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Varietal diallel analysis for yield and yield related traits in fennel (*Foeniculum vulgare* Mill.)

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Abstract

A half diallel of nine genetically diverse varieties was made and resulting 36 F_1 populations along with the parents were evaluated during rabi 1997-98. The analysis of variance indicated that heterosis was significant for all the characters, except for branches per plant. The heterosis components were also significant for most of the traits studied. Specific heterosis component accounted for more than 50% of the overall heterosis, indicating complex type of inheritance for seed yield and its component traits. The crosses UF (M)-1 x UF-134, RF-125 x JF-29 and UF-90 x HF-71 exhibited significant and positive heterobeltiosis for seed yield per plant.

Key words: fennel, *Foeniculum vulgare*, heterosis, seed yield, varietal diallel.

Introduction

Fennel (*Foeniculum vulgare* Mill.) is an important spice crop grown for its seeds which are used for mastication and chewing. All the aerial plant parts are aromatic due to the presence of volatile oil which is responsible for the pleasant flavour. The volatile oil is also used as a perfume and scenting agent in many preparations. Though, fennel has potential as a cash crop in Rajasthan, its genetic improvement has been neglected. As a result, local types having low productivity and susceptibility to diseases are cultivated, resulting in poor production.

Fennel is an allogamous crop with cross pollination to an extent of 82.2 to 91.4% (Ramanujam *et al.* 1964). The existing varieties were developed using mass selection. Inbreds have not yet been developed in this crop. Gardner & Eberhart (1966) proposed varietal diallel for such situation and gave a statistical genetic model which serves as a guide to plant breeders in the design and analysis of their experiments, concerning a fixed set of random mating varieties. Here the term "variety" represents an allogamous population. The present work was undertaken to study the genetics of yield, so that the generated information could be used for designing breeding programme.

Materials and methods

A study was carried out on half diallel of nine genetically diverse varieties (open pollinated populations) namely, RF-125, UF(M)-1, UF-90, RF-101,UF-134, JF-29, HF-71, HF-102 and local type. The resulting 36 F_1s along with their nine parents were grown during rabi 1997-98 in a randomized complete block design with three replications. In each replication, parents and F_1s were sown in a plot of 2.0 m x 0.9 m size accommodating two rows of 2 meters length spaced 45 cm apart with an intra-row spacing of 20 cm. All the recommended package of practices were followed (Sharma *et al.* 1996). Observations on height upto main umbel, total plant height, number of branches per plant, umbels per plant, umbellets per umbel, seeds per umbel, biological yield per plant, harvest index and seed yield per plant were recorded on ten randomly selected plants from each plot. For days to 50% flowering and test weight, the data were recorded on whole plot basis. Data were subjected to diallel analysis according to model II of Gardner & Eberhart (1966). This model assumes that parents used are a fixed set of random mating varieties with no epistasis and diverse gene frequencies. The genetic effects are defined as functions of gene frequencies and additive and dominance effects for individual loci.

When parents and their half diallel crosses are grown together, the additive effect (A) and dominance effect (D) are confounded and must therefore, be estimated jointly. Under such a condition, depending upon the presence or absence of heterosis and its components, four models are suggested. They are :

1. $Y_{jj'} = \mu_v + {}^{\cdot}(V_j + V_{j'})$
2. $Y_{jj'} = \mu_v + {}^{\cdot}(V_j + V_{j'}) + \delta h$
3. $Y_{jj'} = \mu_v + {}^{\cdot}(V_j + V_{j'}) + \delta h + \delta\,(h_j + h_{j'})$
4. $Y_{jj'} = \mu_v + {}^{\cdot}(V_j + V_{j'}) + \delta(h) + \delta(h_j + h_{j'})$

Where,

$Y_{jj'}$ = Mean of a cross j and j'

μ_v = Mean of all parental varieties included.

V = The variety effect when parent varieties are included in the analysis, as done in the present case

h = Average heterosis, h_j and $h_{j'}$ refer to varietal heterosis and $S_{jj'}$ refers to the specific combining ability of the cross between j and j'.

d = 0 when j = j' and 1 when j $^{\cdot}$ j'.

Results and discussion

The analysis of variance indicated significant differences for most of the traits revealing the existence of variability among parents and their hybrids. The parents vs F_1s interaction was also significant indicating the existence of heterosis. This is also supported by the results obtained from the partitioning of variation due to entries into varieties and heterosis (Table 1). This partitioning further indicated the importance of heterosis in the inheritance of the traits. This component accounted for more than 80% of the total variation. This was true even for number of branches per plant, for which the heterosis was non-significant, but the contribution was more than 95% of total variation. This indicated that all the characters were controlled by additive, dominance and epistatic components (Bailey *et al.* 1980).

Further, partitioning of overall heterosis indicated that contribution of SCA was considerably higher (Table 2). This suggests that data would fit the model 4 and the data did fit to the model supporting the observation of complex inheritance including additive, dominance and epistatic component. Each of these genetic components can not be estimated separately in the model II (Gardner & Eberhart 1966) because of the confounding effect.

On the basis of *per se* performance, RF-125, JF-29 and RF-101 were superior (Table 3). Comparison of mean values of seed yield with the mean values of other morphological traits indicated that the parents and hybrids showed similarity in pattern i.e. parents and hybrids which were superior for seed yield were also superior for seeds per umbel followed by branches per plant, total plant height and umbellets per umbel. Hence improvement in seed yield could be expected even when selection is based on the component characters of seed yield.

The sign of $\bar{h}$ effect is generally dependent upon the distribution of genes in the parents and difference between the heterozygotes and the mid parent value at any given locus. The average heterosis was observed to be in the desirable direction for seed yield per plant. Based on $S_{jj'}$ effects which represent SCA effects of Griffings (1956) notation the crosses UF(M)-

Table 1. Analysis of variance and the extent of heterosis observed for different characters in fennel

Character	Source of variation		Error	Heterosis as per cent of total variance
	Variety (V_j) (8)	Heterosis ($h_{jj'}$) (36)	(88)	
Days to 50% flowering	15.43**	19.52*	4.23	85.05
Height upto main umbel (cm)	87.58	249.98**	137.66	92.78
Total plant height (cm)	232.44*	186.52**	103.42	78.31
Branches per plant	0.19	2.04	1.91	98.02#
Umbels per plant	34.12*	86.07**	16.16	91.90
Umbellets per umbel	12.25	43.75**	7.26	94.14
Seeds per umbel	9767.20*	17512.13**	4750.24	88.97
Test weight (g)	0.95	1.83**	0.49	89.63
Biological yield per plant (g)	121.69	809.33**	95.52	96.77
Harvest Index (%)	40.03**	33.64**	12.81	79.08
Seed yield per plant (g)	13.09**	79.87**	6.21	96.49

Figures in parentheses represent degree of freedom
* Significant at P = 0.05
** Significant at P = 0.01
# Mean square not significant at P = 0.05

Table 2. Analysis of variance for heterosis components for different characters in fennel

Character	Average ($\bar{h}$) (1)	Variety (h_j) (8)	SCA ($S_{jj'}$) (27)
Days to 50% flowering	238.64**	8.12#	14.78**
	(33.96)	(9.24)	(56.79)
Height upto main umbel (cm)	1195.23**	245.90#	216.18 #
	(13.28)	(21.86)	(64.86)
Total plant height (cm)	928.38**	225.47*	147.50 #
	(13.83)	(26.86)	(59.31)
Branches per plant	16.75**	1.23#	1.73 #
	(22.81)	(13.39)	(63.60)
Umbels per plant	1.59#	87.14**	88.88**
	(0.05)	(22.49)	(77.45)
Umbellets per umbel	341.02**	48.11**	31.45**
	(21.65)	(24.44)	(53.91)
Seeds per umbel	25572.04*	17799.52**	17128.47**
	(4.06)	(22.59)	(73.36)
Test weight (g)	2.79*	2.92**	1.48**
	(4.23)	(35.46)	(60.66)
Biological yield per plant (g)	4310.55**	794.90**	683.93**
	(14.79)	(21.83)	(63.38)
Harvest Index (%)	83.92*	31.49*	32.41**
	(6.93)	(20.80)	(72.26)
Seed yield per plant (g)	187.83**	41.02**	87.38**
	(6.53)	(11.41)	(82.05)

Figures in parentheses represent percentage of $h_{jj'}$ mean squares
* Significant at P = 0.05
** Significant at P = 0.01
# Mean square not significant at P = 0.05

Table 3. The mean seed yield and rank of the parents along with the mean rank over different characters, varietal effect and the heterotic effect in fennel

Parent	Seed yield (g plant^{-1})	Rank	Mean rank	Varietal effect (V_j)	Heterotic effect (h_j)
RF-125	16.45	1	4.0	3.37	1.24
UF(M)-1	13.54	4	4.7	0.46	-1.96
UF-90	10.52	8	5.9	-2.56	-0.12
RF-101	14.26	3	4.4	1.18	-0.91
UF-134	12.11	7	4.8	-0.97	2.06
JF-29	15.37	2	5.0	2.29	-1.22
HF-71	12.56	6	4.6	-0.52	1.06
HF-102	12.83	5	5.4	-0.25	-1.02
Local type	10.10	9	6.2	-2.98	0.86
Mean				13.08 (μv)	2.95
S.E.				±2.35	±1.40

1 x UF-134 (133.09), RF-125 x JF-29 (70.40) and UF-90 x HF-71 (68.79) were best having desirable and significant S_{ij} effects for seed yield per plant. These crosses also showed superior heterobeltiosis.

The parents RF-125 and JF-29 were superior based on V_j and h_j values. These two parents appeared in majority of the crosses which showed superiority on the basis of S_{ij} and heterobeltiosis. The other parents worth considering were UF-134 and HF-71.

The parents and crosses which showed superiority for seed yield were also superior for biological yield per plant and seeds per umbel followed by branches per plant, total plant height and umbellets per umbel. Hence improvement in yield can be expected even when selections are based on these component traits.

A high amount of heterosis exists for various traits including seed yield, as revealed by the present study and hence development of hybrid varieties holds promise. RF-125 and JF-29 merit attention as parents in the development of hybrids. Crossing in fennel is difficult due to small size of flower. Hence use of recurrent selection and development of composites are suggested to improve yielding ability in fennel. However, the quick emasculation technique as proposed by Singh *et al.* (2000), if perfected, development of hybrids should become easy.

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