Growth, Yield and Phenological Response of Fennel (*Foeniculum vulgare* Mill.) to Time of Sowing, Variety and Crop Geometry Under Semi-Arid Region of Banaskantha, Gujarat

Abstract

The yield of crops depends on climatic, soil and crop management factors, among them selection of variety, optimum time of sowing and crop geometry as per plant geometry deciding yield per unit area so that present investigation was carried out in rabi season of 2015-16 to examine the consequences of different time of sowing, varieties and row spacing on growth and yield of *rabi* fennel. The significantly higher plant height (60, 90 and 120 DAS), number of primary, secondary and tertiary branches per plant, number of seeds per umbellate, seed yield per plant, seed, stover and biological yield as well as more number days to 50 per cent flowering and days to physiological maturity recorded with fennel variety GF-12 under early sown *i.e.* 3rd week of October at optimum row space of 45 cm than rest of the treatment. However, spacing did not exhibit a significant influence on harvest index, days to 50 per cent flowering and days to physiological maturity. The Interaction effect of time of sowing and row spacing was found significant in primary branches, number of umbels and seed yield per plant as well as seed yield. It was noticed that growth as well as yield attributing parameters showed positive significant correlation with seed yield.

Key words: Growth, yield, phenology, time of sowing, spacing, variety

Introduction

Seed spices are annual herbs, whose dried seeds are used as spices and is one of the important crops being cultivated in the arid and semi-arid region of the country having dry or wet cool weather conditions. These crops are attaining importance day by day due to its aromatic and medicinal values, the present era is reflecting high international demand of Indian seed spices. India is world's largest producer, exporter and consumer of seed spices from India and that's why India is known as home of spices. However, Rajasthan and Gujarat and parts of Madhya Pradesh can be called as the 'bowl of seed spices" contributing more than 80% of the country's annual production.

Fennel (saunf) is important *rabi* spices crop, originated from southern Europe and Asia minor comes under 'Apiaceae' family commonly grown for its seed, leaves and edible shoots. The data showed that in 2022-23, India produces 137 thousand metric tones from 82142 hectare area with average productivity of 1672 kg/ha. (Anon, 2023[a]). It produced 98272 metric tones of fennel from 47549 ha area with average productivity of 2066 kg/ha (Anon, 2023[b]). 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. (Anon, 2023[c]).

The selection of an appropriate sowing time is crucial for optimizing plant growth and achieving maximum yield by utilizing natural resources efficiently during the growing seasons. 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. 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 and yield. 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 recorded significantly higher plant height, number of primary, secondary and tertiary branches and umbels per plant, umbellates per umbel, seeds per umbel, seed yield and oil content as compared to 30 cm and 60 cm row spacings. (Amin *et al*., 2005). 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.

MATERIALS AND METHODS

Site Specifications and weather

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. 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. Average temperature in winter season is 12.2°C. The annual average rainfall is about 620.9 mm with about 27 rainy days.

Sampling and analyses

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 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.

Experimental setup

The experiment was laid out in spilt plot design with three sowing times (D_1:3rd week of October, D_2:1st week of November and D_3: 3rd week of November) as main plot, three varieties (V_1: Gujarat Fennel-2, V_2: Gujarat Fennel-11 and V_3: Gujarat Fennel-12) and two spacings (S_1: 45 cm and S_2: 60 cm) in sub plot in *rabi* season in split plot design having eighteen treatment combinations with four replications. 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.

Observation recorded

The five plants were selected from each plot for recording various growth and yield attributes. The harvesting of rows of net plot was done manually. Harvest index was calculated by using the formula given by Donald and Hamblin (1962). 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 and simple correlation coefficient ('r') of each character was calculated.

Results and discussion

Effect of time of sowing

The presented in Table 1 showed that significantly higher plant height (11.5, 47.0, 127.6 and 145.2 cm at 30, 60, 90 and 120 DAS, respectively) as well as number of primary (6.8), secondary (6.4) and tertiary (5.0) branches per plant recorded under 3rd week of October as compared late sown crop. The per cent increase in number of primary, secondary and tertiary branches per plant due to early sowing (3rd week of October) were 7.9, 8.9 and 6.3 higher than sowing on 1st week of November and 18.8, 31.7 and 18.3 than 3rd week of November sowing, respectively. This might be due to favourable climatic conditions and availability of more sunshine hours for vegetative growth might have helped to increase number of branches per plant. Unfavourable climatic condition during vegetative growth under late sown crop might had reduced number of branches per plant. Similar findings have been reported by Patel (2000), Yadav and Khurana (2000), Mohan *et al*. (2001), Singh *et al*. (2005), Ayub *et al*. (2008), Bagari *et al*. (2010) and Selim *et al*. (2013).

The data showed in Table 2 reveal that significantly higher number of seeds per umbellate (20.5), seed yield per plant (26.1 g), seed (1.4 t/ha), stover (4.1 t/ha) and biological yield (5.5 t/ha) as well as more number days to 50 per cent flowering (110.9) and days to physiological maturity (173.8) recorded under early sown fennel *i.e.* 3rd week of October. The favourable climatic condition throughout the crop season under early sown crop and availability of more sunshine hours for vegetative growth might have production of more photosynthates as well as its translocation to the sites enhanced growth which showed significantly positive correlation with seed and stover yield. 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 yield. These results are with line of work reported by Singh *et al.* (2005), Ayub *et al.* (2008), Singh *et al.* (2009), Bagari *et al.* (2010) and Meena *et al.* (2015).

Effect of variety

The results in (Table 1) revealed that the significantly higher plant height was observed under variety GF-12 (V_3) at 30 (11.1 cm), 60 (46.1 cm), 90 (128.8 cm) and 120 (143.4 cm) DAS as well as number of primary (6.8), secondary (6.4) and tertiary (5.0) branches per plant over GF-2 and was at par with GF-11. But varieties could not exhibit any influence on plant population at initial and at harvest. Inherent characteristic of particular variety plays a vital role on growth and development of crop which might be responsible for plant growth in terms of plant height. These findings are in close agreement with those of Malik *et al.* (2009), Singh *et al.* (2009) and Sengupta *et al.*

(2014).

The data presented in Table 2 revealed that the significantly higher number of seeds per umbellate (20.8), seed yield per plant (26.1 g), harvest index (25.9), seed (1.4 t/ha), stover (4.0 t/ha) and biological yield (5.4 t/ha) as well as more number days to 50 per cent flowering (111.1) and days to physiological maturity (172.0) were observed under GF-12 over GF-2. As compared to GF-2, cultivar GF-11 and GF-12 recorded 5.7 and 15.6 as well as 12.2 and 20.2 per cent higher number of umbels per plant and number of umbellates per umbel, respectively. The higher yield attributes recorded under GF-12 might be due to genetic potential of particular variety. Similar results were observed by Singh *et al.* (2003), Malik *et al.* (2009) and Sengupta *et al.* (2014).

The maximum seed and stover yield secured with GF-12 (V_3) was 10.9 and 23.9 as well as 4.4 and 13.4 per cent higher over GF-11 and GF-2, respectively. Taller plants with more number of branches per plant were observed under GF-12 and GF-11 is contributed to genetic setup of particular variety, which could have increased stover yield of that cultivar. Better vegetative and reproductive growth of GF-12 is attributed to inherent build up and thereby produced higher seed yield. These findings are in close agreement with those of Malik *et al.* (2009), Singh *et al.* (2009), Meena and Singh (2013) and Sengupta *et al.* (2014).

Effect of spacing

The data presented in Table 1 revealed that the significantly higher plant population at initial (324.7) and harvest (312.2), plant height at 60 (45.8 cm), 90 (126.5 cm) and 120 (141.3 cm) DAS as well as number of primary (6.5), secondary (5.9), tertiary (4.8) branches per plant were recorded with 45 cm row spacing as compared to wider row

spacing *i.e.* 60 cm. Plant height at 30 DAS was not differed remarkably due to different spacings. This might be due to availability of comparatively less space for each plant which increased the competition for light within the plants. The results are in agreement with those reported by Patel (2000), Amin *et al.* (2005) and Mehta *et al.* (2011).

The data presented in Table 2 revealed that the significantly higher number of seeds per umbellate (19.9), seed yield per plant (24.9 g), seed (1.4 t/ha), stover (3.9 t/ha) and biological yield (5.2 t/ha) were recorded with 45 cm row spacing as compared to wider row spacing *i.e.* 60 cm. Inter row spacings did not cause any positive or negative effect on harvest index as well as days to 50 per cent flowering and physiological maturity. As compared to 60 cm row spacing, the percentage rise in umbels per plant and umbellates per umbel with 45 cm row spacing were 7.9 and 4.0, respectively. Optimum space available for individual plants *i.e.* 45 cm might have resulted in better utilization of resources *viz.*, space, nutrients, moisture, carbon dioxide and radiant energy to improve vegetative growth in terms of number of branches per plant and consequently reproductive growth. These findings are corroborated with the results of Patel (2000), Yadav *et al.* (2000), Singh (2001), Amin *et al.* (2005), Singh *et al.* (2009) and Bhuva *et al*. (2017).

The increase in seed and stover yield due to sowing of crop at 45 cm apart was 11.9 and 5.4 per cent, respectively than wider row spacing of 60 cm. Optimum availability of space with adequate number of plants per unit area under 45 cm row spacing increased growth and yield which showed significant positive correlation with seed and stover yield. These findings are in conformity with results reported by Patel (2000), Singh (2001), Yadav and Khurana (2000), Amin *et al.* (2005) and Singh *et al.* (2009).

Interaction effect of sowing time and variety

Interaction effect between time of sowing and variety was found significant for number of primary branches per plant, number of umbels, seed yield per plant and seed yield. (Table 3). Significantly the highest primary branches per plant (6.9), number of umbels per plant (20.6), seed yield per plant (28.3 g) as well as seed yield (1.5 t/ha) were recorded when crop sown in 3rd week of October keeping 45 cm row spacing (D_1S_1). Whereas number of primary branches per plant and umbels per plant it was found statistically at par with treatment combinations of D_2S_1 and D_1S_2. Availability of optimum space and favourable climatic condition during vegetative growth period might have increased vegetative and reproductive growth. While, the favourable climatic condition with availability of optimum space for individual plants and optimum plants per unit area increased seed and stover yield. The results are fully supported by those of Patel (2000), Singh *et al.* (2005), Singh *et al*. (2006), Ayub *et al.* (2008) and Selim *et al.* (2013).

Correlation coefficient

The correlation coefficient ('r') between seed yield and growth as well as yield attributing character was worked out as per (Table 4). It was noticed that growth as well as yield attributing parameters viz. number of primary, secondary and tertiary branches per plant, number of seeds per umbellate and seed yield per plant showed positive significant correlation with seed yield.

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Fig. 1: Mean weekly weather parameters recorded during crop growth period of 2015-16

Fig.2: Effect of of time of sowing, variety and row spacing on plant height at 30, 60, 90 and 120 DAS.

Fig. 3: Effect of of time of sowing, variety and row spacing on number of primary, secondary and tertiary branches per plant

Fig. 4: Effect of of time of sowing, variety and row spacing on seed, stover and biological yield (t/ha)

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

Treatments	Plant population		Plant height (cm)				Nu
	Initial	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	Prin
Times of sowing (D)							
D_1:3rd week of October	284.2	274.8	11.5	47.0	127.6	145.2	6
D_2 :1st week of November	274.9	266.7	10.7	45.1	126.7	140.2	6
D_3 :3rd week of November	275.5	265.9	9.7	42.0	115.1	131.7	5
S.Em.±	7.2	7.1	0.3	1.1	3.0	3.0	0
C.D. at 5%	NS	NS	1.0	3.7	10.4	10.3	0
Varieties (V)							
V_1 : GF 2	276.6	263.9	10.2	43.3	117.4	135.3	6
V_2 : GF 11	277.9	270.8	10.7	44.7	123.0	138.4	6
V_3 : GF 12	280.1	272.7	11.1	46.1	128.8	143.4	6
S.Em.±	4.9	6.0	0.2	0.7	2.1	1.9	0
C.D. at 5 %	NS	NS	0.6	2.0	5.9	5.4	0
Spacings (S)							
S_1 : 45 cm	324.7	312.2	10.9	45.8	126.5	141.3	6
S_2 : 60 cm	231.7	226.1	10.4	43.7	119.7	136.7	6
S.Em.±	4.0	4.9	0.2	0.6	1.7	1.5	0

C.D. at 5%	11.5	13.9	NS	1.7	4.8	4.4	0

Table 2: Influence of time of sowing, variety and row spacing on growth parameters of *rabi* fennel

Treatments	Days to 50 per cent flowering	Days to physiological maturity	Number of seeds per umbellate	Seed yield per plant (g)	Harvest index (%)	Seed Y (t/ha
Times of sowing (D)						
D_1	110.9	173.8	20.5	26.1	25.8	1.4
D_2	109.4	169.0	19.7	24.1	24.9	1.3
D_3	102.5	166.0	18.1	22.3	24.3	1.1
S.Em.±	2.0	1.7	0.4	0.7	0.5	0.0
C.D. at 5%	6.9	5.8	1.5	2.3	NS	0.1
Varieties (V)						
V_1	104.7	167.0	18.3	22.3	24.2	1.1
V_2	107.0	169.8	19.3	24.0	24.8	1.3
V_3	111.1	172.0	20.8	26.1	25.9	1.4
S.Em.±	1.6	1.4	0.3	0.5	0.5	0.0
C.D. at 5 %	4.4	3.8	0.9	1.5	1.3	0.1
Spacings (S)						
S_1	107.9	169.9	19.9	24.9	25.5	1.4
S_2	107.3	169.3	19.0	23.4	24.5	1.2
S.Em.±	1.3	1.1	0.3	0.4	0.4	0.0
C.D. at 5%	NS	NS	0.8	1.3	NS	0.1

Note: See Table 1 for treatment details.

Table 3: Interaction effect of time of sowing and row spacing

Treatments	Primary branches per plant		Number of umbels per plant		Seed yield per plant	
Spacings (S)	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
Times of sowing (D)						
D_1	6.9	6.8	20.6	20.2	28.3	23.9
D_2	6.8	5.9	20.3	17.3	23.8	24.4

D_3	5.7	5.8	18.0	17.1	22.7	21.8
S.Em.±	0.2		0.6		0.9	
C.D. at 5%	0.6		1.8		2.7	

Note: See Table 1 for treatment details.

Table 4: The values of correlation coefficient 'r' between seed yield and growth as well as yield attributing characters

Sr. No.	Characters	
•	Number of primary branches per plant	
•	Number of secondary branches per plant	
•	Number of tertiary branches per plant	
•	Number of seeds per umbellate	
•	Seed yield per plant	

* = Significant at 5 per cent level

** = Significant at 1 per cent level