

## Effects of Varying Nitrogen Levels and Row Spacing on Fennel (*Foeniculum vulgare* mill.) Growth and Seed Yield

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The climatic conditions in Haryana are favorable for fennel cultivation but it is cultivated only in a limited area due to lack of awareness and knowledge among farmers about the cultural practice and nutrient requirement for effective cultivation. Therefore, the current investigation was carried out during the Rabi season of 2021–2022 at research area, Department of Vegetable Science, CCSHAU, Hisar with four levels of N (0, 25, 50 and 75 kg·ha<sup>-1</sup>) and three types of rows to row spacing (30 × 20, 45 × 20 and 60 × 20 cm). Sowing of crop variety “HF-143” was done on 30th October 2021 in factorial RBD and harvesting on 10<sup>th</sup> May, 2022. Three replications of each treatment were used to record the characteristics of vegetative growth and yield of seeds (per plot & hectare). Results of the study revealed that 75 kg·ha<sup>-1</sup> nitrogen dose with 60 × 20 cm spacing was well suited for vegetative growth except for plant height that was best in 30 × 20 cm spacing. The yield attributes were also found highest at 75 kg·ha<sup>-1</sup> nitrogen with 60 × 20 cm spacing and observed to be statically at par with 30 × 20 with 50 kg·ha<sup>-1</sup> nitrogen and 45 × 20 cm spacing. The largest reported yield of seed is at 75 kg·ha<sup>-1</sup> nitrogen with a spacing of 45 × 20 cm. With the same spacing, this was statistically at par to 50 kg·ha<sup>-1</sup> nitrogen dose. The result of this study can further be used to obtain sustainable yield with optimum use of fertilizers to sustain soil health.

**Keywords:** Factorial RBD, HF-143, Rabi season, Vegetative growth, Yield attributes

### Introduction

In India, Fennel (Saunf) is reported to be one of the earliest spices belonging to the Apiaceae family and is contributed to be the native to Southern Europe and the Mediterranean region of the world.<sup>1</sup> Fennel plant has one main stem, 8–10 primary branches, 15–17 secondary branches with one main umbel as shown in Fig. 1. Its seed can be used to prepare soups, salads, processed meats, sausages, sauces, pickles, and whole or ground and used as a condiment. Fennel seed contains 9.5% protein, 18.5% fiber, 13.4% minerals, and a significant amount of vitamins, including ascorbic acid, vitamin A, thiamine, riboflavin, and niacin.<sup>2</sup> Because fennel seed oil contains trans-anethol and other chemical elements including di- and tri-terpenes, it is also commonly used in the confectionary, fragrance, beverage, and textile sectors.<sup>3</sup> Fennel seeds are used in industry and cooking, but they also have medicinal properties. It is said that fennel essential oil possesses antifungal, antibacterial, anticancer, and antioxidant qualities.<sup>4</sup> In addition to their digestive, stimulative, appetizing, and carminative qualities, fennel seeds exhibit estrogenic qualities. They are also

used to treat diarrhea, dysentery, flatulence, and cough.<sup>5</sup> A hot fruit infusion is used in traditional medicine to encourage lacteal production.<sup>6</sup> Due to its hardiness, this plant can be grown in many different agroclimatic conditions across the world, such as those found in Argentina, Bulgaria, China, India, Italy, Morocco, Spain, and Turkey. India is the world's biggest producer of fennel, with an estimated 137.29 thousand MT produced from an area of about 82 thousand hectares.<sup>7</sup> It is farmed for commercial use in Indian states like Gujarat, Maharashtra, Rajasthan, West Bengal, Madhya Pradesh etc.<sup>8</sup>

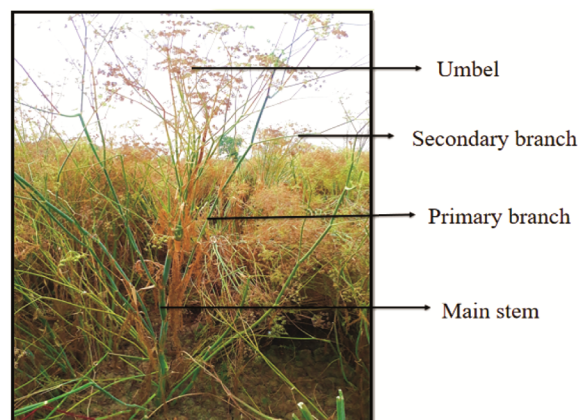


Fig. 1 — A capture of the Fennel plant from the field.

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Nitrogen is one of the most crucial elements in crop development, yield, and quality. Proteins, enzymes, hormones, vitamins, alkaloids, chlorophyll, and other materials all include it. Lack of nitrogen inhibits the growth of plants since it is observed to be a necessary component of enzymes, protein and chlorophyll.<sup>9</sup> Plant spacing is another crucial factor in plant growth and productivity. In order to maximize the use of available production components such as water, fertilizers, light, and CO<sub>2</sub>, the ideal number of plants per unit space is needed. When the plant population puts the greatest amount of pressure on all production variables, the maximum use of these elements is achieved.<sup>10</sup> Even though India's environment is perfect for growing fennel, it is still only grown in a small area at this time. Due to earlier neglect of its cultural components and farmers' ignorance of the cultural prerequisites for productive cultivation, cultivation has been restricted. Since row spacing affects both the microclimate surrounding the field and the amount of sunlight that reaches the plant canopy, it plays a significant role in crop growth. The increasing demand for fennel seeds due to their economic, medicinal, and industrial importance necessitates a higher yield, which can be achieved through appropriate agronomic practices. Considering the aforementioned, the purpose of this experiment was to determine the optimal amount of nitrogen fertilizer and spacing to increase the nutrient use efficiency and thereby productivity of this novel fennel variety HF-143 of Northern India.

### Materials and Methods

The current study was carried out in the Rabi season of 2021–2022 at Chaudhary Charan Singh Haryana Agricultural University, Hisar, in the Research Farm, Vegetable Science Department. The coordinates of the field experimental location were 29° 10' North latitude and 75° 46' East longitude. It was situated in the subtropics at an elevation of 215.2 meters above mean sea level. Three distinct row spacings — 30, 45, and 60 centimeters as well as four nitrogen levels — 0, 25, 50, and 75 kg·ha<sup>-1</sup> are used in this experiment. Three replications of a factorial RBD were used to assess the treatments. On October 30, 2021, the fennel cultivar HF-143 was sown. Forty-five days after sowing, half of the nitrogen dose was administered as a top dressing and the other half was given as basal dose. All timely agronomic recommendations were followed to

successfully raise the crop. On May 10, 2022, the crop was harvested upon reaching full maturity. Four to five days later, threshing took place in the field following sun drying. Seven randomly chosen plants were chosen to record the following parameters: days to emergence, plant height, number of umbels per plant, the number of umbellates per umbel, the number of seeds per umbellet, the number of seeds per umbel, and the seed yield (per plot and per ha). Other variables include primary and secondary branches (30, 60, 90 DAS, and at harvest). Every plot's observational plants were tagged. In order to document observations, border row plants were avoided. Panse and Sukhatme, 1985<sup>(11)</sup> statistical design and OPSTAT Software with two-factor analysis was used to statistically analyze the average of various recorded observations.

## Results & Discussion

### Effect of N Fertilizer Level

#### *Growth Attributes*

The amount of N fertilizer was discovered to have a significant impact on the vegetative development metrics, including height, the number of main and subsidiary branches, and the amount of time until half of the plant blossoms as illustrated in Table 1. A notable maximum plant height at DAS of 60, 90, and harvest (42.82, 94.29, and 144.46 cm, respectively) was noted among varied nitrogen levels with the application of 75 kg·ha<sup>-1</sup>. Nitrogen supplied @ 50 kg·ha<sup>-1</sup> followed immediately (8.86, 42.09, 92.64 and 142.83 cm respectively). On the other hand, at every stage of plant growth, the minimum plant height at harvest was measured with control. Among all treatments, the variation in plant height at 30 DAS was not statistically significant. As a result, as the dose of nitrogen increased, so did plant height. Waskela *et al.*<sup>12</sup> and Sharma and Aishwath<sup>13</sup> found that plant height increases in fennel in proportion to the amount of nitrogen present. This might be the case since nitrogen is a nutrient that is necessary for biological processes, specifically for the chlorophyll, protein and other organic component synthesis. Higher amounts of nitrogen in the plant stimulate development through active cell division and elongation, which results higher plant growth, because of its greater availability, efficient absorption and there by transport to different organs. As the nitrogen dose grew, the number of primary and

Table 1 — Effect of different nitrogen levels and spacing on growth parameters (plant height, number of branches and days to flowering)

Treatments	Plant height (cm)				Number of primary branches			Number of secondary branches			Days to 50% flowering
	30 DAS	60 DAS	90 DAS	Harvest	60 DAS	90 DAS	Harvest	60 DAS	90 DAS	Harvest	
T <sub>1</sub> : Control	6.86	24.58	71.23	124.32	3.87	5.64	8.66	1.38	6.50	15.80	111.77
T <sub>2</sub> :25 kg/ha	7.46	36.61	82.56	134.69	4.01	5.86	8.98	1.71	6.62	15.94	112.33
T <sub>3</sub> : 50 kg/ha	8.86	42.09	92.64	142.83	4.11	6.09	9.42	2.01	6.99	16.28	114.55
T <sub>4</sub> : 75 kg/ha	9.05	42.82	94.29	144.46	4.16	6.16	9.50	2.10	7.06	16.37	115.44
Mean T	8.05	36.52	85.18	136.57	4.03	5.93	9.14	1.80	6.79	16.09	113.52
SE (m)	0.54	0.70	0.32	0.65	0.03	0.03	0.04	0.08	0.04	0.06	0.16
CD at 5%	NS	2.08	0.97	1.94	0.08	0.09	0.09	0.25	0.11	0.13	0.49
S <sub>1</sub> : 30 × 20 cm	8.34	37.57	88.39	139.49	3.99	5.84	8.99	1.64	6.66	15.96	113.50
S <sub>2</sub> : 45 × 20 cm	8.16	36.65	86.32	137.89	4.05	5.96	9.18	1.86	6.84	16.14	112.66
S <sub>3</sub> : 60 × 20 cm	7.71	35.36	80.83	132.34	4.07	6.01	9.24	1.89	6.88	16.18	114.41
Mean S	8.05	36.52	85.18	136.57	4.03	5.93	9.14	1.80	6.79	16.09	113.52
SE (m)	0.47	0.61	0.28	0.56	0.02	0.02	0.03	0.07	0.03	0.04	0.14
CD at 5%	NS	NS	0.84	1.68	NS	0.08	0.08	NS	NS	NS	0.86

Table 2 — Effect of different nitrogen levels and spacing on seed yield and yield parameters

Treatments	Umbels per plant	Umbellets per umbel	Seeds per umbellet	Seeds per umbel	Seed yield per plot (kg)	Seed yield per hectare (q/ha)
T <sub>1</sub> : Control	21.10	20.76	13.77	282.93	0.73	13.67
T <sub>2</sub> : 25 kg/ha	30.61	23.71	16.64	396.53	0.83	15.59
T <sub>3</sub> : 50 kg/ha	36.23	26.11	20.15	526.07	0.94	17.54
T <sub>4</sub> : 75 kg/ha	36.94	26.40	20.39	533.40	0.95	17.55
Mean T	31.23	24.24	17.73	434.73	0.86	16.08
SE (m)	0.35	0.12	0.11	3.71	0.002	0.02
CD at 5%	1.05	0.37	0.33	10.05	0.005	0.07
S <sub>1</sub> : 30 × 20 cm	28.04	23.85	17.20	414.74	0.81	15.13
S <sub>2</sub> : 45 × 20 cm	32.38	24.36	17.92	441.08	0.90	16.85
S <sub>3</sub> : 60 × 20 cm	33.28	24.54	18.09	448.37	0.88	16.29
Mean S	31.23	24.24	17.73	434.73	0.86	16.08
SE (m)	0.31	0.10	0.09	3.21	0.001	0.02
CD at 5%	0.91	0.32	0.29	9.48	0.004	0.06

secondary branches increased as well, since nitrogen is known to encourage profuse vegetative development in plants. Among the various nitrogen levels tested, the application of 75 kg·ha<sup>-1</sup> nitrogen results in the highest number of primary branches at (60, 90 DAS and harvest) *i.e.*, 4.16, 6.16 and 9.50 respectively. However, the minimal number of primary branches was observed in control plots at every development stage, *i.e.*, 3.87, 5.64, and 8.66 respectively. This was equivalent to nitrogen provided at 50 kg·ha<sup>-1</sup> (4.11, 6.09, and 9.42, respectively). Secondary branches showed a comparable result. Plots with nitrogen fertilizer administered at 75 kg·ha<sup>-1</sup> showed the greatest number of secondary branches at 60, 90 DAS, and harvest (2.10, 7.06, and 16.37 respectively). This was comparable to the nitrogen dose of 50 kg·ha<sup>-1</sup> (2.01, 6.99, and 16.28 respectively). The lowest amount of branches was found in plots without nitrogen fertilization. In fennel, Rai *et al.*<sup>14</sup>, Mehta *et al.*<sup>11</sup> and Waskela *et al.*<sup>12</sup> discovered similar outcomes. They claimed that the higher nitrogen inputs caused the branches to branch out more quickly,

forcing a greater amount of canopy development with abundant branching and enhanced solar energy absorption, interception, and utilization, which in turn produced more photosynthates and, ultimately, more dry matter per plant. Nitrogen lengthens the time until flowering by promoting vegetative growth and delaying flowering. Minimum days to 50% flowering were noted at control (0 kg·ha<sup>-1</sup>), and maximum days to maximum flowering were noted at 75 kg·ha<sup>-1</sup> nitrogen dose (115.44). Menaria and Maliwal<sup>15</sup>, Meena *et al.*<sup>16</sup>, Waskela *et al.*<sup>12</sup> in fennel and Kadbe *et al.*<sup>17</sup> in dill all reported similar findings. The possible cause of this condition is that nitrogen application altered the physiological and biochemical processes in plants, resulting in an increase in the vegetative phase and a delay in the reproductive stage, which in turn led to a complete enhance in the number of days to fifty percent flowering in plants.

#### Seed Yield and Yield Attributes

The significant impact of N fertilizer on seed yield and yield attributes is illustrated in Table 2. The

highest nitrogen application rate of  $75 \text{ kg}\cdot\text{ha}^{-1}$  resulted in the following observations: the maximum umbels per plant (36.94), umbellets per umbel (26.40), seed per umbel (20.39), seed yield per plot (0.946 kg), and seed yield per hectare ( $17.55 \text{ q}\cdot\text{ha}^{-1}$ ). Results were observed to be statistically comparable to nitrogen supplied at rate of  $50 \text{ kg}\cdot\text{ha}^{-1}$ . In contrast, the control group recorded the lowest value for both the yield parameter and the seed yield. The overall improvement in vigor and crop growth may be responsible for the notable improvement in fennel yield attributes following N fertilization. Increased biomass plant at later growth stages crop, along with nitrogen, support the theory that better nutrient availability and synthesis of metabolites synchronized well with the needs of the crop at peak growth and development stages (reproductive) the fennel plant and contributed to the faster growth of plants. The results obtained by Raj and Thakral<sup>18</sup>, Singh and Amin<sup>19</sup>, Bhardwaj and Kumar<sup>20</sup> and Meena *et al.*<sup>16</sup> in fennel are quite similar to the current findings. They claimed that enhanced growth and yield components might have contributed to the higher seed yield in fennel, as growth and yield aspects demonstrated a significantly positive correlation with seed yield. This led to a higher yield in the end. Strong sink and source activity formation under higher nitrogen levels led to the significant change or increase in seed yield.

#### Effect of Spacing

##### Growth Attributes

According to the results, of the present investigation study, height, primary and secondary branches, along with the number of days until 50% of the plants flowered were among the vegetative growth metrics that spacing significantly affected. The maximum plant height of crop at 30, 60, 90 DAS, and at harvest (8.34, 37.57, 88.39 and 139.49 cm, respectively) was found to be produced with a  $30 \times 20$  cm spacing. This was followed immediately by a  $45 \times 20$  cm spacing (8.16, 36.65, 86.32 and 137.89 cm respectively). On the other hand, at every stage of plant growth, the minimum plant height at harvest was measured with  $60 \times 20$  cm spacing. Plant height thus drastically decreases as spacing increases. Plants may have been driven to grow vertically in search of light due to increased competition among them for available light. Additionally, plants that are closely spaced have less area for lateral growth, which causes them to expand vertically. Bhuva *et al.*<sup>21</sup>

reported similar results in fennel, showing that plant height increased along with plant density.

Because there were more resources available, there were more primary and secondary branches with greater spacing between them. A minimum of  $30 \times 20$  cm was recorded at both the growth stage, *i.e.*, 5.84 and 8.99 respectively, while the maximum number of primary branches at (90 days after sowing and at harvest *i.e.*, 6.01 and 9.24 respectively, were observed with  $60 \times 20$  cm row to row spacing which were statistically at par with  $45 \times 20$  cm spacing (5.96 and 9.18 respectively). There was no discernible variation in the quantity of secondary branches at any stage of growth. The maximum number of secondary branches, however, was measured at  $60 \times 20$  cm (1.89, 6.88, and 16.18, respectively) at 60, 90 DAS and harvest, which was comparable to  $45 \times 20$  cm (1.86, 6.84, and 16.14, respectively) spacing. In contrast, the fewest branches were seen in plots spaced  $30 \times 20$  cm apart. This could be because there are more resources—such as nutrients, light and water—available for the fewer plants per unit area at wider spacing. As a result, there were more branches per plant and vegetative growth. Because there was less room for each plant in a dense population with closer plant geometry, there were fewer branches per plant, increasing competition for resources among the plants. The outcomes supported the conclusions made in fennel by Bagari *et al.*<sup>22</sup>, Selim *et al.*<sup>23</sup>, & Diksha *et al.*<sup>24</sup> The number of days to 50% flowering also changes dramatically with spacing. The minimum number of days required to 50% flowering was observed to be at  $45 \times 20$  cm (112.66), the maximum number of days required for 50% flowering was at  $60 \times 20$  cm (114.41), and the minimum number of days required was at  $30 \times 20$  cm (113.50). It could be because a plant with a wider spacing will have less competition, receive more nutrients, and continue growing vegetatively, whereas a plant with a closer spacing will likely experience delays in the reproductive phase due to a lack of resources and nutrients. The ideal spacing is defined as the distance at which a plant took the fewest number of days to flower. According to current research, the ideal fennel spacing is  $45 \times 20$  cm.

##### Seed Yield and Yield Attributes

The yield characteristics and seed production are both significantly impacted by the spacing. The highest number of umbels per plant (33.28), umbellets per umbel (24.54), seed per umbel (18.09),



Table 4 — Interaction effect of two different factor (nitrogen levels and spacing) on seed yield and yield parameters

Treatments	Umbels per plant	Umbellets per umbel	Seeds per umbellet	Seeds per umbel	Seed yield per plot (kg)	Seed yield per hectare (q/ha)
T <sub>1</sub> S <sub>1</sub>	18.22	20.31	13.45	270.15	0.65	12.05
T <sub>1</sub> S <sub>2</sub>	21.86	20.87	13.83	285.62	0.80	14.75
T <sub>1</sub> S <sub>3</sub>	23.23	21.10	14.03	293.02	0.76	14.21
T <sub>2</sub> S <sub>1</sub>	25.36	23.36	16.31	381.00	0.80	14.87
T <sub>2</sub> S <sub>2</sub>	32.67	23.81	16.71	400.85	0.87	16.20
T <sub>2</sub> S <sub>3</sub>	33.81	23.98	17.92	407.73	0.84	15.70
T <sub>3</sub> S <sub>1</sub>	33.90	25.71	19.39	501.51	0.91	16.80
T <sub>3</sub> S <sub>2</sub>	37.12	26.23	20.45	534.39	0.98	18.23
T <sub>3</sub> S <sub>3</sub>	37.7	26.41	20.61	542.30	0.95	17.61
T <sub>4</sub> S <sub>1</sub>	34.67	26.02	19.66	506.31	0.90	16.81
T <sub>4</sub> S <sub>2</sub>	37.86	26.52	20.69	543.47	0.98	18.24
T <sub>4</sub> S <sub>3</sub>	38.30	26.68	20.82	550.42	0.95	17.63
SE (m)	0.62	0.21	0.19	6.42	0.003	0.04
CD at 5%	1.82	NS	NS	NS	0.01	0.12

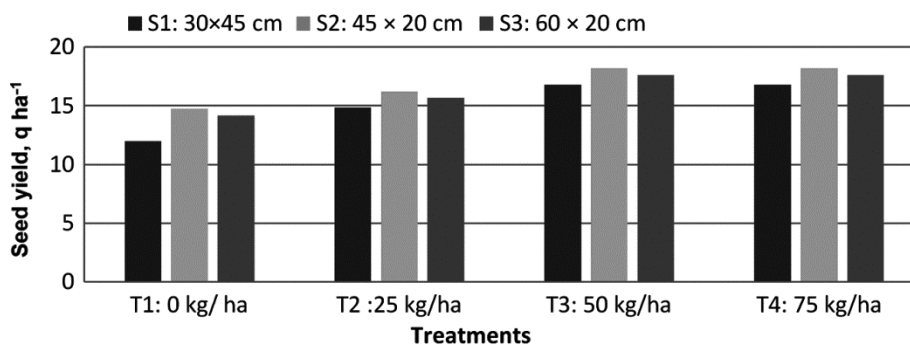


Fig. 2 — Effect of nitrogen levels and row spacing on seed yield per hectare on fennel

interaction between nitrogen levels and spacing, but not the number of umbelletes or seeds per umbel as depicted in Table 4. The treatment T<sub>4</sub>S<sub>3</sub>, (nitrogen @ 75 kg·ha<sup>-1</sup>; 60 × 20 cm spacing) yielded the highest umbels per plant (38.30). This combination was statistically comparable to T<sub>4</sub>S<sub>2</sub> (37.86), T<sub>3</sub>S<sub>3</sub> (37.67), and T<sub>3</sub>S<sub>2</sub> (37.12). Conversely, the treatment combination T<sub>0</sub>S<sub>1</sub> produced the fewest umbels (18.22) per plant. There was no discernible interaction impact among the number of umbelletes per umbel and the number of seeds per umbel. The maximum number of umbelletes per umbel and seeds per umbel were observed in T<sub>4</sub>S<sub>3</sub> (nitrogen @ 75 kg·ha<sup>-1</sup>; 60 × 20 cm spacing) followed by T<sub>4</sub>S<sub>2</sub> whose values were 26.68; 550.42 and 26.52; 543.47, respectively). However, the minimum values were recorded for T<sub>0</sub>S<sub>1</sub> as 20.31 and 270.15 respectively. It was found that nitrogen levels, spacing, and seed production (per hectare and per plot) interacted significantly. The maximum seed yield (per plot and per hectare) was achieved for T<sub>4</sub>S<sub>2</sub> (0.980 kg) and (18.24 q·ha<sup>-1</sup>). This combination was statistically comparable to T<sub>3</sub>S<sub>2</sub>

(0.977 kg) and (18.23 q·ha<sup>-1</sup>) as depicted in Fig. 2. Comparatively, T<sub>0</sub>S<sub>1</sub> resulted in the lowest seed yield per plot (0.647 kg).<sup>29,30</sup>

### Conclusions

Based on the study's findings, treatment T<sub>3</sub>S<sub>2</sub> was determined to be the most effective in achieving a higher seed yield. Fertilization of the fennel crop @ 50 kg·ha<sup>-1</sup> at a spacing 45 × 20 cm is must for ensuring maximum growth and yield-attributing qualities and, eventually, a large seed output. Beyond 50 kg·ha<sup>-1</sup> of nitrogen supply will raise the cultivation costs without increasing the yield. The result of this study can further be used to obtain sustainable yield with optimum use of fertilizers to sustain soil health. However, since, this study was focused on one season and one location; it needs further study for recommendation of specific nitrogen levels and spacing for specific varieties.

### Conflict of Interest

No conflicts of interest are disclosed by the writers.

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