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Diallel Analysis in Taramira (*Eruca sativa*)

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Abstract

Eight genetically diverse open pollinated populations of taramira [*Eruca sativa* Mill] were crossed in a diallel mating design. The resulting 28 F_1 along with parents were evaluated in RBD with 3 replications during two consecutive years named season I and II. Varieties (v_i) mean squares were significant in both the seasons for days to flowering, plant height, 1000-seed weight and oil content (%). Heterosis (h_{ii}) mean square was significant for all the characters in the season I and for 6 characters in season II. Average mean squares were significant only for the characters plant height, siliqua length, seeds per siliqua and 1000-seed weight in both the seasons whereas, for rest of the characters it was non- significant in either one or both the seasons. Varietal heterosis (h_i) mean square was significant for plant height, seeds per siliqua, 1000-seed weight and oil content in both the seasons. Specific heterosis (s_{ii}) mean squares were also significant for six characters in the season I and for 3 characters in season II. Specific heterosis (s_{ii}) component accounted for more than 50 % to over all heterosis (h_{ii}) sum of squares. This indicates presence of additive, dominance and epistatic components in the genetic control of the characters in the present investigation. Among the parents (varieties) RTM-314 in the season I and RTM 1112 in season II, while RTM-885 and T-27 in both the seasons were found superior based on v_i effects and *per se* performance for seed yield per plant. Other parents considering on the basis of (h_i) values were RTM-910, RTM-917 in the season I, while RTM-910, RTM-969 and RTM-314 in season II. Thus these parents may be used in hybridization programme to improve seed yield.

***Key words**: Diallel, heterosis, taramira, Eruca sativa*

Introduction

Taramira (*Eruca sativa* Mill.) is an oilseed belongs to rapeseed group. Taramira is believed to be native of South Europe and North Africa and is cultivated to an extent in Sweden, Germany, France, Poland, Canada and China. In India the Chief growing states are Rajasthan, Haryana, Punjab, Madhya Pradesh and Uttar Pradesh. Among these states, the area and production of Taramira in the country is highest in Rajasthan. It is mainly grown on marginal and sub marginal lands with poor fertility. Being a highly drought tolerant crop, it can be successfully grown as a rainfed crop even on soils with moderate water retaining capacity. The crop is especially suitable for the areas having meager or no irrigation facilities as it has efficient root system to extract moisture from deep soil horizons. During the periods of severe drought coupled with late *Rabi* rains, taramira is the only alternative available for sowing on soils having limited moisture supply. Good yields and economic returns could be obtained by a crop sown as late as December first week. Taramira oil is mainly used in industries. However, the crop has limited improved varieties adapted to wide agroclimatic conditions. This situation demands urgent development of a versatile variety for taramira growing area. For succesfull implementation of any breeding programme the knowledge of gene action is essential. The diallel mating design provides a systematic approach to study the inheritance of quantitative characters and help in the identification of superior parents and crosses.

Materials and methods

Eight genetically diverse open pollinated populations of taramira (RTM-314, TMCN-5, RTM-885, RTM-917, RTM-910, RTM-911, RTM-969 and T-27) were crossed in all possible cross combinations (excluding reciprocals) using polycrossing technique. The resulting 28 F_1s along with parents were evaluated in the ensuing two seasons at Agronomy farm, SKN College of Agriculture, Jobner during 2007-08 and 2008-09. In each season the progenies and the parents were evaluated in RBD with 3 replications. Each F_1 and parent was sown in a plot having two rows of 3 m length with a row to row distance of 30 cm. The intra row spacing of 10 cm was maintained by thinning. Non experimental rows were planted all round the experiment to eliminate the border effects. A sample of ten plants was selected randomly and was tagged before commencement of flowering, so as to reduce the biasness in the plant selection. Observations on various morphological traits namely days to flowering, plant height (cm), fruiting branches per plant, siliquae per plant, siliqua length (cm), seed per siliqua, 1000-seed weight (g), seeds yield per plant (g), were noted on these sample plants. Oil content was also estimated using the pooled seed sample using Soxlet's method. The data were subjected to the varietal diallel analysis as suggested by Gardner and Eberhart (1966) method II.

Results and discussion

The general ANOVA indicated significant differences between the progenies for all the characters. The partitioning of the entries mean square into variety (v_i) and heterosis (h_{ii}) components (table 1), indicated that the variety component (v_i) was significant for days to flowering, plant height, test weight and oil content, for the rest of the characters it was non-significant in either one or both the seasons, indicating that sufficient genetic diversity in the parental material for these characters. This is in contrast to Nehra (1992) who found significant v_i component for the same characters as of the present study. The overall heterosis (h_{ii}) was highly significant for all the characters in the season I whereas for plant height, siliquae per plant, seeds per siliqua, 1000-seed weight, seed yield per plant and oil content in the season II, indicating the importance of heterosis. This is in agreement with the finding of Nehra (1992) who has studies the same characters but with different parental material.

Table 1 : Analysis of variance of 8 varieties and their 28 crosses giving mean squares for different characters in the season I and season II (According to Gardner and Eberhart (1966) model, analysis-II)

Source of variation	df	Season	Days to flowering	Plant height (cm)	Fruiting branches per plant	Siliquae per plant	Siliqua length (cm)	Seeds per siliqua	1000-seed weight (g)	Seed (g) yield per plant	Oil content (%)
Replication	2	I	11.6	123.5	1.4	57.3	0.02	4.6	0.17	0.2	0.56**
		II	8.6	16.6	2.0	480.7	0.01	3.2	0.16	7.1	0.34
Entries	35	I	12.0**	86.1**	4.1**	476.9**	0.04**	3.5*	0.25**	2.4**	2.07**
		II	9.6**	65.5**	0.7	781.4	0.01	1.8	0.21**	9.6**	1.92**
Varieties (v_i)	7	I	14.2**	142.7**	0.7	80.1	0.04	3.2	0.31**	0.5	2.85**
		II	27.6**	133.4**	0.4	494.2	0.01	0.3	0.25**	7.0	1.21**
Heterosis (h_{ii})	28	I	11.5**	72.1*	5.0**	576.1**	0.04**	3.6*	0.23**	2.9**	1.87**
		II	47.2**	53.5	0.8	1610.6	0.01	2.1*	0.19**	10.3**	2.09**
Average (ʻh)	1	I	148.6**	70.4	33.8**	4008.3**	0.00	4.6	0.05	23.2**	1.79**
		II	47.2**	53.5	5.3**	1610.6	0.04	1.1	0.01	68.9**	0.23
Variety (h_i)	7	I	14.8**	120.6*	2.9**	129.5	0.04*	6.3**	0.53**	0.5	3.16**
		II	5.1	81.0**	1.2	1190.1*	0.01	3.9**	0.31**	852.9*	2.27**
Specific (s_{ii})	20	I	3.5	55.0	4.2**	560.8**	0.03*	2.5	0.13	2.7**	1.43**
		II	3.1	37.6	0.4	697.3	0.10	1.5	0.16**	8.0**	2.12**
Error	70	I	4.0	42.2	1.1	224.6	0.02	1.9	0.08	0.5	0.08
		II	3.5	24.7	0.7	520.0	0.02	1.3	0.07	3. 5	0.11

*significant at p=0.05 and **significant at p=0.01

The proportion of h_{ii}, components was above 60% to the entry sum of squares in both the seasons except days to flowering (42.73 days) in the season II (table 2), indicating the importance of heterosis in the genetic control of the traits studied. This is accepted as the h_{ii}, was significant for most of the characters in comparison to v_i component. Overall heterosis mean squares was partitioned in to three components namely average ('h), variety (h_i) and specific (s_{ii}) heterosis. The average heterosis ('h)

Table 2: Percentage of entry sum of squares accounted by the heterosis sum of squares; per cent heterosis sum of squares accounted by average heterosis, parent heterosis and specific combining ability sum of squares

Characters	Heterosis SS as % of entry SS	% Heterosis SS accounted for by		
		Average	Variety	SCA
Season I				
Days to flowering	76.5	44.7	31.2	21.0#
Plant height (cm)	66.9	3.5	41.9	54.6#
Fruiting branches per plant	96.8	24.3	13.5	62.1
Siliquae per plant	96.6	24.4#	5.6#	69.5
Siliqua length (cm)	80.0	0.1#	30.0	69.4
Number of seeds per siliqua	81.4	4.6#	44.5	50.9#
Test weight (g)	74.8	0.8#	57.8	41.8#
Seed yield per plant (g)	96.1	28.5	4.5#	67.0
Oil content (%)	72.3	3.4	42.3	54.6
Season II				
Days to flowering	42.7#	32.8	24.7#	42.5#
Plant height (cm)	59.3	3.9#	41.7	54.4#
Fruiting branches per plant	87.9#	24.4	38.8#	33.0#
Siliquae per plant	87.3	6.7#	34.9	58.3#
Siliqua length (cm)	87.5#	13.2#	15.0#	71.4#
Number of seeds per siliqua	96.5	1.9#	46.5	51.2#
Test weight (g)	75.6	0.1#	40.0	59.7
Seed yield per plant (g)	85.4	24.0	20.2	55.7
Oil content (%)	87.3	0.4#	27.2	72.5

Mean squares were not significant at p=0.05

contributed by a particular set of parents is the difference between the mean of all crosses and the mean of all parents and it results from difference in gene frequencies among the parents and degree of dominance. While the varietal heterosis (h_i) results from the gene frequency of a parent, as opposed to the average gene frequency of other parents besides degree of dominance. The specific heterosis (s_{ii}) on other hand measures the deviation between the observed performance of the specific cross and its expected performance based on the v_i,'h and h_i effects and results from the differences in the gene frequencies in the two parents and degree of dominance.

The mean squares due to average heterosis ('h) was significant for all the characters in both the seasons except plant height, siliqua length, seeds per siliqua and 1000-seed weight in both the seasons, and for siliquae per plant and oil content in the season II. Varietal heterosis (h_i) mean square was significant for all the characters in both the seasons except siliquae per plant and seed yield per plant in the season I, while days to flowering, days to maturity, fruiting branches per plant and siliqua length in the season II. Specific heterosis (s_{ii}) mean square was also significant for the characters seed yield and oil content in both the seasons; for primary branches per plant, fruiting branches per plant, siliquae per plant and siliqua length in the season I and for test weight in season II.

Among the three components *i.e.* 'h, h_i and $s_{ii,}$ the s_{ii} components accounted for more than 50 per cent of heterosis sum of squares for most of the characters. The heterosis in crosses may results due to different causes, namely, (i) differences in gene frequencies, (ii) dominance effect and effects at individual loci, and (iii) interaction among genes in a polygenic trait (Hallauer and Miranda, 1989). Following the analogy of Parodi *et al.* (1983), it could be inferred that in the present investigation, dominance, additive and epistatic components controlled the inheritance of these characters.

Components of heterosis

The critical analysis of the data with regard to variety effects (v_i) and mean performance of each parent for different characters has indicated high correlation (r = 1.00) between v_i and *per se* performance of parents. This is expected as the v_i values represent the deviation of variety (parents in the present study) mean from the overall mean of the varieties. The varietal effects (v_i) were significant only for oil content in five varieties (two with positive sign and three with negative sign) in the season I, while in the season II, v_i effects were significant for days to flowering in only one variety (negative sign), in one variety with negative direction in plant height and in three varieties for oil content (of which two in negative direction and one in positive direction) (table3). This indicates that the diversity among parents could not be expressed fully. Comparison of the seasons indicated that low rainfall contributed to poor expression of parents.

Among the varieties (parents) RTM-314, RTM-885 and T-27 in the season I and TMCN-5, RTM-885 and T-27 in season II were top seed yielders with high v_i effects.The variety RTM-314 was top ranking for all the characters except number of seeds per siliqua in the season I and had a mean rank of 2.36. The variety TMCN-5 had the lowest among all the parents in both the seasons. The variety RTM-885 was found to be second best. Total heterosis was divided into three components namely average heterosis ('h), varietal heterosis (h_i) and specific heterosis (s_{ii}). The high average heterosis (h) was observed to be desirable for all the characters in both the seasons except days to flowering and test weight in both the seasons, while days to maturity in the season I.

Comparison of h_i with mean values indicated the existence of an inverse relationship between the two. Generally varieties with high mean values were having very low and/ or undesirable h_i effects and vice versa. A negative correlation (r = -0.476) was found between h_i and *per se* performance of parents. Such a relationship is commonly observed in cross pollinated crops; in corn by Dudley *et al.* (1977); in *Eruca sativa* by Nehra and Sastry (1995); in pearl millet by Sharma (1996); in fennel by Dashora (2000) and Rajput and Singhania (2004). The sign of h_i effects is generally dependent upon 'h i.e. average heterosis and the distribution of genes in the parents and the differences between heterozygotes and the mid parental value at any given locus. According to Dudley et al. (1977) the varietal heterotic effect is the result of deviation of a heterozygote from the mean and the number of loci involved in the genetic control.

Among the parents desirable positive h_i effects for seed yield per plant were observed with RTM-910, RTM-911 and RTM-917 in the season I and RTM-910, RTM-969 and RTM-314 in the season II, thus from heterosis point of view these parents are desirable. In a polygenic trait, positive h_i effects are expected in varieties with many loci at a high gene frequency, varieties with many loci at a low gene frequency, and varieties that show a dispersion of gene frequency (high and low) relative to the average gene frequency at each locus (Vencovsky, 1970).

The parental varieties used in the present

Table 3: Varieties and crosses showing significant desirable components of heterosis in both the seasons

Characters	V_i		h_i		S_{ii}	
	I	II	I	II	I	II
Days to flowering	-	RTM1112* (4.958)	RTM1112* (-3.125)	-	-	-
Days to maturity	-	-	RTM1112* (-1.042)	-	-	-
Plant height (cm)	-	RTM-314* (-11.788)	-	-	-	RTM-969 x RTM-917* (8.773)
Primary branches per plant	-	-	-	-	RTM 1112 x RTM-885* (2.125) RTM-917 x RTM-885* (1.924)	-
Fruiting branches per plant	-	-	-	-	RTM-917 x RTM-885* (2.432) RTM 1112 x RTM-885* (1.932)	-
Siliquae per plant	-	-	-	-	-	-
Siliqua length (cm)	-	-	-	-	-	-
Number of seeds per siliqua	-	-	-	-	-	-
Test weight (g)	-	-	RTM1112* (0.412)	-	-	-
Seed yield per plant (g)	-	-	-	-	RTM-917 x RTM-885* (1.629) RTM-969 x RTM-314* (1.618) RTM 1112x RTM-885* (1.472)	RTM-969 x RTM-910* (3.728)
Oil content (%)	RTM-314* (1.363) RTM-969* (0.823) RTM-911* (-0.703) TMCN-5* (-1.203) RTM-910* (-1.337)	RTM-314* (0.896) RTM-910* (-0.804) RTM1112* (-0.871)	RTM-911* (0.448) RTM-910* (-0.464) RTM-314* (-1.336)	RTM-314* (-0.929)	RTM 1112 x RTM-910** (1.201) RTM-969 x RTM-917** (0.839) T-27 x RTM-911** (0.817) RTM-314 x RTM-911* (0.612) T-27 x RTM 1112* (0.523) T-27 x RTM-910* (-0.583) RTM-314 x RTM-910* (-0.622) RTM-917 x RTM-885** (-0.755) RTM-969 x RTM-911** (-1.166) TMCN-5 x RTM-911** (-1.466)	RTM 1112 x RTM-910** (1.817) RTM-917 x RTM-911** (1.111) T-27 x RTM 1112** (0.900) T-27 x RTM-911** (0.800) RTM-969 x RTM-885* (0.767) RTM-969 x RTM-314* (0.756) T-27 x RTM-910* (0.683) RTM-3 14 x RTM 1112* (-0.594) T-27 x RTM-969* (-0.617) RTM-314 x RTM-910* (-0.644) RTM-910 x RTM-885* (-0.700) RTM-969 x RTM-911** (-1.050) RTM 1112 x RTM-911** (-1.367)

*significant at p=0.05 and **significant at p=0.01

investigation had diverse origin; therefore, the gene frequencies are not expected to be similar. Only few parental varieties were observed to have significant and desirable h_i effects (table 3). None of the parents exhibited significant h_i effects for all the characters in both the seasons except days to flowering days to maturity and test weight in the season I, while oil content in both the seasons. Significant desirable h_i effects were observed in RTM 1112 for days to flowering, days to maturity and test weight; in RTM-911 for oil content in the season I, whereas in the season II, significant desirable h_i effects were not observed in any of the parents. This is in contrast to the findings of Nehra (1992). This may be attributed to the inherent diversity among the parents. Taramira is a common crop of Rajasthan and mostly grown in dry and marginal lands. Moreover it is a cross pollinated crop. Therefore, the diversity among the collections is most probably limited.

Perusal of data in Table 3 indicated that very few crosses exhibited significant SCA effects. In the season I, significant with desirable SCA effects were observed in crosses RTM 1112 x RTM-885 and RTM-917 x RTM-885 for primary branches per plant; in crosses RTM 1112 x RTM-885 and RTM-917 x RTM885 for fruiting branches per plant; in crosses RTM-917 x RTM-885, RTM-969 x RTM-314 and RTM 1112 x RTM-885 for seed yield per plant; and in crosses RTM 1112 x RTM-910, RTM-969 x RTM-917, T-27 x RTM-911, RTM-314 x RTM-911 and T-27 x RTM 1112 for oil content, whereas in the season II, significant with desirable SCA effects were observed in crosses RTM-969 x RTM-917 for plant height; in crosses RTM-969 x RTM-910 for seed yield per plant; and in crosses RTM 1112 x RTM-910, RTM-917 x RTM-911, T-27 x RTM 1112, T-27 x RTM-911, RTM-969 x RTM-885, RTM-969 x RTM-314 and T-27 x RTM-910 for oil content.

Among the crosses in the season-I, RTM 1112 x RTM-885 and RTM-917 x RTM-885 were found as desirable crosses having positive SCA effects for three characters including seed yield per plant. Based on s_{ii} values, best cross for each character indicated that parent RTM-885 was involved in 6 crosses for three characters, RTM 1112 in 5 crosses for four characters, RTM-917 in 4 crosses for four characters, RTM-969 in 2 crosses for two characters and RTM-314 in 2 crosses for two characters in the season I, whereas in the season II, parent RTM-969 was involved in 4 crosses for three characters, RTM-910 in 3 crosses for two characters, RTM-917 in 2 crosses for two characters and RTM 1112 in 5 crosses one characters. In the present study heterosis components namely average (h), variety (h_i) and specific (s_{ii}) for most of the characters indicated that all the three components namely additive, dominance and epistatic components controlled the inheritance of these characters. This is also indicated from the positive association between *per se* performance of parents and v_i effects as well as negative association between parents and hi effects. Non- significance of these components as observed in some of the traits can be attributed to less diversity among the parents. Further, the differences in the gene frequencies contributed most to the heterosis observed in the parents. Under such conditions, ample progress can be expected if population improvement methods like mass selection, recurrent selection or production of composites are used. If inbred line could be generated, there is great scope for the production of hybrid. Nevertheless, development of inbred lines will be complicated due to the presence of self- in-compatibility. Bud pollinations are routinely followed to over come this problem in germplasm maintenance (Sastry *et. al*., 1992).

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