Biological Forum – An International Journal 15(9): 492-500(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Studies on Heterosis and Evaluation of Powdery Mildew Resistant hybrids in Chili

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(Received: 28 June 2023; Revised: 29 July 2023; Accepted: 27 August 2023; Published: 15 September 2023)
(Published by Research Trend)

ABSTRACT: A research was conducted at college of agriculture Raichur during Kharif and rabi 2019-22. To search for resistance source against powdery mildew disease and hestrosis for 40 crosses in chilli. Fourteen genotypes including ten lines and four testers of chilli were crossed to derive 40 F_1 hybrids. The 40 crosses were screened against powdery mildew and evaluated for heterosis in yield and its contributing traits. The crosses JNA1 × Mattur Local, JNA1 × G4, JNA1 × GCV111, and JNA1 × Rajput Yellow, showed resistance against powdery mildew and the range of heterosis expressed by the hybrids over their respective mid parent varied from -23.89 (Sankeshwar × Rajput yellow) to 65.82 per cent (JNA1 × G4) with an overall mean of 5.75 per cent. Sixteen crosses recorded significant positive heterosis over mid parent. The range of heterosis expressed by the crosses over their respective better parent varied from -31.23 (B. dabbi × G4) to 59.70 (JNA1 × G4) with a mean of -3.27 per cent. Eight crosses recorded significant positive heterosis over better parent for the trait fruit yield per plant. Hybrid JNA1 × G4 (65.82) and JNA1 × GCV111 (32.70) showed highest positive significant heterosis over better parent for the trait fruit yield per plant. These results hold substantial promise, paving the way for the development of chili varieties that not only exhibit resistance to powdery mildew but also deliver enhanced yields. These advancements contribute significantly to the sustainability and resilience of chili farming systems, offering tangible benefits to chili growers and the broader agricultural industry.

Keywords: Chilli, Powdery mildew, Resistance and heterosis.

INTRODUCTION

Capsicum is, at least economic-wise, one of the essential spice cum vegetable crop belonging to Solanaceae family with diploid chromosome number 2n=24, which has about 90 genera, and 2000 species. India is the primary producer, consumer and exporter of chilli globally. This crop is mainly cultivated in tropical and subtropical countries *viz*., India, Africa, Japan, Mexico, Turkey, USA etc. Chilli originates from South and Central America (Darshan *et al*., 2017; Misra *et al*., 2011; Thakur *et al*., 2019). The Portuguese introduced chilli crop into India towards the end of the 15th century, and its cultivation became popular in the 17th century.

Chilli pepper fruits constitute large amounts of beneficial compounds including carbohydrates, minerals, proteins, amino acids, antioxidants, phytochemicals, and vitamins (Olatunji and Afolayan 2018). Capsicum fruits could be employed in food and medicine as a source of natural antibacterial agents. The nutritional value, flavour, aroma, texture, and colour of several chilli components are all essential. Chilli is valued for two qualities: its red colour, which comes from the pigment capsanthin and its piercing pungency, which comes from capsaicin.

Chilli suffers from many diseases caused by fungi, bacteria and viruses. Among the fungal diseases, powdery mildew, Cercospora leaf spot and anthracnose or fruit rot are the most prevalent ones. Powdery mildew has long been known as important disease of plants in all parts of the world. The powdery mildew caused by *Leveillula taurica* (Lev.) Arn is one of the devastating disease of chilli that cause significant yield losses up to 24 per cent (Gohokar and Peshney 1981). The disease noticed generally on all aerial parts of the plants which cause both qualitative and quantitative loss of dry fruit yield. The reduction in photosynthetic activity and physiological changes are considerable, which lead to potential decrease in yield (24-80 %) depending on stage and time at which the disease appears (Sharmila *et al*., 2006). However, disease intensity depends upon the cultivar, growing period and environmental conditions. The disease has world-wide importance, occurring wherever it is grown. The loss caused by chilli powdery mildew is proportional to the disease severity varies remarkably depending on the stage of infection, genotypes and environmental conditions.

Even though India ranks first in chilli area and production, the yield potential is low due to poor yielding varieties and high incidence of pests and diseases. One of the methods to achieve quantum jump in yield and quality is heterosis breeding. Hybridization between pepper varieties or species was generally used for fundamental research to identify genes of interest, but more recently it has become common place as a breeding tool per se (Lozada, 2022). Hybridization breeding allows the combination of dominantly inherited traits, including disease resistance and agronomic traits (Zhao, *et al.* 2015).

Another advantage of hybrids is that they can display considerable hybrid vigour, or heterosis (Hochholdinger and Baldauf 2018). Heterosis is a complex phenomenon, which has been fundamental in improving the yield of many annual crops (Chen, 2013) Therefore, to meet this objective in a shorter time the heterosis breeding has been undertaken to develop and identify the suitable best performing hybrids.

For improvement of complex polygenic characters, such as green fruit and its component characters and its quality attributes, parents were primarily selected on basis of *per se* performance: however, many high yielding genotypes may not be able transmit this superiority to progeny.

To study heterotic effects and magnitude of gene effects of green fruit yield, the knowledge of contribution of its component characters and quality fruits has immense value. The simplest method with minimum no. of crosses is Line × Tester mating design where set of inbreds taken as male are crossed with all inbreeds from another set taken as female. Line × Tester analysis is one of the important biometrical tools to obtain necessary data on the expression of heterosis for the future. Keeping the above two facts in mind the present study was undertaken to determine the hybrids which showing resistance to powdery mildew and to analyze the genetic behavior of yield using 40 chilli crosses.

MATERIALS AND METHODS

For the confirmation of resistance, a field experiment was conducted during *kharif* and *rabi* 2019-22 at College of Agriculture, Raichur under natural epiphytotic conditions. 40 F_1 crosses were sown in plastic trays along with Byadagi dabbi as susceptible check. Each cross were transplanted in 4.2 m length row with spacing 60 × 45 and two replications. All the recommended package of practices was applied except protection for control of powdery mildew under natural filed condition. Later, the observations on the intensity of powdery mildew disease was recorded using 0-5 scale given by Mayee and Datar (1986) on five marked plants of each genotype at fruiting stage of the crop. The recorded grade values were converted into Percent Disease Index (PDI) by using following formula proposed by Wheeler (1969).

Recording powdery mildew severity.

Grade	Percent disease severity	Level of resistance / susceptibility
0	No symptom of powdery mildew	HR (Highly resistant)
1	Small scattered powdery mildew specks covering 10 per cent or less leaf area	R (Resistant)
2	Small powdery lesions covering 11-25 per cent of leaf area	MR (Moderately Resistant)
3	Powdery lesions enlarged covering 26-50 per cent of leaf area	MS (Moderately Susceptible)
4	Powdery lesions coalesce to form big patches covering of leaf area 51-75 per cent	S (Susceptible)
5	Big powdery patches covering >75 per cent or more of leaf area and defoliation occur	HS (Highly Susceptible)

$$\text{Per cent Disease Index (PDI)} = \frac{\text{Total sum of numerical rating}}{\text{No.of leaves observed} \times \text{Max. grade value}} \times 100$$

The experimental materials included 10 lines and four testers of chilli. All 10 lines were crossed with four testers and a total of 40 F_1 hybrids were generated by hand emasculation except JNA1 (Sterile line) followed by hand pollination. All the 14 parents were selfed and selfed seed was extracted manually. The selfed seeds of parents and F_1 seeds of 40 crosses were used for heterosis studies.

Analysis of variance technique suggested by Panse and Sukhatme (1978) was followed to test the differences between the genotypes for all the characters. Mean values of the five random plants selected from each genotype for plant and yield attributing parameters were utilized and subjected to line × tester analysis with randomized block design (Kempthorne, 1957). The mean values of crosses were used for the calculation of heterosis. Magnitude of heterosis for all the hybrids was estimated over mid parent and better parent and the two types of heterosis were expressed as percentage. Data pertaining to different characters were tabulated and subjected to statistical analysis as per the completely randomized design. Analysis was done with Indostat 8.1 version software. Comparison of genotypes was also performed statistically.

RESULTS AND DISCUSSION

A. Screening of chilli crosses against powdery mildew (Leveillula taurica)

Among 40 crosses of chilli four crosses *viz.*, JNA1 × Mattur Local, JNA1 × G4, JNA1 × GCV111 and JNA1 × Rajput Yellow showed resistance. Five crosses *viz.*, KA2 Long × GCV111 and JNB1 × GCV111, JNB1 × Mattur Local, JNB1 × Rajput Yellow, JNB1 × G4, showed moderately resistance. Seven crosses *viz.*, Sankeshwar × GCV111, Sankeshwar × Mattur Local, BVC42 × GCV111, BVC42 × Mattur Local, BVC42 × Rajput Yellow, KA2 Long × Mattur Local and KA2 Long × G4 showed moderately suscptable reaction.

However fourteen crosses *viz.*, Sankeshwar × Rajput Yellow, B. dabbi × Mattur Local, B. dabbi × Rajput Yellow, B. dabbi × G4, G4L × Rajput Yellow, G4L × G4, M262R × GCV111, M262R × Mattur Local, M262R × Rajput Yellow, KA2 Long × Rajput Yellow, LCA625 × Mattur Local, LCA625 × Rajput Yellow, LCA625 × G4, and LCA620 × Mattur Local showed susceptible reaction and 10 crosses *viz.*, Sankeshwar × G4, B. dabbi × GCV111, BVC42 × G4, G4L × GCV111, G4L × Mattur Local, M262R × G4, LCA625 × GCV111, LCA620 × GCV111, LCA620 × Rajput Yellow and LCA620 × G4 exhibited highly susceptible reaction against powdery mildew as presented in Table 1 and 2. The Similar results were found by Hareesh *et al*. (2015) ; Wankhade and Mohir (2015).

Table 1: Screening of chilli crosses against powdery mildew (*Leveillula taurica*) under field conditions.

Sr. No.	Name of the Crosses	PDI	Scale	Reaction
1.	Sankeshwar × GCV111	50.63	3	MS
2.	Sankeshwar × Mattur local	22.45	2	MS
3.	Sankeshwar × Rajput yellow	66.42	4	S
4.	Sankeshwar × G4	82.15	5	HS
5.	B.dabbi × GCV111	78.15	5	HS
6.	B.dabbi × Mattur local	68.55	4	S
7.	B.dabbi × Rajput yellow	68.14	4	S
8.	B.dabbi × G4	62.16	4	S
9.	BVC42 × GCV111	48.55	3	MS
10.	BVC42 × Mattur local	50.14	3	MS
11.	BVC42 × Rajput yellow	44.36	3	MS
12.	BVC42 × G4	76.85	5	HS
13.	G4L × GCV111	82.16	5	HS
14.	G4L × Mattur local	80.18	5	HS
15.	G4L × Rajput yellow	60.33	4	S
16.	G4L × G4	68.35	4	S
17.	M262R × GCV111	74.15	4	S
18.	M262R × Mattur local	64.89	4	S
19.	M262R × Rajput yellow	68.65	4	S
20.	M262R × G4	76.18	5	HS
21.	JNA1 × GCV111	10.55	1	R
22.	JNA1 × Mattur local	9.85	1	R
23.	JNA1 × Rajput yellow	10.12	1	R
24.	JNA1 × G4	10.89	1	R
25.	KA2 Long × GCV111	24.85	2	MR
26.	KA2 Long × Mattur local	50.36	3	MS
27.	KA2 Long × Rajput yellow	62.14	4	S
28.	KA2 Long × G4	48.17	3	MS
29.	JNB1 × GCV111	20.16	2	MR
30.	JNB1 × Mattur local	20.28	2	MR
31.	JNB1 × Rajput yellow	19.78	2	MR
32.	JNB1 × G4	19.27	2	MR
33.	LCA625 × GCV111	82.85	5	HS
34.	LCA625 × Mattur local	60.36	4	S
35.	LCA625 × Rajput yellow	62.73	4	S
36.	LCA625 × G4	70.46	4	S
37.	LCA620 × GCV111	90.85	5	HS
38.	LCA620 × Mattur local	70.84	4	S
39.	LCA620 × Rajput yellow	78.44	5	HS
40.	LCA620 × G4	78.47	5	HS

HR-Highly resistant; R-Resistant; MR-Moderately resistant
MS-Moderately susceptible; S-Susceptible; HS-Highly susceptible

Table 2: Grouping of chilli crosses as per the reaction to powdery mildew (*Leveillula taurica*).

Sr. No.	Name of the crosses	Scale	Reaction	Number of crosses
1.	JNA1 × G4, JNA1 × Mattur Local JNA1 × Rajput Yellow JNA1 × GCV111,	1	R	4
2.	JNB1 × GCV111, JNB1 × G4, JNB1 × Rajput Yellow, JNB1 × Mattur Local, KA2 Long × GCV111	2	MR	5
3.	Sankeshwar × GCV111, Sankeshwar × Mattur Local, BVC42 × GCV111, BVC42 × Mattur local, BVC42 × Rajput yellow, KA2 Long × Mattur local KA2 Long × G4	3	MS	7
4.	Sankeshwar × Rajput yellow, B.dabbi × Mattur Local, B.dabbi × Rajput Yellow, B.dabbi × G4, G4L × Rajput Yellow, G4L × G4, M262R × GCV111, M262R × Mattur Local, M262R × Rajput Yellow, KA2 Long × Rajput Yellow, LCA625 × Mattur Local, LCA625 × Rajput Yellow, LCA625 × G4 LCA620 × Mattur Local	4	S	14
5.	LCA620 × G4, LCA620 × Rajput Yellow, LCA620 × GCV111, LCA625 × GCV111, M262R × G4, G4L × Mattur Local, G4L × GCV111, BVC42 × G4, B.dabbi × GCV111 Sankeshwar × G4	5	HS	10

HR-Highly resistant; R-Resistant; MR-Moderately resistant;
MS-Moderately susceptible; S-Susceptible; HS-Highly susceptible

B. Analysis of variance for different quantitative characters

The analysis of variance showed that mean sum of squares due to genotypes were highly significant for green fruit yield and 12 other contributing traits. This implies that for every character at least one genotype was significantly differing from all other genotypes as presented in Table 3.

The mean sum of squares due to genotypes was further partitioned into different sources of variances like parents, lines, testers, line *vs* tester, parent *vs* crosses and crosses. Parental variances were found highly significant for all the characters except moisture content implying that at least one parent for each character except moisture content was significantly deferring from others. Variation for moisture content was purely due to environment and random allocation of units and error associated with it.

Variances of quantitative characters were found to be highly significant for all the characters except for moisture content in lines and tester indicating the presence of significant amount of variability among lines and testers. Significant variance due to lines *vs* testers was attributed to genotypic variability presented between the male and female parents except for plant height, number of primary branches per plant, fruit weight, seed weight, number of fruits per plant, moisture content and fruit yield per plant. This indicated that line and tester parents differed significantly with respect to majority of the characters.

The mean sum of squares due to parents *vs* crosses were highly significant for all characters except for number of primary branches, seed weight and moisture content indicating significant amount of heterosis generated in the present investigation.

The analysis of variance for 40 hybrids developed by crossing using line × tester design revealed that hybrids were significantly differing for all the characters indicating the existence of considerable genetic variability among the hybrids for all the characters under study.

Table 3: Analysis of variances for different quantitative characters.

Source of variation	Degrees of Freedom	Plant height (cm)	No. of Primary Branches per plant	Fruit Diameter (mm)	Fruit Length (cm)	Fruit Weight (g)	No. of Seeds per fruit
Replicates	1	35.20	0.03	0.59	0.39	0.004	35.82
Treatments	53	341.25 **	0.10 **	4.00 **	2.14 **	0.13 **	381.62 **
Parents	13	217.88 **	0.06 **	8.42 **	4.06 **	0.14 **	411.59 **
Lines	9	192.80 **	0.07 **	7.95 **	4.76 **	0.17 **	491.29 **
Testers	3	354.55 **	0.08 **	11.54 **	1.93 **	0.12 **	238.42 **
Parents (L vs T)	1	33.64	0.009	3.25 **	4.16 **	0.002	213.85 **
Parents vs Crosses	1	655.95 **	0.03	16.97 **	4.63 **	0.006 *	50.96 *
Crosses	39	374.31 **	0.11 **	2.19 **	1.44 **	0.13 **	380.11 **
Error	53	10.29	0.01	0.16	0.13	0.0012	11.02
Total	107	174.46	0.05	2.06	1.13	0.068	194.82

* Significant at 0.05 probability level and ** Significant at 0.01 probability level

Table 3. Contd…

Source of variation	Degrees of freedom	Test weight (g)	No. of Fruit/ Plant	Dry Matter (%)	Moisture Content (%)	Pericarp Thickness (mm)	Fruit Edible Portion (cm)	Fruit Yield / Plant (g)
Replicates	1	0.20	35.627	13.860	28.40	0.0029	0.28	22.140
Treatments	53	0.61 **	330.00 **	271.75 **	43.60 **	0.038 **	2.44 **	263.76 **
Parents	13	0.78 **	278.28 **	338.10 **	14.55	0.065 **	3.54 **	199.07 **
Lines	9	0.90 **	321.25 **	378.50 **	8.99	0.078 **	3.77 **	164.81 **
Testers	3	0.63 **	242.06 **	260.71 **	35.58 *	0.00467 **	2.24 **	360.33 **
Parents (L vs T)	1	0.17	0.13	206.67 **	1.47	0.12 **	5.35 **	23.58
Parents vs Crosses	1	0.18	238.55 **	36.89 **	33.72	0.13 **	1.74 **	251.58 **
Crosses	39	0.57 **	349.59 **	255.65 **	53.54 **	0.02 **	2.10 **	285.64 **
Error	53	0.056	9.92	4.60	9.94	0.00081	0.096	6.83
Total	107	0.335	168.71	137.01	26.79	0.0197	1.263	134.24

* Significant at 0.05 probability level and ** Significant at 0.01 probability level

C. Mean performance and heterosis of quantitative characters in chilli

Mean performance and heterosis values of crosses over mid-parent, better parent and commercial check for 13 different quantitative characters are presented in Table 4.

The heterosis for the trait plant height over mid parent ranged from -29.36 (LCA625 × G4) to 35.81 (LCA620 × Rajput yellow) per cent with a mean of 7.18 per cent. Significant positive heterosis for this trait over mid and better parent was observed in twenty crosses *viz.*, Sankeshwar × GCV111 (16.98), Sankeshwar × Mattur local (32.28), Sankeshwar × Rajput yellow (35.09), Sankeshwar × G4 (12.34), B.dabbi × Mattur local (17.80), B. dabbi × G4 (24.62), BVC42 × GCV111(30.15), BVC42 × Mattur local (35.63), BVC42 × Rajput yellow (11.22), BVC42 × G4 (14.29), G4L × GCV111 (10.63), G4L × G4 (6.58), M262R × G4 (13.49), KA2 Long × GCV111 (9.08), KA2 Long × G4 (22.26), JNB1 × Mattur local (11.44), JNB1 × Rajput yellow (13.08), LCA625 × Rajput yellow (19.17), LCA620 × GCV111 (26.22) and LCA620 × Rajput yellow (35.81) and nine of the crosses *viz.*, Sankeshwar × GCV111 (13.65), Sankeshwar × Mattur local (30.37), Sankeshwar × Rajput yellow (13.65), Sankeshwar × G4 (8.68), BVC42 × GCV111 (22.96), BVC42 × Mattur local (26.40), KA2 Long × G4 (14.44), LCA620 × GCV111 (14.26) and LCA620 × Rajput yellow (28.54) crosses respectively. This result is concordance with the earlier findings of Rohini and Lakshmanan (2017); Aiswarya *et al.* (2019). However, the heterosis for fruit diameter over mid parent ranged from -35.36 (JNA1 × G4) to 16.29 (Sankeshwar × Mattur local) per cent with a mean of -9.10 per cent. Significant positive heterosis over mid and better parent was observed in three crosses *viz.*, Sankeshwar × GCV111 (14.16), Sankeshwar × Mattur local (16.29) and M262R × Rajput yellow (12.90). However, one cross Sankeshwar × Mattur local (14.45) showed significant positive heterosis over better parent. The heterosis for the trait fruit length over mid parent ranged from -18.95 (M262R × G4) to 15.55 (KA2 Long × Mattur local) per cent with overall mean of -2.89 per cent. The result revealed that significant positive heterosis over mid and better parent was observed in five crosses *viz.*, Sankeshwar × GCV111 (7.82), G4L × Mattur local (14.44), KA2 Long × Mattur local (15.55), JNB1 × GCV111 (9.85) and LCA625 × GCV111 (14.92). However, one cross KA2 Long × Mattur local (15.88) showed significant positive heterosis against better parent. The variation for the trait fruit weight among the crosses was from 0.49 (LCA625 × GCV111) to 1.75 g (KA2 Long × Mattur local) with an overall mean of 0.79 g. Significant positive heterosis over mid and better parent was observed in fourteen out of 40 crosses *viz.*, Sankeshwar × Mattur local (20.00), BVC42 × GCV111 (22.76), BVC42 × Mattur local (16.62), BVC42 × Rajput yellow (33.33), G4L × GCV111 (21.25), G4L × Mattur local (20.00), KA2 Long × GCV111 (60.00), KA2 Long × Mattur local (59.82), JNB1 × Rajput yellow (20.00), JNB1 × G4 (30.14), LCA625 × Rajput yellow (23.53), LCA620 ×

G4 (16.43), LCA620 × Rajput yellow (12.25), and LCA620 × G4 (19.08). However, five crosses *viz.*, Sankeshwar × Mattur local (12.50), BVC42 × Rajput yellow (31.09), KA2 Long × GCV111 (43.93), KA2 Long × Mattur local (56.25) and LCA620 × G4 (13.04) out of 40 depicted significant positive heterosis over the better parent in the trait fruit weight. In trait number of fruits per plant significant positive heterosis over mid parent was observed in twenty one crosses *viz.*, Sankeshwar × Mattur local (22.79), Sankeshwar × Rajput yellow (10.50), Sankeshwar × G4 (17.65), B.dabbi × G4 (9.05), BVC42 × GCV111 (17.94), BVC42 × Mattur local (14.93), BVC42 × Rajput yellow (10.21), G4L × GCV111 (9.25), G4L × Mattur local (9.65), G4L × Rajput yellow (11.83), M262R × Mattur local (26.41), JNA1 × Mattur local (11.13), KA2 Long × GCV111 (35.75), KA2 Long × G4 (22.98), JNB1 × GCV111 (12.25), JNB1 × Mattur local (9.28), LCA625 × GCV111 (19.07), LCA625 × Mattur local (10.19), LCA620 × GCV111 (17.16), LCA620 × Mattur local (10.03) and LCA620 × G4 (10.42). While three crosses *viz.*, Sankeshwar × Mattur local (15.46), M262R × Mattur local (19.10) and KA2 Long × GCV111 (31.96) exhibited significant positive heterosis over better parent. Significant positive heterosis over mid and over better parent was observed in sixteen crosses *viz.*, Sankeshwar × GCV111 (15.28), Sankeshwar × Mattur local (13.77), B.dabbi × GCV111 (7.64), B.dabbi × Mattur local (9.27), BVC42 × Mattur local (25.06), BVC42 × Rajput yellow (13.46), G4L × G4 (13.88), M262R × GCV111 (43.19), JNA1 × GCV111 (32.70), JNA1 × G4 (65.82), KA2 Long × GCV111 (27.81), JNB1 × GCV111 (50.72), JNB1 × G4 (20.94), LCA625 × GCV111 (28.75), LCA620 × Mattur local (17.73) and LCA620 × G4 (14.61) and eight crosses *viz.*, Sankeshwar × Mattur local (7.49), M262R × GCV111 (33.91), JNA1 × GCV111 (21.99), JNA1 × G4 (59.70), KA2 Long × GCV111 (15.25), JNB1 × GCV111 (41.49), JNB1 × G4 (13.99) and LCA625 × GCV111 (23.26) respectively. All the above mentioned crosses those are showing significant positive heterosis over mid parent in the above mentioned traits indicating that additive gene action plays a pivotal role in governing the expression of these traits. In such cases, the progeny exhibited trait values that exceeded the average of their parents, offering substantial potential for continued trait improvement through controlled breeding programs. Whereas, all the crosses those are showing significant positive heterosis over better parent heterosis for the particular above mentioned trait's expression may be due to the presence of complete or overdominance gene action, where the offspring outperformed the better-performing parent in these traits. This gene action type opens up exciting prospects for hybrid development, as it suggests the potential to create combinations with enhanced trait expression. This finding is in accordance with the prior research outcomes (Janaki *et al*. (2017); Aiswarya *et al.* (2019); Vijeth *et al*. (2019); Nikornpun (2020). The substantial heterotic response observed in the majority of the crosses in our study strongly reinforces the significant contribution of non-additive genetic components in the inheritance of the studied traits. This observation underscores the intricate genetic interactions at play, where the combination of genetic material from both parent lines results in offspring with traits that surpass the average of their parents. Such a pronounced non-additive effect emphasizes the potential for harnessing hybrid vigor and exploiting the complementarity of parental genomes to achieve superior trait expression in breeding programs.

For traits influenced by additive gene action, breeders can focus on selecting and crossing parent lines with favorable trait values, gradually enhancing the traits of interest over generations. On the other hand, traits governed by complete or overdominance gene action provide opportunities for the development of high-performing hybrids. By carefully selecting parent lines and exploiting the potential for gene interactions, breeders can create hybrid varieties with superior trait expression, thus addressing specific needs in chili cultivation.

Table 4: Mean performance and magnitude of heterosis for different quantitative characters in chilli

Sr. No.	Characters	PH		NoPB		FD		FL		FW		NoSF	
	Genotypes	**Mid**	**BP**	**Mid**	**BP**	**Mid**	**Mid**	**BP**	**BP**	**Mid**	**BP**	**Mid**	**BP**
1.	Sankeshwar × GCV111	16.98 **	13.65 **	12.00 **	7.69	14.16 **	20.81 **	13.18 **	2.92	7.82 *	2.75	4.63	-2.04
2.	Sankeshwar × Mattur Local	32.28 **	30.37 **	-0.8	-4.62	16.29 **	11.56 **	5.68	14.45 **	0.1	-3.73	20.00 **	12.50 **
3.	Sankeshwar × Rajput Yellow	35.09 **	13.65 **	21.74 **	16.67 **	-0.11	6.05	-2.11	-3.48	-3.87	-17.16 **	-12.54 **	-30.61 **
4.	Sankeshwar × G4	12.34 **	8.68 *	20.00 **	15.38 **	-12.51 **	6.63	-0.17	-26.52 **	-9.67 **	-19.41 **	-13.75 **	-29.59 **
5.	B.dabbi × GCV111	-5.91	-17.05 **	-3.2	-6.92	-11.50 **	3.1	0.87	-22.24 **	-5.06	-10.84 **	-5.13	-13.45 **
6.	B.dabbi × Mattur Local	17.80 **	2.56	7.60 *	3.46	-0.11	-13.02 **	-23.99 **	-1.42	-3.91	-8.94 *	-3.56	-21.43 **
7.	B.dabbi × Rajput Yellow	-0.21	-2.79	-5.22	-9.17 *	0.34	-13.41 **	-26.08 **	-0.22	-15.20 **	-27.85 **	-4.69	-13.48 **
8.	B.dabbi × G4	24.62 **	4.23	-4.8	-8.46 *	-17.43 **	-21.63 **	-32.24 **	-32.26 **	-11.02 **	-21.67 **	2.64	-3.55
9.	BVC42 × GCV111	30.15 **	22.96 **	5.19	1.43	-19.67 **	11.47 **	-0.4	-24.62 **	-2.35	-5.63	22.76 **	4.09
10.	BVC42 × Mattur Local	35.63 **	26.40 **	-0.74	-4.29	-19.19 **	1.44	1.09	-32.05 **	-5.32	-9.34 *	16.62 **	-10.71 **
11.	BVC42 × Rajput Yellow	11.22 *	0.86	-8.00 *	-17.86 **	-18.05 **	4.53	1.36	-32.12 **	-5.12	-11.95 **	33.33 **	31.09 **
12.	BVC42 × G4	14.29 **	1.96	3.7	0	-11.36 **	2.81	1.2	-12.90 **	-1.2	-4.76	-7.82	-9.68
13.	G4L × GCV111	10.63 **	0.81	-3.2	-6.92	-12.97 **	-14.89 **	-26.33 **	-27.40 **	-4.62	-15.15 **	21.25 **	1.75

14.	G4L × Mattur Local	-7.20 *	-14.31 **	2.4	-1.54	7.21	-4.46	-7.53 *	-0.33	14.44 **	0.96	20.00 **	-8.93 **
15.	G4L × Rajput Yellow	-17.44 **	-34.15 **	-5.65	-9.58 *	-1.49	-12.78 **	-13.25 **	-6.79	3.7	2.44	5.63	5.17
16.	G4L × G4	6.58 *	3.01	-4.8	-8.46 *	-21.43 **	-10.57 **	-12.39 **	-38.49 **	7.11	1.75	5	1.61
17.	M262R × GCV111	7.46	3.36	-0.83	-8.46 *	-9.36 **	0.83	-1.33	-10.38 **	-11.95 **	-21.62 **	-6.36	-7.43
18.	M262R × Mattur Local	-1.54	-6.61	20.00 **	10.77 *	-11.20 **	-3.4	-12.26 **	-20.28 **	-11.57 **	-20.61 **	-10.78 **	-20.54 **
19.	M262R × Rajput Yellow	-5.83	-16.03 **	-0.91	-0.91	12.90 **	-13.34 **	-23.21 **	-0.3	-14.98 **	-31.00 **	-14.48 **	-29.14 **
20.	M262R × G4	13.49 **	2.96	9.17 *	0.77	-19.26 **	-11.27 **	-20.30 **	-26.24 **	-18.95 **	-32.09 **	-14.38 **	-26.86 **
21.	JNA1 × GCV111	5.44	1.55	-0.77	-0.77	-19.47 **	2.38	-16.75 **	-24.91 **	-7.94 *	-15.02 **	-4.33	-21.64 **
22.	JNA1 × Mattur Local	6.81	1.46	-11.92 **	-11.92 **	-18.70 **	-8.28 **	-17.38 **	-32.01 **	-11.01 **	-17.12 **	-6.50 *	-14.18 **
23.	JNA1 × Rajput Yellow	-5.66	-15.98 **	-6.67	-13.85 **	-21.65 **	-10.30 **	-17.14 **	-35.46 **	-10.93 **	-25.37 **	-28.98 **	-49.25 **
24.	JNA1 × G4	3.63	-5.87	-7.69 *	-7.69	-35.36 **	-12.03 **	-19.87 **	-36.06 **	-14.59 **	-26.01 **	-29.59 **	-48.51 **
25.	KA2 Long × GCV111	9.08 *	8.49	-13.33 **	-20.00 **	5.16	12.46 **	1.32	-4.7	5.16	4.49	60.00 **	43.93 **
26.	KA2 Long × Mattur Local	5.13	3.07	12.08 **	3.46	4.42	37.84 **	36.10 **	2.19	15.55 **	15.18 **	59.82 **	56.25 **
27.	KA2 Long × Rajput Yellow	-9.76 *	-21.87 **	21.36 **	21.36 **	-2.66	-0.8	-4.67	-6.47	-2.75	-13.03 **	-17.33 **	-36.45 **
28.	KA2 Long × G4	22.26 **	14.44 **	-5	-12.31 **	-4.16	-1.53	-3.95	-19.14 **	-7.72 *	-14.42 **	-15.98 **	-33.64 **
29.	JNB1 × GCV111	-3.7	-10.29 *	7.2	3.08	-12.64 **	-7.49	-16.55 **	-23.42 **	9.85 *	0.22	-4.69	-28.65 **
30.	JNB1 × Mattur Local	11.44 **	2.43	-0.8	-4.62	-0.39	-29.18 **	-42.34 **	-1.96	-9.74 *	-18.37 **	-24.92 **	-48.21 **
31.	JNB1 × Rajput Yellow	13.08 **	3.95	16.96 **	12.08 **	-6.94	14.52 **	-8.71 *	-7.2	-6.4	-7.87	20.00 **	4.35
32.	JNB1 × G4	-23.36 **	-32.52 **	-3.6	-7.31	-22.50 **	-22.51 **	-37.51 **	-36.56 **	3.07	0.62	30.14 **	9.68
33.	LCA625 × GCV111	-7.73 *	-9.67 *	-12.31 **	-12.31 **	-13.08 **	-6.52	-6.9	-22.74 **	14.92 **	5.84	-24.62 **	-42.69 **
34.	LCA625 × Mattur Local	4.05	0.42	6.92	6.92	-1.74	-21.43 **	-30.26 **	-1.74	-1.74	-10.30 *	-28.43 **	-50.00 **
35.	LCA625 × Rajput Yellow	19.17 **	4.6	20.42 **	11.15 **	-9.54 *	-15.56 **	-26.82 **	-11.22 *	3.56	0.9	23.53 **	9.57
36.	LCA625 × G4	-29.36 **	-34.85 **	-16.15 **	-16.15 **	-20.10 **	-23.25 **	-32.61 **	-33.76 **	7.35	5.88	16.43 **	0
37.	LCA620 × GCV111	26.22 **	14.26 **	-12.31 **	-12.31 **	-14.08 **	1.12	-0.78	-23.34 **	-2.76	-4.49	-9.39 *	-18.13 **
38.	LCA620 × Mattur Local	-6.83	-16.74 **	0	0	-0.43	-3.7	-12.75 **	-0.86	-5.26	-6.05	-17.13 **	-33.04 **
39.	LCA620 × Rajput Yellow	35.81 **	28.54 **	11.67 **	3.08	-10.06 *	-10.86 **	-21.20 **	-12.10 **	-3.42	-14.51 **	12.25 *	2.9
40.	LCA620 × G4	-19.03 **	-30.58 **	-13.85 **	-13.85 **	-25.20 **	11.55 **	-0.06	-37.78 **	1.02	-7.31	19.08 **	13.04 *

PH: Plant Height; NoPB: Number of Primary Branches; FD: Fruit Diameter; FL: Fruit Length ; FW: Fruit Weight; NoSF: Number of Seeds per Fruit

Table 4. Contd…

Character	TW		NoFP		FDM		FMC		FPT		FEP		FYP	
Sr. No.	Mid	BP	Mid	BP	Mid	BP	Mid	BP	Mid	BP	Mid	BP	Mid	BP
1.	7.87	0.72	3.44	2.56	11.66 **	2.16	3.43	1.38	7.46 *	-4	-14.23 **	-17.31 **	15.28 **	6.49
2.	13.96 **	13.27 **	22.79 **	15.46 **	-21.18 **	-37.15 **	1.15	0.16	-3.5	-8.00 *	6.47	2.31	13.77 **	7.49 *
3.	15.40 **	3	10.50 **	1.4	-26.84 **	-46.62 **	-2.22	-4.38	-14.07 **	-22.67 **	-10.49 *	-25.64 **	-23.89 **	-30.19 **
4.	4.02	1.37	17.65 **	0.21	-14.06 **	-27.30 **	-2.08	-6.17	-25.76 **	-34.67 **	-14.33 **	-26.03 **	-12.15 **	-27.15 **
5.	-3.79	-8.96 *	-8.36 *	-16.56 **	-1.11	-6.16	-15.05 **	-15.56 **	12.30 **	-17.97 **	6.34	1.9	7.64 *	0.93
6.	-1.01	-1.81	-4.49	-6.95	-7.31	-16.67 **	14.85 **	12.15 **	-29.59 **	-46.09 **	7.36 *	2.53	9.27 **	1.7
7.	7.67 *	-2.68	-1.15	-1.15	9.75 *	-11.31 **	-0.74	-4.26	-28.72 **	-47.66 **	-5.82	-22.15 **	-5.89	-12.39 **
8.	1.98	0.78	9.05 *	-16.23 **	-4.28	-7.7	4.54	1.56	-43.78 **	-59.37 **	-14.52 **	-26.58 **	-18.12 **	-31.23 **
9.	-3.9	-7.35	17.94 **	0.71	7.39 *	-2.11	2.34	1.78	7.69 *	-1.41	6.58	4.01	-7.3	-15.85 **
10.	0.79	-1.93	14.93 **	4.45	-22.88 **	-38.70 **	7.98 *	4.28	-6.47	-8.45 *	1.14	-0.97	25.06 **	0.98
11.	6.13	-2.35	10.21 *	2.61	-28.91 **	-48.26 **	-1.73	-6.25	-8.40 *	-15.49 **	7.97	-5.59	13.46 **	3.73
12.	2.72	1.93	0.79	-0.36	-17.06 **	-30.07 **	2.24	0.44	-9.37 *	-18.31 **	-17.68 **	-24.96 **	5.74	3.21
13.	-5.26	-9.68 *	9.25 **	4.87	1.76	0	2.19	1.65	9.09 *	-1.37	-10.29 *	-19.34 **	2.47	1.04
14.	0.4	-1.19	9.65 **	-18.85 **	-10.22 **	-21.79 **	-1.19	-3.58	-2.13	-5.48	10.72 *	-0.14	-3.74	-14.54 **
15.	9.40 *	-0.41	11.83 **	-22.62 **	-24.25 **	-40.41 **	-0.81	-4.39	-12.78 **	-20.55 **	20.29 **	13.84 *	-15.51 **	-17.33 **
16.	1.77	1.37	-20.82 **	-35.22 **	-5.43	-11.87 **	3.23	0.35	-24.62 **	-32.88 **	2.88	1.9	13.88 **	-0.07
17.	-15.98 **	-27.42 **	-10.69 **	-21.16 **	-14.20 **	-25.31 **	7.02	2.86	13.89 **	-3.53	9.35 **	-3.39	43.19 **	33.91 **
18.	2.23	-6.53	26.41 **	19.10 **	11.38 *	9.53	16.08 **	14.89 **	-12.42 **	-21.18 **	-1.98	-13.67 **	-6.97	-22.96 **
19.	-2.79	-19.38 **	7.26	3.63	-7.74	-19.42 **	1.33	1.1	-25.52 **	-36.47 **	7.12	-17.16 **	-12.33 **	-17.41 **
20.	4.37	-6.27	-4	-8.64	7.62	1.64	7.3	0.87	16.90 **	-2.35	-4.04	-23.20 **	3	-2.55

21.	2.43	-3.92	-14.35 **	-27.36 **	-18.13 **	-33.01 **	2.95	1.47	7.09	0	8.57 *	-1.9	32.70 **	21.99 **
22.	7.19	-5.18	11.13 **	0.25	-11.71 *	-16.66 **	10.74 **	6.01	-8.82 *	-8.82 *	-10.89 **	-19.73 **	-7.54 *	-24.54 **
23.	-17.35 **	-18.68 **	-7.18	-14.24 **	7.52	0.52	-2.69	-7.97	-10.94 **	-16.18 **	-11.54 **	-30.32 **	-13.19 **	-19.62 **
24.	-12.12 **	-20.88 **	1.3	0.96	-8.22	-19.09 **	-11.35 **	-12.13 **	-21.60 **	-27.94 **	-21.04 **	-35.56 **	65.82 **	59.70 **
25.	6.07	2.68	35.75 **	31.96 **	10.25 **	6.99 *	13.99 **	12.52 **	17.07 **	12.50 **	0.28	-0.55	27.81 **	15.25 **
26.	16.21 **	5.87	-9.67 **	-17.92 **	44.99 **	21.37 **	17.70 **	15.73 **	30.30 **	26.47 **	4.12	3.62	-20.06 **	-22.52 **
27.	1.44	-0.24	-12.73 **	-22.54 **	39.20 **	5.84	0.8	-2.11	3.23	0	0.65	-13.20 **	-5.27	-15.17 **
28.	-7.41	-14.09 **	22.98 **	1.64	-12.86 **	-22.26 **	3.89	0.25	-15.70 **	-20.31 **	-1.8	-11.80 **	1.1	-17.90 **
29.	-5.97	-9.68 *	12.25 **	1.17	22.63 **	0.45	-0.99	-1.68	8.27 *	-2.7	10.82 *	-1.66	50.72 **	41.49 **
30.	13.35 **	10.70 *	9.28 *	5.3	7.66	1.77	12.24 **	9.71 *	-15.49 **	-18.92 **	-4.37	-14.88 **	-8.30 *	-23.81 **
31.	-9.07 *	-16.63 **	0.1	-1.03	5.69	-1.32	-11.73 **	-14.78 **	-13.43 **	-21.62 **	8.08	3.74	-15.81 **	-20.38 **
32.	18.16 **	17.70 **	-5.91	-12.42 **	13.81 **	0.46	7	3.85	-12.98 **	-22.97 **	-10.46 *	-10.93	20.94 **	13.99 **
33.	-4.15	-7.36	19.07 **	1.94	20.73 **	2.59	-1.84	-2.01	3.33	1.64	-3.7	-15.47 **	28.75 **	23.26 **
34.	-6.99	-15.38 **	10.19 *	0.44	4.56	3.32	-7.14	-10.00 *	5.43	0	-16.75 **	-26.70 **	-5.7	-20.33 **
35.	-1.03	-2.51	6.82	-0.25	-7.05	-16.75 **	6.31	1.78	0.83	0	-4.42	-7.13	7.13	3.33
36.	-3.25	-10.37 *	2.26	0.76	8.90 *	0.14	-3.29	-5.34	11.86 **	8.2	4.13	2.29	-6.5	-13.55 **
37.	-7.74	-12.37 **	17.16 **	5.05	19.59 **	1.11	-0.99	-2.23	-18.64 **	-18.64 **	-6.69	-10.32 *	4.53	2.57
38.	4.03	2.79	10.03 *	5.44	7.46	5.53	-1.51	-3.19	-3.94	-10.29 *	3.46	-0.89	17.73 **	1.58
39.	4.43	-5.27	0.46	-1.24	2.1	-8.05	-3.15	-5.98	-24.37 **	-25.00 **	5.92	-12.23 **	-6.43	-7.47
40.	3.16	2.35	10.42 *	3.34	8.94 *	-0.4	-1.09	-4.54	-12.07 **	-13.56 **	6.21	-8.54 *	14.61 **	3.55

SW: Test Weight; No FP: Number of fruit per plant; FDM: Fruit Dry Matter; FMC: Fruit Moisture Content; FPT: Fruit Pericarp Thickness
FEP: Fruit Edible Portion ; FYP: Fruit Yield per Plant

CONCLUSIONS

In present investigation, we have explored the efficacy of disease management through host plant resistance as the most economical and practical choice across various crops. Employing resistant cultivars within farming systems emerges as a straightforward, highly effective, and cost-efficient method for disease control. Beyond its economic advantages, this approach also contributes to the conservation of natural resources and significantly reduces the expenditure of time and energy compared to alternative disease management methods.

Within the scope of our study, we tested 40 chili crosses in field conditions, meticulously screening them for their resistance against powdery mildew. Among these crosses, four pairs, namely JNA1 × Mattur Local, JNA1 × G4, JNA1 × GCV111, and JNA1 × Rajput Yellow, demonstrated noteworthy resistance levels. These findings hold immense promise for future breeding programs aimed at developing robust, disease-resistant chili varieties. Moreover, considering both individual performance and heterosis, we identified two crosses of particular interest JNA1 × G4 and JNB1 × GCV111 showcasing superior traits related to yield along with highly resistance to powdery mildew disease in chilli. These two selected crosses hold the potential to drive forward chili breeding programs for enhanced productivity.

The study underscores the pivotal role of host plant resistance in disease management, highlighting its potential to revolutionize chili breeding programs. These results pave the way for the development of chili varieties that not only exhibit resistance to powdery mildew but also offer improved yields, thereby contributing to the sustainability and resilience of chili farming systems.

Acknowledgement: The authors are thankful to science and engineering research board (SERB), DST, Govt. of Indian as the work is funded by research grant SB/EMEQ/2019/176.

Conflict of Interest. None.

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How to cite this article: Umesh Babu B.S., B.V. Tembhurne, P.H. Kuchanur, Hasan Khan, D.S. Aswathanarayana and B. Kisan (2023). Studies on Heterosis and Evaluation of Powdery Mildew Resistant hybrids in Chili. *Biological Forum – An International Journal, 15*(9): 492-500.