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PREDICTION OF HETEROSIS AND COMBINING ABILITY FOR YIELD AND YIELD CHARACTERS AT SEEDLING STAGE IN SWEET PEPPER (*CAPSICUM ANNUUM* L.)

RAVINDRA MULGE* AND N. ANAND

Division of Vegetable Crops, Indian Institute of Horticultural Research Hessaraghatta, Bangalore 560089

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ABSTRACT

An attempt was made to predict heterosis and combining ability for yield and yield components at seedling stage in crosses between 12 powdery mildew resistant (PMR) lines and 3 powdery mildew susceptible (PMS) testers of sweet pepper. Heterosis over MP, BP and the best parent was recorded for seedling height, number of leaves, growth rate, leaf production per week, and number of basal and secondary roots at transplanting. Results of line x tester analysis and correlation studies suggest that F_1 hybrids with high sca effects and parents with high gca effects for yield and yield components can be identified at seedling stage using parameters like height at transplanting and seedling growth rate.

Key words: Combining ability, heterosis, seedling analysis, sweet pepper.

Improvement of yield in sweet pepper has been limited due to lack of genetic variability for yield and yield contributing characters and high occurrence of diseases like leaf curl virus and powdery mildew. At the Indian Institute of Horticultural Research, Bangalore, more than hundred powdery mildew resistant (PMR) lines have been developed following modified back-cross breeding using several sweet pepper varieties as recurrent parents and *Capsicum baccatum* var. *pendulum* as source of resistance. With the introgression of genes from wild species, variability observed in these lines was significant and many lines outyielded the existing best variety [1]. With the dominance of PMR trait [1], the F_1 hybrids offer great opportunity for increasing the productivity. A faster and efficient technique is required to screen large materials for heterosis and combining ability.

Early expression of heterosis was reported in carrot [2], maize [3] and wheat [4]. Expression of heterosis for various traits right from seedling stage and its relationship with

*Present address: Cardamom Research Centre, Indian Institute of Spices Research, Appangala, Madikeri, Karnataka 571201.

heterosis for grain yield was also observed in maize [5]. The importance for gca and sca variances for coleoptile length, seedling height and peduncle length for prediction of heterosis for grain yield has been recognized in wheat [6]. In the event of correlation between combining ability effects for seedling and yield characters, the superior combiners and crosses can be reliably identified at seedling stage which could enhance the efficiency of heterosis breeding.

The study reported was carried out with the objective of identifying good combiners and assessing the magnitude of heterosis at the seedling stage, and also to assess the predictability of heterosis and combining ability for yield components at seedling stage in sweet pepper (*Capsicum annuum* L.) where F_1 hybrids have been commercialized and breeders are in constant search for ideal parents. Such information is not available in literature, although it would be extremely helpful if a few easy-to-score seedling characters can be identified which could form a dependable basis to predict heterosis for fruit yield.

MATERIALS AND METHODS

Twelve PMR lines viz., PMR 8, PMR 12, PMR 14, PMR 27, PMR 28, PMR 31, PMR 44, PMR 52, PMR 54, PMR 56, PMR 59 and PMR 68 developed at IIHR Bangalore and three commercial varieties (testers), viz., Arka Mohini (AM), Plaor (IHR 1023) and Pick Me Quick (IHR 1208), were used in the present investigation. Thirty six F_1s were developed through line x tester approach by crossing the three testers with the 12 lines. Eight seeds of each entry (F_1s and parents) were sown on raised sand beds with a spacing of 10 x 10 cm in three nursery beds, each representing one replication. On 20th and 40th days after sowing (DAS) seedling height and number of leaves were recorded in all the entries of three replications. Growth rate and leaf production per week were calculated as follows:

$$\text{Growth rate, mm/day} = \frac{\text{Height 40 DAS} - \text{Height 20 DAS}}{20}$$

$$\text{Leaf production per week} = \frac{\text{No. of leaves 40 DAS} - \text{No. of leaves 20 DAS}}{20} \times 7$$

The beds were drenched with water 40 DAS and seedlings were carefully uprooted with complete root frame. The roots were thoroughly washed in water and number of basal and secondary (below basal roots) roots arising from primary (tap) root were counted, and fresh and dry weights of roots and shoots were recorded.

In a separate experiment, five-week-old seedlings of the 51 entries (12 lines, 3 testers and 36 F_1s) were transplanted from the nursery to the field in three replications with the spacing of 60 x 40 cm. Ten plants of each entry were planted per replication with the plot size of 2.4 m^2. Observations on growth, yield and yield components were recorded.

Replication means for various seedling characters and growth, yield and yield components recorded on the parents and hybrids were subjected to line x tester analysis [7]. Heterosis was calculated as per cent increase or decrease of mean F_1 performance over the mean values of mid-parents (MP), better parents (BP), and the best parent among the 15 parents used in crosses. Simple correlation coefficients were worked out between different seedling growth characters, yield and yield characters of the parents and hybrids using mean values (per se performance) and combining ability effects.

RESULTS AND DISCUSSION

Significant variability was observed among entries (including parents and crosses) as well as among crosses and lines for seedling height, number of leaves 40 DAS, and growth rate at seedling stage [1]. The hybrids were significantly superior to parents in all these characters. Maximum heterosis observed over MP and the best parent for seedling height (54.0%, 23.5%) and number of leaves (35.5%, 16.5%) 40 DAS, growth rate (79.6%, 34.6%), leaf production per week (55.9%, 23.4%) and number of basal (132.3%, 26.3%) and secondary (263.8%, 149.6%) roots (Table 1) at seedling stage, indicated expression of heterosis even at early development stages. The yield potential of the best hybrid was 43.8% higher (37.1 tonnes/ha in the cross PMR 12 x AM) compared to the best line (25.8 tonnes/ha in PMR 28), 82.8% higher than in the best tester (20.3 tonnes/ha in IHR 1208) and 152.4% higher than in ruling variety Arka Mohini (14.7 tonnes/ha) (Table 2).

Table 1. Magnitude of heterosis for seedling and yield characters in sweet pepper

Character	Maximum heterosis (%) over	
	mid-parent	best parent
Seedling characters:		
Seedling height 40 DAS	54.0	23.5
No. of leaves per plant 40 DAS	34.5	16.5
Growth rate	79.6	34.6
Leaf production per week	55.9	23.4
No. of basal roots	132.3	26.3
No. of secondary roots	263.8	149.6
Yield characters:		
No. of fruits per plant	116.7	42.1
Fruit yield per plant	112.2	43.8

The correlation studies revealed that fruit yield and number of fruits per plant were significantly correlated with seedling height, number of leaves 40 DAS, growth rate, leaf production per week, and number of basal and secondary roots at seedling stage (Table 3). This indicated that heterosis expressed at seedling stage for various characters was a good indication of heterosis for fruit yield. The hybrids PMR 52 x IHR 1208 and PMR 28 x IHR 1023 with significant heterosis over the best parent for seedling height and number of leaves

40 DAS, growth rate, leaf production per week, and number of basal and secondary roots at seedling stage also expressed significant heterosis over the best parent for number of fruits and high heterosis over the best parent for fruit yield (Table 4). The hybrids PMR 12 x AM, PMR 44 x IHR 1023, and PMR 54 x IHR 1208 with significant heterosis over best parent for seedling characters also expressed significant heterosis over the best parent for fruit number and high heterosis over the best parent for total yield per plant (Table 4). Thus, expression of heterosis was maintained right from seedling stage to reproductive phase (Tables 1, 4). These results suggest that heterosis for yield and yield components can be predicted using the seedling characters.

Table 2. Yield potential of best hybrids, lines and commercial checks in sweet pepper

Entry	Fruit yield (tonnes/ha)
Hybrids:	
PMR 12 x AM	37.1
PMR 68 x IHR 1208	36.2
PMR 52 x IHR 1208	33.9
PMR 28 x IHR 1023	33.8
PMR 54 x IHR 1023	33.6
Lines:	
PMR 28	25.8
PMR 14	25.7
PMR 59	24.1
PMR 56	21.2
Testers (commercial checks):	
Arka Mohini (AM)	14.7
Plaor (IHR 1023)	15.7
Pick Me Quick (IHR 1208)	20.3
CD at P = 0.05	3.5

Identification of good combiners for yield and yield components is possible at seedling stage, if there is association between seedling and yield characters for their combining ability effects [8]. The gca effects for seedling growth rate and gca effects for number of fruits per plant were significantly correlated ($r_p = 0.52$) (Table 5). Number of fruits per plant, as expected, was even more strongly associated ($r_p = 0.87$) with total yield (Table 3). The parents PMR 59, 31, 44 and 52, which exhibited significant gca effects for growth rate at seedling stage, also exhibited high gca effects for fruit yield per plant and very high gca effects for number of fruits per plant. The sca effects for seedling height ($r_p = 0.53$) and growth rate ($r_p = 0.45$) were significantly correlated with sca effects for fruit yield per plant

Table 3. Simple correlation coefficients among different characters of seedling and yield in sweet pepper

Character	No. of leaves 40 DAS	Growth rate	Leaf production per week	No. of basal roots	No. of secondary roots	Fruit yield per plant	No. of fruits per plant
Seedling ht. 40 DAS	0.54**	0.86**	0.20**	0.24**	0.32**	0.43**	0.45**
No. of leaves 40 DAS		0.59**	0.69**	0.08**	0.19*	0.44**	0.40**
Growth rate			0.29**	0.23**	0.32**	0.45**	0.47**
Leaf production per week				0.03	0.13	0.35**	0.28**
No. of basal roots					0.26**	0.38**	0.36**
No. of secondary roots						0.45**	0.49**
Fruit yield per plant							0.87**

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

Table 4. Heterosis (%) over best parent for seedling and yield characters in selected crosses of sweet pepper

Cross		Seedling height 40 DAS	No. of leaves 40 DAS	Growth rate mm/day	Leaf production per week	No. of basal roots	No. of secondary roots	No. of fruits per plant	Fruit yield per plant
Line	Tester								
PMR 12	AM	12.8**	-3.5	12.4**	-11.5	-17.3	63.6**	42.1**	43.6
	IHR 1023	5.6**	-10.3	10.0**	-18.3	-6.2	58.1**	13.4**	5.8
	IHR 1208	-6.0	-13.1	-5.9	-23.4	-21.0	54.3**	-2.7	9.2
PMR 28	AM	0.5	0.8	-2.8	-6.0	4.9	82.9**	2.1	2.3
	IHR 1023	4.6**	8.2**	9.5**	16.3**	23.5**	103.9**	41.8**	31.2
	IHR 1208	-16.1	2.6**	15.0**	8.7**	-7.8	38.0**	-30.8	14.5
PMR 44	AM	20.0	-8.2	-17.8	-8.3	-39.9	69.0**	-23.2	-16.5
	IHR 1023	4.8**	-6.9	-9.7**	-12.7	7.5**	120.0**	37.0**	17.1
	IHR 1208	-0.9	3.1**	13.3**	17.5**	12.3**	64.3**	-10.3	-14.7
PMR 52	AM	6.0**	4.7**	8.3**	6.3**	-17.7	50.4**	1.7	1.9
	IHR 1023	7.3**	4.8**	12.1**	5.2**	-22.6	52.7**	-1.3	16.2
	IHR 1208	23.5**	12.6**	35.6**	18.7**	25.5**	21.7**	13.1**	31.7
PMR 54	AM	-2.0	-3.7	0.2	-5.6	26.3**	65.9**	-16.8	0.8
	IHR 1023	6.6**	7.0**	12.6**	-18.9	-18.9	80.6**	13.1**	30.4
	IHR 1208	13.5**	16.5**	21.9**	23.4**	-9.9	10.9**	11.3**	19.2

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

(Table 5), indicating that, good specific combiners for yield can be identified at seedling stage. The results of this study confirm that hybrids with high sca effects and parents with high gca effects for yield can be identified at seedling stage. This technique can help in rejecting the inferior lines rather than selecting the best line from the huge number of lines.

Table 5. Correlation coefficients for seedling characters with number of fruits and fruit yield per plant for gca and sca effects

Character	Gca effects		Sca effects	
	fruit No.	fruit yield	fruit No.	fruit yield
Seedling height 40 DAS	0.44	0.37	0.21	0.53**
Growth rate	0.52*	0.24	0.40	0.45*

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

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