14.55*
9801 × P-8	2.54	-2.09	-14.01*	-1.44	5.22*	0.71
Punjab Suhawani × Hisar Unnat	-8.41*	2.30	-10.15*	1.07	1.49	-2.86
Punjab Suhawani × Palam Komal	-0.14	-13.26*	-23.82*	-10.87*	-2.64	-6.81*
Punjab Suhawani × P-8	5.90	1.11	-11.19*	3.36	10.35*	5.63*
Kashi Vibhuti × Hisar Unnat	3.18	15.25*	1.22	-13.80*	-7.53*	-11.50*
Kashi Vibhuti × Palam Komal	15.86*	-3.50	-15.25*	-9.69*	-1.35	-5.58*
Kashi Vibhuti × P-8	8.50	3.60	-9.01*	-15.74*	-9.61*	-13.48*
Kashi Pragati × Hisar Unnat	-6.44	4.51	-8.21*	-4.97*	-4.57	-8.66*
Kashi Pragati × Palam Komal	8.52	4.38	-8.33*	-6.06*	2.61	-1.79
Kashi Pragati × P-8	8.69	4.55	-8.18*	-8.91*	-2.75	-6.92*
Kashi Satdhari × Hisar Unnat	-3.82	7.44	-5.64	0.93	1.35	-2.99
Kashi Satdhari × Palam Komal	19.05*	-4.09	-15.77*	-6.19*	2.47	-1.92
Kashi Satdhari × P-8	1.17	-3.40	-15.16*	-12.10*	-6.16*	-10.18*
Palam 5 ridged× Hisar Unnat	-0.43	11.23*	-2.31	-5.41*	-5.01*	-9.08*
Palam 5 ridged× Palam Komal	4.84	-15.53*	-25.82*	-9.56*	-1.21	-5.45*
Palam 5 ridged× P-8	-21.22*	-24.77*	-33.93*	-9.35*	-3.22	-7.37*
Palam Round× Hisar Unnat	6.82	19.32*	4.79	-9.35*	-7.49*	-11.45*
Palam Round× Palam Komal	25.47*	8.27	-4.91	-3.25	5.69*	1.16
Palam Round× P-8	14.24*	9.08	-4.19	-5.77*	0.61	-3.71
VRO-4 × Hisar Unnat	3.41	15.51*	1.45	4.92*	5.36*	0.85
VRO-4 × Palam Komal	33.99*	7.95	-5.19	-9.27*	-0.89	-5.13*
VRO-4 × P-8	3.00	-1.65	-13.62*	-6.51*	-0.19	-4.46*
HPO-1 × Hisar Unnat	-1.11	10.47*	-2.98	-4.55	-4.15	-8.26*
HPO-1 × Palam Komal	-5.63	-23.97*	-33.23*	-6.08*	2.59	-1.81
HPO-1 × P-8	5.60	0.83	-11.44*	-4.72*	1.73	-2.63
S.E. ± (d)	7.67	7.67	7.67	0.33	0.33	0.33

* Significant at 5% level; Standard heterosis 1: over standard check (Samrat); Standard heterosis 2: over standard check (Shakti)

(2014), Vani (2105), Manubhai (2017), More *et al*. (2017), Kulkarni *et al*. (2018), Vekariya *et al*. (2019), Das *et al*. (2020), Patel *et al*. (2020), Rajani *et al*. (2021) and Singh (2021). For fruit diameter, 9801 × P-8 revealed maximum negative significant heterosis over better parent and Kashi Pragati × Hisar Unnat exhibited maximum negative significant standard heterosis I and standard heterosis II. As many as 12, 3 and 3 crosses showed significant negative heterosis over BP, SC1 and SC2, respectively. These results are in consonance with those of Jagan *et al*. (2013), Solankey *et al*. (2013), Babubhai (2017) and Makdoomi *et al*. (2018).

For average fruit weight, Kashi Satdhari × P-8 recorded maximum positive significant heterobeltiosis whereas over standard check 1 and standard check 2, maximum positive significant heterosis displayed by Palam Round × Hisar Unnat. As many as 2, 15 and 11 crosses exhibited significant positive heterosis over BP, SC1 and SC2, respectively. Solankey *et al*. (2013), Shaikh (2014), Vani (2015), More *et al*. (2017), El-Sherbeny *et al*. (2018), Kulkarni *et al*. (2018), Makdoomi *et al*. (2018), Vekariya *et al*. (2019), Das *et al*. (2020), Patel *et al*. (2020), Rajani *et al*. (2021) and Singh (2021) observed significant positive heterosis in their respective studies. For fruits

Table 6. Estimates of heterosis for fruit diameter and average fruit weight

Trait	Fruit diameter (cm)			Average fruit weight (g)		
Cross	**Better parent**	**Standard heterosis 1**	**Standard heterosis 2**	**Better parent**	**Standard heterosis 1**	**Standard heterosis 2**
9801 × Hisar Unnat	-0.63	3.50	4.65	-3.48	19.32*	11.96
9801× Palam Komal	-10.29*	-6.56*	-5.53*	-10.68	9.44	2.69
9801 × P-8	-12.10*	-3.06	-1.99	4.71	15.27	8.16
Punjab Suhawani × Hisar Unnat	-1.56	-3.50	-2.43	-7.07	14.88	7.79
Punjab Suhawani × Palam Komal	1.36	-1.97	-0.88	1.09	23.86*	16.22*
Punjab Suhawani × P-8	-5.56*	4.16	5.31	5.92	9.92	3.14
Kashi Vibhuti × Hisar Unnat	-5.42*	-0.66	0.44	1.90	27.95*	20.06*
Kashi Vibhuti × Palam Komal	-6.67*	-1.97	-0.88	-12.84*	9.45	2.70
Kashi Vibhuti × P-8	-5.36*	4.38	5.53*	-7.22	16.49*	9.31
Kashi Pragati × Hisar Unnat	-8.71*	-10.50*	-9.51*	5.34	30.22*	22.19*
Kashi Pragati × Palam Komal	-7.81*	-9.63*	-8.63*	0.45	23.07*	15.48*
Kashi Pragati × P-8	-11.11*	-1.97	-0.88	-5.64	-2.08	-8.12
Kashi Satdhari × Hisar Unnat	8.85*	7.66*	8.85*	-16.91*	2.71	-3.62
Kashi Satdhari × Palam Komal	5.75*	4.60	5.75*	8.70	33.18*	24.97*
Kashi Satdhari × P-8	-3.17	6.78*	7.96*	16.22*	26.07*	18.29*
Palam 5 ridged× Hisar Unnat	-3.26	-2.63	-1.55	-0.77	22.67*	15.10*
Palam 5 ridged× Palam Komal	3.91	4.60	5.75*	-4.71	16.75*	9.55
Palam 5 ridged× P-8	-5.56*	4.16	5.31	-23.29*	-12.61	-18.00*
Palam Round× Hisar Unnat	3.57	1.53	2.65	9.41	35.25*	26.91*
Palam Round× Palam Komal	5.43	1.97	3.10	6.47	30.44*	22.40*
Palam Round× P-8	-9.13*	0.22	1.33	15.58*	19.95*	12.55
VRO-4 × Hisar Unnat	2.20	1.53	2.65	0.73	24.52*	16.84*
VRO-4 × Palam Komal	5.73*	5.03	6.19*	-14.73*	4.48	-1.96
VRO-4 × P-8	-3.37	6.56*	7.74*	-26.21*	-11.15	-16.63*
HPO-1 × Hisar Unnat	4.91	2.84	3.98	-0.26	23.31*	15.70*
HPO-1 × Palam Komal	3.62	0.22	1.33	-16.99*	1.71	-4.57
HPO-1 × P-8	-11.90*	-2.84	-1.77	-1.63	2.09	-4.21
S.E. ± (d)	0.04	0.04	0.04	0.96	0.96	0.96

* Significant at 5% level; Standard heterosis 1: over standard check (Samrat); Standard heterosis 2: over standard check (Shakti)

per plant, Palam Round × Hisar Unnat exhibited maximum positive significant heterosis over standard check 1. None of the cross-combination showed positive significant heterosis over BP and SC2 but highest positive non-significant heterosis displayed by Palam Round × Hisar Unnat. Jagan *et al*. (2013), Shaikh (2014), Vani (2015), Babubhai (2017), Manubhai (2017), More *et al*. (2017), El-Sherbeny *et al*. (2018), Kulkarni *et al*. (2018), Makdoomi *et al*. (2018), Vekariya *et al*. (2019), Das *et al*. (2020), Patel *et al*. (2020), Rajani *et al*. (2021) and Singh (2021) also reported positive heterosis for this trait.

For fruit yield per plant, four cross-combinations viz., HPO-1 × P-8, Kashi Vibhuti × Hisar Unnat, Palam Round × Hisar Unnat and VRO-4 × Hisar Unnat exhibited significant positive heterosis over better parent while three crosses *viz*., Palam Round × Hisar Unnat, Kashi Vibhuti × Hisar Unnat and VRO-4 × Hisar Unnat displayed significant positive heterosis over both SC1 and SC2. Solankey *et al*. (2013), Neetu (2015), Vani (2015), Babubhai (2017), Manubhai (2017), More *et al*. (2017), El-Sherbeny *et al*. (2018), Kulkarni *et al*. (2018), Makdoomi *et al*. (2018), Das *et al*. (2020), Patel *et al*. (2020), Rajani *et al*. (2021) and

Table 7. Estimates of heterosis for fruits per plant and fruit yield per plant

Trait	Fruits per plant			Fruit yield per plant (g)		
Cross	Better parent	Standard heterosis 1	Standard heterosis 2	Better parent	Standard heterosis 1	Standard heterosis 2
9801 × Hisar Unnat	-19.08*	-5.31	-11.11*	-18.26*	-3.74	-4.05
9801× Palam Komal	-24.14*	-11.23*	-16.67*	-34.14*	-22.44*	-22.69*
9801 × P-8	-8.97*	6.53	0.00	-11.43*	4.31	3.97
Punjab Suhawani × Hisar Unnat	-11.72*	-6.49	-12.22*	-8.01	-9.40	-9.70*
Punjab Suhawani × Palam Komal	-17.43*	-20.40*	-25.28*	-25.31*	-19.41*	-19.67*
Punjab Suhawani × P-8	-0.84	-11.24*	-16.69*	-12.73*	-14.04*	-14.32*
Kashi Vibhuti × Hisar Unnat	-3.67	2.03	-4.22	27.19*	21.49*	21.09*
Kashi Vibhuti × Palam Komal	-15.78*	-18.80*	-23.78*	-29.59*	-24.02*	-24.27*
Kashi Vibhuti × P-8	-4.12	-14.18*	-19.44*	-12.09*	-17.58*	-17.85*
Kashi Pragati × Hisar Unnat	-17.64*	-12.76*	-18.11*	-7.35	-11.51*	-11.80*
Kashi Pragati × Palam Komal	-6.55	-9.90*	-15.43*	-9.74*	-2.61	-2.93
Kashi Pragati × P-8	7.38	-3.89	-9.78*	-0.97	-22.62*	-22.87*
Kashi Satdhari × Hisar Unnat	-14.40*	-9.33	-14.89*	-13.76*	-17.63*	-17.90*
Kashi Satdhari × Palam Komal	-14.67*	-17.74*	-22.78*	-13.68*	-6.85	-7.16
Kashi Satdhari × P-8	-5.76	-14.09*	-19.35*	2.04	-16.81*	-17.08*
Palam 5 ridged× Hisar Unnat	-5.72	-0.14	-6.26	4.13	-0.55	-0.87
Palam 5 ridged× Palam Komal	-1.64	-5.17	-10.98*	-13.54*	-6.71	-7.01
Palam 5 ridged× P-8	4.28	-5.76	-11.54*	-29.50*	-33.60*	-33.81*
Palam Round× Hisar Unnat	8.96	15.41*	8.33	21.73*	33.77*	33.33*
Palam Round× Palam Komal	-14.47*	-10.91*	-16.37*	-17.54*	-9.38	-9.68*
Palam Round× P-8	-16.33*	-12.84*	-18.19*	-24.96*	-17.54*	-17.81*
VRO-4 × Hisar Unnat	-5.23	0.37	-5.78	15.63*	11.91*	11.54*
VRO-4 × Palam Komal	-5.77	-9.15	-14.72*	-25.30*	-19.39*	-19.66*
VRO-4 × P-8	-4.50	-8.27	-13.89*	-12.75*	-15.56*	-15.83*
HPO-1 × Hisar Unnat	-11.49*	-6.25	-12.00*	1.38	-3.17	-3.48
HPO-1 × Palam Komal	3.40	-0.32	-6.43	-21.48*	-15.27*	-15.55*
HPO-1 × P-8	-0.82	-11.23*	-16.67*	30.78*	2.19	1.86
S.E. ± (d)	0.81	0.81	0.81	9.85	9.85	9.85

* Significant at 5% level; Standard heterosis 1: over standard check (Samrat); Standard heterosis 2: over standard check (Shakti)

Singh (2021) have also reported hybrid vigour with variable magnitude for fruit yield per plant in good number of crosses.

From the above discussion, it can be concluded that among 27 F_1 hybrids, Palam Round × Hisar Unnat was identified as superior hybrid as it displayed significant positive heterosis over standard check 1 and standard check 2 for fruit yield. It also exhibited desirable heterosis over SC1 for nodes per plant, plant height, average fruit weight and fruits per plant and over SC2 for average fruit weight along with fruit yield per plant. Highest yield is the basic objective of all crop improvement programmes. In literature, most of the research work refers to average heterosis and heterobeltiosis only. Jagan *et al*. (2013), Neetu (2015), Manubhai (2017) and Singh (2021) also worked out average heterosis and heterobeltiosis in their respective studies. However, standard heterosis is of practical interest to the breeders as well as growers. Heterosis breeding has an upper hand over the open pollinated cultivars as hybrids developed have the advantage of higher yields with uniform maturity, size shape and colour of the fruits. The results suggest that heterosis for fruit yield is obtained through component heterosis. Even the slight hybrid vigour for individual yield components may have synergistic effects on yield.

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