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Yield, Quality and Economics of *Rabi* Fennel (*Foeniculum vulgare* Mill.) as Influenced by Different Time of Sowing, Variety and Spacing

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A B S T R A C T

A field experiment was conducted during *rabi* season of 2015-16 at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar to study the effect of sowing time, variety and spacing on yield, quality and economics of *rabi* fennel (*Foeniculum vulgare* Mill.). Eighteen treatment combinations comprising of three sowing times *i.e.*, 3rd week of October (D_1), 1st week of November (D_2) and 3rd week of November (D_3), three varieties *viz.*, Gujarat Fennel 2 (V_1), Gujarat Fennel 11 (V_2) and Gujarat Fennel 12 (V_3) and two spacings *i.e.*, 45 (S_1) cm and 60 cm (S_2) were evaluated in split plot design with four replications by keeping time of sowing as main plot and combination of variety and spacing in sub plot. The results revealed that crop sown in 3rd week of October (D_1) recorded significantly superior growth, yield, quality attributes as well as economics. While, variety GF 12 (V_3) noticed higher values of growth, yield, quality attributes and economics. Similarly, superior growth parameters, yield and quality attributing characters and economics were registered with 45 cm (S_1) row spacing as compared to wider row spacing *i.e.* 60 cm (S_2). The test weight was not remarkably influenced by different spacing but marked effect of different times of sowing and varieties was recorded. This study revealed that higher growth, yield, quality attributing characters and economics can be achieved by sowing the fennel variety GF 12 during 3rd week of October at 45 cm row spacing under North Gujarat Agro-climatic condition

Introduction

Fennel (*Foeniculum vulgare* Mill.) commonly known as variyali or saunf is native of Mediterranean countries and belonging to the family of Apiaceae. India is the world's largest producer, consumer and exporter of seed spices that's why India is known as home of spices. Gujarat and Rajasthan together contribute more than 80 per cent of the total seed spices production in the country and thus, both the states together are known

as "Seed Spices Bowl" of India. Gujarat alone account for more than 90 per cent of the fennel production in the country. The area, production and productivity of fennel in India during 2014-15 were 54,000 hectares, 70,000 metric tonnes and 1296 kg ha^{-1}, respectively (Anon, 2015[a]).

Gujarat produced 63,845 tonnes from 30,200 ha area with average productivity of 2114 kg ha^{-1} (Anon, 2015[b]). Gujarat ranks first in average productivity not only in India, but at international level also. India earned Rs. 132 crores through export of fennel during 2015, which was 599 per cent higher than 2001 (Anon, 2015[c]).

Fennel seeds have a fragrant odour and a pleasent aromatic taste. They are widely used in various food preparation, candies, soups, sauces, pastries, pickles, liquors, bakery items *etc*. The leaves and seeds are digestive used for cough, flatulence, colic, thirst, constipation, dysentery and diarrhoea (Randhawa *et al*., 1978). Fennel seeds contain 1.4 to 4.0 per cent essential volatile oil, pale yellow in colour. It also contains carbohydrate 7.29 g, dietary fibre 3.1 g, protein 1.24 g, fat 0.20 g, potassium 414 mg, phosphorus 50 mg and calcium 49 mg per 100 g value. The main constituents of fennel oil are anethole and fenchone.

Time of sowing is an important factor to decide growth and production. Adjustment in sowing time creates favourable environmental condition for better performance of all physiological processes in plant and for escaping from pest and diseases which provides great opportunity to maximize the production. Selection of superior variety having resistance to biotic and abiotic stresses plays an important role for enhancing the crop yield. Optimum plant geometry being non-monetary inputs exhibits dominant in increasing the yield of fennel crop.

A wider spacing increased photosynthetic area along with availability of more sunlight and minimize the competition within the crop plants for nutrient, air and water, but reduced plant population. Very meager information is available on optimum time of sowing, variety and spacing in fennel. Therefore, the investigation was conducted with an objective to find out suitable variety, optimum time of sowing and spacing for realizing higher growth and yield of *rabi* fennel.

Materials and Methods

A field experiment was conducted at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar during *rabi* season of 2015-16 to study the effect of sowing time, variety and spacing on yield, quality and economics of *rabi* fennel (*Foeniculum vulgare* Mill.). Eighteen treatment combinations comprising of three sowing times *i.e.*, 3rd week of October (D_1), 1st week of November (D_2) and 3rd week of November (D_3), three varieties *viz.*, Gujarat Fennel 2 (V_1), Gujarat Fennel 11 (V_2) and Gujarat Fennel 12 (V_3) and two spacings *i.e.*, 45 (S_1) cm and 60 cm (S_2) were evaluated in split plot design with four replications by keeping time of sowing as main plot and combination of variety and spacing as sub plots.

Geographically, Sardarkrushinagar is situated at 24°/19' North latitude and 72°/19' East longitude with an elevation of 154.52 meters above mean sea level. The climate type of this area is sub-tropical. The soil of experimental plot was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus and potash content (Table 1). EC (0.09 dS m^{-1}) was very low showing that the soil was free from salinity hazard. The crop was fertilized with recommended dose of fertilizer *i.e.* 90 kg N and 30 kg P_2O_5 per hectare. As per

treatments, the required quantity of seeds of fennel varieties *viz*., GF 2, GF 11 and GF 12 were taken by keeping uniform seed rate of 5 kg per hectare. To save the crop from disease *viz*., Rumularia blight and pest *viz.*, Aphid during the life cycle of crop, adequate and timely plant protection measures were taken by spraying recommended fungicide, *i.e*. Dithane-M-45 (0.2 %) and pesticide *i.e.* Dimethoate (0.03 %) in the field. The five plants were selected from each plot for recording various growths and yield attributes. The harvesting of rows of net plot was done manually. The net plot wise yield was recorded and converted in kg per hectare. The statistical analysis of data for each characters studied in the experiment was carried out as per design of the experiment.

Table.1 Chemical properties of experimental field

Chemical properties				
(a)	Soil pH (1 : 2.5, Soil : Water ratio)	7.0	7.4	**Potentiometric method (Jackson, 1973)**
(b)	Electrical Conductivity (dS/m)	0.09	0.10	**Schofield method (Jackson, 1973)**
(c)	Organic carbon (%)	0.17	0.15	**Walkley and Black's method (Jackson, 1973)**
(d)	Available N (kg/ha)	159	147	**Alkaline Potassium Permanganate method (Jackson, 1973)**
(e)	Available P_2O_5 (kg/ha)	39	36	**Olsen's method (Olsen *et al.*, 1954)**
(f)	**Available K_2O (kg/ha)**	**274**	**271**	**Flame Photometer method (Jackson, 1973)**

Estimation of quality attributes

Protein content (%)

The estimation of nitrogen in seed was done by adopting the micro Kjeldahl's method as described by Jackson (1967). Protein content calculated by using following formula (Bhuiya and Chaudhary, 1974).

Protein content (%) =
Nitrogen content (%) × 6.25

Volatile oil content (%)

The volatile oil content was determined in percentage by steam distillation method (AOAC, 1970). The volume of oil so obtained was converted into percentage by using following formula.

$$\text{Volatile oil (\%) (v/w)} = \frac{\text{Vol. of oil (ml)}}{\text{Wt. of sample}} \times 100$$

Volatile oil yield (kg ha^{-1})

Volatile oil yield (kg ha^{-1}) was calculated for different treatments by using the following formula.

$$\text{Volatile oil yield (kg ha-1)} = \frac{\text{Volatile oil content in seed (\%)} \times \text{seed yield (kg ha-1)}}{100}$$

Results and Discussion

Effect of time of sowing

Data exhibited in Table 2 and 3 inferred that significantly the higher plant height (155.68 cm), total number of branches per plant (18.28), test weight (8.00 g), seed yield (1423 kg ha^{-1}) and stover yield (4080 kg ha^{-1}), productivity per day (8.37 kg $ha^{-1}day^{-1}$), volatile oil content (1.59 %), volatile oil yield (24.20 kg ha^{-1}), protein content (13.96 %), gross realization (108728 ₹ha^{-1}), net realization (64065 ₹ ha^{-1}), net income per day (377 ₹ $ha^{-1}day^{-1}$) and BCR (2.43) (Fig. 1) were recorded under early sown crop *i.e* 3rd week of October (D_1) as compared to late sown *i.e.* 1st week of November (D_2) and 3rd week of November (D_3). Whereas, seed and stover yield, productivity per day and protein content were statistically at par with 1st week of November.

The maximum seed yield was recorded under early sown crop *i.e.* 3rd week of October (D_1) was 7.7 and 31.8 per cent over 1st week of November (D_2) and 3rd week of November (D_3), respectively. Favourable climatic condition throughout the growth period had increased seed yield and consequently net profit, net income per day and BCR.

Nitrogen supply seems to be involved in an increased conversion of primary fatty acids metabolites end product of fatty acids, which resulted in increased volatile oil content in seed and important role in synthesis of different amino acid, which constitutes building blocks of protein and that might have resulted in higher protein content. Whereas, Increased in temperature at maturity stage under late sown condition increased the loss of volatile oil through volatilization might have reduced the volatile oil content of seed. These findings are in accordance with the results of Ayub *et al.*, (2008), Bagari *et al.*, (2010), Selim *et al.*, (2013), Singh *et al.*, (2005) and Yadav *et al.*, (2000).

Effect of variety

The perusal of data presented in Table 2 and 3 revealed that the significantly higher plant height (153.16 cm), total number of branches per plant (18.10), test weight (8.01 g), seed yield (1411 kg ha^{-1}) and stover yield (4030 kg ha^{-1}), productivity per day (8.75 kg $ha^{-1}day^{-1}$), volatile oil content (1.53 %), volatile oil yield (24.22 kg ha^{-1}), protein content (14.52 %), gross realization (107853 ₹ ha^{-1}), net realization (63556 ₹ ha^{-1}), net income per day (393₹ $ha^{-1}day^{-1}$) and BCR (2.42) (Fig. 1) was recorded under variety GF 12 over GF 11 and GF 2.

Whereas, stover yield, productivity per day and volatile oil content were statistically at par with GF 11. Inherent characteristic and genetic potential of a particular variety plays a role in exploitation of higher yield, volatile oil and protein content and there by remuneration. Accordingly, GF 12 (V_3) expressed its superiority. Similar results were observed by Malik *et al.*, (2009), Meena and Singh (2013) and Sengupta *et al.*, (2014).

Effect of spacing

The data presented in Table 2 and 3 revealed that significantly the higher plant height (151.89 cm), total number of branches per plant (17.13), seed yield (1346 kg ha^{-1}) and stover yield (3914 kg ha^{-1}), productivity per day (8.34 kg $ha^{-1}day^{-1}$), volatile oil yield (21.67 kg ha^{-1}), gross realization (102883 ₹ ha^{-1}), net realization (58586 ₹ ha^{-1}), net income per day (362 ₹ $ha^{-1}day^{-1}$) and BCR (2.31) (Fig. 1) was recorded with 45 cm (S_1) row spacing as compared to wider row spacing *i.e.* 60 cm (S_2). Test weight, volatile oil and protein content of seed were not differed remarkably due to different spacings.

Table.2 Effect of sowing time, variety and spacing on growth, yield and quality parameters of *rabi* fennel

Treatments	Plant height (cm)	Total number of branches per plant	Test weight (g)	Yield (kg ha^{-1})		Productivity per day (kg ha^{-1}day^{-1})	Volatile oil content (%)	Volatile oil yield (kg ha^{-1})	Protein content (%)
				Seed	Stover				
Times of sowing (D)									
D_1:3rd week of October	155.68	18.28	8.00	1423	4080	8.37	1.59	24.20	13.96
D_2 :1st week of November	151.18	16.95	7.64	1321	3996	8.20	1.47	20.29	13.73
D_3 :3rd week of November	141.44	14.87	6.78	1079	3365	7.14	1.39	16.02	13.08
S.Em.±	3.11	0.16	0.16	33	105	0.21	0.02	0.46	0.14
C.D. at 5%	10.76	0.54	0.54	115	362	0.72	0.06	1.61	0.49
C.V. %	10.19	12.07	10.20	12.82	13.45	12.97	6.19	11.27	5.15
Varieties (V)									
V_1 : GF 2	146.09	15.64	6.94	1138	3552	7.06	1.44	16.20	12.89
V_2 : GF 11	149.05	16.38	7.46	1272	3860	7.90	1.48	20.09	13.36
V_3 : GF 12	153.16	18.10	8.01	1411	4030	8.75	1.53	24.22	14.52
S.Em.±	1.58	0.13	0.14	25	71	0.16	0.02	0.39	0.11
C.D. at 5 %	4.50	0.38	0.39	72.36	202	0.45	0.05	1.10	0.31
Spacings (S)									
S_1 : 45 cm	151.89	17.13	7.51	1346	3914	8.34	1.48	21.67	13.68
S_2 : 60 cm	146.99	16.28	7.44	1202	3713	7.47	1.48	18.67	13.50
S.Em.±	1.29	0.11	0.11	21	58	0.13	0.01	0.31	0.09
C.D. at 5%	3.67	0.31	NS	59.08	165	0.37	NS	0.90	NS
Sig. interaction	D × S	-	-	D × S	D × S	-	-	-	-
C.V. %	5.17	10.28	8.91	9.76	9.10	9.83	5.74	9.36	3.97

Table.3 Effect of sowing time, variety and spacing on economics of *rabi* fennel

Treatments	Gross realization (₹ ha^{-1})	Total cost of cultivation (₹ ha^{-1})	Net realization (₹ ha^{-1})	Net income per day (₹ ha^{-1}day^{-1})	BCR
Times of sowing (D)					
D_1 : 3rd week of October	108728	44663	64065	377	2.43
D_2 : 1st week of November	101049	44663	56386	351	2.25
D_3 : 3rd week of November	82596	43563	39032	259	1.89
S.Em.±	-	-	-	-	-
C.D. at 5%	-	-	-	-	-
C.V. %	-	-	-	-	-
Varieties (V)					
V_1 : GF 2	87164	44296	42867	265	1.96
V_2 : GF 11	97356	44296	53059	328	2.19
V_3: GF 12	107853	44296	63556	393	2.42
S.Em.±	-	-	-	-	-
C.D. at 5 %	-	-	-	-	-
Spacings (S)					
S_1 : 45 cm	102883	44296	58586	362	2.31
S_2 : 60 cm	92032	44296	47736	296	2.07
S.Em.±	-	-	-	-	-
C.D. at 5%	-	-	-	-	-
C.V. %	-	-	-	-	-

Table.4 Interaction effect of time of sowing and spacing (D x S)

Treatments	Plant height (cm)		Seed yield (kg ha^{-1})		Stover yield (kg ha^{-1})	
Spacings (S)	**S_1 : 45 cm**	**S_2 : 60 cm**	**S_1 : 45 cm**	**S_2 : 60 cm**	**S_1 : 45 cm**	**S_2 : 60 cm**
Times of sowing (D)						
D_1 : 3rd week of October	157.73	153.64	1549	1296	4318	3842
D_2 : 1st week of November	156.90	145.46	1377	1265	4085	3907
D_3 : 3rd week of November	141.03	141.86	1111	1046	3339	3390
S.Em.±	2.73		43.96		122.70	
C.D. at 5%	7.79		125		349.82	
C.V. %	5.17		9.76		9.10	

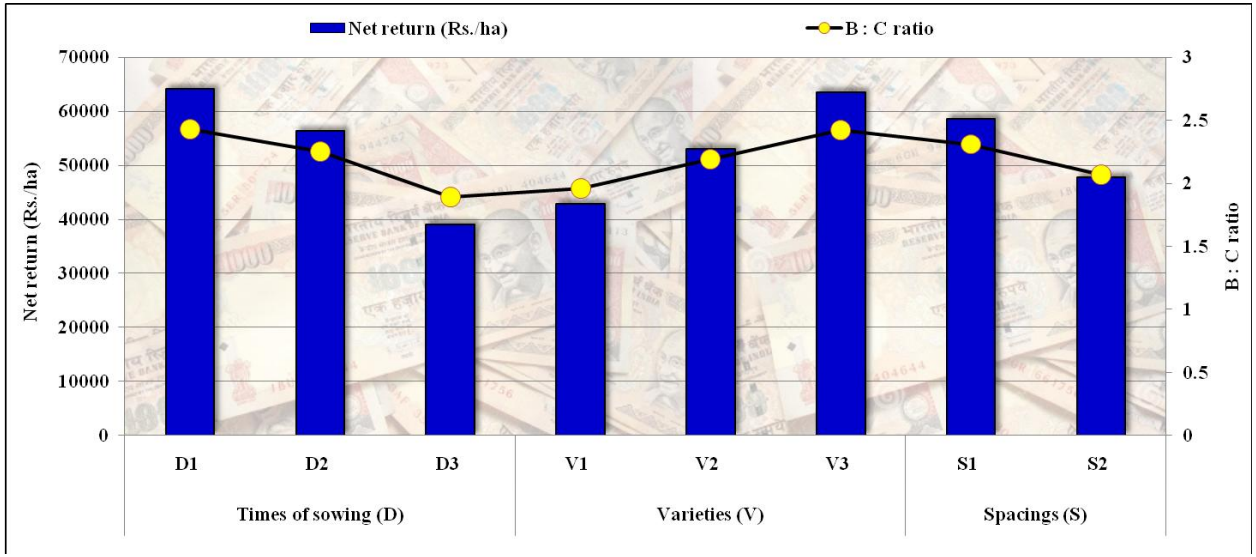

Fig.1 Economics of rabi fennel as influenced by times of sowing, varieties and row spacings

Optimum space available for individual plants *i.e.* 45 cm (S_1) and adequate plants per unit area might have resulted in better utilization of resources *viz.*, space, nutrients, moisture, carbon dioxide and radiant energy to improve vegetative growth consequently reproductive growth and ultimately increase in net profit, net income per day and BCR. These findings are corroborate with the results of Amin *et al.*, (2005), Singh *et al.*, (2009) and Yadav *et al.*, (2000).

Interaction effect of sowing time and spacing (D x S)

The data presented in Table 4 revealed that the significantly the highest plant height (157.73 cm), seed yield (1549 kg ha^{-1}) and stover yield (4318 (kg ha^{-1}) was recorded when crop sown in 3rd week of October at 45 cm row spacing (D_1S_1). Whereas in plant height at harvest was found statistically at par with treatment combinations of D_2S_1 and D_1S_2 but in stover yield it was found statistically at par with D_2S_1 only. The favourable climatic condition with availability of optimum space for individual plants and optimum plants per unit area increased seed and stover yield. These finding corroborated the results reported earlier by Ayub *et al.*, (2008), Selim *et al.*, (2013), Singh *et al.*, (2005) and Singh *et al.*, (2006).

On the basis of field experiment conducted at Sardarkrushinagar it is concluded that, higher yield and net profit can be achieved by sowing the fennel variety GF 12 during 3rd week of October at 45 cm row spacing under North Gujarat Agro-climatic condition.

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