RESEARCH ARTICLE

EXPLOITATION OF HETEROSIS FOR SEED YIELD AND QUALITY TRAITS IN CROSSES OF FENNEL (*FOENICULUM VULGARE* MILL.)

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Abstract: Sixty six hybrids of fennel (*Foeniculum vulgare* Mill.) resulting from crossing of twelve open pollinated varieties (RF-125, UF(M)-1, UF-90, RF-101, UF-133, UF-134 and Local from Rajasthan; JF-25 and JF-29 from Gujarat; HF-71, HF-102 and HF-104 from Haryana) in diallel design excluding reciprocals were evaluated in randomized block design at research farm of S.K.N. College of Agriculture, Jobner (Rajasthan) for seed yield and quality. Heterosis was estimated over mid parent and better parent. Heterosis over mid parent and better parent (Heterobeltiosis) ranged from -25.63 to 61.89 per cent and –25.97 to 54.28 per cent for seed yield per plant; -27.54 to 50.85 per cent and -30.00 to 45.90 per cent for volatile oil content; -45.76 to 49.65 and -43.95 to 64.09 per cent for crude fibre content; -39.61 to 75.74 per cent and –41.91 to 71.79 per cent for total soluble sugars content. The desirable cross combinations, UF-134 x Local and UF-90 x HF-102 were identified which showed higher magnitude of heterosis for seed yield and volatile oil content.

Keywords: Diallel design, Fennel, Heterosis, Seed yield, Quality

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill.), belongs to family Apiaceae. It is a diploid species with chromosome number, 2n=22 and native of Europe and Mediterranean region Agarwal *et al.* (2001). India is the largest seed spices producer, consumer and exporter in the world. Fennel is an important seed spice crop, mainly grown in the states of Gujrat and Rajasthan and to some extent in other states covering a total; area of about 0.753 lakh ha with annual production of approximately 1.28 lakh tonnes in 2019-2020. Based on its medical value and export potential as spices the importance of fennel was recognized long back yet remained neglected for long from scientific attention towards improvement in its productivity as well as quality.

With the change in life style, the value added form of seed spices has become the thrust area. The main constraints for the production of value added products are lack of sufficient number of improved varieties having high volatile oil, low crude fibre, high soluble sugars and high seed yield. Manifestation of heterosis breeding was reported in fennel by Dashora (2000), Singh (2000) and Dashora *et al.* (2003). However these studies were restricted to the seed yield and quality traits. The objectives of this investigation were to determine the magnitude of the heterosis over mid (average heterosis) and better parents (heterobeltiosis) for grain yield and quality traits in crosses obtained from twelve fennel genotypes.

MATERIALS AND METHODS

Sixty six hybrids of fennel resulting from crossing of twelve open pollinated varieties in diallel design excluding reciprocals along with their twelve parents were evaluated in a randomized block design with three replications at the research farm, S.K.N. College of Agriculture, Jobner (Rajasthan). Each entry was grown in two rows of 4.0 m in length. The spacing was maintained 45 cm between rows and 20 cm between plants. Observations were recorded on a sample of ten randomly selected plants for seed yield per plant, volatile oil content, crude fibre content and total soluble sugar content. For quality analysis of seeds; volatile oil content was estimated by essential oil distillation assembly (A.O.A.C., 1970), the total soluble sugar content was determined by colorimetric method of Dubois *et al.* (1951) using anthrone reagent while crude fibre content was determined by the method of crude fibre determination (A.O.A.C., 1970) in fat free material. Heterosis was estimated over mid-parent (relative heterosis) and better-parent (heterobeltiosis) as per the procedure suggested by Fonesca and patterson (1968).

RESULTS AND DISCUSSION

The analysis of variance revealed significant differences among parents and F_1 hybrids for all the characters. Per cent heterosis over mid-parent and better-parent were estimated to know the possible gene action as well as to exploit heterosis for seed yield and quality attributes. The magnitude of heterosis manifested over mid-parent and better-parent estimated for seed yield and quality attributes of the present study are presented in Table 1. Literature reveals that for increasing export of fennel and to fetch high prices, it is essential that besides other quality standards the produce should have high volatile oil contest, high soluble sugars content and lower crude fibre content. Hence positive heterosis

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for volatile oil, total soluble sugar content and seed yield and negative heterosis for crude fibre content is desired to exploit heterosis for high seed yield with better quality.

Volatile oil content: The magnitude of heterosis over mid-parent ranged from -27.54 (UF-90 x JF-25) to 50.85 per cent (UF-134 x JF-29). Twenty two of the sixty six hybrids exhibited positive significant heterosis over mid-parent. The magnitude of heterosis over better-parent varied from -30.00 (RF-125 x JF-29) to 45.90 per cent (UF-134 x JF-29). Significant positive heterosis was observed in 14 hybrids. Significant negative heterosis was observed for eight hybrids over mid-parent and fifteen hybrids over better-parent. Thus for volatile oil content cross UF-134 x JF-29 exhibited highest heterosis over both the mid-parent as well as better-parent.

Total soluble sugars content: The heterosis over mid-parent and better-parent ranged from -39.61 to 75.74 per cent and -41.91 to 71.79 per cent respectively. Positive significant heterosis over mid-parent and better-parent was observed for twenty and fourteen hybrids respectively. The cross JF-25 x HF-104 recorded highest significant positive thus most desirable heterosis over better-parent (71.79%) as well as mid-parent (75.74%).

Crude fibre content: Mid-parent heterosis ranged from -45.76 (UF(M)-1 x UF-134) to 49.65 per cent (UF-90 x JF-25). Fifteen crosses exhibited significant positive and thirty four crosses significant negative heterosis over mid-parent. Heterosis over better-parent, calculated by considering a parent having lower crude fibre content as better-parent, varied from -43.95 (UF(M)-1 x UF-134) to 64.09 per cent (RF-125 x JF-29). Out of sixty six crosses, a total of twenty two crosses exhibited significant positive and twenty four significant negative heterobeltiosis.

Seed yield per plant: Forty hybrids had desired significant positive heterosis over mid-parent. The cross UF-134 x Local recorded highest positive heterosis (61.89%) over mid-parent followed by UF(M)-1 x HF-102 (58.34%). Mid-parent heterosis ranged between -25.63 and 61.89 per cent, whereas range of heterobeltiosis was also of similar magnitude with minimum limit of -25.97 (JF-29 x HF-104) and maximum limit of 54.28 per cent ((UF (M)-1 x HF-104). A total of thirty three crosses exhibited significant positive and fourteen crosses significant negative heterobeltiosis.

Maximum desirable heterosis over mid-parent was observed for total soluble sugar content (75.74%) followed by seed yield per plant (61.89%), volatile oil content (50.85%) and crude fibre content (-45.76%). Similar trend of heterosis over better parent was observed for TSS content (71.79%), followed by seed yield/ plant (54.28%), volatile oil content (45.90%) and crude fibre content (-43.95%).

Fifty per cent of the hybrids exhibited significant heterosis over mid-parent for all the traits studied indicating the importance of both additive and non additive gene action for these traits. Better parent heterosis indicated over dominance for higher levels of volatile oil, soluble sugars and seed yield. The very low and mostly negative heterosis for some characters may be due to the presence of large epistatic gene effects or due to the incomplete dominant gene effects.

Table 1. Per cent heterosis in fennel over mid parent (MP) and over better parent (BP)

Crosses	Volatile oil content		Crude fibre content		Soluble sugar content		Seed yield per plant	
	MP	BP	MP	BP	MP	BP	MP	BP
RF-125 x UF(M)-1	-2.90	-16.25**	4.82	38.07**	-18.24**	-27.63**	32.23**	28.28**
RF-125 x UF-90	-14.67**	-20.00**	27.22**	45.54**	8.93	1.15	50.31**	38.39**
RF-125 x RF-101	1.47	-13.75*	-0.61	31.41**	5.41	2.25	-7.78*	-10.75*
RF-125 x UF-133	-17.81**	-25.00**	36.53**	61.48**	29.17**	24.95**	43.41**	42.92**
RF-125 x UF-134	-9.22	-20.00**	18.52**	50.05**	-20.59**	-32.05**	10.34*	-0.69
RF-125 x JF-25	-12.16*	-18.75**	33.12**	51.94**	43.34**	38.48**	-9.59*	-12.18**
RF-125 x JF-29	-18.25**	-30.00**	25.25**	64.09**	-0.66	-3.72	22.30**	22.30**
RF-125 x HF-71	-9.59	-17.50**	17.40**	38.79**	5.61	3.02	11.03**	5.29
RF-125 x HF-102	-12.50*	-21.25**	17.83**	45.45**	-2.21	-13.89*	-11.30**	-16.09**
RF-125 x HF-104	-11.72*	-20.00**	18.26**	47.16**	-6.07	-7.19	10.76**	10.25*
RF-125 x LOCAL	3.70	-12.50*	-6.76	29.16**	49.08**	42.23**	7.67	-8.05
UF(M)-1 x UF-90	10.94	1.43	-11.30**	0.63	14.76*	-4.74	27.48**	20.78**
UF(M)-1 x RF-101	24.56**	22.41**	-20.72**	-20.48**	-23.44**	-30.36**	14.65**	7.24
UF(M)-1 x UF-133	3.23	-3.03	-2.37	7.25	-9.64	-17.59**	12.40**	8.68

UF(M)-1 x UF-134	47.90**	44.26**	-45.76**	-43.95**	-39.61**	-41.91**	37.91**	27.63**
UF(M)-1 x JF-25	9.52	1.47	-11.57**	0.56	-2.01	-15.82*	17.70**	17.56**
UF(M)-1 x JF-29	6.09	5.17	-5.59	-5.17	-3.40	-12.05	-6.16	-8.97
UF(M)-1 x HF-71	30.65**	22.73**	-33.25**	-26.65**	14.51*	-0.80	17.65**	14.91**
UF(M)-1 x HF-102	0.00	-4.69	-0.81	4.78	-8.90	-9.44	58.34**	54.28**
UF(M)-1 x HF-104	13.82*	7.69	-17.69**	-13.66**	4.26	-8.67	-3.77	-7.06
UF(M)-1 x LOCAL	45.13**	41.38**	-40.52	-38.05**	-4.22	-11.49	50.63**	32.03**
UF-90 x RF-101	6.35	-4.29	-7.12	5.73	9.66	-0.98	27.56**	13.98**
UF-90 x UF-133	23.53**	20.00**	-28.49**	-26.35**	5.63	-4.87	1.49	-6.85
UF-90 x UF-134	8.40	1.43	-11.52**	-3.14	59.26**	28.19**	33.33**	30.05**
UF-90 x JF-25	-27.54**	-28.57**	49.65**	49.96**	11.54	7.05	0.00	-5.37
UF-90 x JF-29	-7.09	-15.71*	6.53	20.27**	23.32**	11.25	23.35**	13.56**
UF-90 x HF-71	1.47	-1.43	-3.90	-1.05	30.10**	23.68**	19.31**	15.64**
UF-90 x HF-102	20.90**	15.71*	-26.54**	-21.38**	15.66*	-4.44	43.24**	39.18**
UF-90 x HF-104	0.74	-2.86	-1.91	5.73	32.08**	24.04**	-9.32*	-16.86**
UF-90 x LOCAL	5.60	-5.71	-11.48**	5.10	15.55*	2.75	27.30**	17.21**
RF-101 x UF-133	19.67**	10.61	-19.50**	-11.27	-7.20	-7.47	-0.33	-3.23
RF-101 x UF-134	31.62**	26.23**	-28.86**	-26.24**	-13.43*	-23.96**	-9.23*	-20.65**
RF-101 x JF-25	-9.68	-17.65**	12.42**	28.28**	4.18	-2.25	45.60**	36.99**
RF-101 x JF-29	18.58**	17.54*	-15.41**	-14.78**	-11.56	-11.64	9.33*	5.81
RF-101 x HF-71	9.84	1.52	-8.05*	1.39	-6.21	-11.18	-7.84*	-15.27**
RF-101 x HF-102	-3.33	-9.37	4.54	10.78*	-29.04**	-35.79**	29.66**	18.92**
RF-101 x HF-104	-7.44	-13.85	9.91**	15.66**	3.07	-1.18	30.97**	27.31**
RF-101 x LOCAL	15.32*	14.29	-14.81**	-11.55**	5.88	4.07	4.53	-13.12**
UF-133 x UF-134	-8.66	-12.12	13.14**	20.04**	-0.93	-12.76*	4.33	-6.39
UF-133 x JF-25	1.49	0.00	4.21	7.58	9.17	2.14	25.00**	21.00**
UF-133 x JF-29	18.70**	10.61	-21.01**	-13.65**	-12.89	-13.06	14.55**	14.16**
UF-133 x HF-71	4.55	4.55	-7.42	-7.39	-6.60	-11.79	20.05**	13.47**
UF-133 x HF-102	-10.77	-12.12	15.34**	19.71**	-10.76	-19.05**	17.68**	10.96*
UF-133 x HF-104	-14.50*	-15.15*	22.23**	27.75**	-15.39*	-19.10*	-3.08	-3.19
UF-133 x LOCAL	30.58**	19.70**	-32.72**	-22.74**	2.59	1.14	35.12**	15.07**
UF-134 x JF-25	-8.53	-13.24	14.87**	26.04**	-26.05**	-38.50**	2.64	-5.12
UF-134 x JF-29	50.85**	45.90**	-43.84**	-42.22**	-16.46**	-26.56**	7.28	-3.45
UF-134 x HF-71	-5.51	-9.09	5.66	12.14*	4.78	-12.17*	46.61**	38.72**
UF-134 x HF-102	4.00	1.56	-3.24	-1.16	-6.37	-9.42	37.23**	30.15**
UF-134 x HF-104	11.11	7.69	-15.08**	-13.85**	-7.09	-21.29**	14.10**	2.28
UF-134 x LOCAL	29.31**	22.95**	-34.59**	-29.49**	-21.63**	-30.12**	61.89**	52.59**
JF-25 x JF-29	12.00	2.94	-11.88**	-0.28	11.17	4.21	-15.98**	-18.39**
JF-25 x HF-71	5.97	4.41	-5.13	-2.11	63.46**	61.84**	50.25**	46.59**
JF-25 x HF-102	15.15*	11.76	-19.40**	-13.54*	-0.46	-14.92*	3.26	0.49

JF-25 x HF-104	8.27	5.88	-15.56**	-8.77	75.74**	71.79**	-5.77	-8.88*
JF-25 x LOCAL	39.84**	26.47**	-37.74**	-25.89**	60.62**	48.30**	42.34**	24.63**
JF-29 x HF-71	36.59**	27.27**	-35.04**	-28.96**	25.54**	18.79*	-21.45**	-25.52**
JF-29 x HF-102	15.70*	9.38	-17.13**	-12.87**	12.27*	1.67	-11.06**	-15.86**
JF-29 x HF-104	11.48	4.62	-14.01**	-10.22*	30.64**	25.15**	-25.63**	-25.97**
JF-29 x LOCAL	46.43**	43.86**	-40.11**	-37.33**	27.72**	25.66**	38.90**	18.62**
HF-71 x HF-102	4.62	3.03	-9.78*	-6.33	2.95	-11.27	38.56**	38.21**
HF-71 x HF-104	-9.92	-10.61	7.44	12.34*	37.88**	36.11**	2.53	-3.19
HF-71 x LOCAL	10.74	1.52	-12.95**	0.00	31.00**	22.06**	10.89*	-0.77
HF-102 x HF-104	10.08	9.23	-19.66**	-19.12**	7.29	-6.51	18.98**	12.07**
HF-102 x LOCAL	19.33**	10.94	-26.81**	-19.30**	1.30	-6.90	-5.17	-14.95**
HF-104 x LOCAL	15.00*	6.15	-22.40**	-15.05**	9.14	2.94	1.20	-13.90**

MP = Mid parent, BP= Better parent

For seed yield per plant and crude fibre content about 75 per cent hybrids exhibited significant heterosis over mid-parent indicating preponderance of non-additive gene action for these traits. This indicates that heterosis breeding can be effectively used for these two traits while developing commercial hybrids/composites with better quality traits. Approximately 45% hybrids exhibited significant heterosis over mid parent for Total Soluble Sugar and volatile oil content indicating preponderance of additive gene action for these two traits. This indicates that mass selection and/or reciprocal recurrent selection can be used.

The desirable cross combinations identified were UF-134 x Local and UF-90 x HF-102 showed higher magnitude of heterosis over better parent for seed yield per plant as well as volatile oil content and lower magnitude for crude fibre content which is desirable. These cross combinations could be used to produce biparental progenies to get superior segregants which may be handled through recurrent selection method of breeding for varietal improvement. As male sterile line are not available and flower size is very small in fennel, under such conditions ample progress can be expected if population improvement methods like mass selection, reciprocal recurrent selection and production of composites is used.

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