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Heterosis and combining ability for resistance to powdery mildew in adult melon plants

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With 4 tables

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Abstract

To estimate the heterosis, general combining ability (GCA) and specific combining ability (SCA) for resistance to powdery mildew, 30 F_1 hybrids developed in a 6 × 5 line × tester mating design were evaluated both under the greenhouse and field conditions. Predominance of non-additive variance over additive variance in the inheritance of resistance to powdery mildew was detected. Inbred lines IIHR 681, IIHR 352, IIHR 190, RM 43, IIHR 121 and IIHR 122 demonstrated consistently high and negative GCA effects. There was a strong correlation between GCA effect and mean per cent disease index (PDI) of parent that would permit the use of the mean performance of the parental lines to predict the value of a resulting hybrid. Six hybrids, that is, Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 190, RM 43 × IIHR 121, IIHR 681 × IIHR 616, IIHR 352 × IIHR 616 and IIHR 352 × IIHR 718 which involved one or both the parents with good GCA effects exhibited low mean PDI with negative mid-parent heterosis and negative SCA effects.

Key words: melon — *Cucumis melo* — combining ability — powdery mildew — *Podosphaera xanthii* — heterosis — adult plant resistance

Powdery mildew is a serious disease which reduces the yields of melon and other cucurbits, worldwide. The powdery mildew pathogens, *Podosphaera xanthii* (Castagne) Braun & Shishkoff (formerly *Sphaerotheca fuliginea* Schlech ex Fr. Poll.) and *Golovinomyces cichoracearum* (DC) V.P. Heluta (formerly *Erysiphe cichoracearum* DC) are the most common and serious in Germany, France, Czech Republic, India, New Zealand and Montenegro (Nayar and More 1998, Lebeda and Kristova 2000, Rankovic 2003, McCreight 2006). Infection by powdery mildew is greatly influenced by the stage of the plant, air humidity and temperature. The fungi can sporulate and cause infection in very dry as well as wet atmosphere (Singh 1987).

Fungicides that are systemic or have translaminar activity are needed to obtain adequate protection on the underside of leaves, where conditions are more favourable for development of pathogen than on upper surfaces (McGrath 1996). Systemic or translaminar fungicides generally have high risk for developing resistance because they have specific modes of action and powdery mildew fungi have a high potential for resistance development. This is especially true for predominate powdery mildew fungus *Podosphaera xanthii* (McGrath 2001). The *P. xanthii* strains have been detected with resistance to as many as four classes of fungicides (Tsay and Tung 1992, O'Brien 1994, Del Pino et al. 1999). Presence of resistant strains has been associated with control failure. The relative ease with which fungicide resistant strains can develop in affected field makes powdery mildew an important disease. Therefore, resistant varieties are being developed and are becoming an increasingly important component of management programmes.

Genotypes with useful genes and quantitative resistance to powdery mildew, independent of environment are of prime importance. Genetic control of resistance/tolerance to powdery mildew has been investigated using progeny resulting from crosses between resistant/tolerant and susceptible genotypes. Sources of resistance to powdery mildew in melon have been identified, and many inheritance studies (Bohn and Whitaker 1964, Sivakami et al. 1979, Cohen and Cohen 1986, Kenigsbuch and Cohen 1989, 1992, Floris and Alvarez 1991, Epinat et al. 1993, Perchepied et al. 2005) have been reported. Although the adult plant stage is usually the important stage for resistance screening, often seedlings were assessed for disease reactions under controlled conditions. However, there is no published study available on heterosis and combining ability for resistance to powdery mildew in adult melon plants. The genetic relationship between resistance in adult greenhouse-grown plants and adult field-grown plants from the same parents could be used to develop elite resistant lines or to identify superior parents or crosses.

Plant breeders must possess an adequate knowledge of combining abilities (Sprague and Tatum 1942), which helps in assessing the lines used as parents in the production of superior hybrid combination for commercial exploitation. The present study was conducted both under field and greenhouse conditions with the following objectives: (i) to estimate per cent heterosis over mid-parent and high-parent for resistance to powdery mildew in the hybrids; (ii) to estimate general combining ability (GCA) and specific combining ability (SCA) effects for resistance to powdery mildew in a set of eleven diverse male and female parental lines; (iii) to estimate genetic parameters useful for describing the mode of inheritance of host resistance to powdery mildew.

Material and Methods

Plant materials: The parents were inbred lines maintained by continuous selfing at the Indian Institute of Horticultural Research (IIHR), Bangalore, India. These inbred parental lines were used to study combining ability and heterosis for resistance to powdery mildew. The set of female parents (lines) included 'Arka Jeet', 'Punjab Sunehri', RM 43, *ms*-1, IIHR 681 (*Cucumis melo* var. *agrestis*), IIHR 352 (*Cucumis melo* var. *reticulatus*). The set of male parents (testers) included IIHR 616, IIHR 190 (*Cucumis melo* var. *reticulatus*), IIHR 718, IIHR 121 and IIHR 122. RM 43, IIHR 681, IIHR 190, IIHR 121 and IIHR 122 were resistant whereas IIHR 616 and IIHR 718 were moderately resistant. 'Arka Jeet' and 'Punjab Sunehri' were susceptible parents.

Experimental plan: Six female parents were crossed to five male parents in a line × tester mating system to obtain 30 hybrids. Seedlings were raised in 50-unit plastic potting trays inside a greenhouse for both the greenhouse and field experiments. At 2–3 leaf stage, seedlings were transplanted to the main field during June 2006 at Vegetable Block, Indian Institute of Horticultural Research (IIHR), Bangalore, India. Seedling spacing was 3.0 m between beds (centre to centre) and 0.45 m within bed. Field plots with 15 plants each arranged in three randomized blocks. Each parent and the F_1 hybrid planted in one plot per block. For the greenhouse screening experiment, 10 plants of each F_1 hybrid and parent were raised in three replicates.

Inoculation in field: The pathogen (*Podosphaera xanthii*) was isolated from a melon growers' field near Bangalore, India. Colonies of *Podosphaera xanthii* was maintained on cucumber plants in the greenhouse at 23–25°C temperature and 50–70% relative humidity. Inoculum of *P. xanthii* was prepared by gently washing powdery mildew infected cucumber leaves in distilled water to release the spores. Inoculation was performed on both abaxial and adaxial leaf surfaces spraying conidiospores suspension containing 5000–6000 sporangia per millilitre using a hand sprayer. Following the above procedure, second inoculation was performed 3 days after first inoculation.

Inoculation in the greenhouse: A piece of powdery mildew infected cucumber leaf of size 1.5 cm × 1.5 cm was stapled to the abaxial surface of leaves of all the test plants at 2–3 leaf stage. Immediately, stapled plants were transferred to a growth chamber (50–70% relative humidity, 23–25°C temperature and 12/12 h day/night). The next day, seedlings were brought back to the greenhouse benches. This method of inoculation was found ideal to initiate *P. xanthii* infection on abaxial surface of leaves in melon plants under the greenhouse conditions. Three days after the first inoculation, second inoculation was performed to ensure uniform spread of disease on adaxial surface of leaves by breath blowing over powdery mildew infected cucumber leaves bearing freshly produced conidia. Immediately, inoculated plants were transferred to a growth chamber (50–70% relative humidity, 23–25°C temperature and 12/12 h day/night). The next day, seedlings were brought back to the greenhouse benches.

In both the screening experiments, 10–12 days after second inoculation, clear fungal growth was noticed on both sides of leaves of the inoculated plants. Symptoms first appeared as white or fluffy circular patches or spots on the under surface of the leaves and later spread to upper surface of leaves. Inoculated plants were maintained on greenhouse benches for 6 weeks. A single application of micronutrients at 0.5 ml/l of water was supplied at 2–3 leaf stage. Seedlings were hand watered daily. A nutrition solution containing 150 mg N, 150 mg P and 150 mg K per litre of water was supplied every week.

Disease assessment: Infection on plants was measured 45 days after inoculation in field experiment and 30 days after inoculation in the greenhouse experiment. A linear 0–5 scale indicating average rating of all the leaves was used to assess the disease in both experiments where, 0 = free from fungal infection, 1 = 1–10%, 2 = 11–25%, 3 = 26–50%, 4 = 51–75% and 5 = > 75% of total leaf area covered with fungal growth.

Per cent Disease Index (PDI) was calculated using the formula proposed by Wheeler (1969): PDI = Sum of numerical values/(No. leaves rated × Maximum rating) × 100. Plants were clustered into three groups based on mean PDI: resistant, moderately resistant and susceptible. Mean PDI between 0 and 15 were grouped as resistant, mean PDI between 15 and 30 as moderately resistant and mean PDI above 30 as susceptible.

Statistical analysis: The data were analysed as per the line × tester method suggested by Kempthorne (1957) using the model proposed by Arunachalam (1974) and described by Singh and Choudhary (1985). Using expected mean sum of squares, the formulae for covariance of half sibs and full sibs that in turn give the variances because of GCA and SCA. The sum squares for genotypes were subdivided into variation among parents, variation among parents × hybrids and variation among hybrids. The sum of squares for parents was subdivided into variation among lines × testers, variation among lines and variation among testers.

Mid-parent heterosis (MPH) and high-parent heterosis (HPH) were estimated as the percentage deviation of the F_1 mean from the mid-parent (MP) and high-parent (HP) values, respectively.

$$\text{MPH}(\%) = 100 \times (\text{F}_1 - \text{MP})/\text{MP}$$

$$\text{HPH}(\%) = 100 \times (\text{F}_1 - \text{HP})/\text{HP}$$

Simple correlation coefficients were calculated between parents and progeny. GCA of all 11 parents was correlated to mean PDI of all parents to calculate GCA–mean PDI of parent correlation. Mean PDI of all 30 hybrids was correlated to mid-parental values of all thirty hybrids to calculate F_1 hybrid–mid-parent correlation.

Results

Analysis of variance

Analysis of variance revealed that the mean sum of squares caused by treatments was significant in both field and greenhouse experiments (Table 1). The partitioning of hybrid mean sum of squares revealed significant differences in the variances caused by parents, lines, testers, lines × testers, hybrids and parents × hybrids found significant (Table 1). The ratio SCA to GCA was 1 : 2.8 in the greenhouse experiment and 1 : 1.6 in field experiment (Table 1).

Mean per cent disease index

The inbred lines IIHR 681, IIHR 352, RM 43, IIHR 190, IIHR 121 and IIHR 122 were found to be resistant exhibiting greatest potential to reduce powdery mildew of progeny from

Table 1: Analysis of variance for resistance to powdery mildew in the greenhouse and field experiments in melon

		Greenhouse experiment	Field experiment
Source of variation	df	MS	MS
Parents	10	1049.52**	1662.08**
Lines	5	2389.69**	27.11.91**
Testers	4	554.76	1079.21**
Lines × Testers	20	472.55**	391.82**
Hybrids	29	820.54**	882.08**
Parents × Hybrids	1	612.85**	88.49**
Error	80	2.69	2.35
σ^2 GCA	–	55.5	83.5
σ^2 SCA	–	156.6	129.8
σ^2 GCA : σ^2 SCA	–	1 : 2.8	1 : 1.6

df, degrees of freedom; MS, mean squares.
Significant at *P = 0.05 and **P = 0.01.

Table 2: Estimates of general combining ability (GCA) of parents, specific combining ability (SCA) of hybrids and mean per cent disease index (PDI) of parental lines for resistance to powdery mildew in the greenhouse and field experiments in melon

	Female (SCA effects of hybrids)						Male	
	Arka Jeet	Punjab Sunehri	RM 43	*ms*–1	IIHR 681	IIHR 352	GCA	Mean PDI
Male								
IIHR 616	15.74**	2.21*	−0.97	−10.58**	−2.87**	−3.78**	4.39**	37.2 (S)
	13.34**	1.91**	−2.70**	−2.43**	−4.31**	−6.06**	4.89**	32.7 (S)
IIHR 718	19.85**	−12.70**	6.63**	−1.28	−1.12	−6.34**	6.69**	23.2 (MR)
	23.70**	−8.94**	1.33	−6.95**	−4.92**	−5.62**	10.10**	17.3 (MR)
IIHR 190	1.26	−13.16**	6.95**	−10.01**	0.52	3.18**	−4.33**	8.8 (R)
	−0.15	−13.66**	7.22**	−8.85**	7.81**	1.70	−5.62**	10.7 (R)
IIHR 121	−9.72**	24.50**	−12.98**	−2.47*	2.03*	4.86**	−3.32**	21.4 (MR)
	−11.88**	21.18**	−9.28**	1.60	−0.19	6.82**	−3.26**	21.9 (MR)
IIHR 122	−27.13**	−0.86	0.64	24.29**	1.43	2.07**	−3.43**	14.4 (R)
	−24.99**	−0.47	3.44**	16.63**	1.61	3.16**	−6.12**	8.7 (R)
Female								
GCA	12.32**	12.28**	−8.86**	6.35**	−15.32**	−15.15**		
	13.77**	12.59**	−11.27**	8.15**	−16.18**	−14.85**		
Mean PDI	65.2 (S)	41.7 (S)	1.8 (R)	33.1 (S)	3.6 (R)	9.2 (R)		
	72.5 (S)	66.6 (S)	1.6 (R)	39.6 (S)	3.5 (R)	5.3 (R)		

Upper lines and lower lines represent values in the greenhouse and field experiments, respectively.
Letters in the parentheses represent the reaction of the each genotype against powdery mildew inoculation: R, resistant; MR, moderately resistant; S, susceptible.
Significant at *P = 0.05 and **P = 0.01.

crosses with other lines. The mean PDI of parental lines varied from 1.8 to 65.2 in the greenhouse experiment and 1.6 to 72.5 in field experiment (Table 2). Of 30 hybrids, 11 hybrids, viz., Arka Jeet × IIHR 122, RM 43 × IIHR 121, IIHR 681 × IIHR 616, IIHR 681 × IIHR 190, IIHR 681 × IIHR 121, IIHR 681 × IIHR 122, IIHR 352 × IIHR 616, IIHR 352 × IIHR 718, IIHR 352 × IIHR 190, IIHR 352 × IIHR 121 and IIHR 352 × IIHR 122 were found to be resistant to powdery mildew (Table 3). Ten hybrids expressed low mean PDI compared with mid-parent value in both the screening experiments (Table 3).

Table 3: Per cent disease index of mid-parent (MP), per cent disease index F_1 hybrid, mid-parent heterosis (MPH), high-parent heterosis (HPH) of thirty F_1 hybrids evaluated in the greenhouse and field experiments for resistance to powdery mildew in melon

	Greenhouse experiment				Field experiment			
Hybrids	MP	F_1	MPH	HPH	MP	F_1	MPH	HPH
Arka Jeet × IIHR 616	51.2	60.5	18.13**	84.98**	52.6	57.2	8.79**	75.02**
Arka Jeet × IIHR 718	41.2	66.9	62.24**	188.50**	47.9	72.8	52.14**	213.90**
Arka Jeet × IIHR 190	37.9	37.3	−1.72	325.60**	40.6	33.2	−18.22**	279.30**
Arka Jeet × IIHR 121	43.6	27.3	−37.31**	89.89**	46.9	23.9	−49.18**	65.99**
Arka Jeet × IIHR 122	37.0	9.8	−73.48**	−54.27**	43.4	7.9	−81.86**	−63.23**
PS × IIHR 616	39.4	46.9	18.97**	43.47**	49.6	44.6	−10.08**	36.45**
PS × IIHR 718	29.5	34.3	16.41**	47.91**	44.9	38.9	−13.12**	68.09**
PS × × IIHR 190	26.2	22.8	−12.80*	160.50**	37.7	18.6	−50.73**	111.80**
PS × IIHR 121	31.8	61.5	93.40**	327.60**	43.9	55.8	26.73**	287.70**
PS × IIHR 122	25.2	27.2	7.94	26.88**	40.5	31.2	−22.90**	45.59**
RM 43 × IIHR 616	19.5	22.6	15.99**	1358.00**	17.1	16.2	−5.69	941.90**
RM 43 × IIHR 718	9.6	32.2	238.70**	1979.00**	12.4	25.4	105.30**	1538.00**
RM 43 × IIHR 190	6.3	21.8	250.50**	1305.00**	5.2	15.6	202.00**	904.50**
RM 43 × IIHR 121	11.8	0.7	−94.34**	−56.77*	11.5	1.4	−87.55**	−17.74*
RM 43 × IIHR 122	5.2	16.4	212.70**	957.00**	7.9	11.3	41.49**	627.10**
ms-1 × IIHR 616	35.1	28.2	−19.77**	−13.76**	36.2	35.9	−0.86	9.63*
ms-1 × IIHR 718	25.2	39.8	58.06**	71.63**	31.4	36.5	16.32**	57.52**
ms-1 × IIHR 190	21.9	20.0	−8.41**	128.80**	24.2	25.6	5.79	192.10**
ms-1 × IIHR 121	27.5	28.6	4.10	99.12**	30.5	31.7	3.95	120.70**
ms-1 × IIHR 122	20.9	55.3	164.30**	157.80**	27.0	43.9	62.56**	104.80**
IIHR 681 × IIHR 616	20.4	14.2	−30.23**	300.90**	18.1	9.6	−46.87**	171.30**
IIHR 681 × IIHR 718	10.4	18.3	75.33**	415.10**	13.4	14.2	6.43	300.80**
IIHR 681 × IIHR 190	7.1	8.9	24.82**	150.70**	6.7	11.2	82.62**	216.60**
IIHR 681 × IIHR 121	12.8	8.0	−37.51**	124.50**	12.5	5.6	−55.16**	57.75**
IIHR 681 × IIHR 122	6.2	11.3	84.08**	219.20**	8.9	4.5	−49.47**	27.61**
IIHR 352 × IIHR 616	23.2	13.5	−41.82**	152.40**	19.0	9.2	−51.54**	72.34**
IIHR 352 × IIHR 718	13.2	13.2	−0.01	147.40**	14.3	14.9	4.14	177.80**
IIHR 352 × IIHR 190	9.9	11.7	18.10**	119.30**	7.1	6.5	−8.29	20.93**
IIHR 352 × IIHR 121	15.6	14.4	−7.33	169.50**	13.4	13.9	4.18	160.70**
IIHR 352 × IIHR 122	9.0	11.5	28.61**	115.39**	9.9	7.4	−24.78*	38.69**

Significant at *P = 0.05 and **P = 0.01.

Combining ability

All the parental lines exhibited significant ($P = 0.01$) GCA effects in both screening experiments (Table 2). Six of 11 parental lines expressed significant and negative GCA effects indicating parental lines could reduce disease level of their progeny from crossing with other lines. The highest negative GCA estimate was obtained in IIHR 681 followed by IIHR 352 and RM 43. The highest positive GCA estimate was detected in the susceptible line 'Arka Jeet' followed by 'Punjab Sunehri'. Estimates of GCA varied from −15.32 to 12.32 in the greenhouse experiment and varied from −16.18 to 13.77 in field experiment (Table 2).

The SCA effects do contribute tangibly in the improvement of disease resistance. Ten hybrids, viz., Arka Jeet × IIHR 121, Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 718, Punjab Sunehri × IIHR 190, RM 43 × IIHR 121, *ms*-1 × IIHR 616, *ms*-1 × IIHR 190, IIHR 681 × IIHR 616, IIHR 352 × IIHR 616 and IIHR 352 × IIHR 718 expressed significant and negative SCA effects. The SCA effects varied from −27.13 to 24.50 in the greenhouse experiment and varied from −24.99 to 23.70 in field experiment (Table 2).

Heterosis

Hybrids with negative MPH value were 12 and 16, respectively, under greenhouse conditions and field conditions (Table 3). Seven hybrids, viz., Arka Jeet × IIHR 121, Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 190, RM 43 × IIHR 121, IIHR 681 × IIHR 616, IIHR 681 × IIHR 121 and IIHR 352 × IIHR 616 expressed significant and negative MPH in both the screening experiments. The MPH varied from −94.34 to 250.80% in the greenhouse and −87.55 to 202.00% in field experiment (Table 3). Hybrids Arka Jeet × IIHR 122 and RM 43 × IIHR 121 expressed significant and negative HPH in both the screening experiments. The HPH varied from −56.77 to 1979.00% in the greenhouse experiment and −63.23 to 1538.00% in field experiment (Table 3).

Some important correlations

The correlation between GCA and mean PDI of parent and F_1 hybrid and mid-parent was significant and strong in both the screening experiments (Table 4).

Discussion

Eleven parental lines representing different types were used to get the proper and reliable estimate of variance components for resistance to powdery mildew. A substantial amount of genetic variation was evident from the analysis of variance. Non-significant replication mean sum of squares under greenhouse and field conditions suggested that infection was uniform and satisfactory in both the screening experiments. Significant parents × hybrids and lines × testers mean sum squares indicated the presence of non-allelic interactions. Significant parents × hybrids mean sum squares indicated thereby that average MPH was significant. Both additive and non-additive gene actions were found to be important for resistance to powdery mildew as suggested by significant GCA and SCA variance. According to Falconer (1996), the GCA variance represents additive and additive × additive gene action, whereas variance caused by SCA represents the dominance, additive × dominance and dominance × dominance gene action.

Quantitative genetic data on resistance are of practical importance to breeders. Disease assessment based on per cent leaf-area-infected was found useful for analysis of resistance to powdery mildew in adult-melon plants. All the three category of disease response (resistant, moderately resistant and susceptible) were found in the set of 11 parents and 30 hybrids indicating large genetic divergence in parental lines. Ten hybrids, which expressed low mean PDI compared with mid-parent value could be attributed to the presence of negative dominance.

Negative GCA/SCA effects indicated greater resistance, and large positive GCA/SCA effects indicated greater susceptibility. Hybrids Arka Jeet × IIHR 121, Arka Jeet × IIHR 122, *ms*-1 × IIHR 190, IIHR 681 × IIHR 616, IIHR 352 × IIHR 616 and IIHR 352 × IIHR 718 expressed negative SCA effects involved one good general combiner as parent, which indicated the predominance of non-additive gene action. On the contrast, hybrids RM 43 × IIHR 190, IIHR 352 × IIHR 190, IIHR 352 × IIHR 121 and IIHR 352 × IIHR 122 expressed positive SCA effects, involved both parental lines with significant and negative GCA effects suggesting predominance of additive gene effects with duplicate type of interactions. This showed that it is not necessarily that both parental lines with negative GCA effects will always give negative SCA effects in their crosses. Punjab Sunehri × IIHR 718 and *ms*-1 × IIHR 616 with negative GCA × negative GCA as parental combination expressed significant and negative SCA effects which implied additive × additive gene effects and complementary gene action.

The most important finding of the present study is the identification of six lines, namely IIHR 681 (*Cucumis melo* var. *agrestis*), IIHR 352 (*Cucumis melo* var. *resticulatus*), IIHR 190 (*Cucumis melo* var. *resticulatus*), RM 43, IIHR 121 and IIHR 122, which demonstrated consistently high and negative GCA effects in both screening experiments. These lines, therefore, have potential for use in developing resistance to powdery mildew in melon. The results in the present study highlight the importance of harnessing useful genes from diverse parental lines to improve resistance to *Podosphaera xanthii* in adapted varieties/cultivars. The hybrids obtained from parents with a higher general combining ability and long genetic distance expressed high heterosis, which implied diverse parents could produce higher resistance. Inbred lines IIHR 121 and IIHR 122 have been reported resistant with dominant inheritance to downy mildew (Shashikumar et al. 2010). Therefore, lines IIHR 121 and IIHR 122 have potential for use in developing combined resistance to powdery and downy mildew in melon.

Mean performance of the inbred lines does not always assure superior hybrids, and it is then necessary to evaluate the

Table 4: Phenotypic correlation coefficients between parent and progeny, F_1 hybrid and mid-parent for resistance to powdery mildew in the greenhouse and field screening experiments in melon

	Correlation coefficient	
Combination	Green house experiment	Field experiment
GCA–Parent *per se*	0.84**	0.88**
F_1 hybrid–Mid-parent	0.66**	0.76**

**Significant at $P = 0.01$.

inbred lines in hybrid combinations (Hallauer et al. 1988, Troyer 1994). Identification of hybrid combinations with resistance to powdery mildew is one of the most important steps in developing melon hybrids. The exploitable resistance of hybrids will depend on mean performance of hybrids, per cent heterosis over mid-parent and/or higher parent and on advances in line development. In this study, line × tester analysis of 11 advanced parental lines resulted in six hybrids, viz., Arka Jeet × IIHR 122, Punjab Sunehri × IIHR 190, RM 43 × IIHR 121, IIHR 681 × IIHR 616, IIHR 352 × IIHR 616 and IIHR 352 × IIHR 718 which were found to be promising based on their mean PDI, MPH and SCA effects, for exploitation of resistance to powdery mildew. Breeding methods like biparental progeny selection (Andrus 1963) might be used to get transgressive segregants from crosses involving negative GCA × negative GCA, negative GCA × positive GCA and positive GCA × negative GCA combination of parents, which expressed negative (desirable) SCA effects.

In the present study, the strong correlation between F_1 hybrid and mid-parent value indicated that the performance of parental lines appears to be a useful indicator of parents of their crosses for powdery mildew resistance breeding. The strong correlation between GCA and mean PDI of parent would be strong enough to permit the use of the performance of the two parental lines to predict the genetic value of a resulting hybrid.

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