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PERFORMANCE OF EXOTIC × INDIGENOUS CROSSES FOR COMBINING ABILITY OVER ENVIRONMENT IN OPIUM POPPY (*PAPAVER SOMNIFERUM* L.). III. HUSK YIELD

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ABSTRACT

Combining ability analysis of husk yield from 50 F_1 crosses of pooled data revealed that nonadditive genetic variance was more important than the corresponding additive genetic variance in all analyses. Year effects were pronounced in pooled analysis and σ^2_{gca} × year interaction was nonsignificant, while σ^2_{sca} × year interaction was significant. Varieties EC 11547, EC 11569, EC 11571, Kali Dandi, Kantia Pink and Dhola Chotta Gotia were good combiners as well as good husk producers. Crosses EC 11548 × Kali Dandi, EC 11556 × Kali Dandi, and EC 11551 × Kantia Pink were the best specific combinations with high sca effects, heterosis, and mean performance in the F_1 and F_2 generations. Single plant selection after inter se mating in segregating generation would be the best way to improve this trait, as nonadditive genetic variance was important in the crosses. Pedigree method would be a better alternative approach in some crosses, e.g. EC 11540 × Dhola Chotta Gotia, EC 11540 × Kali Dandi, and EC 11547 × Kantia Pink, where additive genetic variance was more important.

Key words: Line × tester, combining ability, opium poppy, *Papaver somniferum* L.

The combining ability analysis helps in identifying the best combiners to exploit heterosis or link up fixable favourable genes that may lead to the development of superior genotypes. Of course, such genotypes often perform better than the existing varieties but information on this aspect is entirely lacking for capsule husk yield in opium poppy. Capsule husk contains 0.15-0.20% of total alkaloids in lanced capsule, and concentrated alkaloids extract such as optopon (morphine 2-20%) and other alkaloids (16-18%) can be used directly as pharmaceutical. In addition, it contains carbohydrates, glucose, fructose, sucrose and a complex polysaccharide.

Keeping this in view, the present study has been undertaken with 10 exotic and 5 indigenous parents in a line × tester mating design. The parents were selected earlier from 75 cultivars through D^2 analysis [1].

MATERIALS AND METHODS

The exotic female parents, namely, EC 11538, EC 11540, EC 11544, EC 11547 EC 11548, EC 11551, EC 11552, EC 11556, EC 11569, and EC 11571, were crossed with five indigenous male parents: Dhola Chotta Gotia, Katalla Dandi, Kantia Pink, Hariana and Kali Dandi, resulting in 50 F_1 crosses and were sown along with 15 parents in randomized complete block design with three replications. In the second year, the same set of 50 F_1 crosses from the left over seed of previous year and 50 F_2 populations from the selfed F_1 plants were raised along with 15 parents in randomized complete block layout with three replications. In both years plant-to-plant and row-to-row spacings were 15 and 30 cm, respectively. Each parent and F_1 was grown in four-row and each F_2 in eight-row plots of 3.6 m length. The capsule husk yield (g) was recorded on each plant, and average husk yield/plot was used for statistical analysis. Combining ability analysis was carried out separately for two sets of F_1 and one set of F_2 populations as per Kempthorne [2], and for pooled F_1 data as suggested by Daljit Singh (personal communication). Heterosis over better parent

Table 1. ANOVA for the design of experiment

Source	d.f.	Mean sum of squares			Pooled F_1
		1977–78	1978–79		
Blocks	2	2.93	17.26		
Treatments		24.72 (64)	29.37 (114)		
Parents	14	27.92**	24.05**		
F_1 hybrids	49	37.42**	34.58**		
F_2 hybrids	49	—	25.20**		
P v. F_1	1	6.22	55.38**		
P v. F_2	1	—	3.75		
Error		1.41 (128)	1.04 (228)		
		F_1	F_1	F_2	
Lines (L)	9	37.54**	37.96**	67.97**	(2) 73.63**
Testers (T)	4	110.26**	99.94**	35.43**	(3) 206.86**
Line × Tester	36	29.30**	26.47**	16.40**	(6) 53.50**
Years (Y)	1	—	—	—	(1) 78.03**
Y × L	9				(4) 1.87
Y × T	4				(5) 3.35*
Y × T × L	36				(7) 2.27*
Error		1.54 (98)	0.68 (98)	0.13 (98)	1.11 (196)
σ^2gca		1.98**	1.88*	1.56*	1.02*
σ^2sca		9.25**	8.59**	5.42**	8.54**
σ^2gca × Y					0.01
σ^2sca × Y					0.38**

Degrees of freedom given in parentheses.
*, **Significant at P=0.05 and 0.01, respectively.

(BP) in F_1 and inbreeding depression from F_1 to F_2 were determined using the standard procedures for 50 cross combinations.

RESULTS AND DISCUSSION

This study suggested that there was enough genetic diversity among the parents, F_1 and F_2 generations, as the respective mean squares were highly significant (Table 1). However, large differences exist between the lower and upper limits of character means in parents (Table 2). This suggests that genetic diversity is related with geographic diversity as the exotics belong to different parts of the world. Such genetic differences have probably arisen due to geographical isolation accompanied by a combination of genetic drift and natural selection in different environments [3]. Thus, the degree of geographical isolation and ancestral relationship can be used as an index of genetic diversity. In the present study, 52.8% increase in F_1 over the better parent possibly reflects the genetic diversity present in the parents as 10 out of 15 parents involved in the crosses were of exotic origin (Table 2).

Table 2. General combining ability effects (gca) and mean performance (m) in F_1, F_2 and pooled data analysis for husk yield (g)

Parent	F_1 1977-78		F_1 1978-79		F_2 1978-79		Pooled	
	m	gca	m	gca	m	gca	m	gca
Female:								
EC 11544	8.5	–**	9.4	+**	9.4	–NS	8.9	–**
EC 11540	10.1	+NS	10.0**	+	10.0	+**	10.1	+NS
EC 11538	13.8	–**	15.3	–**	15.3	–NS	14.5	–**
EC 11547	9.0	+**	8.9**	+**	8.9	+**	9.0	+**
EC 11548	10.0	–NS	10.4	+NS	10.4	+*	10.2	–NS
EC 11551	9.4	–**	10.3	–**	10.3	–**	9.8	–**
EC 11552	12.0	–	11.6	–NS	11.6	–NS	11.8	–*
EC 11556	12.9	–**	12.4	–**	12.4	–**	12.7	–**
EC 11571	12.8	+NS	11.4	+**	11.4	+**	12.1	+**
EC 11569	10.9	+**	11.3	+**	11.3	+**	11.1	+**
Male:								
DCG	12.5	+**	13.9	+**	13.9	+**	13.2	+**
KTD	18.1	–**	16.1	–**	16.1	–**	17.1	–**
KP	16.4	+**	16.9	+**	16.9	+**	16.6	+**
Hariana	15.9	–**	15.5	–**	15.5	–**	15.7	–**
KD	16.8	+**	17.4	+**	17.4	+**	17.1	+**

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

COMBINING ABILITY

This study indicated that both additive and nonadditive genetic variance played a prominent role in the F_1 and F_2 populations in both years as well as in pooled F_1 data analyses, as the respective mean squares for gca and sca were highly significant (Table 1). However, large magnitude of σ^2sca than the corresponding σ^2gca suggested predominance of nonadditive gene action, while its lower estimates in F_2 indicated that much of nonadditive genetic variance was lost in the F_2 generations [4]. Larger estimates of such variance are considered to be due to negative correlation between genes [5]. Such genetic variances in the initial and advanced generations are caused due to linkage or changed environment in F_1 [6], or due to the presence of repulsion linkage disequilibrium [7], much of which is reduced in advanced generations [8]. Since this part of genetic variance (nonadditive) is frequently available along with additive genetic variance in the populations of self-pollinated crops, it is best to conserve it for rapid improvement by inter se mating at F_2 level [9]. Inter se mating generates further variability in the material and breaks the tight linkage between characters. Using this technique, a substantial progress has been made in the elite population in comparison to F_3 progenies in pearl millet [10].

GENOTYPE × ENVIRONMENT INTERACTION

The knowledge about the nature of various G × E interactions is important for deciding the breeding methods and testing procedures [11]. The pooled analysis revealed that year effects were very pronounced. Performance of male parents and F_1 hybrids was affected by seasons, as the respective mean squares were highly significant. However, the performance of female parent over two years and its nonsignificant mean squares, i.e. year × line in pooled analysis, indicated that exotics were of stable nature. It is significant that the exotics gave good performance for capsule husk in Indian conditions, as earlier studies with 11 indigenous cultivars for morphine strength [12] and opium yield and capsule size [13] showed varying performance over five environments. Stable performance of exotics is important for cultivating this crop in late sown conditions without much loss in husk yield. As a matter of fact, similar assessment of some hybrids in both years indicated much lower stability in their performance. In this connection it is emphasized that hybrids should be first selected for mean yield over environments and then the relative stability of high yielding hybrids should be determined [14]. Besides, the magnitude of nonadditive genetic variance was much more affected over environments than the magnitude of corresponding additive genetic variance. Similar observations were also reported for opium [15] and seed yield [16]. Sprague and Federer [17] found that the dominance component was more, equally or less sensitive than the additive component

GCA EFFECTS

An acceptable level of productivity along with good gca effect of a parent is desirable to isolate superior segregants [18], and a close approximation between them confirms that the breeding value of a line may be determined by its per se performance. Such relationship has been established in the present study for the parents EC 11547, EC 11569, EC 11571, Dhola Chotta Gotia, Kantia Pink, and Kali Dandi in both years by pooled analysis with a few exceptions. Crossing the varieties like Kali Dandi, EC 11571, EC 11569 and Kantia Pink inter se and simulating random mating in only two segregating generations would permit greater recombination and breaking of unfavourable linkages and create a wide genetic base simultaneously. Also, improvement in this trait would ultimately lead to a significant increase in opium yield of the cultivars/hybrids as these two characters are positively correlated [19].

SCA EFFECTS, HETEROSIS AND INBREEDING DEPRESSION

These estimates revealed that varying number of crosses showed significant values for sca effects in different sets of analysis, i.e. 17, 20, 21 and 19 crosses with positive effects in F_1 and F_2 analyses (Table 3). Significant positive heterosis was noted for 7, 10 and 9 crosses in F_1. For inbreeding depression, cross EC 11556 × Kali Dandi was important as it gave the maximum significant value. However, EC 11548 × Kali Dandi was the only cross with maximum positive value for sca and mean performance in all sets of analysis. The most heterotic crosses were EC 11569 × Dhola Chotta Gotia and EC 11540 × Dhola Chotta Gotia. A critical examination of Table 3 shows that in most cases the estimated sca effects and heterosis in F_1 generation of a cross in one year deviate from the F_1 generation in the next year both in magnitude and direction. This is presumed to be due to genotype × environment interaction [20]. This was also true for gca effect of a line and its per se performance which indicated that the breeding value of a line/cross can be determined on the basis of its per se performance. However, a few crosses were observed with negative sca effects, though it was of no practical significance because of nonsubstantive additive gene effects. Such incidences are frequent when the genotypes are tested in different environments [21] and it is due to the presence of unfavourable gene combinations in the parents [22]. Earlier reports in sorghum [23] suggested that negative heterosis in some crosses may involve complementary action of allelic as well as nonallelic genes, and substantial hybrid vigour may be due to favourable dominant genes, overdominance or epistatic gene action [24]. A very few cases were observed where sca effects were comparatively very high than of the corresponding F_1 data but gca effects of the parents involved were poor or low and it is attributed to the change in the distribution of genes in the F_2 population or may be due to coupling phase of linkage [25]. Such type of crosses may be processed further with simple pedigree method of breeding to exploit the additive genetic variance present in the crosses. Arunachalam [26] suggested that such crosses must be utilized further in developing multiple crosses.

In view of the substantial nonadditive genetic variance, which is frequently available in the population as well as in some of the crosses like EC 11548 × Kali Dandi, EC 11556 × Kali Dandi, and EC 11551 × Kantia Pink, the best way of making further improvement in these crosses would be through biparental mating in F_2. On the other hand, there is scope for further improvement in the crosses with predominant additive genetic variance (e.g., EC 11540 × Dhola Chotta Gotia, EC 11540 × Kantia Pink, and EC 11547 × Kali Dandi). The pedigree method would be the best way to improve capsule husk yield.

Table 3. Selected crosses on the basis of specific combining ability effects (sca), heterosis percentage over better parent (H), inbreeding depression (IBD) and mean performance in grams (m) in two years of analysis

Cross	1977-78 (F_1)			1978-79 (F_1)			Pooled (F_1)			1978-79 (F_2)		
	m	sca	H	m	sca	H	m	sca	H	m	sca	IBD
EC 11540 × DCG	16.80	+**	+**	18.40	+**	+**	17.60	+**	+**	18.20	+**	+NS
EC 11560 × DCG	19.10	+**	+**	18.30	−NS	+**	18.70	+NS	+**	16.40	+**	+**
EC 11540 × KP	17.30	+**	+NS	18.40	+**	+NS	18.12	+**	+NS	17.00	−**	+NS
EC 11551 × KP	17.13	+**	+NS	15.90	+NS	+**	17.02	+**	+NS	15.40	+**	+NS
EC 11552 × Hariana	14.20	+**	−**	16.20	+**	+NS	15.20	+**	+NS	12.90	−NS	+**
EC 11571 × Hariana	15.53	+**	−NS	17.40	+**	+**	16.47	+**	+	13.90	+**	+**
EC 11547 × KD	19.63	+**	+**	19.90	+**	+**	19.77	+**	+**	18.40	+**	+NS
EC 11548 × KD	21.83	+**	+**	20.60	+**	+**	21.22	+**	+**	19.40	+**	+NS
EC 11556 × KD	14.83	+**	−**	18.30	+**	+NS	16.42	+**	+NS	13.70	+NS	+**

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

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