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Comparative assessment of heterosis in brinjal under conventional and natural farming system

Hitaishi Kuriyal[1], Alka Verma[1]*, Imamuddin Shah[1,2], Ayush Bahuguna[3], Neelima Rawat[4], Gourav Gupta[2], Mohni Parmar[2], Anupam Singh[2] & R K Singh[5]

[1]Department of Vegetable Science, Govind Ballabh (GB) Pant University of Agriculture and Technology, Pantnagar 263 145, Uttarakhand, India

[2]Department of Horticulture, AKS University, Satna 485 001, Madhya Pradesh, India

[3]Department of Agricultural Chemistry and Soil Science, CCR PG), Muzaffarnagar 251 001, Uttar Pradesh, India

[4]Department of Agriculture, Shivalik College of Engineering, Dehradun 248 197, Uttarakhand, India

[5]Department of Vegetable Science, College of Horticulture and Forestry, Rani Laxmibai Central Agricultural University, Jhansi 284 003, Uttar Pradesh, India

***Correspondence:** alkadvs@gmail.com

Abstract

Brinjal (*Solanum melongena* L.) is an important solanaceous vegetable crop cultivated widely for its economic and nutritional value. The effective use of heterosis as a strategy to boost brinjal yield is getting a lot of attention in recent times. The present investigation was conducted at Vegetable Research Centre (VRC), Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand during the kharif 2023 and summer 2024, to estimate the extent of heterosis for fruit yield and its components in brinjal under conventional farming system (CFS) and natural farming system (NFS). The experiment was laid out in randomised block design (RBD) with 3 replications. A total of 21 cross combinations evolved from 10 parents of brinjal genotypes following a line × tester mating design with 7 lines and 3 testers. Two standard varieties i.e., Pant Rituraj (PR) and Kashi Uttam (KU) were used for comparing with crosses. In both farming systems, the crosses PB-416 × PR and PB-413 × PB-413 demonstrated significantly positive heterosis for yield parameters. The comparison of heterosis in CFS and NFS showed that CFS is clearly better for hybrid vigour in total fruit yield per plant. Across different hybrids, the levels of better-parent and standard heterosis were consistently higher in CFS. On the other hand, heterosis values in NFS were generally lower, which is still below what was achieved in CFS.

Keywords: brinjal; conventional farming; heterosis; hybrid; natural farming

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Introduction

Brinjal (*Solanum melongena* L.) is a warm-weather crop widely cultivated in tropical and subtropical regions of the world. Two other cultivated brinjal species, the scarlet brinjal (*Solanum aethiopicum* L.) and the Goma brinjal (*Solanum macrocarpon* L.), are less known but have local importance in sub-Saharan Africa (1). Brinjal, also known as eggplant, is referred to as the king of vegetables due to its wide culinary utility (2). It is one of the main sources of reliable revenue with important income sources (3). Farming practices play a crucial role in determining the sustainability, productivity and environmental impact of agricultural systems. Conventional farming and natural farming are two distinct approaches adopted by farmers worldwide. Each system has its own methodology, benefits and challenges, significantly influencing crop yield, soil health and ecosystem sustainability. In terms of the conventional farming system (CFS), it can be said to be a traditional method of farming that heavily depends upon synthetic fertilisers, pesticides and other agro-chemicals to boost crop yield and to protect the crop from pests and diseases. Due to the use of agro-chemicals in high quantities in the field, it helps farmers to promote growth and suppress pest populations, which ultimately benefit the farmers (4). But due to the extensive use of these chemicals, they lead to soil degradation, water pollution and loss of biodiversity (5). Also, prolonged exposure to agrochemicals has been linked to various health issues in farm workers and nearby communities (6). However, despite its drawbacks, farmers choose this method for its immediate benefits, particularly in developed countries, due to its ability to meet the high food demand of growing populations. Nowadays, changing consumer preferences and increasing health concerns are encouraging some farmers to shift toward alternative farming systems. Natural farming emphasises the use of organic fertilisers, crop

rotations, intercropping and other techniques that enhance biodiversity and soil health. Frequent use of agrochemicals produces an unsustainable ecology, which also depletes secondary plant nutrients and micronutrients. Studies indicate that the micronutrient deficiency in Indian soil is in the order of 36, 44, 23, 13, 8 and 4 % for zinc (Zn), sulphur (S), boron (B), iron (Fe), manganese (Mn) and copper (Cu) respectively (7). Therefore, natural farming will help in improving soil structure, fertility and biodiversity through organic amendments and reduced chemical inputs. This method is seen as more sustainable in the long-term, promoting ecosystem health and resilience against pests and diseases (8).

The main challenge in natural farming is lower yield compared to conventional methods, as natural systems take time to establish and require significant knowledge and management. Farmers using natural methods may face challenges in accessing markets that prefer conventional produce due to perception and pricing differences (9). While conventional farming often achieves higher short-term yield, natural farming provides benefits in terms of soil health and long-term sustainability. Farmers are increasingly looking for a balance between immediate productivity and environmental impact (10). A growing number of farmers are adopting practices from both systems, leading to integrated approaches that use conventional methods while incorporating sustainable practices, such as reduced chemical use and organic amendments (11). Considering the importance of brinjal under both farming systems, there is a need to develop high-yielding varieties adaptable to conventional and natural farming conditions. Hence, the current investigation was conducted with an objective to estimate the heterosis for fruit yield and its component in brinjal under conventional and natural farming systems (NFS).

Materials and Methods

The experiment was carried out in CFS and NFS at the Vegetable Research Centre (VRC), Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar, Uttarakhand, for estimating heterosis for fruit yield and its component in 10 brinjal genotypes during the kharif season of 2023 and the summer season of 2024 respectively. The trial material consisted of 7 lines (PB-411, PB-413, PB-416, PB-415, PB-405, PB-407 and PB-410) and 3 testers (Pant Rituraj (PR), Kashi Uttam (KU) and PB-414). Pant Rituraj and KU were also used as check varieties for comparison with F_1 hybrids. A total of 21 crosses were made between the parents with a line tester (*l* × *t*) design. These crosses, along with their parental lines, were cultivated in a randomised block design (RBD) with 3 replications. Except for 'KU' (from Indian Institute of Vegetable Research (IIVR), Varanasi), all source parental lines were from GBPUAT, Pantnagar. The distance from row to row was 60 cm and from plant to plant was 45 cm and the total number of plants in one replication was 525. Hybridisation was done by the method of hand emasculation and hand pollination. A total of 315 plants were pollinated, with 60 % of the flowers developing into fruit; of these, 15 % of the fruits were damaged by fruit borers during the early stages. In the conventional system of brinjal cultivation, regular irrigation, spraying of pesticides for shoot and fruit borers, weeding and all other primary methods were used. In this system, the recommended dose of nitrogen, phosphorus and potassium (NPK) was applied in a 120 : 60 : 50 ratio and the insecticide 'Coragen' was used at a rate of 0.5 mL per litre of water. In contrast, in the NFS, these practices were avoided and Jeevamrut and Neemastra were used at 15-day intervals. The plots of these agricultural systems were contiguous, resulting in shared climatic parameters, including rainfall and temperature, for both fields. Days to 50 % flowering (DF), plant height (cm), number of primary branches, number of flowers per cluster, fruit length (cm), fruit diameter (cm) and number of fruits per cluster were recorded from each replication using five randomly selected plants at different growth stages.

Liquefied sources and application

Jeevamrut

The beneficial microorganisms help improve soil fertility and aid in plant development. When Jeevamrut is applied to the soil, the beneficial microorganisms within it convert the existing nutrients-which plants cannot otherwise absorb directly-into a soluble form. Jeevamrut is sprayed on the crop field at 15-day intervals until the soil becomes fertile. The method for preparing Jeevamrut is as follows:

Take 200 L of water and mix in 10 kg of cow dung, 5–10 L of cow urine, 1–2 kg of jaggery, 1 kg of pulses flour and a handful of soil. Subsequently, a 10 % solution was prepared and applied to the crops by spraying it onto the leaves.

Neemastra

Neemastra is a natural and biodegradable insecticide; it leaves behind no harmful residues. To prepare Neemastra, the details are as follows:

Take 200 L of water and add 5 kg of neem leaves and 5–10 L of cow urine. After that, this mixture is well stirred for a few days and sprayed on the crop. After this, an 8 % solution was prepared with water and applied to the crops via foliar spraying.

Statistical analysis

The magnitude of heterosis was estimated in relation to relative heterosis, heterobeltiosis and the standard parent. Heterosis for each trait was calculated by using the overall mean of each hybrid over replications for each trait (12).

Better parent heterosis was estimated as per cent deviation of hybrid value from its better-parental value. The formula used for estimating heterobeltiosis as follows:

$$\text{Heterobeltiosis} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where,

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BP = better parent

Standard heterosis was expressed as percent increase or decrease observed in F_1 over standard check.

$$\text{Standard heterobeltiosis} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

where,

SC = standard heterosis

The statistical analysis was done using Tamil Nadu Agricultural University Statistical Package (TNAUSTAT) software.

Results and Discussion

The results of heterosis observed for different traits can be used to identify superior parents and hybrids for different traits, with the best indicators for different traits. The data for better parent and standard heterosis with mean performance for different growth and yield parameters are presented in Tables 1–7, respectively and the data on the mean performance of yield and yield-related traits are illustrated in Fig. 1.

Estimation of heterosis for growth and flowering traits in conventional farming system

The mean performance of parents in plant height under the conventional system varied from 108.62 (PB-410) to 59.36 (PB-405); on the other hand, the mean of the hybrids ranged from 118.36 (B-410 × KU) to 59.90 (PB-411 × PB-414) (Table 1).

The magnitude of heterosis in the conventional system ranged from -48.55 (PB-410 × PB-414) to 14.87 (PB-405 × PB-414) over the better parent and from -25.98 (PB-410 × PB-414) to 56.78 (PB-410 × KU) and –20.82 (PB-410 × PB-414) to 67.72 (PB-410 × KU) over two standard checks (PR and KU) respectively. Under the conventional system, 7 out of 21 F_1 hybrids expressed significantly positive heterosis over the better parent, with the tallest height being recorded in PB-405 × PB-414 followed by PB-415 × Kashi Uttam. The significant heterobeltiosis towards the positive direction showed its desirability for this trait (Fig. 2).

Table 1. Mean performance of different genotypes in conventional and natural farming system (CFS and NFS) for growth and flowering traits

Genotype	Plant height (cm)		Number of primary branches		Leaf area (cm^2)		Days to 50 % flowering		Number of flowers per cluster	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411	86.47	75.98	10.82	10.93	3.20	3.38	51.95	51.95	3.20	3.38
PB-413	83.56	70.61	10.02	9.93	3.00	3.57	59.17	59.17	3.00	3.57
PB-416	87.29	76.06	13.83	12.28	3.45	2.63	50.81	50.78	3.45	2.63
PB-415	65.06	73.58	10.20	9.40	4.19	3.99	54.70	54.69	4.19	3.99
PB-405	59.36	60.01	9.02	9.06	3.09	3.06	59.11	59.10	3.09	3.06
PB-410	108.62	99.01	9.49	8.66	3.22	3.04	50.79	50.81	3.22	3.04
PB-407	74.10	73.29	8.68	8.31	3.80	2.50	54.23	54.23	3.80	2.50
Pant Rituraj	75.50	75.74	5.71	5.97	1.17	1.09	62.99	62.99	1.17	1.09
Kashi Uttam	70.57	70.57	4.79	4.78	1.24	1.15	68.00	67.99	1.24	1.15
PB-414	72.02	70.02	10.00	9.94	3.60	2.03	72.00	71.99	3.60	2.03
PB-411 × PR	92.63	79.71	11.93	8.77	4.16	3.81	66.61	57.50	4.16	3.81
PB-411 × KU	70.24	79.61	11.48	9.09	4.12	3.82	67.23	58.63	4.12	3.82
PB-411 × PB-414	59.90	65.81	9.68	9.00	3.39	3.95	70.36	61.83	3.39	3.95
PB-413 × PR	67.71	59.96	8.88	10.33	3.94	2.60	60.60	59.53	3.94	2.60
PB-413 × KU	66.19	73.11	10.57	6.95	3.00	3.79	68.12	63.04	3.00	3.79
PB-413 × PB-414	66.32	66.42	10.87	10.40	3.34	2.93	58.29	67.30	3.34	2.93
PB-416 × PR	95.30	71.01	14.38	13.21	2.70	3.07	72.02	55.34	2.70	3.07
PB-416 × KU	71.37	80.95	14.14	12.97	4.03	3.18	62.09	55.89	4.03	3.18
PB-416 × PB-414	61.34	80.54	10.54	12.86	3.93	3.19	69.86	62.05	3.93	3.19
PB-415 × PR	67.81	64.29	10.63	8.81	4.20	2.97	58.39	60.06	4.20	2.97
PB-415 × KU	78.25	74.49	10.69	9.62	3.60	3.07	62.82	62.66	3.60	3.07
PB-415 × PB-414	79.13	74.11	10.60	10.13	3.00	2.48	71.53	65.32	3.00	2.48
PB-405 × PR	80.14	64.63	10.64	7.85	4.12	3.42	65.74	60.58	4.12	3.42
PB-405 × KU	77.64	72.19	9.96	7.99	3.60	3.47	66.40	63.39	3.60	3.47
PB-405 × PB-414	82.73	73.09	7.98	7.21	2.41	3.77	64.16	65.30	2.41	3.77
PB-410 × PR	111.86	67.46	8.88	9.50	3.20	3.52	66.95	56.25	3.20	3.52

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PB-410 × KU	118.36	63.10	9.99	9.54	3.80	3.37	67.74	64.25	3.80	3.37
PB-410 × PB-414	55.88	63.75	10.04	7.63	2.99	3.23	65.60	64.25	2.99	3.23
PB-407 × PR	64.97	65.42	8.41	9.83	4.40	3.22	71.34	58.21	4.40	3.22
PB-407 × KU	75.35	78.17	8.86	8.03	4.00	3.01	71.44	61.10	4.00	3.01
PB-407 × PB-414	73.61	65.10	7.54	7.53	4.15	2.80	64.13	63.49	4.15	2.80
C.D. (5 %)	**5.26**	**3.48**	**0.63**	**0.31**	**9.96**	**10.52**	**1.58**	**2.89**	**0.39**	**0.44**
C.D. (1 %)	**6.99**	**4.62**	**0.83**	**0.82**	**13.24**	**13.98**	**2.10**	**3.84**	**0.51**	**0.59**

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

Table 2. Mean performance of different genotypes in conventional and natural farming system for yield and yield attributing traits

Genotype	Fruit length (cm)		Fruit diameter (mm)		Number of fruits per cluster		Total fruit yield per plant (kg)	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411	8.03	8.16	78.81	79.30	2.60	2.45	2.21	1.10
PB-413	10.31	9.99	67.90	67.90	2.61	2.91	1.97	1.00
PB-416	8.70	8.46	78.03	64.36	2.40	2.38	1.86	1.17
PB-415	7.39	7.47	85.59	82.59	3.00	2.84	1.02	1.21
PB-405	7.91	7.87	49.19	46.19	2.80`	3.13	2.01	1.25
PB-410	9.85	9.67	72.21	60.21	2.60	2.77	2.08	1.50
PB-407	8.62	8.50	63.19	63.19	1.56	2.08	2.84	1.66
Pant Rituraj	9.52	9.27	77.04	77.00	1.08	1.10	2.26	1.19
Kashi Uttam	10.00	10.35	72.62	68.29	1.39	1.46	1.72	1.22
PB-414	10.03	12.43	73.33	71.00	2.80	2.69	1.83	0.77
PB-411 × PR	8.87	8.62	92.46	65.02	3.12	2.77	0.62	0.83
PB-411 × KU	8.12	7.33	91.99	80.68	2.92	2.60	0.65	1.00
PB-411 × PB-414	9.16	6.85	94.00	93.43	2.09	3.04	0.78	1.04
PB-413 × PR	9.59	10.16	89.00	90.50	2.07	2.50	0.92	1.11
PB-413 × KU	12.03	10.29	72.65	92.00	2.15	3.23	1.88	0.81
PB-413 × PB-414	13.14	10.74	64.00	84.00	3.06	2.54	0.91	0.80
PB-416 × PR	15.17	11.05	87.97	90.84	3.50	2.61	1.04	1.19
PB-416 × KU	8.27	13.03	98.99	72.13	4.69	2.20	1.80	1.06
PB-416 × PB-414	11.85	10.03	77.48	77.27	2.94	2.06	2.02	1.00
PB-415 × PR	7.17	7.57	79.00	79.80	3.06	2.38	1.01	0.82
PB-415 × KU	9.01	10.87	114.00	75.59	1.71	1.99	0.98	1.04
PB-415 × PB-414	8.40	8.22	93.00	90.91	2.09	1.99	0.95	0.95
PB-405 × PR	8.48	10.07	82.99	82.95	3.20	2.80	0.84	0.57
PB-405 × KU	10.93	8.18	70.93	69.30	1.59	2.75	1.09	1.00
PB-405 × PB-414	7.02	7.50	80.99	75.12	2.12	2.61	1.02	0.89
PB-410 × PR	8.71	11.13	71.00	58.87	3.05	2.92	0.75	0.82
PB-410 × KU	9.61	10.71	80.80	81.08	3.08	3.17	0.77	0.68
PB-410 × PB-414	8.98	8.23	75.76	73.02	2.06	1.98	0.83	0.90
PB-407 × PR	8.46	9.56	73.62	73.78	2.05	2.00	1.16	1.10
PB-407 × KU	8.39	10.53	77.75	74.37	2.76	2.23	1.06	0.99
PB-407 × PB-414	10.67	9.23	77.66	75.16	2.55	1.91	0.99	0.75
C.D. (5 %)	0.47	0.62	4.83	3.07	0.39	0.47	0.20	0.07
C.D. (1 %)	0.63	0.83	6.41	4.08	0.52	0.63	0.27	0.10

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

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Table 3. Heterosis for plant height (cm) and number of primary branches in conventional and natural farming system

F_1 hybrids	Plant height (cm)						Number of primary branches					
	Better-parent		Standard heterosis (PR)		Standard heterosis (KU)		Better-parent		Standard heterosis (PR)		Standard heterosis (KU)	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411 × PR	7.12*	4.90*	22.69**	5.24*	31.25**	12.94**	10.26**	-19.76**	108.99**	46.96**	148.96**	83.54**
PB-411 × KU	-18.76**	4.7*	-6.96	5.11*	-0.47	12.80**	6.10*	-16.86**	101.11**	52.26**	139.57**	90.17**
PB-411 × PB-414	-30.72**	-13.39**	-20.65**	-13.12**	-15.12**	-6.75*	-10.59**	-17.71**	69.47**	50.70**	101.88**	88.21**
PB-413 × PR	-18.97**	-20.84**	-10.31*	-20.84**	-4.05	-15.04**	-11.31**	3.99	55.58**	73.03**	85.33**	116.11**
PB-413 × KU	-20.79**	3.55	-12.33**	-3.47	-6.21	3.60	5.52	-30.00	85.11**	16.47**	120.51**	45.47**
PB-413 × PB-414	-20.63**	-5.93*	-12.15**	-12.30**	-6.02	-5.88*	8.49**	4.66	90.31**	74.26**	126.70**	117.64**
PB-416 × PR	9.17**	-6.65**	26.23**	-6.25*	35.04**	0.61	3.98	7.60**	151.84**	121.27**	200.00**	176.36**
PB-416 × KU	-18.24**	6.43**	-5.47	6.88**	1.13	14.71**	2.27	5.62*	147.69**	117.20**	195.06**	171.27**
PB-416 × PB-414	-29.73**	5.89*	-18.76**	6.34**	-13.09**	14.13**	-23.79**	4.78	84.59**	115.47**	119.89**	169.11**
PB-415 × PR	-10.18**	-15.12**	-10.18*	-15.12**	-3.91	-8.91**	4.15	-6.28	86.11**	47.52**	121.70**	84.24**
PB-415 × KU	10.87**	1.24	3.64	-1.65	10.87*	5.55*	4.80	2.34	87.27**	61.08**	123.09**	101.19**
PB-415 × PB-414	9.88**	0.72	4.82	-2.15	12.13**	5.01	3.89	1.95	85.64**	69.74**	121.14**	111.99**
PB-405 × PR	6.15	-14.67**	6.15	-14.67**	13.56**	-8.43**	17.97**	-13.35**	86.28**	31.55**	121.91**	64.30**
PB-405 × KU	10.01**	2.29	2.84	-4.69	10.01*	2.29	10.43**	-11.84**	74.37**	33.84**	107.72**	67.15**
PB-405 × PB-414	14.87**	4.39	9.58*	-3.50	17.23**	3.57	-20.17**	-27.50**	39.81**	20.71**	66.55**	50.77**
PB-410 × PR	2.99	-31.87**	48.17**	-10.94**	58.51**	-4.42	-6.39	9.66**	55.58**	59.07**	85.33**	98.68**
PB-410 × KU	8.97**	-36.27**	56.78**	-16.68**	67.72**	-10.58**	5.27	10.16**	74.96**	59.80**	108.41**	99.58**
PB-410 × PB-414	-48.55**	-35.62**	-25.98**	-15.83**	-20.82**	-9.67**	0.37	-23.21**	75.77**	27.86**	109.39**	59.69**
PB-407 × PR	-13.94**	-13.63**	-13.94**	-13.63**	-7.94	-7.31**	17.57**	18.29**	47.29**	64.66**	-0.21	105.65**
PB-407 × KU	1.68	6.66**	-0.20	3.21	6.76	-7.75**	26.79**	-3.41	55.11**	34.45**	-2.42	67.92**
PB-407 × PB-414	-0.67	-11.17**	-2.50	-14.04	4.30	7.32**	-6.64	-24.21**	32.05**	26.19**	-10.84**	57.60**

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

Table 4. Heterosis for leaf area (cm^2) and days to 50 % flowering in conventional and natural farming system (CFS and NFS)

F_1 hybrids	Leaf area (cm^2)						Days to 50 % flowering					
	Better-parent		Standard heterosis (PR)		Standard heterosis (KU)		Better-parent		Standard heterosis (PR)		Standard heterosis (KU)	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411 × PR	4.89*	-38.23**	4.89*	-38.23**	22.30**	-28.48**	5.75*	-8.71**	5.75	-8.71**	-2.03	-15.43**
PB-411 × KU	-2.14	1.05	-16.07**	-12.33**	-2.14	1.50	-1.12	-13.78**	6.73*	-6.92**	-1.12	-13.78**
PB-411 × PB-414	19.43**	25.30**	-19.59**	-16.30**	-6.25*	-3.09	-18.45**	-14.12**	-6.79*	-1.84	-13.65**	-9.07**
PB-413 × PR	-20.64**	-18.59**	-20.64**	-18.59**	-7.47**	-5.74*	-3.80	-5.49*	-3.80	-5.49*	-10.88**	-12.45**
PB-413 × KU	20.43**	20.76**	3.29	4.31	20.43**	20.76**	0.19	-7.28**	8.14**	0.09	0.19	-7.28**
PB-413 × PB-414	43.16**	34.82**	12.72**	15.18**	31.43**	33.35**	-19.03**	-6.52**	-7.46*	6.84**	-14.27**	-1.02
PB-416 × PR	25.03**	-14.33**	25.03**	-14.33**	45.79**	-0.82	14.32**	-12.15**	14.32**	-12.15**	5.91*	-18.61**
PB-416 × KU	-16.71**	-3.88	-18.75**	-16.98**	-5.26	-3.858	-8.69**	-17.81**	-1.43	-11.27**	-8.69**	-17.81**
PB-416 × PB-414	-17.76**	23.56**	-19.77**	-19.09**	-6.45*	-6.33*	-2.97**	-13.81**	10.90**	-1.48	2.74	-8.74**
PB-415 × PR	-0.11	-9.01**	-0.11	-9.01**	16.47**	5.34*	-7.30**	-4.65*	-7.30*	-4.65	-14.12**	-11.67**
PB-415 × KU	-17.76**	-20.69**	-29.46*	-28.04**	-17.76**	-16.68**	-7.61**	-7.85**	-0.27	0.52	-7.61**	-7.85**
PB-415 × PB-414	-3.42	-27.07**	-34.98**	-33.83**	-24.19**	-23.39**	-0.64**	-9.74**	13.56**	3.17	5.20	-4.43*
PB-405 × PR	15.91**	15.88**	15.91**	15.88**	35.15**	34.16**	4.36	-3.82	4.36	-3.82	-3.32	-10.90**

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PB-405 × KU	-6.25*	-3.35	-19.60**	-16.52**	-6.25*	-3.35	-2.35	-6.77**	5.40	0.64	-2.35	-6.77**
PB-405 × PB-414	64.06**	71.47**	10.45**	12.28**	28.78**	29.99**	-10.89**	-9.30**	1.85	3.67	-5.65*	-3.97
PB-410 × PR	9.95**	-56.12**	9.95**	-56.12**	28.20**	-49.19**	6.28*	-10.69**	6.28*	-10.69**	-1.54	-17.27**
PB-410 × KU	-29.06**	-29.24**	-39.16**	-38.88**	-29.06**	-29.24**	-0.38	-5.50*	7.54*	2.01	-0.38	-5.50*
PB-410 × PB-414	44.52**	55.10**	-2.70	1.56	13.44**	17.58**	-8.89**	-13.95**	4.13	-1.65	-3.53	-8.89**
PB-407 × PR	25.47**	25.02**	25.47**	25.02**	46.44**	44.74**	13.25**	-7.58**	13.25**	-7.58**	4.92	-14.38**
PB-407 × KU	27.39**	28.33**	9.25**	10.84**	27.39**	28.33**	5.06*	-10.13**	13.40	-2.99	5.06	-10.13**
PB-407 × PB-414	44.52**	52.70**	-2.71	0.73	13.44**	16.63**	-10.93**	-11.82**	1.80	0.79	-5.69*	-6.63**

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

Table 5. Heterosis for number of flowers per cluster and fruit length (cm) in conventional and natural farming system (CFS and NFS)

F_1 hybrids	Number of flowers per cluster						Fruit length (cm)					
	Better-parent		Standard heterosis (PR)		Standard heterosis (KU)		Better-parent		Standard heterosis (PR)		Standard heterosis (KU)	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411 × PR	30.10**	5.59	255.84**	120.06**	235.75**	59.62**	-6.86**	-7.01	-6.86**	-7.01	-11.36**	-16.69**
PB-411 × KU	28.65**	10.87	251.85**	131.07**	231.99**	67.61**	-18.83**	-29.16**	-14.71**	-20.93**	-18.83**	-29.16**
PB-411 × PB-414	-5.65	14.32	190.03**	194.50**	173.66**	113.62**	-8.64**	-44.85**	-3.78	-26.07**	-8.43**	-33.76**
PB-413 × PR	31.44**	25.03**	237.04**	211.97**	218.01**	126.29**	-6.95**	1.77	0.74	9.64*	-4.13	-1.77
PB-413 × KU	-0.11	-0.13	156.13**	149.19**	141.67**	80.75**	16.72**	-0.52	26.37**	11.04*	20.26**	-0.52
PB-413 × PB-414	-7.14	35.80**	185.47**	249.84**	169.35**	153.76**	27.46**	-13.55**	37.99**	15.89**	31.32**	3.83
PB-416 × PR	-21.91**	18.28	130.48**	180.58**	117.47**	103.52**	59.31**	19.17**	59.31**	19.17**	51.62**	6.77
PB-416 × KU	16.70**	33.29**	244.44**	216.18**	225.00**	129.34**	-17.33**	25.90**	-13.13**	40.52**	-17.33**	25.90**
PB-416 × PB-414	9.27	21.61*	235.90**	213.27**	216.94**	127.23**	18.22**	-19.29**	24.51**	8.20	18.49**	-3.06
PB-415 × PR	0.08	-35.16**	258.69**	72.49**	238.44**	25.12	-24.72**	-18.30**	-24.72**	-18.30**	-28.36**	-26.80**
PB-415 × KU	-14.23**	-14.60	207.41**	127.18**	190.05**	64.79**	-9.90**	5.09	-5.32*	17.33**	-9.90**	5.09
PB-415 × PB-414	-28.54**	-35.40**	156.13**	71.84**	141.67**	24.65	-16.26**	-33.85**	-11.80**	-11.87**	-16.06**	-20.55**
PB-405 × PR	33.44**	-41.68**	252.42**	55.34**	232.53**	12.68	-10.96**	8.63*	-10.96**	8.63*	-15.26**	-2.67
PB-405 × KU	16.40*	-40.34**	207.41**	58.90*	190.05**	15.26	9.23**	-21.04**	14.78**	-11.87**	9.23**	-21.04**
PB-405 × PB-414	-32.99**	-8.02	105.98**	144.98**	94.35**	77.70**	-29.99**	-39.67**	-26.26**	-19.13**	-29.82**	-27.55**
PB-410 × PR	-0.72	5.28	173.22**	157.93**	157.80**	87.09**	-11.54**	15.10**	-8.51**	20.03**	-12.93**	7.54
PB-410 × KU	17.91**	29.33**	224.50**	216.83**	206.18**	129.81**	-3.93	3.48**	0.95	15.50**	-3.93	3.48
PB-410 × PB-414	-16.77**	15.95	155.84**	198.71**	141.40**	116.67	-10.44**	-3.74**	-5.67*	-11.18*	-10.23**	-20.43**
PB-407 × PR	15.80**	25.53	275.78**	73.46**	254.57**	25.82	-11.17**	3.13	-11.17**	3.13	-15.46**	-7.60
PB-407 × KU	5.27	10.07	241.60**	52.10*	222.31**	10.33	-16.16**	1.80	-11.90**	13.63**	-16.16**	1.80
PB-407 × PB-414	9.22	-50.75**	254.42**	26.86	234.41**	-7.98	6.45**	-25.80**	12.11**	-0.54	6.70**	-10.89**

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

Table 6. Heterosis for fruit diameters (cm) and number of fruits per cluster in conventional and natural farming system (CFS and NFS)

F_1 hybrids	Fruit diameters (cm)						Number of fruits per cluster					
	Better-parent		Standard heterosis (PR)		Standard heterosis (KU)		Better-parent		Standard heterosis (PR)		Standard heterosis (KU)	
	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS	CFS	NFS
PB-411 × PR	17.32**	-18.01**	20.02**	-15.56**	27.33**	-4.79	19.72*	13.06	187.69**	152.58**	124.76**	89.29**
PB-411 × KU	16.72**	1.74	19.41**	4.77*	26.68**	18.14**	12.29	6.26	169.85**	137.39**	110.82**	77.90**
PB-411 × PB-414	19.26**	17.82**	22.01**	21.33**	29.44**	36.81**	-25.15**	13.03	93.23**	176.90**	50.96**	107.52**

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PB-413 × PR	15.52**	17.53**	15.52**	17.53**	22.56**	32.52**	-20.82**	-13.99	90.77**	127.96**	49.04**	70.84**
PB-413 × KU	0.05	34.71**	-5.70	19.48**	0.05	34.71**	-17.50*	11.24	98.77**	194.83**	55.29**	120.96**
PB-413 × PB-414	-12.73**	18.31**	-16.93**	9.09**	-11.87**	23.00**	9.42	-12.73	182.46**	131.31**	120.67**	73.35**
PB-416 × PR	12.74**	17.97**	14.18**	17.97**	21.14**	33.02**	46.18**	9.65	223.38**	138.30**	152.64**	78.59**
PB-416 × KU	26.87**	5.63*	28.50**	-6.32**	36.32**	5.63*	95.83**	-7.55	333.23**	100.91**	238.46**	50.57**
PB-416 × PB-414	-0.70	8.83**	0.57	0.35	6.70	13.14**	5.13	-23.33*	171.38**	87.84**	112.02**	40.77*
PB-415 × PR	-7.70**	-3.38	2.54	3.64	8.79*	16.86*	2.22	-16.31	182.77**	116.72**	120.91**	62.41**
PB-415 × KU	33.18**	-8.48**	47.97**	-1.84	56.98**	10.68**	-42.83**	-29.81**	58.15**	81.76**	23.56	36.22**
PB-415 × PB-414	8.56**	10.07**	20.72**	18.06**	28.07**	33.12**	-30.14**	-29.93**	93.23**	81.46**	50.96**	35.99*
PB-405 × PR	7.73*	7.72**	7.73*	7.72**	14.29**	21.46**	14.54**	-10.64	195.69**	155.32**	131.01**	91.34**
PB-405 × KU	-2.32	1.48	-7.93*	-10.00**	-2.32	1.48	-43.03**	-12.34	47.08*	150.46**	14.90	87.70**
PB-405 × PB-414	10.45**	5.80*	5.13	-2.45	11.54**	10.00**	-24.08**	-16.60*	96.00**	138.30**	53.12**	78.59**
PB-410 × PR	-7.84*	-23.55**	-7.84*	-23.55**	-2.32	-13.80**	17.33*	5.66	181.23**	166.57**	119.71**	99.77**
PB-410 × KU	11.27**	18.72**	4.88	5.29*	11.27**	18.72**	18.61*	14.70	184.31**	189.36**	122.12**	116.68**
PB-410 × PB-414	3.31	2.85	-1.67	-5.16*	4.32	6.93**	-26.34**	-28.55**	90.15**	80.24**	48.56**	35.08*
PB-407 × PR	-4.44	-4.19*	-4.44	-4.19	1.38	8.03**	31.62*	-3.69	89.54**	82.67**	48.08**	36.90*
PB-407 × KU	7.07*	8.91**	0.93	-3.41	7.07	8.91**	76.71**	7.21	154.46**	103.34**	98.80**	52.39**
PB-407 × PB-414	5.90	5.86**	0.80	-2.39	6.95	10.06**	-8.70	-29.03**	135.69**	73.86**	84.13**	30.30

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

Table 7. Heterosis for total fruit yield per plant (kg) in conventional and natural farming system (CFS and NFS)

F_1 hybrids	Total fruit yield per plant (kg)					
	Better-parent		Standard heterosis (PR)		Standard heterosis (KU)	
	CFS	NFS	CFS	NFS	CFS	NFS
PB-411 × PR	91.35**	-0.30	91.35**	-0.30	109.46**	10.74**
PB-411 × KU	86.44**	0.34	70.32**	-9.67**	86.44**	0.34
PB-411 × PB-414	87.58**	23.94**	61.10**	6.34	76.34**	18.12**
PB-413 × PR	-11.82	9.97**	-11.82	9.97**	-3.47	22.15**
PB-413 × KU	89.91**	26.17**	73.49**	13.60**	89.91**	26.17**
PB-413 × PB-414	109.73**	98.67**	80.12**	35.65**	97.16**	50.67**
PB-416 × PR	145.24**	50.76**	145.24**	50.76**	168.45**	67.45**
PB-416 × KU	106.40**	19.00**	95.10**	7.85*	113.56**	19.80**
PB-416 × PB-414	57.32**	22.33**	48.70**	10.88**	62.78**	23.15**
PB-415 × PR	58.50**	-29.91**	58.50**	-29.91**	73.50**	-22.15**
PB-415 × KU	-41.01**	-16.11**	-46.11**	-24.47**	-41.01**	-16.11**
PB-415 × PB-414	-36.60**	-12.41**	-44.09**	-9.67**	-38.80**	0.34
PB-405 × PR	-32.28**	-6.04	-32.28**	-6.04	-25.87*	4.36
PB-405 × KU	-12.93	12.08**	-20.46*	0.91	-12.93	12.08**
PB-405 × PB-414	89.60**	-1.63	62.82**	-26.89**	78.23**	-18.79**
PB-410 × PR	-21.04*	-27.19**	-21.04*	-27.19**	-13.56	-19.13**
PB-410 × KU	-1.58	19.80**	-10.09	7.85*	-1.58	19.80**
PB-410 × PB-414	81.54**	40.27**	55.91**	-4.23	70.66**	6.38
PB-407 × PR	74.35**	-9.67**	74.35**	-9.67**	90.85**	0.34
PB-407 × KU	-4.42	-17.79**	-12.68	-25.98**	-4.42	-17.79**
PB-407 × PB-414	-1.34	15.99**	-15.27	-5.74	-7.26	4.70

CFS: conventional farming system; NFS: natural farming system; PR: Pant Rituraj; KU: Kashi Uttam.

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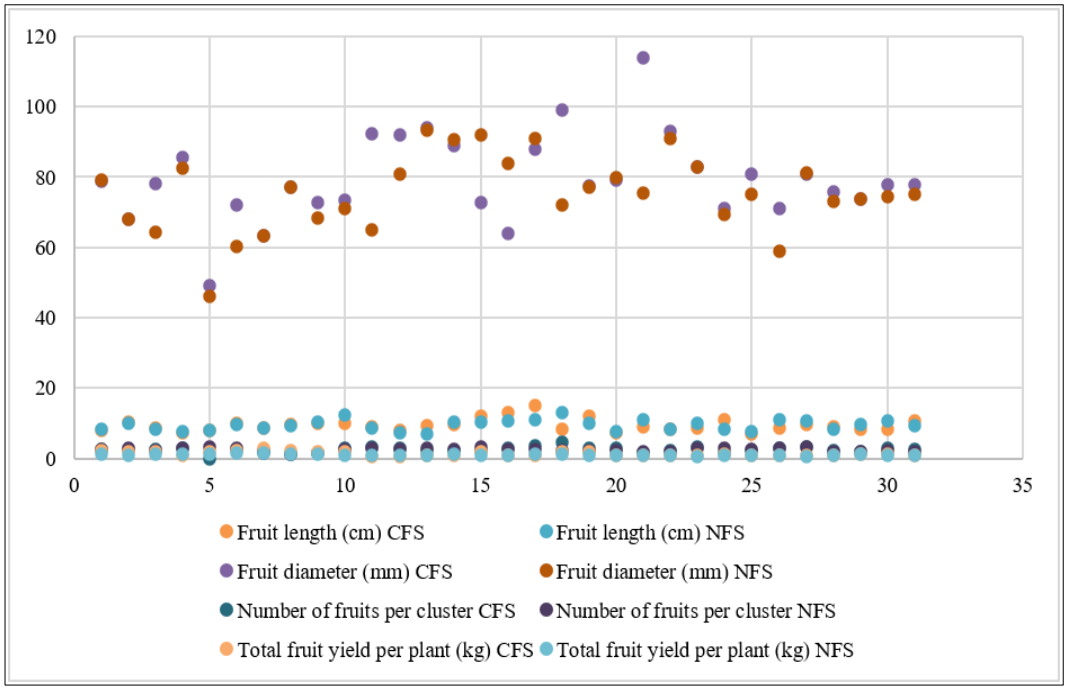


Fig. 1. Mean performance of different genotypes in conventional and natural farming system (CFS and NFS) for yield and yield attributing traits.

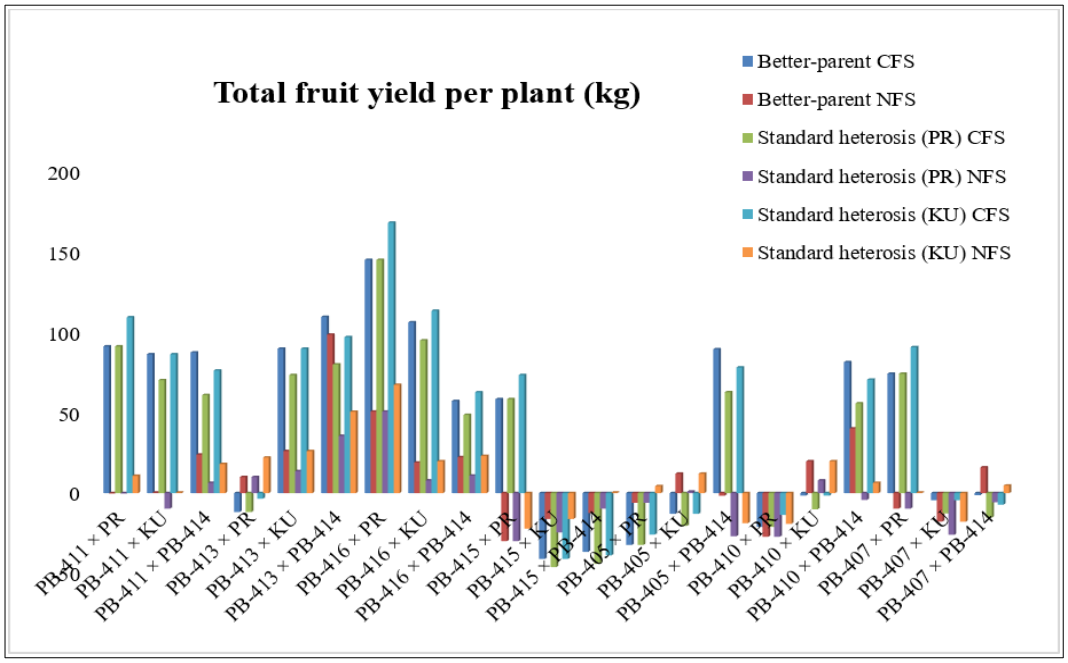


Fig. 2. Heterosis for total fruit yield per plant in conventional and natural farming system (CFS and NFS).

As a greater number of primary branches per plant can support a large canopy, which helps in enhancing photosynthesis, ultimately resulting in better plant vigour and higher yield. The mean performance of parents for the number of primary branches per plant varied from PB-416 (13.83) to KU (4.79) and for hybrids, it ranged from PB-416 × PR (14.38) to PB-407 × PB-414 (7.54). The better parent heterosis ranged from -23.79 % (PB-416 × PB-414) to 26.79 % (PB-407 × KU) and for two standard checks viz., PR heterosis ranged from 15.84 (PB-416 × PR) to 32.05 (PB-407 × PB-414) and KU ranged from 200.00 (PB-416 × PR) to -10.84 (PB-407 × PB-414). Hybrids which showed positive estimation over the better parent were PB-416 × KU and PB-416 × PR.

Among the parents and hybrids, leaf area varied from 4.19 cm² (PB-415) to 1.17 cm² (PR) and 4.40 (PB-407 × PR) to 2.41 (PB-405 × PB-414) in the CFS, respectively. Out of 21 F_1 hybrids, twelve, eight and twelve hybrids exhibited significant positive heterosis over the better parent and two standard checks (PR and KU)

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respectively. The range for heterosis over the better parent in the conventional system varied from -29.06 (PB-410 × KU) to 64.06 (PB-405 × PB-414), whereas it ranged from -39.16 (PB-410 × KU) to 25.47 (PB-407 × PR) and -29.06 (PB-410 × KU) to 46.44 (PB-416 × PR) over two standard checks (PR and KU) respectively.

The negative heterosis for DF is desirable for breeding short-statured hybrids. The mean performance of parents in the conventional system for DF varied from 50.79 (PB-410) to 72.00 (PB-414); on the other hand, the mean of the hybrids ranged from 58.29 (PB-413 × PB-414) to 72.02 (B-416 × PR). In the conventional system, out of 21 F_1 hybrids, 10 crosses expressed significant negative heterosis over the better parent and for two standard checks, only three and eight crosses expressed significant negative heterosis for PR and KU, respectively. The magnitude for heterosis varied from -0.64 (PB-415 × PB-414) to -19.03 (PB-413 × PB-414), -6.79 (PB-411 × PB-414) to -7.46 (PB-413 × PB-414) and -5.65 (PB-405 × PB-414) to -14.27 (PB-413 × PB-414) over the better parent and two standard checks (PR and KU) respectively. Crosses which showed the minimum number of days to flowering were PB-413 × PB-414 followed by PB-411 × PB-414.

We observed a broad spectrum in the number of flowers per cluster; the mean performance of parents and hybrids in the conventional system ranged from 4.19 (PB-415) to 1.17 (PR) and 4.40 (PB-407 × PR) to 2.41 (PB-405 × PB-414) respectively. Out of 21 F_1 hybrids, eight and all 21 hybrids exhibited significant positive heterosis over the better parent and two standard checks (PR and KU) respectively. The range of heterosis over the better parent varied from -32.99 (PB-405 × PB-414) to 33.44 (PB-405 × PR), whereas it ranged from 105.98 (PB-405 × PB-414) to 275.78 (PB-407 × PR) and 94.35 (PB-405 × PB-414) to 254.57 (PB-407 × PR) over two standard checks (PR and KU) respectively.

Estimation of heterosis for yield and yield attributing traits in conventional farming system

In the CFS for fruit length, the mean performance of parents ranged from 10.03 (PB-414) to 7.39 (PB-415), whereas the range in hybrids varied from 15.17 (PB-416 × PR) to 7.02 (PB-405 × PB-414) as shown in Table 2.

Among 21 F1 hybrids, only six crosses were found highly significant and positive over better parents, with the range from -29.99 (PB-405 × PB-414) to 59.31 (PB-416 × PR), whereas for both standard heterosis (PR and KU) the range varied from -26.26 (PB-405 × PB-414) to 59.31 (PB-416 × PR) and -29.82 (PB-405 × PB-414) to 51.62 (PB-416 × PR), respectively. Hybrids which showed maximum fruit length were PB-416 × PR followed by PB-413 × PB-414.

Mean performance of fruit diameter for parents and hybrids in the CFS ranged from 85.59 (PB-415) to 49.19 (PB-405) and 114.00 (PB-415 × KU) to 64.00 (PB-413 × PB-414) respectively. Among 21 F_1 hybrids, twelve, nine and twelve hybrids showed significant positive estimation over the better parent and standard checks (PR and KU), respectively. The range for the better parent in the CFS varied from -12.73 (PB-413 × PB-414) to 33.18 (PB-415 × KU) and for both standard checks (PR and KU), it varied from -16.93 (PB-413 × PB-414) to 47.97 (PB-415 × KU) respectively. Hybrids which showed positive estimation over the better parent were PB-415 × KU followed by PB-416 × KU.

Mean performance for the number of fruits per cluster for parents and hybrids in the CFS ranged from 3.00 (PB-415) to 1.08 (PR) and 4.69 (PB-416 × KU) to 1.59 (PB-405 × KU) respectively. Among 21 F_1 hybrids, eight, twenty-one and nineteen hybrids showed significant and positive estimation over the better parent and two standard checks (PR and KU) respectively. The range for the better parent in the CFS varied from -43.03 (PB-405 × KU) to 95.83 (PB-416 × KU) and for two standard checks (PR and KU) it varied from 47.08 (PB-405 × KU) to 333.23 (PB-416 × KU) and 48.08 (PB-407 × PR) to 238.46 (PB-416 × KU) respectively. Hybrids which showed the highest number of fruits per cluster were PB-416 × KU followed by PB-407 × KU.

Among the parents and hybrids, the mean performance of total fruit yield per plant varied from 1.17 kg (PR) to 4.19 kg (PB-415) and 2.41 kg (PB-405 × PB-414) to 4.40 kg (PB-407 × PR) in the CFS. Out of 21 F_1 hybrids, twelve hybrids exhibited significant positive heterosis over the better parent and two standard checks (PR and KU), respectively. The range for heterosis over the better parent in the CFS varied from -41.02 (PB-415 × KU) to 145.24 (PB-416 × PR), whereas it ranged from -46.11 (PB-415 × KU) to 145.24 (PB-416 × PR) and -41.01 (PB-415 × KU) to 168.45 (PB-416 × PR) over two standard checks (PR and KU) respectively.

Estimation of heterosis for growth and flowering traits in natural farming system

In the case of the NFS for plant height, the mean performance of parents and hybrids varied from 99.01 (PB-410) to 60.01 (PB-405) and 80.95 (PB-416 × KU) to 59.96 (PB-413 × PR) respectively. The magnitude of heterobeltiosis ranged from -36.27 (PB-410 × KU) to 6.66 (PB-407 × KU); for the two standard checks, it ranged from -20.84 (PB-413 × PR) to 6.88 (PB-416 × KU) and -15.04 (PB-413 × PR) to 14.71 (PB-416 × KU) respectively. Hybrids which showed significant positive heterobeltiosis were PB-407 × Kashi Uttam followed by PB-416 × Kashi Uttam.

For the number of primary branches, the mean performance of parents ranged from 12.28 (PB-416) to 4.78 (Kashi Uttam) and hybrids ranged from 13.21 (PB-416 × PR) to 6.95 (PB-413 × KU). The magnitude of heterosis for the better parent in NFS ranged from -27.50 (PB-405 × PB-414) to 18.29 (PB-407 × PR) and for two standard checks viz., for PR it ranged from 121.27 (PB-416 × PR) to 16.47 (PB-413 × KU) and for KU it ranged from 176.36 (PB-416 × PR) to 45.47 (PB-413 × KU), respectively. Hybrids which showed the maximum number of primary branches per plant were PB-407 × PR followed by PB-410 × KU.

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For leaf area (cm^2), the mean performance of parents ranged from 3.99 (PB-415) to 1.09 (PR) and hybrids ranged from 3.95 (PB-411 × PB-414) to 2.60 (PB-413 × PR). Out of 21 F_1 hybrids, 18, 5 and 9 hybrids expressed positive estimation over the better parent and two standard checks (PR and KU) respectively. The range of heterosis over the better parent varied from -56.12 (PB-410 × PR) to 71.47 (PB-405 × PB-414).

When compared to the natural system for DF, the mean performance of parents varied from 71.99 (PB-414) to 50.78 (PB-416); on the other hand, the mean of the hybrids ranged from 67.30 (B-413 × PB-414) to 55.34 (PB-416 × PR). The F_1 hybrid expressed significant negative heterosis over the better parent, while for two standard checks (PR and KU), 10 and 19 crosses showed negative estimation, respectively. The magnitude for heterosis for the natural system varied from -0.64 (PB-415 × PB-414) to -5.94 (PB-413 × PR), -12.15 (PB-416 × PR) to -6.92 (PB-411 × KU) and -6.63 (PB-407 × PB-414) to -18.61 (PB-416 × PR) over the better parent and two standard checks (PR and KU) respectively. Crosses which showed early flowering were PB-416 × KU followed by PB-411 × KU.

In the case of the number of flowers per cluster, the mean performance of parents and hybrids ranged from 3.99 (PB-415) to 1.09 (PR) and 3.95 (PB-411 × PB-414) to 2.48 (PB-415 × PB-414), respectively. In terms of heterosis, out of 21 F_1 hybrids, 10, 20 and 13 hybrids exhibited positive estimation over the better parents and two standard checks (PR and KU) respectively. The range of heterosis over the better parent and two standard checks (PR and KU) in the natural farming system ranged from -50.75 (PB-407 × PB-414) to 35.80 (PB-413 × PB-414), 52.10 (PB-407 × KU) to 249.84 (PB-413 × PB-414) and 59.62 (PB-411 × PR) to 153.76 (PB-413 × PB-414) respectively. For this trait, the primary branch plays a very significant role in determining the plant's overall flowering capacity.

Estimation of heterosis for yield and yield attributing traits in natural farming system

When compared to the NFS, for fruit length, the mean performance of parents and hybrids ranged from 12.43 (PB-414) to 7.47 (PB-415) and 13.03 (PB-416 × KU) to 6.85 (PB-411 × PB-414) respectively. Among 21 F_1 hybrids, only two hybrids showed significant and positive estimation over the better parent and two standard checks (PR and KU) showed 9 and 1 hybrids with significant and positive estimation respectively. The range for the better parent and two standard checks ranged in the NFS from -44.85 (PB-411 × PB-414) to 25.90 (PB-416 × KU), -26.07 (PB-411 × PB-414) to 40.52 (PB-416 × KU) and -33.76 (PB-411 × PB-414) to 25.90 (PB-416 × KU) respectively. Highest fruit length was recorded in PB-416 × KU followed by PB-410 × PR.

In the NFS for fruit diameter, the mean performance of parents and hybrids varied from 82.59 (PB-415) to 46.19 (PB-405) and 93.43 (PB-411 × PB-414) to 58.87 (PB-410 × PR), respectively. For this trait, out of 21 F_1 hybrids, 17, 9 and 18 hybrids expressed significant and positive estimation over the better parent and two standard checks (PR and KU), respectively. For the better parent, the range varied from -23.55 (PB-410 × PR) to 34.71 (PB-413 × KU) and for two checks (PR and KU) the range varied from -23.55 (PB-410 × PR) to 21.33 (PB-411 × PB-414) and -13.80 (PB-410 × PR) to 36.81 (PB-411 × PB-414) respectively. Hybrids which showed positive estimation over the better parent for this trait were PB-413 × KU followed by PB-410 × KU.

Under the natural farming system, the mean performance of parents and hybrids for the number of fruits per cluster ranged from 3.13 (PB-405) to 1.10 (Pant Rituraj) and 3.23 (PB-413 × KU) to 1.98 (PB-410 × PB-414), respectively. Among 21 F_1 hybrids, six hybrids showed significantly negative estimation over the better parent, which ranged from -29.93 (PB-415 × PB-414) to -16.60 (PB-405 × PB-414). The range for two standard checks (PR and KU) varied from 73.86 (PB-405 × PB-414) to 194.83 (PB-413 × KU) and 35.08 (PB-410 × PB-414) to 120.96 (PB-413 × KU) respectively.

In the NFS for total fruit yield per plant, the mean performance of parents and hybrids varied from 0.77 kg (PB-414) to 1.66 kg (PB-407) and 0.68 kg (PB-410 × KU) to 1.19 kg (PB-416 × PR) respectively. For this trait, out of 21 F_1 hybrids, 11, 7 and 10 hybrids expressed significant and positive estimation over the better parent and two standard checks (PR and KU) respectively. For the better parent, the range varied from -29.91 (PB-415 × PR) to 98.67 (PB-413 × PB-414) and for two checks (PR and KU) the range varied from -27.19 (PB-410 × PR) to 50.76 (PB-416 × PR) and -19.13 (PB-410 × PR) to 50.67 (PB-413 × PB-414), respectively (Table 7).

Discussion

Growth parameters

The greater plant height observed under conventional farming may be attributed to the use of synthetic fertilisers and pesticides, which provide an immediate and high concentration of nutrients, leading to faster growth and taller plants in the short term. In contrast, natural farming relies on organic methods that take longer to improve soil fertility and may not provide the same rapid nutrient boost. Plant height can significantly influence the growth and development of primary branches and the number of flowers per cluster in plants (13). Most of the genotypes exhibited relatively similar plant heights in both systems, forming a tight cluster. Genotype PB-410 × KU performed well in both systems with consistent plant height, indicating robustness across farming methods, whereas parent PB-414 showed better performance in conventional as compared to NFS. PB-407 × PB-414 showed the tallest height in conventional farming. As a greater number of primary branches can support a large canopy, which helps in enhancing photosynthesis, ultimately resulting in better plant vigour and higher yield. A good balance of primary branches can help farmers to get higher yield as it will result in better fruit size and quality. As the number of primary branches increases, so

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does the number of flowers per cluster. Genotypes which showed the highest number of primary branches are represented in the top right corner of the CFS and NFS axis, respectively, whereas the lower left corner of the CFS and NFS axis, respectively, represented minimum branches. Genotypes which are in a cluster show similarity in both farming systems, which suggests a consistent performance. From a farmer's perspective, an increase in primary branches leads to a higher yield from each plant. Therefore, by adhering to agronomic practices, farmers can boost their productivity in both farming systems. In the case of conventional farming, there would be more primary branches, resulting in more flowers due to subsequent nutrients from additional sources. Conversely, in natural farming, there would be fewer primary branches compared to conventional farming (13–15). While this may not increase productivity, it will undoubtedly improve the quality of fruits, as less competition will lead to more nutrient supplementation in other parts of the crop. Leaf area plays a vital role as it helps plants to convert sunlight into energy. The larger the leaf area, the more sunlight is absorbed, which will boost energy production and support the development of fruits (15). Leaf area varied considerably between parental lines and hybrids within both production systems. Few genotypes appeared to consistently have the best leaf area across environments and others were relatively poor performers. Although natural farming generally reduced leaf area, some hybrids continued to perform well, indicating greater adaptability. In natural farming, leaf area decreased due to limited nutrient availability and other environmental conditions, which in turn reduced the vegetative growth of the plants (14).

The matrix plot represents the comparison of DF for various genotypes under CFS and NFS. Points aligned close to the diagonal line indicate genotypes that perform similarly in terms of DF under both farming systems. Genotypes such as PB-405 × KU and PB-410 × PR show minor differences between CFS and NFS, suggesting stability across both systems. Pant Rituraj showed early flowering in natural farming, which may be due to better adaptation to organic inputs and soil fertility, however, PB-407 × KU, which shows delayed flowering under natural farming when compared to conventional due to a higher response to fertilisers. Genotypes like PB-405 and PB-416 × PR exhibit significant differences between CFS and NFS, indicating their reliance on specific inputs or conditions offered in CFS. Genotypes which are near to the diagonal were more preferable for farmers since they show stable performance in both systems. Genotypes which showed earlier flowering under natural farming could help farmers by reducing the crop duration, potentially leading to cost savings and faster crop cycles (14, 16). Most genotypes in both systems tend to cluster around the 2–3 flowers per cluster range, indicating a general similarity in performance under both farming practices. PB-405 × PB-414, PB-413 × KU and PR demonstrate consistently higher flower counts (3–4) under both systems. But there are some genotypes like PB-410 × PB-414 and PB-415 × KU that appear in similar ranges for both systems, showcasing stability. PB-405 × PR showed lower counts of flowers per cluster under both systems, indicating limited adaptability or lower productivity. Outliers with high flower counts could be targeted in breeding programmes to improve productivity under specific farming systems (17).

Yield parameters

Fruit length and diameter are essential factors influencing brinjal output because they have a direct impact on marketable fruit weight and productivity. Fruits that are larger in length and diameter often weigh more. Because yield is the total weight of all harvested fruits, larger individual fruits contribute to higher overall production. Brinjal fruit size (length and diameter) is frequently used to measure marketability. Higher marketable output improves farmers' economic returns. Consumers prefer specific sizes of brinjal which have optimum length and diameter and are more appealing, making them more marketable. Farmers can select and cultivate specific brinjal varieties according to market preferences. By focusing on these characteristics, they can enhance their profitability through better yields and higher quality produce. As seen in the matrix plot, the top right axis indicates genotypes performing well in both systems. Top right indicates genotypes that perform better in conventional farming than in the natural farming system and vice versa. Genotypes which showed consistent performance across both farming systems were PB-410 × KU and PB-407 × KU, showing stability. While PB-411 × PB-414, PB-405 × KU and PB-415 × PR, PB-405 × PB-414 show better fruit length under the conventional and natural farming system respectively. Genotypes in the bottom right quadrant may benefit from conventional farming due to their better adaptability to input-intensive practices, whereas genotypes in the top left quadrant could be promoted for natural farming as they thrive well without intensive inputs. Genotypes in the matrix plot indicate consistent performance in both systems, showing high fruit diameter regardless of farming conditions. The top left quadrant of genotypes showed maximum fruit diameter in conventional, while the left quadrant showed maximum fruit diameter in natural farming. However, genotypes shown in the bottom left quadrant showed poor performance in both farming systems. In CFS, genotypes like PB-411 × PR and PB-415 × PR demonstrate high performance, indicating suitability for conventional practices. While, PB-407 × KU and PB-410 × PB-414 showed highest FD values in NFS (14, 15).

There was a direct correlation between the number of fruits and flowers per cluster and the number of fruits per plant; a higher number of flowers corresponds to a higher number of fruits. In conventional farming, effective agronomic practices foster healthy plants with ample leaf area, optimal growth conditions and effective disease management, thereby enhancing fruit production from a larger proportion of flowers. Compared to natural farming, we have observed a higher number of stressed plants, which in turn has affected the number of flowers, resulting in a lower yield. As shown in the matrix plot, genotypes like PB-405 × PR, PB-413 × PR and PB-407 × PB-414 have a higher number of fruits per plant, indicating better adaptation to conventional farming practices.

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Whereas, genotypes like PR and PB-410 × PR reflected less favourable performance under conventional conditions. Genotypes which are in a cluster toward the middle of both axes, such as PB-413 × PB-414, display moderate NFPP under both systems, suggesting stability but with potential for improvement in natural farming, with genotypes such as PB-416 and PB-411 × PB-414, indicating a need for improvement or better management practices for these varieties under natural systems (14). Therefore, if farmers are interested in adopting any farming system, they should implement improved practices to optimise their yield. As mentioned above, environmental conditions affect fruit bunches, making it difficult to achieve higher yields. The PB-405 × PR hybrid performed better under the given environmental conditions.

Conclusion

The results of the present investigation revealed that some genotypes showed significant heterotic capacity in conventional as well as in natural farming systems (NFS) as compared to the rest of the genotypes during the hybridisation. The hybrids demonstrated improved parent heterosis and standard heterosis, resulting in a higher fruit yield per plant. Pant Rituraj (PR) and Kashi Uttam (KU) were used for comparisons with crosses. In both farming systems, the crosses PB-416 × PR and PB-413 × PB-413 showed significantly positive heterosis for yield measures. The current findings show the promise of the mentioned parents and crosses for use in selection and future breeding programmes. They also provide a valuable genetic resource for developing strong, early-bearing and high-yield hybrids. Future breeding programmes could further assess these characteristics to capitalise on the heterosis and also use them to create desirable segregants for the development of superior genotypes for both farming systems.

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Authors' contributions

HK carried out the field trial, data analysis and drafting of the manuscript. AV advised and critically supervised the research work. IS helped with the field trial, manuscript drafting and data analysis. AB, NR, GG and MP assisted with manuscript drafting, editing and/or data analysis. AS and RKS helped with manuscript editing. All the authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

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