



## **Effect of Seed Sowing Time and Nutrients on the Growth and Yield of Fennel (*Foeniculum vulgare*)**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/AJRCS/2022/v7i330141

### **Open Peer Review History:**

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: <https://www.sdiarticle5.com/review-history/88742>

**Original Research Article**

**Received 15 May 2022**  
**Accepted 20 July 2022**  
**Published 05 August 2022**

### **ABSTRACT**

In order to investigate the influence of seed sowing time and nutrients on the growth and yield of fennel, an experiment based on Randomized Complete Block Design with twelve treatments and three replications at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during October, 2019 to July, 2020 season was carried out. Fennel variety 'BARI Mouri-1' was used as planting material in this study. The experiment consisted of two factors: Factors-A: Sowing time (4 levels): S<sub>1</sub> = First week of November, S<sub>2</sub> = Last week of November, S<sub>3</sub> = First week of December and S<sub>4</sub> = Last week of December; Factors-B: Nutrients (4 levels): T<sub>0</sub> = Control, T<sub>1</sub> = Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub> = NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) and T<sub>3</sub> = Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>). The result revealed that in case of seed sowing time S<sub>2</sub> (Last week of November) and in case of different level of nutrients T<sub>3</sub> [Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)] treatment exhibited its superiority to other treatments in terms of plant height, number of leaves, number of primary branches, number of secondary branches, number of umbel per plant, number of umbellet per umbel, no. of days to first flowering, seed weight per umbel, weight of 1000-seeds and seed weight per ha. Significantly the highest seed yield (2.34t ha<sup>-1</sup>) was found in S<sub>2</sub>T<sub>3</sub> [(Last week of November with Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)] interaction due to the tallest plant at harvest (117.59 cm), number of leaves (15.07), number of

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primary branches (7.62), number of secondary branches (20.18), minimum days to first flower (82.60), maximum number of umbellets umbel<sup>-1</sup> (27.72), number of umbel plant<sup>-1</sup> (26.75), maximum weight of 1000-seeds (6.38 g), maximum seed weight umbel<sup>-1</sup> (2.09 g).

**Keywords:** Seed sowing time; nutrients; vermicompost; growth; yield; fennel.

## 1. INTRODUCTION

*Foeniculum vulgare* Mill., universally known as fennel, is a medicinal and aromatic plant belonging to the Apiaceae (Umbelliferae) family. All parts of the plant such as root, stem, leaves and especially seeds are aromatic and can be used in many ways [1]. Phenols, phenolic glycosides and volatile aroma compounds such as trans-anethole, estragole and fenchone have been reported as the major phytoconstituents of this species. The phenolic compounds isolated from fennel are considered to be responsible for its antioxidant activity while the volatile aroma compounds make it an excellent flavouring agent. Mean essential oil content is 1.0-1.5% in leaves, 0.6-0.7% in roots and 2.0-6.0% in fruits [2]. Fennel is widely cultivated in Europe, Asia, the USA and many African countries as well as Brazil and Argentina for medicinal and feeding purposes [3]. Fennel is a minor spice crop in Bangladesh and is cultivated throughout the country in winter season. In Bangladesh and neighbouring country seeds are used for flavouring soaps, meat dishes and sauces, bread rolls, pastries and confectionery, liquors and in the manufacture of pickles.

Sowing date is an very important parameters in crop 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. In very early seeding, the low temperatures of the soil and frost damages cause a weak growth of plants in spring. On the other hand, very delaying seeding leads to a reduction in the growth period of plants and the chance of coincidence in the blossoming time since high temperatures which will have an opposite impact on the plant growth. One of the most important factors of agricultural production management is choosing the suitable time for cultivation to obtain optimum use of natural resources during the growth season [4].

Plant nutrient one of the most important factors that increase plant production. Adequate supply of nutrients increase the yield. Chemical

fertilizers are key components for providing crop nutrient needs in recent years. In many cases, using chemical fertilizers has different negative environmental effects such as soil, water and air pollution, which increase environmental production cost [5]. To avoid the risk of these negative effects of chemical fertilizers, it is necessary to use organic or biological fertilizers which provide plant nutrients and also increase long term sustainability of agroecosystems. There is a strong relation between soil organic matter content and soil fertility, widely and universally accepted. At present, using organic manures and biofertilizers, such as vermicompost has led to a decrease in the application of chemical fertilizers and provide high quality products free of harmful agro chemicals for human safety [6]. Vermicompost is produced as an alternative to fertilizer to improve plant growth while not at the outlay of the environment. Vermicompost increased the bioavailability of nutrients from mineralization, which encourages high germination and dry matter production of plants [7]. Application of nutrients such as NPK and vermicompost induce the fennel production. [8] reported that vermicompost contains the most nutrients in plant available forms, such as nitrates, phosphates and exchange ablecalcium and soluble potassium. Soil treated with vermicompost, total porosities were 24% higher than in the unfertilized soil [9]. Some studies have reported that vermicompost can increase the quantity and quality of essential oil in a few medicinal plants such as basil [10] coriander [11], fennel [12]. The aim of this study was to determine growth and yield of fennel (*Foeniculum vulgare*) essential oil as affected by the sowing time and application of vermicompost and NPK fertilizer.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site and Experimental Framework

The research work was conducted at "Horticulture Farm" of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from November 2019 to March 2020.

The location of the site was 23°74' N Latitude and 90°35' E Longitude with an elevation of 8.2 meters from the sea level (Anon, 1987). There are two factors named as factor-A (sowing time): S<sub>1</sub> = First week of November, S<sub>2</sub> = Last week of November, S<sub>3</sub> = First week of December, S<sub>4</sub> = Last week of December and Factor-B (nutrients): T<sub>0</sub> = Control, T<sub>1</sub> = Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub> = NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub> = Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>). The two-factorial experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was divided into three equal blocks. Each block was divided into 12 plots where 12 treatments combination were distributed randomly. There were 36 unit plots altogether in the experiment.

## 2.2 Planting Materials

The seeds of fennel cv. BARI Mouri-1 variety was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

## 2.3 Application of Manures and Fertilizers

Farmyard manure (FYM), Urea, TPS and MoP and were applied @ 2.5-ton ha<sup>-1</sup>, 80, 50 and 60 kg ha<sup>-1</sup>, respectively as per treatment. The FYM was applied after opening the land. The total amount of TSP and MoP were applied at the final land preparation. Total urea was applied in two installments. The 1<sup>st</sup> installments were applied at final land preparation and 2<sup>nd</sup> installments were applied 45 days after planting as top dressing as per treatment. The fertilizer was thoroughly mixed with the soil.

## 2.4 Statistical Analysis

The collected data were compiled and tabulated. Statistical analysis was done on various plant characters to find out the significance of variance resulting from the experimental treatments. Data were analyzed using analysis of variance (ANOVA) technique with the help of the computer package program MSTAT-C (software) and the mean differences were adjudged by least significant difference test (LSD) as laid out by [13].

## 3. RESULTS AND DISCUSSION

### 3.1 Plant Height (cm)

Plant height is an important parameter which reflects the vegetative growth of plants. The plant

height was significantly influenced by different sowing time on fennel (Fig. 1). At 45 DAS, first week of November (S<sub>1</sub>) showed the longest plant (9.25 cm) which was statistically identical to S<sub>2</sub> (9.11 cm) whereas, the shortest plant (7.83 cm) was found from last week of December (S<sub>4</sub>) treatment. The last week of November (S<sub>2</sub>) showed the longest plant (49.04 cm and 107.44 cm at 90 and 135 DAS, respectively) and the shortest plant (38.72 and 97.15 cm at 90 and 135 DAS, respectively) was found from last week of December (S<sub>4</sub>) treatment. This might be due to the fact that last week of November possibly received favorable condition for the quickest growth than those of other sowing time. This result agrees with the result obtained by [14] they reported that the sowing of fennel in the first date (20<sup>th</sup> November) resulted in increase of all studied vegetative [15].

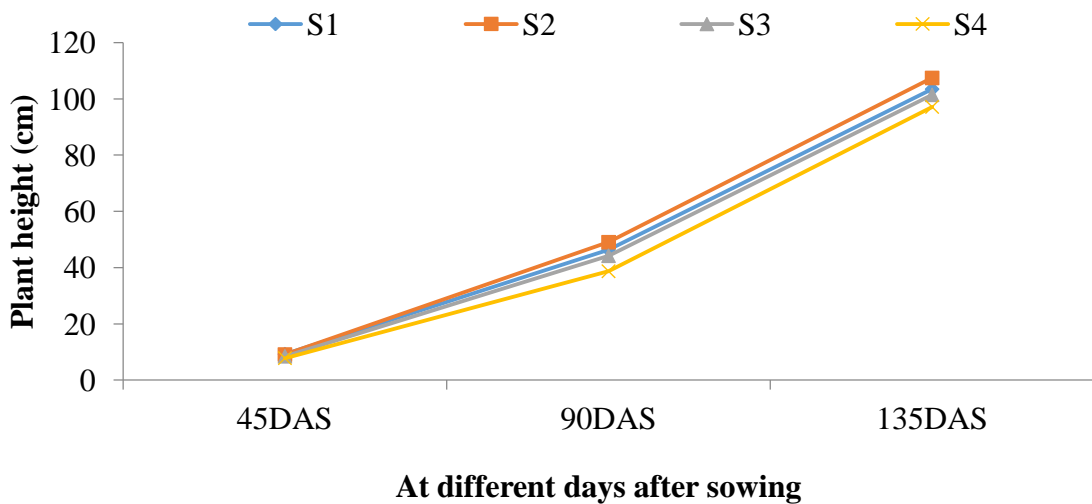
The plant height was observed significantly influenced by different nutrient application (Fig. 2). The tallest plant (10.84, 56.25 and 114.83 cm, respectively) was recorded from T<sub>3</sub> (Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)) application at 45, 90 and 135 DAS, while the shortest plant (6.63, 32.06 and 86.33 cm, respectively) was observed from the control (T<sub>0</sub>) treatment at the same growth stage. The tallest plant at all dates of observations were found when vermicompost with NPK application. The variation in plant height as influenced by different nutrients was perhaps due to proper utilization nutrients, moisture and light. This result is agreed with the findings [16,17]. [18] also conducted that the application of vermicompost increased the growth measurements.

The combined effect of different sowing time and nutrients was found statistically significant on all dates of observation (Table 1). At 45 DAS, the tallest plant (11.83 cm) was measured from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment, which was statistically similar to S<sub>1</sub>T<sub>3</sub> (11.33 cm) and the shortest plant (6.00 cm) was recorded from S<sub>3</sub>T<sub>0</sub> (first week of December with control) treatment, which was statistically similar to S<sub>4</sub>T<sub>0</sub> (6.33 cm) and S<sub>2</sub>T<sub>0</sub> (7.04 cm). At 90 DAS, the tallest plant (60.73 cm) was measured from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment which was statistically similar to S<sub>1</sub>T<sub>3</sub> (59.20 cm) whereas, the shortest plant (29.27 cm) was recorded from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment which was statistically similar to S<sub>3</sub>T<sub>0</sub>

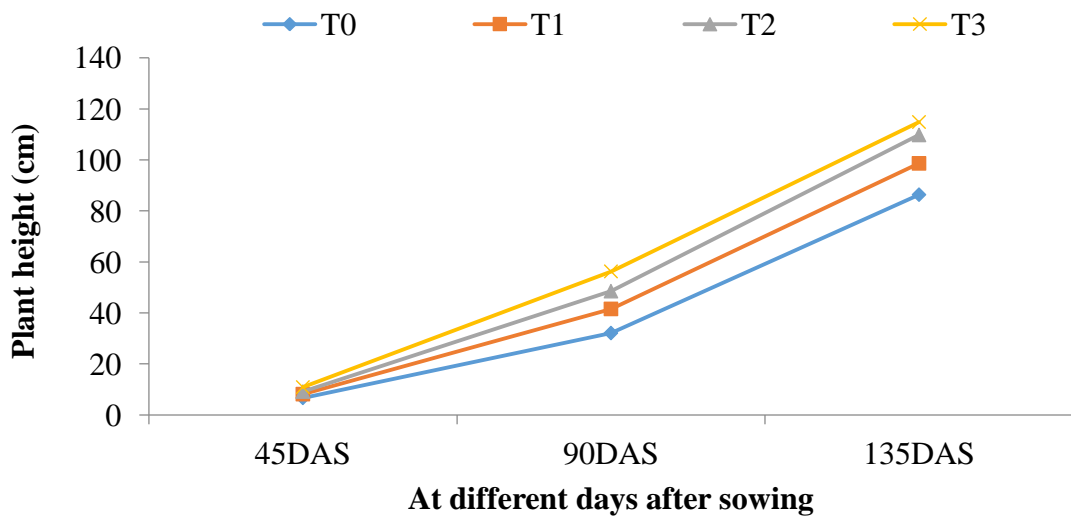
(30.00 cm). At 135 DAS, the longest plant (117.59 cm) was measured from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment while, the shortest plant (82.00 cm) was recorded from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment. This might be due to the fact that environmental conditions for vegetative growth were favorable for older seedlings for completing vegetative growth.

### 3.2 Number of Leaves Plant<sup>-1</sup>

Good foliage indicates higher growth, development and production of plant. In the present study, the number of leaves per plant was found to be significantly influenced by the different sowing time (Table 2). The maximum number of leaves (12.68) plant<sup>-1</sup> of fennel was observed from S<sub>2</sub> (last week of November)



**Fig. 1. Effect of different sowing time on plant height (cm) at different days after sowing of fennel (*Foeniculum vulgare*)**  
 Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December and S<sub>4</sub>– Last week of December



**Fig. 2. Effect of different nutrients on plant height (cm) at different days after sowing of fennel (*Foeniculum vulgare*)**  
 Here, Nutrient: T<sub>0</sub>- Control, T<sub>1</sub>- Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub>- NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub>- Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

treatment. A similar trend was obtained by [14] who reported that the planting of fennel plant in the first date (20<sup>th</sup> November) resulted in increase of number of leaves plant<sup>-1</sup>.

The results showed a highly significant effect of different nutrient application on the number of leaves plant<sup>-1</sup> (Table 3). The maximum number of leaves (14.02) was recorded from T<sub>3</sub> (Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment. It was observed that the number of leaves per plant was higher in plants with all nutrient's applications. This result agrees with the findings of [16].

The maximum number of leaves (15.07) was recorded from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment which was statistically similar (14.00) by S<sub>3</sub>T<sub>3</sub> (first week of December with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment. On the other hand, the minimum number of leaves (8.20) was observed from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment of fennel which was statistically similar to S<sub>3</sub>T<sub>0</sub> (9.33) and S<sub>4</sub>T<sub>1</sub> (9.40) treatment.

### 3.3 Number of Primary Branches

Effect of different sowing time significantly influenced number of primary branches plant<sup>-1</sup> (Table 2). The highest number of primary branches plant<sup>-1</sup> (6.99) was recorded from the S<sub>1</sub> (first week of November) treatment. The lowest number (6.00) of primary branches plant<sup>-1</sup> was recorded from the S<sub>4</sub> (last week of December) treatment. This study revealed that first week of November produced the maximum number of primary branches plant<sup>-1</sup>. These findings are in accordance with the results of [19,20].

Effect of different nutrient application significantly influenced number of primary branches plant<sup>-1</sup> (Table 3). The highest number (7.42) of primary branches plant<sup>-1</sup> was recorded from the Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup> (T<sub>3</sub>) treatment. On the other hand, the lowest number (5.56) of primary branches plant<sup>-1</sup> was recorded from the control (T<sub>0</sub>) treatment. This study revealed that all nutrient application produced the maximum number of primary branches plant<sup>-1</sup>. [21] showed that the integrated nutrient management significantly affected different growth and yield attributes of fennel viz., plant height (cm), number of branches per plant.

The combined effect of different sowing time and nutrients application was also found to be statistically significant in this respect (Table 4) The highest number (7.99) of primary branches plant<sup>-1</sup> was recorded from S<sub>1</sub>T<sub>3</sub> (first week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment which was statistically similar to S<sub>1</sub>T<sub>3</sub> (7.62) treatment. On the other hand, the lowest number (4.81) of primary branches plant<sup>-1</sup> was observed from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment of fennel which was statistically identical to S<sub>3</sub>T<sub>0</sub> (5.08) treatment.

### 3.4 Number of Secondary Branches

Effect of different sowing time significantly influenced number of secondary branches plant<sup>-1</sup> (Table 2). The maximum number of secondary branches plant<sup>-1</sup> (17.64) was recorded from the S<sub>2</sub> (last week of November) treatment whereas, the minimum (15.45) was recorded from the S<sub>4</sub> (last week of December) treatment. This study revealed that last week of November produced the highest number of secondary branches plant<sup>-1</sup>.

Effect of different nutrient application significantly influenced number of secondary branches plant<sup>-1</sup> (Table 3). The maximum number (18.61) of secondary branches plant<sup>-1</sup> was recorded from the T<sub>3</sub> (Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment whereas, the minimum (13.87) was recorded from the control (T<sub>0</sub>) treatment. This study revealed that all nutrients application produced the maximum number of secondary branches plant<sup>-1</sup>.

The combined effect of different sowing time and nutrient application was also found to be statistically significant in this respect (Table 4). The maximum number of secondary branches plant<sup>-1</sup> (20.18) was recorded from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment combination which was statistically similar to S<sub>1</sub>T<sub>3</sub> (19.61) treatment whereas, the minimum number (12.73) of secondary branches plant<sup>-1</sup> was observed from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment.

### 3.5 Number of Umbel Plant<sup>-1</sup>

Different sowing time had a significant effect on number of umbel plant<sup>-1</sup> of fennel (Fig. 3). The highest number of umbel plant<sup>-1</sup> (22.94) was recorded from S<sub>2</sub> (last week of November) treatment. In comparison, the lowest number of umbel plant<sup>-1</sup> (17.53) was recorded from S<sub>4</sub> (last

week of December) treatment of sowing time. Ayub et al. [19] found that the number of umbels per plant was affected significantly by different sowing date.

The different nutrients application had a significant effect on number of umbel plant<sup>-1</sup> of fennel (Fig. 4). The highest number of umbel plant<sup>-1</sup> (24.39) was recorded from T<sub>3</sub> (vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment. In comparison, the lowest number of umbel plant<sup>-1</sup> (16.79) was recorded from T<sub>0</sub> (control) treatment of nutrient application.

The combined effect of different sowing time and nutrient application showed significant effect on the number of umbel plant<sup>-1</sup> of fennel (Table 4). The highest number of umbel plant<sup>-1</sup> (26.75) was recorded from treatment combination of the last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup> (S<sub>2</sub>T<sub>3</sub>) which was statistically similar to S<sub>1</sub>T<sub>3</sub> (25.80) treatment. In comparison, the lowest number of umbel plant<sup>-1</sup> (14.53) was recorded from last week of December with control treatment combination (S<sub>4</sub>T<sub>0</sub>).

**Table 1. Combined effect of different sowing time and nutrients on plant height at different days after sowing of fennel (*Foeniculum vulgare*)**

Treatments	Plant height (cm)		
	45 DAS	90 DAS	135 DAS
S <sub>1</sub> T <sub>0</sub>	7.17 gh	33.13 j	87.07 i
S <sub>1</sub> T <sub>1</sub>	8.50 de	42.47 g	98.00 f
S <sub>1</sub> T <sub>2</sub>	10.00 c	50.47 d	113.53 b
S <sub>1</sub> T <sub>3</sub>	11.33 ab	59.20 ab	115.27 b
S <sub>2</sub> T <sub>0</sub>	7.04 hi	35.83 i	92.00 h
S <sub>2</sub> T <sub>1</sub>	8.41 d-f	46.27 f	105.40 d
S <sub>2</sub> T <sub>2</sub>	9.13 d	53.33 c	114.77 b
S <sub>2</sub> T <sub>3</sub>	11.86 a	60.73 a	117.59 a
S <sub>3</sub> T <sub>0</sub>	6.00 j	30.00 k	84.27 j
S <sub>3</sub> T <sub>1</sub>	7.77 fg	40.13 h	96.00 fg
S <sub>3</sub> T <sub>2</sub>	9.13 d	48.27 e	110.47 c
S <sub>3</sub> T <sub>3</sub>	11.07 b	58.53 b	115.07 b
S <sub>4</sub> T <sub>0</sub>	6.33 ij	29.27 k	82.00 k
S <sub>4</sub> T <sub>1</sub>	7.73 f-h	37.20 i	95.00 g
S <sub>4</sub> T <sub>2</sub>	8.13 ef	41.87 gh	100.20 e
S <sub>4</sub> T <sub>3</sub>	9.10 d	46.53 ef	111.40 c
LSD <sub>(0.05)</sub>	0.7238	1.9092	2.0084
CV%	4.91	2.49	3.08

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December, S<sub>4</sub>– Last week of December and Nutrient: T<sub>0</sub> - Control, T<sub>1</sub> - Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub> - NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub> - Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

**Table 2. Effect of different sowing time on number of leaves, number of primary branches, number of secondary branches and number of umbellet umbel<sup>-1</sup> of fennel (*Foeniculum vulgare*)**

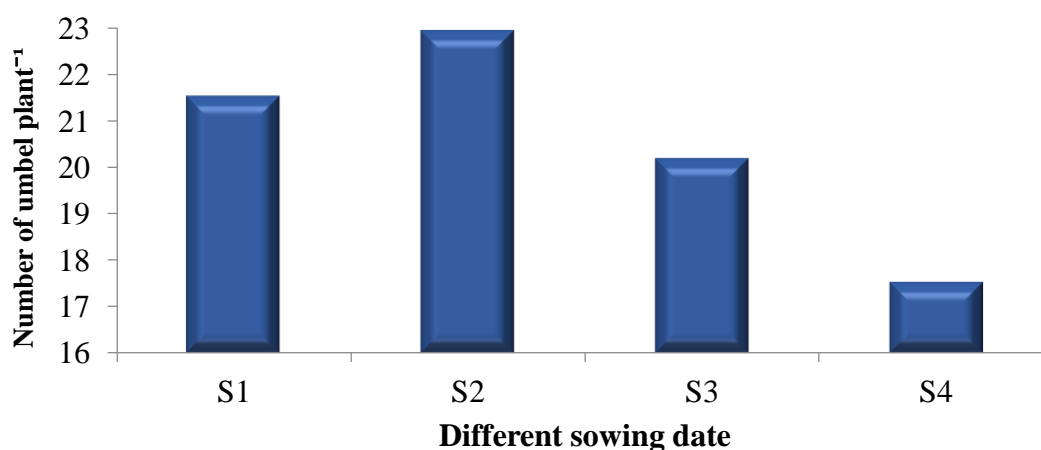
Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbellet umbel <sup>-1</sup>
S <sub>1</sub>	11.67 b	6.99 a	16.40 b	23.51 b
S <sub>2</sub>	12.68 a	6.73 b	17.64 a	24.53 a
S <sub>3</sub>	11.33 b	6.26 c	15.82 c	22.63 c
S <sub>4</sub>	10.42 c	6.00 d	15.45 d	21.65 d
LSD <sub>(0.05)</sub>	0.6283	0.2444	0.3389	0.5526
CV %	6.32	4.51	2.49	2.96

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December and S<sub>4</sub>– Last week of December

**Table 3. Effect of different nutrients on number of leaves, number of primary branches, number of secondary branches and number of umbellet umbel<sup>-1</sup> of fennel (*Foeniculum vulgare*)**

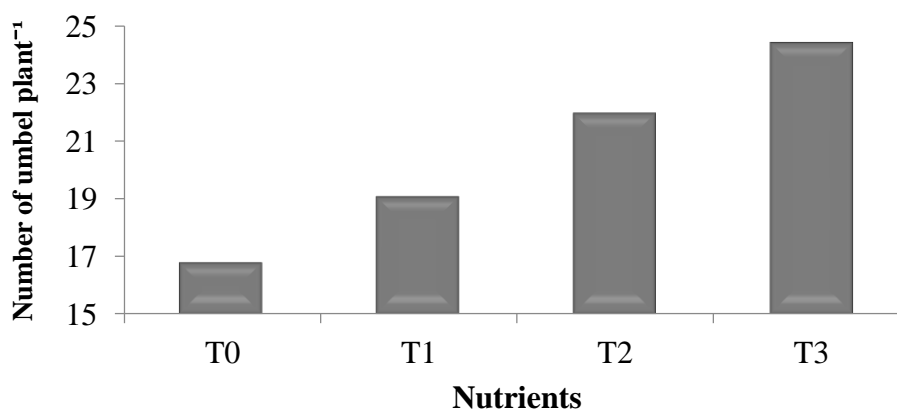
Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbellet umbel <sup>-1</sup>
T <sub>0</sub>	9.30 d	5.56 c	13.87 d	20.34 d
T <sub>1</sub>	10.77 c	6.38 b	16.03 c	21.85 c
T <sub>2</sub>	12.02 b	6.62 b	16.81 b	24.55 b
T <sub>3</sub>	14.02 a	7.42 a	18.61 a	25.58 a
LSD <sub>(0.05)</sub>	0.6283	0.2444	0.3389	0.5526
CV %	6.32	4.51	2.49	2.96

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Nutrient: T<sub>0</sub>- Control, T<sub>1</sub>- Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub>- NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub>- Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)



**Fig. 3. Effect of different sowing time on number of umbel plant<sup>-1</sup> of fennel (*Foeniculum vulgare*)**

(LSD value = 0.6279). Here, Sowing time: S<sub>1</sub>- First week of November, S<sub>2</sub>- Last week of November, S<sub>3</sub>- First week of December and S<sub>4</sub>- Last week of December



**Fig. 4. Effect of different nutrients on number of umbel plant<sup>-1</sup> of fennel (*Foeniculum vulgare*)**

(LSD value = 0.6279). Here, Nutrient: T<sub>0</sub>- Control, T<sub>1</sub>- Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub>- NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub>- Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

### 3.6 Number of Umbellet Umbel<sup>-1</sup>

Different sowing time had a significant effect on the number of umbellet umbel<sup>-1</sup> of fennel (Table 2). The maximum number of umbellet umbel<sup>-1</sup> (24.53) was recorded from S<sub>2</sub> (last week of November) treatment and the minimum (21.65) was recorded from S<sub>4</sub> (last week of December) treatment of sowing time.

The different nutrients application had a significant effect on the number of umbellet umbel<sup>-1</sup> of fennel (Table 3). The maximum number of umbellet umbel<sup>-1</sup> (25.58) was recorded from T<sub>3</sub> (vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment whereas, the minimum number of umbellet umbel<sup>-1</sup> (20.34) was recorded from T<sub>0</sub> (control) treatment of nutrient application.

Combination effect of different sowing time and nutrients application showed significant effect on number of umbellet umbel<sup>-1</sup> of fennel (Table 4). The maximum number of umbellet umbel<sup>-1</sup> (27.72) was recorded from treatment combination of S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>).

On the other hand, the minimum number of umbellet umbel<sup>-1</sup> (19.07) was recorded from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment combination.

### 3.7 DAS to First Flower

Significant variation was observed for DAS (days after sowing) to first flower among the different sowing time (Table 5). The maximum DAS to first flower (88.43 day) was observed in S<sub>4</sub> (last week of December) treatment, while the minimum (82.76 day) was observed during S<sub>1</sub> (first week of November) treatment. The minimum number of days after sowing to first flower was observed with the crops sown on the first week of November.

Significant variation was observed for DAS to first flower among the different nutrient's application of fennel (Table 6). The maximum DAS to first flower (88.45 day) was observed in T<sub>0</sub> (control) treatment whereas, the minimum (83.30 day) was observed during T<sub>3</sub> (Vermicompost 2.5 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment.

**Table 4. Combined effect of different sowing time and nutrients on number of leaves, number of primary branches, number of secondary branches, number of umbel plant<sup>-1</sup> and number of umbellets umbel<sup>-1</sup> of fennel (*Foeniculum vulgare*)**

Treatments	Number of leaves	Number of primary branches	Number of secondary branches	Number of umbel plant <sup>-1</sup>	Number of umbellet umbel <sup>-1</sup>
S <sub>1</sub> T <sub>0</sub>	9.67 d	6.33 de	14.00 i	17.40 i	20.67 ij
S <sub>1</sub> T <sub>1</sub>	11.67 c	6.80 cd	15.00 gh	20.20 fg	22.13 gh
S <sub>1</sub> T <sub>2</sub>	12.00 c	6.88 c	17.00 d	22.73 d	24.67 cd
S <sub>1</sub> T <sub>3</sub>	13.33 b	7.99 a	19.61 ab	25.80 ab	26.58 b
S <sub>2</sub> T <sub>0</sub>	10.00 d	6.03 e	15.20 f-h	19.00 gh	21.40 hi
S <sub>2</sub> T <sub>1</sub>	12.00 c	6.47 c-e	17.00 d	21.13 ef	23.75 d-f
S <sub>2</sub> T <sub>2</sub>	13.67 b	6.80 cd	18.17 c	24.85 bc	25.25 c
S <sub>2</sub> T <sub>3</sub>	15.07 a	7.62 ab	20.18 a	26.75 a	27.72 a
S <sub>3</sub> T <sub>0</sub>	9.33 de	5.08 f	13.53 i	16.23 i	20.20 j
S <sub>3</sub> T <sub>1</sub>	10.00 d	6.13 e	14.83 h	18.73 h	21.27 h-j
S <sub>3</sub> T <sub>2</sub>	12.00 c	6.40 c-e	15.80 ef	21.53 de	25.52 bc
S <sub>3</sub> T <sub>3</sub>	14.00 ab	7.41 b	19.12 b	24.27 c	23.53 ef
S <sub>4</sub> T <sub>0</sub>	8.20 e	4.81 f	12.73 j	14.53 j	19.07 k
S <sub>4</sub> T <sub>1</sub>	9.40 de	6.13 e	17.27 d	16.20 i	20.27 j
S <sub>4</sub> T <sub>2</sub>	10.40 d	6.40 c-e	16.27 e	18.67 h	22.75 fg
S <sub>4</sub> T <sub>3</sub>	13.67 b	6.68 cd	15.53 fg	20.73 ef	24.50 c-e
LSD <sup>(0.05)</sup>	1.2566	0.4888	0.6777	1.2558	1.1051
CV%	6.32	4.51	2.49	3.48	2.96

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December, S<sub>4</sub>– Last week of December and Nutrient: T<sub>0</sub>- Control, T<sub>1</sub> - Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub> - NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub> - Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)



Combined effect of different sowing time with different nutrients applications showed significant variation in DAS to first flower on fennel (Table 7). The maximum DAS to first flower (90.83 day) was recorded from  $S_4T_0$  treatment. On the other hand, the minimum DAS to first flower (80.20 day) was observed from  $S_1T_3$  treatment, which was statistically identical to that of  $S_1T_2$  (80.57 day) treatment. The lowest number of DAS to first flower was observed in crops sown on first week of November with Vermicompost  $2.5 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$  application.

### 3.8 Seed Weight Umbel<sup>-1</sup> (g)

The different sowing time had a significant effect on seed weight umbel<sup>-1</sup> of fennel (Table 5). The maximum seed weight umbel<sup>-1</sup> (1.48 g) was recorded from  $S_4$  (Last week of December) treatment, whereas, the minimum seed weight umbel<sup>-1</sup> (1.27 g) was recorded from  $S_3$  (first week of December) treatment of sowing time which was statistically identical (1.33 g) to  $S_2$  (last week of November). Rassam et al. [22] reported that delay in planting date caused significant reduction in seed weight per umbel.

The different nutrients application had significant effect on seed weight umbel<sup>-1</sup> of fennel (Table 6). The maximum seed weight umbel<sup>-1</sup> (1.92 g) was recorded from  $T_3$  (vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) treatment whereas, the minimum seed weight umbel<sup>-1</sup> (0.88 g) was recorded from  $T_0$  (control) treatment of nutrients application.

The combination effect of different sowing time and nutrient application showed significant effect on seed weight umbel<sup>-1</sup> of fennel (Table 7). The maximum seed weight umbel<sup>-1</sup> (2.09 g) was recorded from treatment combination of  $S_2T_3$  (last week of November with Vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) treatment which was statistically identical (2.08 g) to  $S_4T_3$  (Last week of December with Vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) treatment. On the other hand, the minimum seed weight umbel<sup>-1</sup> (0.78 g) was recorded from last week of November with control treatment combination ( $S_2T_0$ ) which was statistically similar to  $S_1T_0$  (0.89 g) treatment combination [23].

### 3.9 1000-Seeds Weight (g)

1000-seeds weight showed significant difference of fennel due to different sowing time (Table 5). The highest weight of 1000 seeds (5.96 g) was

recorded from  $S_2$  (last week of November) treatment, which was statistically similar to  $S_1$  (5.83 g), whereas the low weight of 1000 seeds (5.39 g) was observed during  $S_4$  (last week of December) treatment. [19] found that the effect of different sowing time on 1000-seed weight of main, primary and secondary umbels was found to be non-significant.

1000-seed weight of fennel differed significantly due to different nutrients application (Table 6). The highest weight of 1000 seeds (5.97 g) was recorded from  $T_3$  (Vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) treatment, which statistically similar to  $T_2$  (5.81 g) treatment. On the other hand, the lowest weight of 1000 seeds (5.49 g) was found  $T_0$  (control) treatment, which statistically similar to  $T_1$  (5.65 g) treatment. Further increase in 1000-seed weight in treatments receiveing NPK dcompared to control might be due to better availability of nutrients that might have helped in producing bolder and heavier seeds.

The combined effect between different sowing time and nutrients application showed significant variation in weight of 1000 seeds (Table 7). The highest 1000-seed weight (6.38 g) was recorded from  $S_2T_3$  (last week of November with Vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) which was statistically similar to  $S_1T_3$  (6.12 g) treatment combination. On the other hand, the lowest 1000-seed weight (5.13 g) was observed in  $S_4T_0$  (last week of December with control), which was statistically similar to  $S_4T_1$  (5.35 g) and  $S_4T_3$  (5.40 g) treatment combination.

### 3.10 Seed Yield Plant<sup>-1</sup> (g)

In the present study, the seed yield plant<sup>-1</sup> was found to be significantly influenced by the different sowing time (Fig. 6). The highest seed yield plant<sup>-1</sup> (32.36 g) of fennel was observed from  $S_2$  (last week of November) treatment, while the lowest seed yield plant<sup>-1</sup> (27.23 g) was observed from  $S_4$  (last week of December) treatment.

The results showed highly a significant effect of different nutrient application on the seed yield plant<sup>-1</sup> (Fig. 7). The highest seed yield plant<sup>-1</sup> (47.76 g) was recorded from  $T_3$  (Vermicompost  $2.50 \text{ t ha}^{-1} + N_{80}P_{50}K_{60} \text{ kg ha}^{-1}$ ) treatment, while the lowest seed yield plant<sup>-1</sup> (15.05 g) of fennel was found from  $T_0$  (control) treatment.

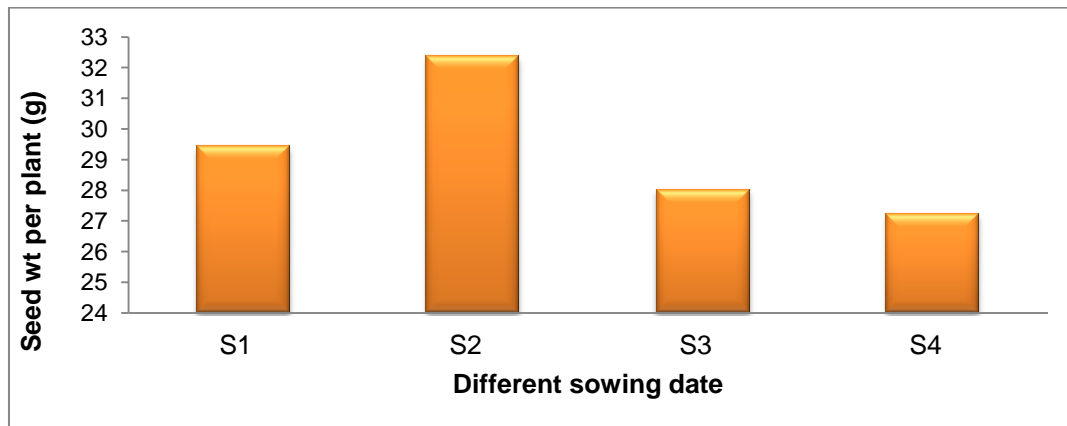
The combined effect of different sowing time and nutrient application was also found to be statistically significant in this respect (Table 7). The highest seed yield plant<sup>-1</sup> (56.04 g) was recorded from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment combination. On the other hand, the lowest seed yield plant<sup>-1</sup> (13.80 g) was observed from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment combination of fennel.

### 3.11 Seed Yield ha<sup>-1</sup> (ton)

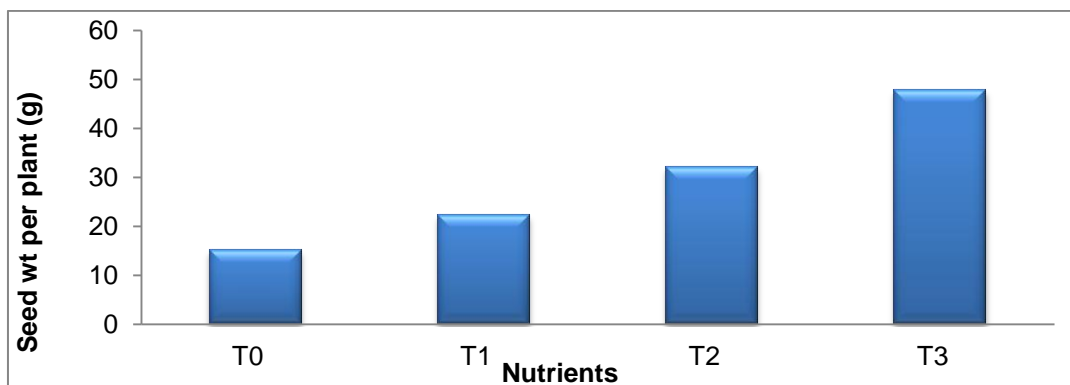
In the present study, the seed yield ha<sup>-1</sup> was found to be significantly influenced by the different sowing time (Table 5). The maximum seed yield ha<sup>-1</sup> (1.35 ton) of fennel was observed from S<sub>2</sub> (last week of November) treatment, while the minimum seed yield ha<sup>-1</sup> (1.13 ton) was observed from S<sub>4</sub> (last week of December) treatment. The obtained results correlated with

those given by authors like [11] they noticed that the earliest sown plants produced the highest seed yields compared with control plants.

The results showed highly a significant effect of different nutrient application on the seed yield ha<sup>-1</sup> (Table 6). The maximum seed yield ha<sup>-1</sup> (1.99 ton) was recorded from T<sub>3</sub> (Vermicompost 2.50 t ha<sup>-1</sup> + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>) treatment, while the minimum seed yield ha<sup>-1</sup> (0.63 ton) of fennel was found from T<sub>0</sub> (control) treatment. It was observed that seed yield ha<sup>-1</sup> was higher in plants with all nutrient's applications. It was probably due to reduced inter plant competition for access to nutrient, moisture and other resources. Increase in yield attributes due to increasing levels of N and P had direct and positive effect on seed, straw and biological yields of fennel. [24] recorded maximum yield and yield attributes of cluster bean with vermicompost @ 2.5 t ha<sup>-1</sup> + 75% NPK.



**Fig. 5. Effect of different sowing time on seed yield plant<sup>-1</sup> (g) of fennel (*Foeniculum vulgare*)** (LSD value = 0.4858). Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December and S<sub>4</sub>– Last week of December



**Fig. 6. Effect of different nutrients on seed yield plant<sup>-1</sup> (g) of fennel (*Foeniculum vulgare*)** (LSD value = 0.4858) Here, Nutrient: T<sub>0</sub> - Control, T<sub>1</sub> - Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub> - NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub> - Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

**Table 5. Effect of different sowing time on seed weight umbel<sup>-1</sup>, seed yield plot<sup>-1</sup>, seed yield ha<sup>-1</sup> and 1000-seed weight of fennel (*Foeniculum vulgare*)**

Treatments	DAS to first flower	Seed weight umbel <sup>-1</sup> (g)	1000-seeds weight (g)	Seed yield ha <sup>-1</sup> (ton)
S <sub>1</sub>	82.76 d	1.38 b	5.83 ab	1.23 b
S <sub>2</sub>	85.28 c	1.33 bc	5.96 a	1.35 a
S <sub>3</sub>	86.70 b	1.27 c	5.73 b	1.17 c
S <sub>4</sub>	88.43 a	1.48 a	5.39 c	1.13 d
LSD <sub>(0.05)</sub>	0.5495	0.0603	0.1833	0.0145
CV %	3.79	2.47	3.63	2.37

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December and S<sub>4</sub>– Last week of December

**Table 6. Effect of different nutrients on seed weight umbel<sup>-1</sup>, seed yield plot<sup>-1</sup>, seed yield ha<sup>-1</sup> and 1000-seed weight of fennel (*Foeniculum vulgare*)**

Treatments	DAS to first flower	Seed weight umbel <sup>-1</sup> (g)	1000-seeds weight (g)	Seed yield ha <sup>-1</sup> (ton)
T <sub>0</sub>	88.45 a	0.88 d	5.49 c	0.63 d
T <sub>1</sub>	86.79 b	1.17 c	5.65 bc	0.93 c
T <sub>2</sub>	84.64 c	1.49 b	5.81 ab	1.33 b
T <sub>3</sub>	83.30 d	1.92 a	5.97 a	1.99 a
LSD <sub>(0.05)</sub>	0.5495	0.0603	0.1833	0.0145
CV %	3.79	2.47	3.63	2.37

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Nutrient: T<sub>0</sub>- Control, T<sub>1</sub>- Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub>- NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub>- Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

**Table 7. Combined effect of different sowing time and nutrients on seed weight umbel<sup>-1</sup>, seed yield plant<sup>-1</sup>, seed yield plot<sup>-1</sup>, seed yield ha<sup>-1</sup> and 1000-seeds weight of fennel (*Foeniculum vulgare*)**

Treatments	DAS to first flower	Seed weight umbel <sup>-1</sup> (g)	1000-seeds weight (g)	Seed yield plant <sup>-1</sup> (g)	Seed yield ha <sup>-1</sup> (ton)
S <sub>1</sub> T <sub>0</sub>	85.68 fg	0.89 fg	5.61 c-g	15.53 j	0.65 j
S <sub>1</sub> T <sub>1</sub>	84.60 gh	1.18 e	5.78 b-e	22.33 h	0.93 h
S <sub>1</sub> T <sub>2</sub>	80.57 j	1.63 c	5.80 b-e	32.13 e	1.34 e
S <sub>1</sub> T <sub>3</sub>	80.20 j	1.84 b	6.12 ab	47.73 b	1.99 b
S <sub>2</sub> T <sub>0</sub>	87.53 de	0.78 g	5.67 c-g	16.13 j	0.67 j
S <sub>2</sub> T <sub>1</sub>	86.731 ef	1.09 e	5.88 b-e	23.20 g	0.97 g
S <sub>2</sub> T <sub>2</sub>	84.27 h	1.36 d	5.92 b-d	34.07 d	1.42 d
S <sub>2</sub> T <sub>3</sub>	82.60 i	2.09 a	6.38 a	56.04 a	2.34 a
S <sub>3</sub> T <sub>0</sub>	89.73 b	0.90 f	5.53 e-g	14.73 k	0.61 k
S <sub>3</sub> T <sub>1</sub>	86.73 ef	1.11 e	5.60 d-g	22.20 h	0.93 h
S <sub>3</sub> T <sub>2</sub>	85.53 g	1.40 d	5.80 b-e	31.13 f	1.29 f
S <sub>3</sub> T <sub>3</sub>	84.80 gh	1.68 c	5.97 bc	43.93 c	1.80 c
S <sub>4</sub> T <sub>0</sub>	90.83 a	0.95 f	5.13 h	13.80 l	0.58 l
S <sub>4</sub> T <sub>1</sub>	89.09 bc	1.32 d	5.35 gh	21.33 i	0.89 i
S <sub>4</sub> T <sub>2</sub>	88.20 cd	1.57 c	5.71 c-f	30.47 f	1.27 f
S <sub>4</sub> T <sub>3</sub>	85.60 g	2.08 a	5.40 f-h	43.33 c	1.81 c
LSD <sub>(0.05)</sub>	1.0991	0.1206	0.3666	0.6967	0.029
CV%	3.79	2.47	3.63	2.37	2.37

In a column means having similar letter (s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 levels of probability. Here, Sowing time: S<sub>1</sub>– First week of November, S<sub>2</sub>– Last week of November, S<sub>3</sub>– First week of December, S<sub>4</sub>– Last week of December and Nutrient: T<sub>0</sub>- Control, T<sub>1</sub>- Vermicompost (2.50 t ha<sup>-1</sup>), T<sub>2</sub>- NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>), T<sub>3</sub>- Vermicompost (2.50 t ha<sup>-1</sup>) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg ha<sup>-1</sup>)

The combined effect of different sowing time and nutrient application was also found to be statistically significant in this respect (Table 7). The maximum seed yield $ha^{-1}$  (2.34 ton) was recorded from S<sub>2</sub>T<sub>3</sub> (last week of November with Vermicompost 2.50 t  $ha^{-1}$  + N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg  $ha^{-1}$ ) treatment combination. On the other hand, the minimum seed yield $ha^{-1}$  (0.58 ton) was observed from S<sub>4</sub>T<sub>0</sub> (last week of December with control) treatment combination of fennel.

#### 4. CONCLUSION

It was revealed that Last week of November sowing gave higher yield of fennel seed with higher values in most of the yield attribute parameters. Among the nutrient application treatments, vermicompost (2.50 t  $ha^{-1}$ ) + NPK (N<sub>80</sub>P<sub>50</sub>K<sub>60</sub> kg  $ha^{-1}$ ) was high yielder than other nutrient treatments. Among the interactions, S<sub>2</sub>T<sub>3</sub> and S<sub>1</sub>T<sub>3</sub> were superior in most of the growth and yield attributing parameters along with grain yield.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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