Response of *Rabi*Fennel (*Foeniculum vulgare* Mill.) on Growth, Yield, Quality and Economicsunder different Time of sowing, Variety and Crop geometryunder Climate Change Era.

ABSTRACT

The present investigation was carried in *rabi* season of 2015-16 at Agronomy InstructionalFarm, S. D. Agricultural University, Sardarkrushinagar, Gujarat to examine the consequences of different time of sowing, varieties and spacing on *rabi* fennel.The experiment was laid out in spilt plot design with threesowing times(D_1:3rdweek of October, D_2:1stweek of Novemberand D_3:3rdweek of November)as main plot, threevarieties (V_1: GF-2, V_2: GF-11 and V_3: GF-12) and twospacings (S_1:45 cm and S_2:60 cm) insub plot with fourreplications. The results revealed that earlysown crop *i.e.*3rdweek of October recorded significantlyhigher growth and yield*viz,* plant height and total number of branches per,number of umbels per plant, number of umbellates per umbel, test weight and seed yield as well as productivity per day, quality attributes*viz.*,volatile oil content, volatile oil yield, protein content as well as economicsin term of gross realization, total cost of cultivation, net realization, net income per day and BCR. While, fennel variety GF-12 superior in terms of growth, yield, quality as well as economics parameters over a GF-2 and GF-11. Whereas, highergrowth, yield, quality attributing characters and economics were registered with45 cm row spacing as compared to over 60 cmbutspacing did not exhibit a significant influence on test weight, volatile oil content and protein content. The interactive between D_1 and S_1 was significantly superior as compared to rest of treatment combination.

Keywords: Growth, yield**,** qualityeconomics, fennel, time of sowing, variety, spacing.

INTRODUCTION

Fennel is native of Mediterranean countries and belonging to the family of Apiaceaeand commonly known as saunf. India is known as home of spices because India is the world's largest producer, consumer and exporter of seed spices.However, Gujarat and Rajasthan together contribute more than eighty percent of the total seed spices production of the country that's way both the states commonly known as "Seed Spices Bowl" of India.In 2022-23, India produces 137 thousand metric tonesfrom 82142 hectares area with the average productivity of 1672 kg/ha. (Anon, 2023[a]). Whereas, Gujarat alone account for more than ninety per cent of the fennel production in the country and produced 98272metric tones from 47549 ha area.Gujarat ranks first in average productivity not only in India, but at international level alsowith average productivity of 2066 kg/ha (Anon, 2023[b]). It is considered one of the most important commercial crops for export, and it isthe top-ranked export of herbs and spices from India, exported about 35 thousand tons of fennel worth of Rs 309 crore during theyear 2022-23.(Anon, 2023[c]).

Fennelis highly sought after throughout the worldfor use in cooking, various food preparation, candies, soups, sauces, pickles, liquors, bakery items *etc*. due to have a fragrant odour and a pleasant aromatic taste, long preservation timeas well as widely used as a medicine and cleaning due to its high content of vitamin C, fiber, andpotassiumwhereas, the leaves and seeds are digestive used for cough, flatulence, colic, thirst, constipation, dysentery and diarrhea (Randhawa *et al*., 1978).

The impact of climate change on agriculture poses a significantthreat globally, as it exacerbates both biotic and abiotic stresses that affect fennel production. Therefore, it is crucial to consider the effects of climate change and sowing time on crop production and modeling to improve growth, yield and quality of the crop. Identifying the optimal sowing timefor new varieties in each region is the most significant and controllable factor for maximizing cropyields (Zhang *et al*. 2023). The selection of an appropriate sowing time

iscrucial for optimizing plant growth stages and achieving maximum yield by utilizing naturalresources efficiently during the growing seasons (Safaei *et al*., 2017). Fennel thrives on a dry and cold weather,long sunny days as well as15-30°C is the optimum temperature favours higher seed production. Whereas,temperature above 25°C for extended period usually retards development of fennel and in early growth may result premature flowering and very low seed yield.By adjustment sowing time as per the crop requirementcreates favorable environmental condition for better performance of all morphological characters and physiological processes in plant and byescaping or avoiding from pest and diseases, which provides great opportunity to maximize the production in fennel.

In general, selectionof variety is an important adaptation strategy in crop production and one of many decisive actions that must be taken up to reliably produce stable yields in changing climate. So that selection of superior of fennel variety having resistance to biotic and abiotic stresses plays an important role in enhancing the growth, yield and quality. The optimum spacein any crop decided by its plant geometry.As per the morphology of fennel plant it requires optimum space to reduce the competition for moisture, space, sunlight and nutrient.A wider spacing increased photosynthetic area along with availability of more sunlight and minimize the competition within the crop plants, but number of plant per unit area. Whereas, closer spacing effect on yield and qualitydue competition within the crop plants for nutrient, air and water.So that, optimum plant geometry as per the crop geometry being non-monetary inputs exhibits dominant in increasing the yield of fennel crop. A study found that 45 cm row spacing resulted in 7.9% rise in umbels per plant and 4.0% rise in umbellates per umbel compared to 60 cm row spacing (Al-Dalain*et al*. 2012). AClimate change is inevitable, incessantly threatening the terrestrial ecosystem and global food security. Although the impacts of climate change on crop yield and the environment have received much attention in recent years, there are few studies on its implications for the

production of high-quality seeds that provide the basic input for food production.The objective of this study to determining the optimum sowing time is to identify the most favorable time for planting cultivars, where the prevailing environmental conditions are conducive to thegermination and vitality of the plants under North Gujaratagro-climatic condition.

MATERIALS AND METHODS

Site Specifications

The present field study was conducted at Agronomy InstructionalFarm of C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat during 2015-16.The site is located in North-east zone of Gujarat which comes under sub-tropical monsoon region having 24°/19' North latitude and 72°/19' East longitude with an elevation of 154.52 meters above mean sea level.

Weather

The weather condition of experiment conducted field is warm and moderately humid. Winter is fairly cold and dry while summer is quite hot and dry. The December and January are the coldest months of winter season with 12.2°C average temperature. Whereas, May is the hottest month of the year with 40.8°C average temperature.The south-west monsoon commences by the middle of June and retreats by the middle of September. The annual average rainfall is about 620.9 mm with about 27 rainy days.

Sampling and analyses

Before the commencement of experiment,collection of soil samples randomly from different spots at a depth of 0-15 and 15-30 cm. The composite soil sample for each depth was prepared and analysed for physical and chemical properties of soil. After the soil analysis in laboratory,it shows that the pH of the experimental soil was neutral in nature (7.4) having electrical conductivity of 0.10 ds/m(Rechard, 1954). The determination of organic carbonby

Walkely and Black (1947),available nitrogenby Subbaiah and Asija (1956), available phosphorus by Olsen *et al*. (1954)and available potassium by Jackson, 1973and it indicated that soil content was 0.17 %, 159 kg/ha, 39 kg/ha and 271 kg/ha oforganic carbon, available nitrogen, available phosphorus and available potassium, respectively.

Experimental setup

The experiment was laid out in spilt plot design with threesowing times (D_1:3rdweek of October, D_2:1stweek of Novemberand D_3: 3rdweek of November)as main plot, threevarieties (V_1: Gujarat Fennel-2, V_2: Gujarat Fennel-11 and V_3: Gujarat Fennel-12) and twospacings (S_1: 45 cm and S_2: 60 cm) insub plot in *rabi* season at Agronomy InstructionalFarm, S. D. Agricultural University, Sardarkrushinagar during 2015-16in split plot design having eighteen treatment combinations with fourreplications. The experimental field was prepared as per the requirement of field and crop by ploughing, harrowing and planking were done with help of tractor to obtain a good tilth. As per plan of experimental design, the bunds and field channels were prepared and levelled the plots with the help of labours. The fennel was fertilized with recommended dose of fertilizer (90: 30: 30 NPK Kg/ha). By keeping uniform seed rate of 4.5 kg per hectare,the required quantity of seeds of fennel varieties were taken for swing.Irrespective of treatments, thinning of extra plant was done 20 DAS by hand pulling to maintain the intra-row spacing of 15 cm. All the need based agronomic practices were carried out for the better crop growth and development. To save the crop from aphid and severedisease *viz.*, Rumularia blight during the life cycle of crop, adequate and timely plant protection measures were taken by spraying recommended pesticide (Dimethoate) and fungicide (Dithane-M-45) in the crop.

Observation recorded

For recording various growth and yield attributesfive plants were selected from each plot.

Estimation of protein content

The nitrogen in seed was estimated by adopting the micro Kjeldahl's (Jackson, 1967).For the calculation of protein content in seed by using following formula given by Bhuiya and Chaudhary, 1974.

$$\text{Protein content (\%)} = \text{Nitrogen content (\%)} \times 6.25$$

Estimation of volatile oil content

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

$$\text{Volatile oil (\%) (v/w)} = \frac{\text{Vol. of oil (ml)}}{\text{Wt. of sample}} x100$$

Estimation of volatile oil yield

By using given formula, the volatile oil yield (kg/ha) was calculated

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

Statistical analysis

The experimental data were statistically analyzed by the methods of analysis of variance (ANOVA) as described by Panse and Sukhatme (1985). The critical difference (CD) was worked out as described by Cochran and Cox (1957) and Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Impact of sowing time

The data shown in Table 1 and 2 that early sown crop *i.e.* 3rd week of October recorded significantly higher plant height (155.68 cm),total number of branches per (18.28), number of umbels(20.39) per plant and umbellates per umbel (19.78), test weight (8.00 g), seed yield (1423 kg/ha), productivity per day (8.37 kg/ha/day), quality attributes *viz.*, oil content (1.59 %), oil yield (24.20 kg/ha), protein content (13.96 %) as well as economics in term of

gross(108728 ₹/ha)and net (64065 ₹/ha)realization, total cost of cultivation (44663₹/ha), net income per day (377₹ ha/day)and BCR (2.43)as compared over D_2 and D_3. Whereas, seed yield, productivity per day and protein content were statistically at par with D_2. The maximum seed yield was recorded $D_1$was 7.7 and 31.8 per cent over D_2 and D_3, respectively.Favourable climatic condition throughout the crop season under early sown crop enhanced growth and yield attributing character. These are the important growth and yield components, which showed significantly positive correlation with seed yieldand consequently net profit, net income per day and BCR. The supply of seems to be involved in an increased conversion of primary fatty acids metabolites, 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 in seed. Delay sowing suppressed the initial vegetative growth and ultimately poor reproductive growth. Moreover, increase in temperature at latter stage brought forced for early maturity in late sown crop consequently reduced seed yieldvolatile oil content of seed. These results are with line of work reported by Singh *et al*. (2006), Bagari *et al*. (2010), Selim *et al.* (2013), Moosavi*et al.* (2014), Meena *et al*. (2015) Babaee*et al.* (2017), Shambhu*et al.* (2019), Sharma*et al.* (2019) and Singh*et al*. (2019).

Impact of variety

The significantly higher plant height (153.16cm), total number of branches per (18.10), number of umbels (20.42) per plant and umbellates per umbel (20.62), test weight (8.01g), seed yield (1411kg/ha), productivity per day (8.75kg/ha/day), quality attributes *viz.*, oil content (1.53%), oil yield (24.22kg/ha), protein content (14.52%) as well as economics in term of gross (107853₹/ha) and net (63556₹/ha)realization, total cost of cultivation (44296₹/ha), net income per day (393₹/ha/day)and BCR (2.42)were recorded under V_3over V_2 and V_1 (Table 1 and 2).Whereas, productivity per day and volatile oil content were

statistically at par with V_2. Accordingly, GF-12 expressed its superiority might be due to genetic potential, favourable of climatic conditions and optimum space available for exploitation of highergrowth, yield, volatile oil and protein content and there by remuneration. Similar results were in consonance with those of Malik *et al.* (2009), Singh *et al.* (2009), SDAU (2010), Meena and Singh (2013) and Sengupta *et al.* (2014).

Impact of spacing

Appreciable effect of different spacing on growth, yield and quality but did not exhibit a significant influence on test weight, volatile oil content and protein content. The significantly the higher plant height (151.89cm), total number of branches per (17.13), number of umbels (19.63)per plant and umbellates per umbel (19.09), seed yield (1346kg/ha), productivity per day (8.34kg/ha/day), quality attributes *viz.*, oil yield (21.67kg/ha)as well as economics in term of gross (102883₹/ha) and net (58586₹/ha)realization, total cost of cultivation (44296₹/ha), net income per day (362₹/ha/day)and BCR (2.31) were recorded under S_1overS_2 (Table 1 and 2). The optimum inter and intra row space available for individual plants and adequate plants per unit area as per the plant geometry might have resulted in better utilization of resourcesviz.,moisture, carbon dioxide,space, nutrients and radiant energy to improve vegetative growth in terms of higher plant height and total number of branches per, yieldin term of number of umbels and umbellates per umbel per plant and consequently increase in net profit, net income per day and BCR. These findings are in close proximity with Yadav *et al.* (2000), Amin *et al.* (2005), Singh *et al.* (2009),Shambhu*et al.* (2019), Choudhary*et al.* (2021)and Rajeshwari*etal*. (2022).

Interaction effect

Interaction effect between sowing time and spacing was showed its significance onplant height and seed yield (Table 3).Significantly the higherplant height and seed yield

was recorded when crop sown in 3rd week of October at row spacing of 45 cm. Whereas, plant height at harvest was found at par with treatment combinations of D_2S_1 and D_1S_2.

Conclusion

The impact of climate change on agriculture poses a significantthreat globally, as it exacerbates both biotic and abiotic stresses that affect fennel production.In order to produce more food and maintain the current pace of food production, the field experiment conducted at Sardarkrushinagar and it concluded that higher growth, yield, quality as well as net profit can be achieved by sowing the fennel at optimum time *i.e.*3rd week of October. As per adaptability to local climatic conditionsselection of suitable variety *i.e.*GF-12and optimum row spacing as per the plant geometry*i.e.*45 cm under North Gujarat Agro-climatic condition.

ACKNOWLEDGEMENT

The authors are highly obliged to Department of Agronomy, C. P. College of Agriculture, SardarkrushinagarDantiwada Agricultural University, Sardarkrushingar, Gujarat for valuable guidance and help during research programme.

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Table 1: Influence of time of sowing, variety and spacing on growth, yield and quality parameters of *rabi* fennel

Treatments	Plant height (cm)	Total number of branches per plant	Number of umbels per plant	Number of umbellates per umbel	Test weight (g)	Seed yield (kg/ha)	Productivity per day (kg/ha/day)	Volatile oil content (%)	Volatile oil yield (kg/ha)	Protein content (%)
Times of sowing (D)										
D_1: 3rd week of October	155.68	18.28	20.39	19.78	8.00	1423	8.37	1.59	24.20	13.96
D_2 : 1st week of November	151.18	16.95	18.81	18.71	7.64	1321	8.20	1.47	20.29	13.73
D_3 :3rd week of November	141.44	14.87	17.53	17.65	6.78	1079	7.14	1.39	16.02	13.08
S.Em.±	3.11	0.16	0.52	0.41	0.16	33	0.21	0.02	0.46	0.14
C.D. at 5%	10.76	0.54	1.80	1.43	0.54	115	0.72	0.06	1.61	0.49
Varieties (V)										
V_1 : GF 2	146.09	15.64	17.65	17.15	6.94	1138	7.06	1.44	16.20	12.89
V_2 : GF 11	149.05	16.38	18.66	18.37	7.46	1272	7.90	1.48	20.09	13.36
V_3 : GF 12	153.16	18.10	20.42	20.62	8.01	1411	8.75	1.53	24.22	14.52
S.Em.±	1.58	0.13	0.37	0.29	0.14	25	0.16	0.02	0.39	0.11
C.D. at 5 %	4.50	0.38	1.06	0.83	0.39	72.36	0.45	0.05	1.10	0.31
Spacings (S)										
S_1 : 45 cm	151.89	17.13	19.63	19.09	7.51	1346	8.34	1.48	21.67	13.68
S_2 : 60 cm	146.99	16.28	18.19	18.34	7.44	1202	7.47	1.48	18.67	13.50
S.Em.±	1.29	0.11	0.30	0.24	0.11	21	0.13	0.01	0.31	0.09
C.D. at 5%	3.67	0.31	0.87	0.68	NS	59.08	0.37	NS	0.90	NS

Table 2: Influence 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/day)	BCR
Times of sowing (D)					
D_1	108728	44663	64065	377	2.43
D_2	101049	44663	56386	351	2.25
D_3	82596	43563	39032	259	1.89
Varieties (V)					
V_1	87164	44296	42867	265	1.96
V_2	97356	44296	53059	328	2.19
V_3	107853	44296	63556	393	2.42
Spacings (S)					
S_1	102883	44296	58586	362	2.31
S_2	92032	44296	47736	296	2.07

Note: See Table 1 for treatment details.

Table 3: Interaction effect of time of sowing and spacing

Treatments	Plant height (cm)		Seed yield (kg/ha)	
Spacings (S)	**S_1**	**S_2**	**S_1**	**S_2**
Times of sowing (D)				
D_1	157.73	153.64	1549	1296
D_2	156.90	145.46	1377	1265
D_3	141.03	141.86	1111	1046
S.Em.±	2.73		43.96	
C.D. at 5%	7.79		125	

Note: See Table 1 for treatment details.

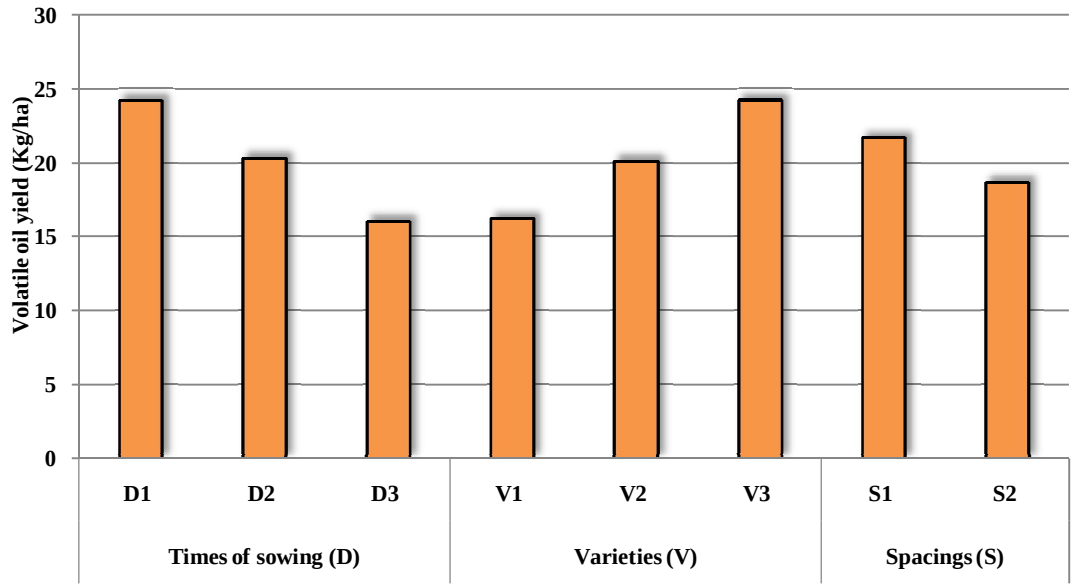

Fig. 1 : Effect of times of sowing, varieties and spacings on volatile oil yield of *rabi* fennel.

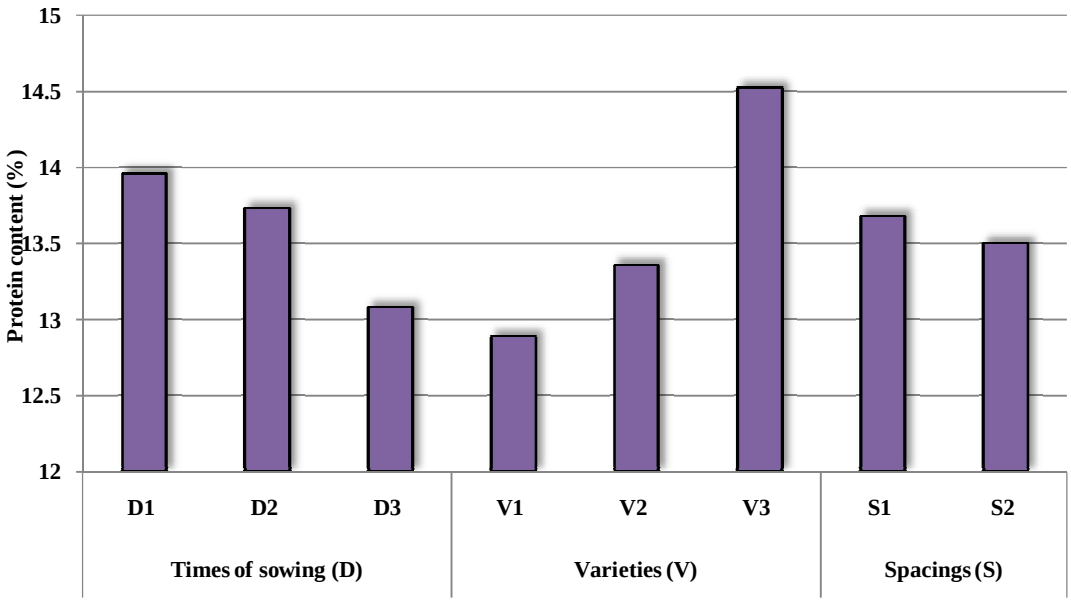

Fig. 2: Effect of times of sowing, varieties and spacings on protein content of *rabi* fennel.

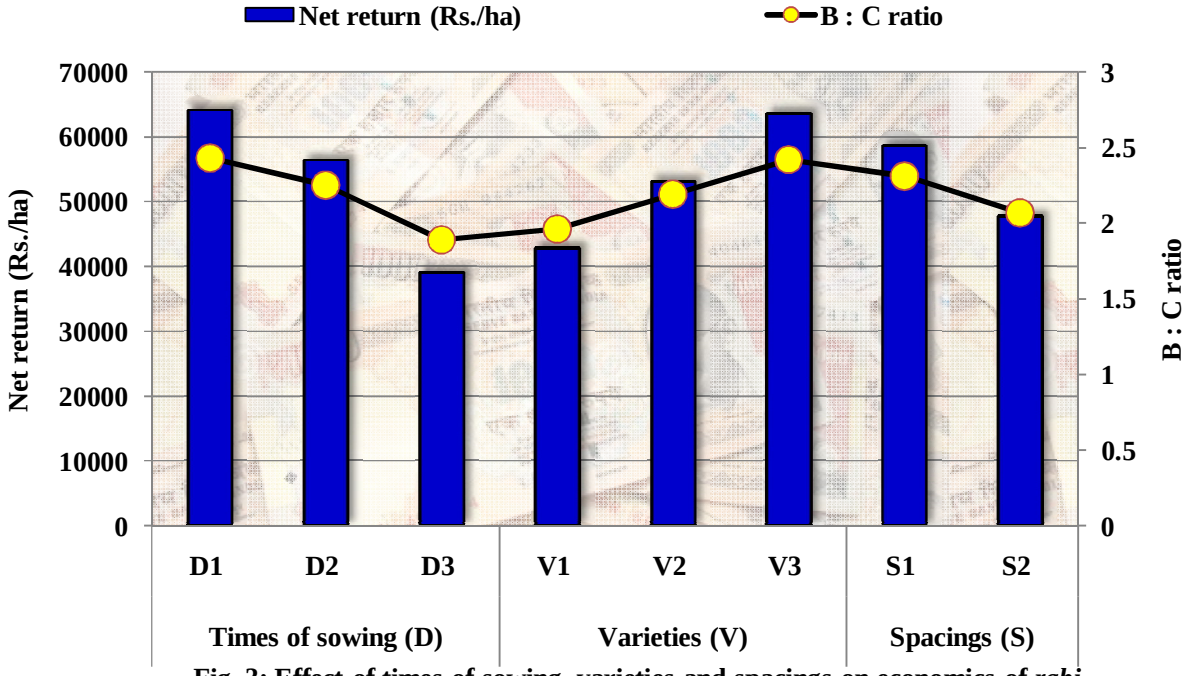

Fig. 3: Effect of times of sowing, varieties and spacings on economics of *rabi* fennel