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Variability and character association in fennel (*Foeniculum vulgare* Mill.) germplasm

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Abstract

Extent of variability was assessed in 50 accessions of fennel using augmented design. The analysis of variance indicated that the accessions differed significantly for most of the characters. The genotypic coefficient of variation was high for umbels plant^{-1} (16.96%) followed by seed yield plant^{-1} (13.13%), plant height up to primary umbel (11.08%) and length of first internodes (10.71%) indicating that these characters have high to moderate amount of genetic variability. The estimates of heritability (broad sense) was high for plant height up to primary umbel (78.66%), plant height up to top of the plant (72.61%), length of first internodes (64.07%) and days to 50% flowering (51.24%). The genetic advance as percentage of mean were high for umbels plant^{-1} (22.75), plant height up to primary umbel (20.24), length of first internodes (17.66) and plant height up to top of the plant (16.43). On the basis of yield as well as other morphological characters the accessions namely JF-406, JF-533-2, NDF-45 and GK/RM/AK-7 were found superior as compared to checks.

Key words : Correlation, *foeniculum vulgare*, genetic advance, heritability, variability.

Introduction

Spices occupy an important place in the lives of peoples since Vedic and Bibilical times. They have been considered requisite in seasoning of foods, flavouring of beverages, perfumeries, cosmetics and medicines. The test and flavour of spices prompted explorers like Columbus and Vasco de Gamma to undertake dangerous sea journey to discover India "the land of spices" (Agrawal *et al*., 2001).

Fennel (*Foeniculum vulgare* Mill.) belonging to family Apiaceae. It is a cross pollinated crop and diploid species. It is having chromosome number, 2n = 22 and is native of Europe and Meditarrean region. Fennel is cultivated throughout the temperate and sub-tropical regions in the world mainly in the countries like, Romania, Russia, Hungary, Germany, France, Italy, India, Sri Lanka, Malaysia, Japan, Argentina and U.S.A. In India, it is mainly grown in the states of Gujarat, Rajasthan, Haryana and some extent in West Bengal and Uttar Pradesh. Total area under the crop in India is about 74660 hectares with production of 124610 tonnes. In Rajasthan, it occupies an area of 30720 hectares with an annual production of 35500 tonnes (Spice Board India, 2016-17).

Steam distillation of dried fruit yields, an essential oil referred as 'Fennel oil', used for flavouring purposes in the many parts of the world (Abdallah *et al.,* 1978; Lawrence, 1992). Fennel and its preparations are used to cure various disorders, and also act as a carminative, digestive and diuretic agent. Fennel increases elasticity of connective tissues and act as anti-aging agent (Arslan *et al.*, 1989). There are some commercial pharmaceuticals with formula based on fennel essential oil. The antimicrobial properties of the essential oil have been also recognized (Elagayyer *et al.*, 2001; Ruberto *et al.*, 2000). The essential oil from plants has usually been isolated by either steam distillation or solvent extraction (Sajid *et al.*, 2008).Information on extent of variation, estimates of heritability and expected genetic advance irrespective of yield and yield determining traits constitutes the basic requirement for a crop improvement programme that is lacking. Keeping in view above facts, the present investigation was aimed to evaluate variability, heritability and genetic advance of grain yield and its component characters fennel genotypes and correlation with yield contributed characters. Therefore this study was conducted and use of these traits for further breeding programme for improvement in fennel crop.

Materials and methods

The present study was carried out in *Rabi* season of 2012-13 at the Research Farm of National Research Centre on Seed Spices, Ajmer (26° 27' 0" N, 74° 38' -1" E and 460 meter above sea level altitude). The region falls under

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agro climatic zone III of Rajasthan. The soil of research farm is sandy loam, poor in fertility and water holding capacity, having pH 8 to 8.3, EC 0.07 to 0.12 and 0.15 to 0.23% organic carbon, available N 178.5 kg ha-^{1} (low), P_2O_5 12 kg ha^{-1} (medium), K_2O 85 kg ha^{-1} (low), Ca 214.7 kg ha^{-1} (high), Mg 258 kg ha^{-1} (medium), S 27 kg ha^{-1} (high). The study was carried out with 50 diverse genotypes from different geographic and genetic origin with five checks in Augmented Block Design. Plot size was kept 6 × 2, row to row spaced 50 cm apart. Plant spacing within rows was maintained 20 cm. The recommended package of practices was adopted for raising healthy crop. Five plants were randomly selected from each line and observations were recorded on plant height, primary branches, umbel plant^{-1}, umbellate umbel^{-1}, seeds umbellate^{-1}, test weight and yield (g). Data were analyzed through Indostate version 8.5 software.

Results and discussion

In the present investigation, augmented block design was used to evaluate the accession along checks. This design is ideal when the number of lines to be evaluated is more and seed supply is less. The analysis of variance revealed that significant amount of variability was present in the germplasm for all the characters studied (Table-1), this suggests that the material used in the study had adequate variability and response to selection may be expected in breeding programme for seed yield plant^{-1}. An appreciable portion of this variability was contributed by genotypic variance which is in agreement with earlier reports of Ramanujam and Joshi (1966), Bhargava *et al.,* (1971), Shukla *et al*., (2003), Lal (2007), Telci *et al.,* (2009), Meena *et al*., (2009) and Malik *et al*., (2009). The block (eliminating check + verities) effects were also significant for duration of complete anthesis, 1000-seed weight (g), expected other characters indicating the sensitivity of genotypes to the environment. These observations are similar to that observed by singh *et al.*, (2004). The check varieties showed significant difference for most the characters. It indicated that checks themselves were diverse.

Estimate of genotypic and phenotypic coefficient variance (GCV& PCV) indicated that in general phenotypic variance were higher than genotypic coefficient variances indicating the role of environmental factors on the characters expression. The variances of characters were compared on basis of coefficient of variation. The range and coefficient of variation indicated that the variability was high for seed yield plant^{-1}, umbel plant^{-1}, moderate for plant height up to primary umbel, 1000-seed weight (g), length of first internodes (cm), it was low for plant height up to top of the plant, seeds umbellates^{-1}, ubmbel plant^{-1}, days to 50% flowering duration of compete anthesis, primary branches plant^{-1}, secondary branches plant^{-1} (Table-2).

It indicated that simple selection for seed yield plant^{-1}, umbel plant^{-1}, umbellets umbel^{-1} and secondary branches plant^{-1}, might be advantageous as compared to other characters under study. Similar pattern of variability for different characters among accession have earlier been repoted by Bhargava *et al.,* (1971), Kathiria (1980), Agnihotry *et al.,* (1997), Shukla *et al*., (2003), Rajput *et al.*, (2004), Meena *et al*., (2009) and Singh *et al.,* (2009). With the help of PCV and GCV alone it is not possible to determine the amount of variation which is heritable. In the present investigation, broad sense heritability was observed to be high for plant height up to primary umbel (cm), plant height up to top of the plant (cm), length of first internodes (cm), days to 50% flowering and similar results were also obtained by Agnihotry *et al.,* (1997), Jain *et al*., (2002), Lal (2007), Singh and Choudhary (2008), Meena *et al*., (2010) and Yogi *et al*., (2013). Moderate heritability (30-60 per cent) was observed for secondary branches plant^{-1}, duration of complete anthesis, diameter of primary umbel (cm), umbels plant^{-1}, primary branches plant^{-1}. Which is in agreement with earlier report of Kathiria (1980), Bhandari and Gupta (1991) in coriander. Low heritability was observed seed yield plant^{-1}, 1000-seed weight, umbellets umbel^{-1}, seeds umbellets^{-1}.

Genetic advance as percentage of mean for the characters ranged from 2.43 % (days to 50%flowering) to 22.75 % (umbels plant^{-1}). High magnitude of genetic advance as percentage of mean was estimated for umbels plant^{-1}, plant height up to primary umbel (cm), length of first inter nodes, which is in agreement with earlier reports of Mathur *et al.,* (1971) in coriander, Agnihotri (1990), Agnihotri *et al.,* (1997) and Meena *et al.* (2010). Modrate genetic advance as percentage of mean was observed for plant height up to top of the plant (cm), secondary branches plant^{-1}, seed yield plant^{-1} (g), diameter of primary umbel, umbellets umbel^{-1}, which is in agreement with earlier reports of Ramanujam *et al.,* (1964), Kathiria (1980), Bandari and Gupta (1991) and Singh *et al.,* (2004). Low genetic advance as percentage of mean was observed for 1000-seed weight (g), seeds umbellets^{-1}, primary umbel plant^{-1}, duration of complete anthesis, days to 50% flowering. These results are in accordance with the early reports of Jain and Dubey (1972) in coriander, Bandari and Gupta (1991).

The plant height up to primary umbel (cm), length of first internodes (cm), plant height up to top of the plant (cm) had higher magnitude of heritability and genetic advance as percentage of mean.

Table 1. Analysis of variance for different characters

Sources of Variation	Df	days to 50% flowering	length of first inter nodes	primary branches plant^{-1}	diameter of primary umbel	duration of complete anthesis	secondary branches plant^{-1}	umbels plant^{-1}	umbellets umbel^{-1}	seeds umbellets^{-1}	plant height up to primary umbel (cm)	plant height up to top of the plant (cm)	1000-seed weight (g)	Seed yield per plant (g)
Block (ignoring Treatments)	4	38.953**	2.704**	0.926	14.658**	24.540**	9.514	59.596	18.191	12.481*	784.195**	1134.654**	1.025	6.071
Treatment (eliminating Blocks)	54	5.415	1.086**	0.524	2.653	0.612	9.055*	79.695	14.231	6.687	187.249**	172.638**	0.641	84.482**
Checks	4	18.040**	2.420**	0.726	0.582	0.742	20.539**	38.698	11.880	10.606	211.184**	180.493*	1.024	388.425**
Checks + Var vs.	50	4.405	0.979**	0.508	2.818	0.602	8.136	82.974	14.419	6.373	185.334**	172.009**	0.611	60.167**
Error	16	2.890	0.308	0.334	2.037	1.149	3.847	41.131	10.414	3.813	35.273	52.286	0.383	17.701
Block (eliminating check + Var)	4	4.740	0.528	0.246	5.628	6.878**	4.691	49.044	4.696	9.014	98.896	80.336	1.481*	3.231
Entries (ignoring blocks)	54	7.950	1.247**	0.575	3.321	1.920	9.412*	80.476	15.230	6.944	238.012**	250.698**	0.608	84.692**
Checks	4	18.040**	2.420**	0.726	0.582	0.742	20.539**	38.698	11.880	10.606	211.184**	180.493*	1.024	388.425**
Varieties	49	7.228*	1.091**	0.567	3.608	2.056	8.256*	84.431	15.814	5.754	221.042**	250.320**	0.548	21.726
Checks vs. Varieties	1	2.940	4.205**	0.336	0.231	0.007	21.584*	53.820	0.054	50.576**	1176.840**	550.084**	1.855*	1955.104**
Error	16	2.890	0.308	0.334	2.037	1.149	3.847	41.131	10.414	3.813	35.273	52.286	0.383	17.701

Table 2. Overall mean value of genotypes, their range, genotypic and phenotypic coefficient of variation, heritability in broad sense, and genetic advance as percent of mean for different characters in fennel.

Characters	Mean	Range	Genotypic coefficient of variation(GCV) %	Phenotypic coefficient of variation (PCV)	Heritability in broad sense (%)	Genetic Advance % of mean
Days to 50% flowering	105.58	100.96-110.16	1.65	2.30	51.24	2.43
Length of first inter nodes	6.91	4.70 - 9.55	10.71	13.38	64.07	17.66
primary branches per plant	7.410	6.03 – 8.99	5.45	9.51	32.89	6.44
Diameter of primary umbel (cm)	14.68	10.22 – 19.43	7.14	12.05	35.07	8.71
Duration of complete anthesis	13.61	10.80 -15.40	5.84	9.80	35.58	7.18
secondary branches per plant	17.95	9.16 – 25.18	9.78	14.66	44.52	13.44
Umbels per plant	32.45	13.64 – 63.74	16.96	26.04	42.43	22.75
Umbellets per umbel	22.51	15.86 – 36.34	8.63	16.73	26.63	9.17
Seeds per umbellets	23.66	18.05 – 28.97	4.92	9.60	26.28	5.20
Plant height up to primary umbel (cm)	102.90	74.92 – 137.10	11.08	12.49	78.66	20.24
Plant height up to top of the plant (cm)	125.25	101.11 – 162.55	9.36	10.98	72.61	16.43
1000-seed weight (g)	5.86	4.02 – 8.97	5.80	12.03	23.26	5.76
Seed yield per plant (g)	12.77	5.16 – 32.23	13.13	35.44	13.73	10.02

Table 3. Correlation coefficient on the basis of genotypic level and phenotypic level between different characters of fennel

Characters	P/G	Length of first inter nodes	primary branches plant^{-1}	Diameter of primary umbel	Duration of complete anthesis	secondary branches plant^{-1}	Umbels plant^{-1}	Umbellets umbel^{-1}	Fruits umbellets^{-1}	Plant height up to primary umbel (cm)	Plant height up to top of the plant (cm)	1000-seed weight (g)	Seed yield plant^{-1} (g)
Days to 50% flowering	G	-0.358**	0.055	0.0755	0.2936*	0.338**	-0.175	-0.17	0.1825	0.1843	0.294*	0.0324	-0.053
	P	-0.44**	0.1346	0.2814*	0.5982**	0.358**	-0.11	-0.0591	0.041	0.317*	0.44**	0.018	-0.041
Length of first inter nodes	G	1	-0.031	-0.372**	-0.186	-0.22	-0.075	0.0608	-0.241*	0.1249	-0.054	-0.092	-0.151
	P	1	-0.0737	-0.384**	-0.3231*	-0.246*	-0.044	-0.0299	-0.064	-0.103	-0.236*	-0.155	-0.189
primary branches per plant	G		1	0.0635	0.0527	-0.03	0.333**	0.31*	0.0637	0.0777	0.217	-0.191	0.0867
	P		1	0.1604	0.0862	0.018	0.2824*	0.3655**	0.093	0.177	0.255*	-0.129	0.048
Diameter of primary umbel	G			1	0.2817*	0.173	0.267*	0.0248	0.0894	0.144	0.344**	0.0394	0.173
	P			1	0.135	0.127	0.1257	0.1542	-0.008	0.308*	0.429**	-0.058	0.173
Duration of complete anthesis	G				1	0.599**	0.251*	0.0523	0.0835	0.4492**	0.525**	0.1018	-0.083
	P				1	0.375**	0.0234	-0.0163	-0.159	0.233*	0.347**	0.009	-0.09
secondary branches per plant	G					1	0.338**	0.0638	-0.081	0.4458**	0.484**	0.2195	0.0358
	P					1	0.3364**	0.1636	-0.2	0.386**	0.414**	0.122	0.125
Umbels per plant	G						1	0.1508	-0.37**	0.0422	0.129	-0.111	0.1985
	P						1	0.1683	-0.48**	0.053	0.043	-0.102	0.179

Characters	P/G	length of first inter nodes	primary branches plant^{-1}	diameter of primary umbel	duration of complete anthesis	secondary branches plant^{-1}	umbels plant^{-1}	umbellets umbel^{-1}	fruits umbellets^{-1}	plant height up to primary umbel (cm)	plant height up to top (cm)	1000-seed weight (g)	seed yield plant^{-1} (g)
Umbellets per umbel	G							1	0.0985	0.2931*	0.275*	-0.01	0.0098
	P							1	0.185	0.382**	0.366**	-0.076	-0.015
seeds per umbellets	G								1	0.172	0.237*	-0.038	-0.137
	P								1	0.229	0.183	-0.039	-0.106
Plant height up to primary umbel (cm)	G									1	0.862**	-0.006	-0.336**
	P									1	0.907**	-0.246*	-0.327*
Plant height up to top of the plant (cm)	G										1	-0.119	-0.257*
	P										1	-0.174	-0.261*
1000-seed weight (g)	G											1	0.0874
	P											1	0.223
Seed yield per plant (g)	G												1
	P												1

Genotypic and phenotypic correlations were worked out among different characters including seed yield. The phenotypic correlation coefficients were generally higher than the respectively genotypic correlation coefficients. Phenotypic correlation coefficient provides a measure of genetic association between characters and thus, help in identifying the traits which need to be considered for improvement of yield. Since, suitable test for significance of phenotypic correlations is not available so their main usefulness is in strengthening the interpretations based on genotypic correlations.

At genotypic level, seed yield per plant had significant negative correlation with plant height up to primary umbel (cm), plant height up to top of the plant (cm), where, it had non significant negative correlation with days to 50% flowering, length of first internodes, duration of complete anthesis, umbellets umbel^{-1}, seeds umbellets^{-1} and non significant positive correlation with 1000-seed weight (g), umbel plant^{-1}, secondary branches plant^{-1}, diameter of primary branches per plant (Table-3).

Plant height up to primary umbel (cm) had positive correlation plant height up to top of the plant (cm), plant height up to primary umbel (cm) with significant negative correlation, seed yield plant^{-1} , 1000-seed weight are in agreement with earlier reports of Jindla and Rang (1986), Agnihotry *et al.,* (1997) and Idhol *et al.,* (2009).

Primary branches plant^{-1} had significant positive correlation umbel plant^{-1}, umbellets umbel^{-1}, plant height up to top of the plant (cm), are in agreement with earlier reports of Kathiria (1980) and Singh *et al.* (2004). Days to 50% flowering had significant positive correlation with secondary branches plant^{-1}, plant height up to primary branches plant^{-1} (cm), are in agreement with earlier reports of Ali *et al*., (1993), Godara (1995) and Agnihotri *et al*. (1997).

Genotypic level of significant and positive correlation with secondary branches plant^{-1} with umbels plant^{-1}, plant height up to primary umbel (cm), plant height up to top of the plant which earlier reports of Singh *et al*.(2009). The association of seeds per umbel with plant height up to top of the plant had significant and positive.

It is also noticed that character which exhibited negative association with seed yield plants^{-1} have also exhibited negative association among themselves. Thus, these characters could be simultaneously improved to increase the seed yield. On the basis of yield as well as other morphological characters the accessions namely JF-406, JF-533-2, NDF-45 and GK/RM/AK-7 were found superior as compared to checks.

References

Abdullah, N., El-Gengaihi, S., Sedrak, E. 1978. The effect of fertilizer treatments on yield of seed and volatile oil of fennel (*Foeniculum vulgare* Mill.), *Die Pharmazie*. 33: 607-608.

Agarwal, A. K., Hatfield, J., Kemery, E., Valenti, S. and Esnault, L. 2001.Web-based education: Changing the equilibrium in managing information technology in a global economy. Proceedings of the IRMA International Conference, May 20-23, 2001, Idea Group Publishing: Hershey London Melbourne Singapore, Toronto, p: 1197.

Agnihotri, P. 1990. Genetic divergence in the germplasm of fennel. M.Sc. (Ag.) Thesis, Rajasthan Agriculture University, Bikaner, Campus-Jobner (Rajasthan)

Agnihotri, P., Dashora, S. L. and Sharma, R. K. 1997. Variability, correlation and path Analysis in fennel (*Foeniculum vulgare* Mill). *Journal of Spicesand Aromatic Crops*,6 (1):51-53.

Ali, S. S., Mishra, A. K., Yadav, L. N. and Maurya, K. N. 1993. Variability and correlation studies in coriander. *International Journal of Tropical Agriculture*, 11 (1):40-42.

Arslan, N., Bayrak, A., Akgul, A. 1989. The yield and component of essential oil in fennel of different origin (*Foeniculum vulgare* Mill).

Bhandari, M. M. and Gupta, A. 1991. Variation and association analysis in coriander. *Euphytica*, 58 (1): 1-4.

Bhargava, P. D., Mathur, S. C., Vyas, H. K. and Anwar, M. 1971. Note on screening on fennel varieties. *Indian Journal of Agricultural Sciences*, 42 (2):18-21.

Elagayyar, M., Draughon, F. A. and Golden, D. A. 2001. Antimicrobial activity of essential oil from plants against selected pathogenic and saprophytic microorganisms, *Journal Food Prot*. 64: 1019-1024.

Godara, B. R. 1995. Assessment of variability and path analysis in coriander (*Coriandrum sativum* L.) germplasm. M. Sc. (Ag) Thesis, Rajasthan Agriculture University, Bikaner, Campus- Jobner.

Idhol, B. D., Desai, R. T., Khandelwal, V. and Ghodke, U. R. 2009. Genetic variability Character association and path analysis studies in coriander (*Coriandurm sativum* L.*)*. Published in national workshop on "Spices and Aromatic Plants in 21st century India`` held at S.K.N. Collage of Agriculture, Jobner (Rajasthan) Pp.52.

Jain, K. K. and Dubey, C. S. 1972. Study of yield attributes and heritability in some varieties of coriander (*coriandrum sativum* L.). *Madras Agriculture Journal*, 69: 193-95.

Jain, U. K., Singh, D. and Jain, S. K. 2002. Assessment of genetic variability in coriander. Annals of plant and soil Research, 4 (2): 329-330.

Jindla, L. N. and Allah, Rang 1986. Variability and association analysis in fennel. *Research and Development Reporter*. 3(1):50-54.

Kathiria, K. B. 1980. Variability and correlation in a selected and unselected bulk of fennel. M.Sc. (Ag.) Thesis, University of Udaipur, Campus- Jobner (Rajasthan).

Lal, R. K. 2007. Association among agronomic traits and path analysis in fennel (*Foeniculam vulgare* Mill.) *Journal of Genetic and Plant Breeding*, 66 (1): 65-66.

Lawrence, B. M. 1992. Progress in essential oils. Perfume and Flavor 17: 44-46.

Malik, T. P., Tehlan, S. K. and Thakral, K. K. 2009. Performance of fennel genotypes for seed yield. Published in national workshop on "spices" and aromatic plants in 21st century India held at S.K.N. Collage of Agriculture, Jobner (Rajasthan), Pp. 62.

Mathur, S. C., Anwar, M. and Bhargava, P. D. 1971. Studies on splitting of phenotypic and genotypic complexes and their correlation in coriander *(coriandrum sativum* L.*). Rajasthan Journal of Agriculture Science*. 2: 63-71.

Meena, R. S., Kakani R. K., Anwer, M. M. and Panwar, A. 2010. Variability of some morphological characters in fennel (*Foeniculum vulgare* Mill.). *Indian Journal of Agricultural Sciences*. 80 (8): 710-712.

Meena, R. S., Anwar, M. M. and Kakani, R. K. 2009. Correlation and path analysis studies for yield improvement in fennel (*Foeniculum vulgare* Mill.). Published in National Workshop on "Spices and Aromatic Plant in 21st century India" held at S.K.N. Collage of Agriculture, Jobner (Rajasthan) PP. 44

Rajput, S. S., Singhania, D. L., Singh, D., Sharma, K. C. and Rathore, V.S. 2004. Assessment of genetic variability in fennel (*Foeniculum vulgare* Mill). Published in national seminar on new perspective in commercial cultivation, Processing and Marketing of Seed Spices and Medicinal Plant held at S.K.N. Collage of Agriculture, Jobner (Rajasthan), Pp.10

Ramanujam, S. and Joshi, B. S. 1966. Recent work on essential oil bearing plants. *Journal of Post Graduate School,* IARI, 4: 146-157.

Ramanujam, S., and Joshi, B. S. and Saxena, M. B. L. 1964. Extent and randomness of cross pollination in some umbelliferous spices of India. *Indian Journal of Genetics and Plant Breeding*, 24: 62-67.

Ruberto, G., Baratta, M. T., Deans, S. G., Dorman, H.J. 2000. Antioxidant and antimicrobial activity of *Foeniculum vulgare* and *Crithmummaritimum* essential oils, Plant. Med. 66 8: 687-693.

Sajid, M., Ohran, I., Ahsan, Z., Arslan, S. and Gulfraz, M. 2008. Fatty acid composition of Sorghum bicolor varieties, Food Chem. 109: 855-859.

Shukla, Sudhir, Singh, P.K., Garg, V.K., Shukla, S. 2003. Study on genetic variability and heritability in fennel grown on sodic soils. National Botanical Research Institute, Lucknow. *Journal of Medicinal and Aromatic Plant Sciences*. 25 (4): 956-958.

Singh, D. and Choudhary, S. P. 2008. Evaluation of ajwain (*Trachyspermum ammi* L.) genotypes suitable for semi arid regions. *Journal of Spices and Aromatic Crop*, 17 (2): 167-171.

Singh, D., Pareek, B. and Sastry, E. D. V. 2009. Quality character analysis in half-sib[1], full-sib and S1 progenies of fennel (*Foeniculum vulgare* Mill.). Published in National Workshop on "Spices and Aromatic Plants in 21st century India" held at S.K.N. collage of Agriculture, Jobner (Rajasthan), pp. 46-47.

Singh, V. V., Singhania, D. L., Sastry, E. V. D., Sharma, K. C. and Rajput, S. S. 2004. Character association in half sib and s_1 progenies of fennel. Published in national seminar on new perspective in commercial cultivation, processing and marketing of seed spices and medicinal plants held at National Research Center on Seed Spices, Tabiji Ajmer (Raj.)

Spices Board India. 2016-2017.

Telci, L., Demirtas, L. and Sahin, A. 2009. Variation in plant properties and essential oil composition of sweet fennel (*Foeniculum vulgare* Mill.) fruit during stages of maturity.*Industrial Crops and Products*, 30 (1):126-130.

Yogi, R., Meena, R. S., Kakani, R. K. Panwar, A.and Solanki, R. K. 2013. Variability of some morphological characters in fennel (*Foeniculam vulgare* Mill.) *International Journal of Seed Spices*, 3 (1): 41- 43

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