



# Impact of Time of Sowing, Variety and Crop Geometry on Growth, Yield, Quality and Economics of *Rabi* Fennel (*Foeniculum vulgare* Mill.)

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## Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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## ABSTRACT

The field experiment was carried in *rabi* season of 2015-16 at Agronomy Instructional Farm, 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 three sowing times (D<sub>1</sub>:3<sup>rd</sup> week of October, D<sub>2</sub>:1<sup>st</sup> week of November and D<sub>3</sub>: 3<sup>rd</sup> week of November) as main plot, three varieties (V<sub>1</sub>: GF-2, V<sub>2</sub>: GF -11 and V<sub>3</sub>: GF-12) and two spacings (S<sub>1</sub>: 45 cm and S<sub>2</sub>: 60 cm) in sub plot with four replications. The results revealed that early sown crop *i.e.* 3<sup>rd</sup> week of October recorded significantly higher growth and yield *viz.* plant height and total number of branches and umbels per plant, number of umbellates per umbel, test weight and seed

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yield as well as productivity per day, quality attributes viz., volatile oil and protein content, volatile oil yield as well as economics in term of gross and net realization, net income per day and benefit cost ratio (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, fennel sown at optimum space of 45 cm recorded significantly higher growth, yield and economics as compared to over 60 cm, however spacing did not exhibit a significant influence on test weight, volatile oil and protein content. The interactive effect between 3<sup>rd</sup> week of October and 45 cm was significantly superior as compared to rest of treatment combination.

**Keywords:** Growth; yield; quality economics; fennel; time of sowing; variety; spacing.

## 1. INTRODUCTION

“Fennel is native to southern Europe and Asia minor and a perennial herb of carrot family ‘Apiaceae’ commonly grown for its seed, leaves and edible shoots and commonly known as saunf. India is known as home of spices because world’s largest producer, exporter and consumer of seed spices from India. However, Gujarat and Rajasthan contribute more than eighty percent of seed spices production of the country that’s way both the states commonly known as India’s “Seed Spices Bowl”. In 2022-23, India produces 137 thousand metric tones from 82142 hectare area with average productivity of 1672 kg/ha” (Anonymous 2023). “Whereas, more than ninety per cent of the fennel production comes from single state *i.e.* Gujarat. It produced 98272 metric tones of fennel from 47549 ha area with average productivity of 2066 kg/ha” (Anonymous 2023). “The average highest productivity of fennel recorded in Gujarat, which is ranks first not only in India, but at international level also. It is considered one of the most important commercial crops for export, and it is the top-ranked export of herbs and spices from India, exported about 35 thousand tons of fennel worth of Rs 309 crore during the year 2022-23” (Anonymous 2023).

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

The impact of climate change on agriculture poses a significant threat 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 time for new varieties in each region is the most significant and controllable factor for maximizing crop yields (Zhang et al., 2023). The selection of an appropriate sowing time is crucial for optimizing plant growth stages and achieving maximum yield by utilizing natural resources efficiently during the growing seasons (Safaei et al., 2017). Fennel thrives on a dry and cold weather, long sunny days as well as 15-30°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 requirement creates favorable conditions in terms of ecological and environmental for better performance of all morphological characters and physiological activities in plant and by avoiding from pest and diseases, which provides opportunity time to increase the fennel yield per unit area.

In general, selection of 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, selecting a superior fennel variety according to the soil and climatic conditions plays an important role in enhancing the growth, yield and quality. The optimum space in 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 allow higher photosynthetic area by availability of more sunlight and minimize the competition within the crop plants results in higher yield per plant, but decrease in number of plants per unit area and ultimately yield. Whereas, closer spacing effect on yield and

quality due competition within the crop plants for nutrient, air and water. So that, optimum plant geometry as per the crop geometry (non-monetary inputs) exhibits higher yield of fennel. 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). Climate change is inevitable so that terrestrial ecosystem and global food security is incessantly threatening. 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 the germination and vitality of the plants under North Gujarat agro-climatic condition.

## 2. MATERIALS AND METHODS

### 2.1 Site Specifications

The present field study was conducted at Agronomy Instructional Farm 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.

### 2.2 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.

### 2.3 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 (Richards 1954). The determination of organic carbon by Walkely and Black (1947), available nitrogen by Subbaiah and Asija (1956), available phosphorus by Olsen et al. (1954) and available potassium by Jackson, 1973 and it indicated that soil content was 0.17 %, 159 kg/ha, 39 kg/ha and 271 kg/ha of organic carbon, available nitrogen, available phosphorus and available potassium, respectively.

### 2.4 Experimental Setup

The experiment was laid out in split plot design with three sowing times (D<sub>1</sub>:3<sup>rd</sup> week of October, D<sub>2</sub>:1<sup>st</sup> week of November and D<sub>3</sub>: 3<sup>rd</sup> week of November) as main plot, three varieties (V<sub>1</sub>: Gujarat Fennel-2, V<sub>2</sub>: Gujarat Fennel-11 and V<sub>3</sub>: Gujarat Fennel-12) and two spacings (S<sub>1</sub>: 45 cm and S<sub>2</sub>: 60 cm) in sub plot in *rabi* season at Agronomy Instructional Farm, S. D. Agricultural University, Sardarkrushinagar during 2015-16 in split plot design having eighteen treatment combinations with four replications. 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. The aphid and severe disease *viz.*, *Rumularia* blight was observed 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.

### 2.5 Observation Recorded

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

### 2.6 Estimation of Protein Content

The nitrogen was estimated from seed by adopting the micro Kjeldahl's (Jackson 1973).

For the calculation of protein content in seed by using formula given by Bhuiya and Chaudhary (1974).

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

## 2.7 Estimation of Volatile Oil Content

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

$$\text{Volatile oil (\%)} = \frac{\text{Volume of oil (ml)}}{\text{Wight of seed sample}} \times 100$$

## 2.8 Estimation of Volatile Oil Yield

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

$$\text{Volatileoilyield(kg/ha)} = \frac{\text{Volatile oil content (\%)} \times \text{yield (kg/ha)}}{100}$$

## 2.9 Statistical Analysis

The experimental data *i.e.* critical difference (CD) analysis of variance (ANOVA) was worked out as described by Panse and Sukhatme (1985), Cochran and Cox (1957) and Gomez and Gomez (1985), respectively.

## 3. RESULTS AND DISCUSSION

### 3.1 Impact of Time of Sowing

The data shown in Tables 1 and 2 that early sown crop *i.e.* 3<sup>rd</sup> 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), 1000-seed weight (8.00 g), seed yield (1423 kg/ha), productivity per day (8.37 kg/ha/day), quality attributes *viz.*, oil (1.59 %) and protein (13.96 %) content, oil yield (24.20 kg/ha) as well as economics in term of gross (108728 ₹/ha) and net (64065 ₹/ha) realization, cost of cultivation (44663 ₹/ha), net income per day (377 ₹/ha/day) and benefit cost ratio of 2.43 as compared over late sowing *i.e.* 1<sup>st</sup> week of November and 3<sup>rd</sup> week of November. Whereas, seed yield, productivity per day and protein content were statistically at par with 1<sup>st</sup> week of November. The maximum seed yield was recorded in 3<sup>rd</sup> week of October was 7.7 and 31.8 per cent over late sowing *i.e.* 1<sup>st</sup> week of

November and 3<sup>rd</sup> week of November, 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 yield and consequently net profit. The conversion of primary fatty acids metabolites resulted in increased volatile oil content in seed and important role in synthesis of different amino acid (building blocks of protein) that might have resulted in higher protein content. Late sowing suppressed initial vegetative growth and ultimately poor reproductive growth and yield. Moreover, high temperature at reproductive stage brought forced for early maturity consequently reduced yield and 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).

### 3.2 Impact of Variety

Significantly tallest plant (153.16 cm), number of branches (18.10) and number umbels (20.42) per plant, umbellates per umbel (20.62), 1000-seed weight (8.01g), seed yield (1411 kg/ha), productivity per day (8.75 kg/ha/day), quality attributes *viz.*, oil (1.53 %), and protein (14.52 %) content, oil yield (24.22 kg/ha) 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 benefit cost ratio of 2.42 were recorded under GF-12 over GF-11 and GF-2 (Tables 1 and 2). However, productivity per day and volatile oil content were statistically at par with GF-11. The fennel variety GF-12 expressed its superiority might be due to genetic potential, favourable of soil and climatic conditions and optimum space available for exploitation of higher growth, yield, 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).

### 3.3 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. Significantly the tallest plant

(151.89 cm), total number of branches (17.13) and umbels (19.63) per plant, umbellates per umbel (19.09), seed yield (1346 kg/ha), productivity of 8.34 kg/ha/day, quality attributes viz., oil yield of 21.67 kg/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 benefit cost ratio of 2.31 were recorded under 45 cm over 60 cm (Tables 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 resources viz., moisture, carbon dioxide, space, nutrients and radiant energy to improve vegetative growth in terms of higher plant height and total number of branches per, yield in term of number of umbels and umbellates per umbel per plant and consequently increase net profit. These findings are in close proximity with Yadav et al. (2020), Amin et al. (2005), Singh et al. (2009), Shambhu et al. (2019), Choudhary et al. (2021) and Rajeshwari et al. (2022) Tamboli et al. (2020).

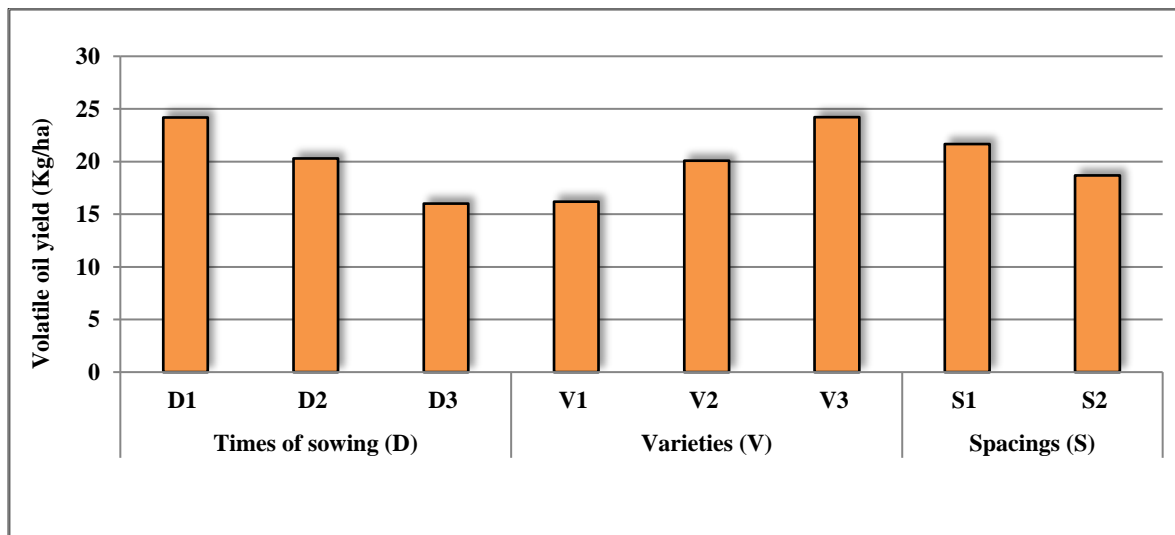


Fig. 1. Effect of times of sowing, varieties and spacings on volatile oil yield of *rabi* fennel

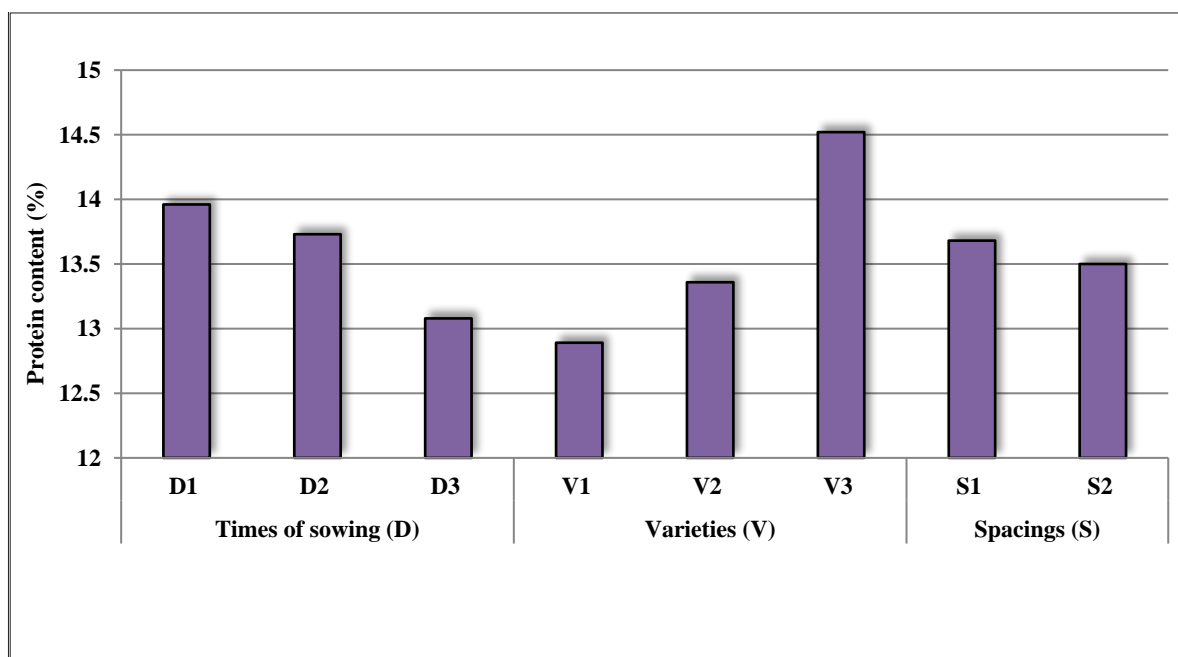


Fig. 2. Effect of times of sowing, varieties and spacings on protein content of *rabi* fennel

**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 (%)
<b>Times of sowing (D)</b>										
D <sub>1</sub> : 3 <sup>rd</sup> week of October	155.68	18.28	20.39	19.78	8.00	1423	8.37	1.59	24.20	13.96
D <sub>2</sub> : 1 <sup>st</sup> week of November	151.18	16.95	18.81	18.71	7.64	1321	8.20	1.47	20.29	13.73
D <sub>3</sub> : 3 <sup>rd</sup> 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
<b>Varieties (V)</b>										
V <sub>1</sub> : GF-2	146.09	15.64	17.65	17.15	6.94	1138	7.06	1.44	16.20	12.89
V <sub>2</sub> : GF-11	149.05	16.38	18.66	18.37	7.46	1272	7.90	1.48	20.09	13.36
V <sub>3</sub> : 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
<b>Spacings (S)</b>										
S <sub>1</sub> : 45 cm	151.89	17.13	19.63	19.09	7.51	1346	8.34	1.48	21.67	13.68
S <sub>2</sub> : 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 <sup>-1</sup> )	Total cost of cultivation (₹/ha <sup>-1</sup> )	Net realization (₹/ha <sup>-1</sup> )	Net income per day (₹/ha/day)	BCR
<b>Times of sowing (D)</b>					
D <sub>1</sub>	108728	44663	64065	377	2.43
D <sub>2</sub>	101049	44663	56386	351	2.25
D <sub>3</sub>	82596	43563	39032	259	1.89
<b>Varieties (V)</b>					
V <sub>1</sub>	87164	44296	42867	265	1.96
V <sub>2</sub>	97356	44296	53059	328	2.19
V <sub>3</sub>	107853	44296	63556	393	2.42
<b>Spacings (S)</b>					
S <sub>1</sub>	102883	44296	58586	362	2.31
S <sub>2</sub>	92032	44296	47736	296	2.07

Note: See Table 1 for treatment details.

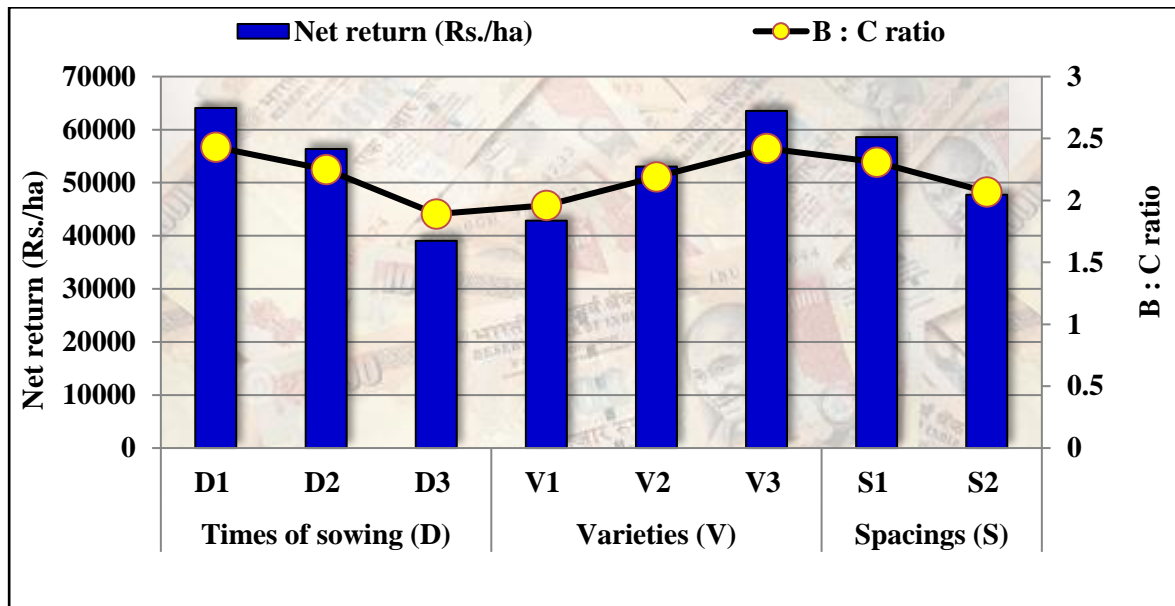


Fig. 3. Effect of times of sowing, varieties and spacings on economics of rabi fennel

Table 3. Interaction effect of time of sowing and spacing

Treatments	Plant height (cm)		Seed yield (kg/ha)	
	S <sub>1</sub>	S <sub>2</sub>	S <sub>1</sub>	S <sub>2</sub>
<b>Times of sowing (D)</b>				
D <sub>1</sub>	157.73	153.64	1549	1296
D <sub>2</sub>	156.90	145.46	1377	1265
D <sub>3</sub>	141.03	141.86	1111	1046
S.E.m.±	2.73		43.96	
C.D. at 5%	7.80		125	

Note: See Table 1 for treatment details.

### 3.4 Interaction Effect

Interaction effect between sowing time and spacing was showed its significance on plant height and seed yield (Table 3). Significantly the tallest plant with higher seed yield was recorded under treatment combination of D<sub>1</sub>S<sub>1</sub> (3<sup>rd</sup> week of October with 45 cm spacing) was found at par with treatment combinations of D<sub>2</sub>S<sub>1</sub> and D<sub>1</sub>S<sub>2</sub>.

### 4. CONCLUSION

The impact of climate change on agriculture poses a significant threat 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.* 3<sup>rd</sup> week of October. As per adaptability to

local climatic conditions selection of suitable variety *i.e.* GF-12 and optimum row spacing as per the plant geometry *i.e.* 45 cm under North Gujarat Agro-climatic condition.

### DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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