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Combining ability in fennel (*Foeniculum vulgare* Mill.) for yield and quality

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Abstract

Twelve genetically diverse varieties of fennel (*Foeniculum vulgare*) were evaluated at Jobner (Rajasthan) following diallel mating design for determining their utility as parents in the development of hybrids and/or high yielding composites. The analysis of variance indicated that varieties and heterosis were significant for most of the characters studied, indicating complex type of inheritance involving additive, dominance and epistatic components. The heterosis sum of squares accounted for more than 75% of the entries sum of squares. Partitioning of overall heterosis variation indicated that contribution of specific heterosis was the highest (>50%) among the three components. Estimates of genetic constants indicated that varietal heterosis effects were significant for all the traits except days to 50% flowering and test weight, while specific heterosis effects were significant for most of the characters. The cross RF-101 x JF-25 showed the highest positive specific heterosis effect for seed yield plant^{-1} along with high specific heterosis effects for umbels and biological yield plant^{-1}. These two parents represented a good choice to initiate inter-population improvement.

Key words: combining ability, fennel, *Foeniculum vulgare.*

The yield potential of fennel (*Foeniculum vulgare* Mill.) can be increased by use of hybrids and composites. In the absence of male sterile lines, commercial exploitation of hybrids in fennel is not feasible. An effort was made in the present investigation to study the combining ability effects of fennel for yield and its components and quality parameters namely, volatile oil, crude fibre and total soluble sugar contents.

The material for the present investigation consisted of 12 open pollinated varieties of fennel, representing diversity in adaptability and variability in characters and geographical origin. Of these, seven (RF-125, UF(M)-1, UF-90, RF-101, UF-133, UF-134 and Local) were from Rajasthan, two (JF-25 and JF-29) from Gujarat and three (HF-71, HF-102 and HF-104) from Haryana. Diallel crosses, excluding reciprocals, were made during *rabi* 2001–02 in an isolation block and the progenies were evaluated during *rabi* 2002–03 at the Research Farm, SKN College of Agriculture, Jobner (Rajasthan). The 66 F_1s (made by diallel crossing excluding reciprocals) along with 12 parents were evaluated in a randomized block design with 3 replications. Each F_1 and parent was sown in a plot of size 4.0 m x

0.9 m accommodating two rows spaced at 45 cm apart. Plant to plant distance of 20 cm was maintained by thinning. Non-experimental rows were planted as border rows in each bed to eliminate the border effect. All recommended cultural practices were followed for raising a good crop. The observations on various traits (Table 1) were recorded on a sample of 10 randomly selected plants except days to 50% flowering, which was recorded on whole plot basis. Volatile oil of seed (AOAC 1970), total soluble sugar content (Dubois *et al.* 1951) and crude fibre content (AOAC 1970) were estimated.

The data were analysed as per analysis II devised by Gardner & Eberhart (1966) to estimate the genetic effects. Singh (1978) and Ordas (1991) have provided details of necessary calculations such as variety effect (v_i), heterosis effect ($h_{ii'}$) (the $h_{ii'}$ effect is partitioned into three components, average heterosis ($\bar{h}$), variety heterosis (h_i) and specific heterosis ($s_{ii'}$) measures) and their expected performance based on v_i, $\bar{h}$ and h_i effects.

Both v_i and $h_{ii'}$ variances were significant for all the characters except test weight and days to 50% flowering, indicating the importance of both additive and non-additive gene effects. A further partitioning of heterosis variation revealed that variation was significant for all the characters except days to 50% flowering and biological yield plant^{-1}; h_i variation for all the characters, and $s_{ii'}$ variation for all the characters except days to 50% flowering (Table 1). More than 50% of the total sum of squares for heterosis of all the characters could be attributed to specific heterosis. Sum of squares due to $s_{ii'}$ effects for seed yield plant^{-1} was not only significant but also a major contributor (77.8%) to the total entries sum of squares. The results are in conformity with findings of Dashora *et al.* (2003) wherein non-additive gene effects were more important in controlling seed yield in fennel. Considering the average seed yield, $s_{ii'}$ and v_i effects, they ultimately selected two varieties to initiate inter-population improvement. None of the genetic constants was found significant for days to 50% flowering (Table 2). With regard to other characters, v_i was significant for all the characters except branches plant^{-1} and 1000-seed weight. h_i was observed to be significant for all the characters except 1000-seed weight, while $s_{ii'}$ exhibited significant differences for all the characters. This further supports the conclusion regarding the presence of complex type of inheritance.

Table 1. Per cent contribution of average, varietal and specific combining ability to heterosis sum of squares in fennel

Character	Heterosis sum of squares as % of entry sum of squares	% heterosis sum of squares accounted for by		
		Average	Variety	SCA
Days to 50% flowering	75.710*	0.027*	44.540	55.426*
Plant height up to main umbel (cm)	93.628	11.800	27.760	60.439
Total plant height (cm)	85.965	8.584	31.505	59.910
Branches plant^{-1}	97.299	19.098	29.651	51.248
Umbels plant^{-1}	87.568	4.884	14.699	80.416
Umbellets umbel^{-1}	83.428	12.647	29.374	57.981
Seeds umbel^{-1}	91.008	3.369	31.594	65.037
1000-seed weight (g)	92.069	16.280	10.701	73.019
Seed yield plant^{-1} (g)	95.151	9.056	13.101	77.842
Biological yield plant^{-1} (g)	88.559	0.011*	28.765	71.224
Harvest Index (%)	93.284	8.589	20.802	70.609
Volatile oil content (%)	89.726	4.570	27.507	68.182
Crude fibre content (%)	87.891	4.189	30.480	65.329
Total soluble sugar content (%)	89.757	1.529	31.081	67.076

*Mean squares are not significant at 5% level
SCA=Specific combining ability

Table 2. Varieties and crosses showing significant desirable components and magnitude of heterosis in fennel

Character	Variety effect (v_i)	Variety heterosis (h_i)	Specific heterosis ($s_{ii'}$)
Days to 50% flowering	-	-	-
Plant height up to main umbel (cm)	RF-125* (-9.764)	UF-133* (-5.979) Local* (-5.692) HF-71* (-4.589)	UF(M)-1x RF-101** (-15.238) UF-133 x HF-104** (-11.297) RF-125 x JF-25** (-10.560) RF-125 x UF-134** (10.087) UF(M)-1 x UF-133** (-9.684)
Total plant height (cm)	RF-125* (-11.739)	UF-134* (-7.008) UF-133* (-5.625)	RF-125 x HF-102** (-10.788) UF(M)-1x UF-133** (-10.504) HF-71 x HF-102* (-8.850) UF-133 x UF-134* (-8.621) UF-90 x Local* (-8.294)
Branches plant^{-1}	-	RF-125* (0.744)	UF-133 x HF-71** (1.567) UF(M)-1 x UF-90** (1.377) RF-101 x JF-29* (1.081) UF-133 x HF-102* (1.064) UF-134 x HF-102* (0.921)
Umbels plant^{-1}	RF-101** (14.153) UF-133** (10.486) RF-125** (9.986)	HF-102* (4.419 UF(M)-1* (4.043) Local* (3.666)	JF-25 x HF-71** (17.565) RF-101 x JF-25** (17.148) RF-125 x UF-90** (13.842) RF-101 x HF-104** (13.721) UF(M)-1 x HF-102** (13.568)
Umbellets umbel^{-1}	UF-133** (4.208)	RF-101** (2.401) Local* (1.614) JF-25* (1.554)	UF(M)-1 x UF-90** (5.637) UF(M)-1 x UF-134** (4.217) RF-101 x UF-133* (2.417) UF-133 x UF-134* (2.267) RF-125 x HF-104* (2.080)
Seeds umbel^{-1}	HF-104* (40.147) RF-125* (36.381) RF-101* (32.814)	UF-90** (31.940)	UF(M)-1 x UF-90** (91.292) RF-125 x HF-102** (57.695) UF-90 x HF-71** (49.401) UF-134 x HF-104** (37.138) JF-25 x HF-71** (33.815)
1000-seed weight (g)	-	-	UF-90 x HF-102** (1.615) JF-25 x Local** (1.098) UF-134 x JF-29* (0.950)
Seed yield plant^{-1} (g)	RF-101* (2.081)	UF(M)-1* (1.101)	RF-101 x JF-25** (5.089) RF-101 x HF-104** (4.736) JF-25 x HF-71** (4.722) RF-125 x UF-133** (4.249) UF(M)-1 x HF-102** (3.979)
Biological yield plant^{-1} (g)	UF-134** (14.653) UF-133* (7.153)	JF-25** (6.265) RF-125** (5.282)	UF-90 x HF-102** (20.606) UF-134 x HF-102** (16.539) RF-125 x UF-133** (11.989) RF-125 x JF-29** (11.323) RF-101 x JF-25** (10.039)

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Table 2. Continued from previous page

Character	Variety effect (v_i)	Variety heterosis (h_i)	Specific heterosis ($s_{ii'}$)
Harvest index (%)	RF-101* (4.998) RF-125* (4.418)	UF-134** (5.180) UF-90** (3.305)	RF-101 x HF-104** (11.308) JF-25 x HF-71** (8.545) UF-134 x Local** (7.914) RF-125 x UF-90** (6.755) HF-102 x HF-104** (6.069)
Volatile oil content (%)	RF-125* (0.539)	Local* (0.338)	UF(M)-1 x UF-134** (0.771) UF-90 x UF-133** (0.567) UF-134 x JF-29** (0.524) UF-90 x HF-102* (0.467) JF-25 x Local* (0.431)
Crude fibre content (%)	RF-125** (-5.055)	Local** (3.591) UF(M)-1**(-1.795) JF-29* (-1.652)	UF-90 x UF-133** (-4.906) UF-134 x JF-29** (-4.050) UF(M)-1 x UF-134** (-3.946) UF-90 x HF-102** (-3.780) JF-25 x HF-102** (-3.103)
Total soluble sugar content (%)	UF-134* (0.306) HF-102* (0.218)	JF-25* (0.161) UF-90* (0.152) HF-71* (0.124)	UF-90 x UF-134** (0.611) JF-25 x HF-104** (0.380) RF-125 x Local** (0.312) RF-125 x UF-133** (0.300) JF-25 x Local** (0.265)

* Significant at 5% level; ** Significant at 1% level

The results on $s_{ii'}$ effects for seed yield plant^{-1} indicated that 20 crosses showed positive significant effect; among these, 5 were RF-101 x JF-25, RF-101 x HF-104, JF-25 x HF-71, RF-125 x UF-133 and UF(M)-1 x HF-102. RF-101 x JF-25 also showed second highest $s_{ii'}$ effect for umbels plant^{-1} and fifth highest for biological yield plant^{-1}. RF-101 x HF-104 showed the highest $s_{ii'}$ effect for harvest index and fourth highest for umbels plant^{-1}. JF-25 x HF-71 showed the highest $s_{ii'}$ effect for umbels plant^{-1} as well as harvest index and fifth highest for seeds umbel^{-1}. RF-125 x UF-133 showed third highest $s_{ii'}$ effect for biological yield plant^{-1} and fourth highest for total soluble sugar content. UF(M)-1 x HF-102 showed fifth highest $s_{ii'}$ effect for umbels plant^{-1}.

The parent RF-101 had the highest (2.081) and Local the lowest (-3.153) v_i effect while the parent UF(M)-1 had the highest (1.101) and JF-29 the lowest (-1.859) h_i effect, for seed yield plant^{-1}. RF-101 involved in the cross RF-101 x JF-25 and RF-101 x HF-104 showed high v_i effects for umbels plant^{-1}, seeds umbel^{-1} and harvest index including seed yield plant^{-1}. RF-101 also showed the highest h_i effect for umbellets umbel^{-1} while JF-25 had the highest h_i effect for biological yield plant^{-1} and total soluble sugar content. HF-104 showed highest v_i effect for seeds umbel^{-1}. RF-101 x JF-25 gave the highest mean seed yield plant^{-1} (21.233 g) which was about 37% higher than the best yield among parent varieties i.e. RF-101 (15.500 g).

The parent variety UF(M)-1 involved in the cross UF(M)-1 x HF-102 showed the highest h_i effect for seed yield plant^{-1} and second highest h_i effect for umbels plant^{-1}, while HF-102 exhibited the highest h_i effect for umbels plant^{-1}. UF(M)-1 x HF-102 also gave second best seed yield plant^{-1} (21.033 g) which was about 54.3% higher than the better parent yield (14.6 g in HF-104). The cross exhibited highest heterobeltiosis for seed yield plant^{-1} and high heterobeltiosis for the traits umbels plant^{-1} and harvest index.

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