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# Optimization of Drip Irrigation Scheduling, Crop Geometry and Mulching for Growth, Yield attributes and Yields of Fennel (*Foeniculum vulgare* Mill.)

**R. K. Meena[1] and S.R. Bhunia[2]**

## Abstract

The field experiment was conducted at Niche Area of Excellence Farm, S.K. Rajasthan Agricultural University, Bikaner (Rajasthan) during *the rabi* season of 2015-16 and 2016-17 for optimization of an appropriate drip irrigation schedule under proper crop geometry for maximizing fennel productivity. The experiment was laid out in a split plot design comprising of four irrigation levels in the main plot, three crop geometry in the sub-plot and two mulch treatments in the sub-subplot and replicated three times. The results revealed that growth attributes viz. plant height (117.8 cm), dry matter accumulation (48.72 g plant$^{-1}$) at harvest and total chlorophyll content (1.83 mg g$^{-1}$ of fresh leaves**)** at 75 DAS, yield attributes viz. number of umbels per plant (20.42), test weight (7.10 g), and seed yield (1684 kg ha$^{-1}$) were recorded as significantly highest with drip irrigation scheduled at 0.8 ETc on pooled result basis. Under crop geometry, paired row sowing of 40 cm x 60 cm recorded significantly higher growth, yield attributes, and seed yield of fennel. Moreover, use of plastic mulch significantly increased yield attributes and yield as compared to without mulch treatment. Thus, in arid and semi-arid parts of Rajasthan, integrated use of drip irrigation scheduled at 0.8 ETc and plastic mulch under paired row sowing of 40 cm x 60 cm proved more viable for ensuring higher productivity of *rabi* fennel.

**Keywords**: Drip Irrigation levels, Crop geometry, Mulches and Fennel.

## Introduction

Fennel (*Foeniculum vulgare* Miller), locally called "saunf," belongs to the family *Apiaceae*, and it is believed to be native to southern Europe and the Mediterranean region. It is grown as an aromatic annual and biennial herb; it has golden yellow blooms and feathery, greenish-yellow leaves (Meena *et al.*,2023). All of its parts, including the leaves, stalks, bulbs, and seeds, are edible. The fennel is primarily grown for its seeds, which have an aromatic taste and pleasant scent due to presence of fenchone and trans-anethole in its volatile oil.

Fennel leaves and seeds also aid in the regulation of symptoms such as cough, flatulence, colic, thirst, constipation, diarrhea, and dysentery (Mahatma *et al*., 2022). It has more health-benefiting essential compounds, antioxidants, minerals, vitamins, and nutrients. Fennel contains nutritionally 42.3% carbohydrate, 18.5% fiber, 13.4% mineral, 10% fat, 9.5% protein, about 0.7% to 6.0% volatile oil depending on genotypes and plant types, 1.3 g calcium, 0.48 g phosphorus, 0.01 g iron, 0.09 g sodium, and 1.7 g potassium, etc. (Singh, 2021). Fennel is cultivated chiefly in Russia, Romania, Hungary, Germany, France, Italy, India, Japan, Argentina, and the USA. In India, nearly 80% of annual production of the seed spices is coming from semi-arid and arid parts of Rajasthan and Gujarat states known as the "bowl of seed spices." In Rajasthan, it occupies an area of 28.10 thousand hectares, and production is 29.31 thousand metric tons with an average productivity of 1043 kg $ha^{-1}$ (Spices Board of India, 2022-23). In spite of its huge demand and production potential in arid and semi-arid parts of Rajasthan, the average productivity of drilled *rabi* fennel is low due to a water crisis and improper irrigation planning.

Worldwide, as well as in arid regions, there are challenges with water availability for the agricultural sector. Today, it's more crucial than ever to use water resources sensibly and to irrigate intelligently by using advanced modern irrigation systems (Jeelani *et al*., 2017).

In the arid and semi-arid regions of Rajasthan, where water is scarce, efficient water usage is required due to the rising demand for agriculture water and the inadequate recharging of groundwater in recent years. Due to its wide spacing, fennel may be cultivated under a drip system with success in regions like Rajasthan that have limited water resources. However, area and productivity can both be increased if drip irrigation is involved in irrigating fennel in arid and semi-arid parts of Rajasthan. An ETc-based method is used to prepare irrigation schedules for various crops. Because it takes into account all environmental parameters, ETc-based irrigation scheduling is the appropriate method for delivering irrigation water through a drip system for the best chance of yielding fennel crops. By allowing water slowly through drippers to the plant's root zone through a network of valves, pipes, tubing, and emitters, water-saving drip systems prove to be an efficient technique for conserving resources like water and fertilizer. (Singh *et al*., 2021).

An important non-monetary input that shows promise in raising fennel crop output is optimal plant shape. It's possible that having the ideal amount of space for each plant at the right crop geometry led to a better use of the resources—such as space, nutrients, moisture, carbon dioxide, and radiant energy—to enhance the vegetative and reproductive growth of fennel. (Tamboli *et al*., 2020). To facilitate sufficient water availability in field crops, crop geometry is modified, keeping plant density unchanged.

Since plastic mulch decreases evaporation from the soil's surface, especially during dry spells, it aids in soil moisture retention, which is essential for fennel growth. Mulching reduces the need for labour-intensive, time-consuming weeding, which in turn promotes healthier and more resilient crops. In addition to these benefits, mulch plays a critical function in maintaining soil temperature and moisture, which promotes fennel development. Mulching is therefore a beneficial and useful way to cultivate fennel and is necessary for the plant's health and productivity. (Kumar *et al*., 2023). Under prevailing water scarcity and drought situations, conservation of soil moisture and enhanced water availability to crops are of much importance. In water deficit areas, judicious use of water and moisture conservation is essential for increasing the area under the fennel crop with limited water supply. Mulching using a drip irrigation system is a successful strategy for controlling the crop-growing environment to boost output and enhance product quality (Kumar and Kumar, 2020). There is an urgent need to work out optimum irrigation scheduling based on various ETc levels for optimum utilization of limited water resources in the state. Keeping this in view, a study on "optimization of drip irrigation levels, crop geometry and mulching for fennel (*Foeniculum vulgare* Mill.)" was undertaken.

## Materials and Methods

**Study area and Weather:** Field experiment was conducted at Niche Area Excellence, Swami Keshwanand Rajasthan Agricultural University, Bikaner, situated in Hyper Arid Partially Irrigated North-

Western plain (Zone Ic) of Rajasthan. The experimental field soil was sandy loam in texture, slightly alkaline in reaction with pH (7.6) and EC (0.31 dS $m^{-1}$). The nutrient status was low in organic carbon (0.11%), available nitrogen (85.31 kg $ha^{-1}$), medium in phosphorus (19.8 kg $ha^{-1}$) and potassium (315.2 kg $ha^{-1}$). The total rainfall (31.3 and 3.0 mm) was received during the entire crop season of 2015-16 and 2016-17, respectively. The average relative humidity of the locality fluctuates between 39.55 to 70.36 per cent during 2015-16 and 29.20 to 68.72 per cent during the period of experimentation 2016-17. The pan-evaporation ranged from 1.1 to 6.9 mm $day^{-1}$ during 2015-16 and 1.6 to 11.4 mm $day^{-1}$ during 2016-17.

**Layout and Experimentation:** The experiment was laid out in a split-split plot design comprising of four irrigation levels (0.4, 0.6, 0.8 and 1.0 ETc) in the main plot, three crop geometry (normal sowing at 50 cm row spacing, paired row sowing at 40 x 60 cm and paired row sowing at 30 x 70 cm) in the sub-plot and two mulch treatments (no mulch and plastic mulch) in the sub-sub plot and replicated thrice. The fennel variety "RF-101" was used as a test crop and it was sown on last week of October by *kera* method in varying geometry as per treatment using a seed rate of 10 kg $ha^{-1}$ at the depth of 2-3 cm and harvested on first week of April during the years 2015-16 and 2016-17, respectively. In normal sowing at 50 cm spacing; two rows at 50 cm were sown around laterals and 50 cm spacing between two groups of crop rows. In paired row sowing (40 × 60 cm); two rows at 40 cm space around laterals and 60 cm spacing between two groups of crop rows, in paired row sowing (30 × 70 cm); two rows at 30 cm spacing around laterals and 70 cm spacing between two groups of crop rows. The recommended dose of N-$P_2O_5$-$K_2O$ *i.e.* 90-40-0 kg $ha^{-1}$ was applied through urea (46% N) and DAP (18% N and 46% $P_2O_5$). The whole amount of phosphorus and 30 kg N was applied as basal dose before to sowing while the remaining nitrogen was top-dressed in two equal splits at 45 DAS and at flowering time. Black polythene films with the thickness of 15 microns was used as mulch, which was spread over earmarked plots and holes were made on plastic mulch at a distance of 20 cm in each row plots and their edges were covered with soil, making a small bund. The fennel crop was raised as per the recommended package of practices for the zone- IC. The drip unit consisted of a main line of 63 mm OD (outer diameter) PVC (polyvinyl chloride) pipes, sub-main of 40 mm OD pipes, laterals of 16 mm LLDPE (low linear density polyethylene) pipes were installed at an interval of 1.0 m spacing (in between each paired row) and drippers (4 lit. $hr^{-1}$ capacity) at 30 cm spacing. For the establishment of the crop, one common irrigation of 25 mm depth was given to all the treatments immediately after sowing. Drip irrigation was operated on an alternate days at 1.5 kg $ha^{-1}cm^2$ pressure based on crop evapotranspiration (ETc) of 0.4, 0.6, 0.8 and 1.0 by adjusting the duration of water release at a constant flow rate of 4 lit $hr^{-1}$. Irrigation through drip was applied based on ETc levels *i.e.* PE * Kp*Kc considering Kc values to be 0.70, 0.95, 1.15 and 0.90 for initial-20 days, crop development-35 days, mid- 60 days and final stage-40 days respectively.

Where, ETc - Crop evapotranspiration;

PE-Mean pan evaporation for the month in mm/day;

Kp-Pan factor;

Kc- Crop co-efficient

The total water applied to the field was calculated at different ETc levels viz., 0.4, 0.6, 0.8 and 1.0. The quantity of average irrigation water supplied through drip irrigation level of 1.0 ETc was 391.63 and rainfall received during the cropping period was 14.2 mm. Under the drip irrigation treatment of 1.0 ETc total water used was 430.83 mm. Chlorophyll 'a', chlorophyll 'b' and total chlorophyll (mg $g^{-1}$ fwt) was measured as per Hiscox and Israelstam,1979.

$$\text{Chlorophyll "a" (mg } g^{-1} \text{ fresh weight of leaves)} = \frac{(12.7 \times A_{663}) - (2.69 \times A_{645})}{1000} \times \frac{\text{Volume of DMSO}}{\text{Weight of leaf sample}}$$

$$\text{Chlorophyll "b" (mg } g^{-1} \text{ fresh weight of leaves)} = \frac{(22.9 \times A_{645}) - (4.65 \times A_{663})}{1000} \times \frac{\text{Volume of DMSO}}{\text{Weight of leaf sample}}$$

Total chlorophyll content was worked out by adding chlorophyll "a" and chlorophyll "b" as under:

Total Chlorophyll (mg $g^{-1}$ fresh weight of leaves) = Chlorophyll a + Chlorophyll b

## Results and Discussion

### Influence of drip Irrigation levels

Perusal of data (Fig.1) reveals that the varying drip irrigation levels failed to brings perceptible variation in plant population at 30 DAS and harvest during both the seasons of 2015-16 and 2016-17. However, drip irrigation levels, 1.0 ETc gave highest plant population at harvest 69898 $ha^{-1}$ in pooled result basis. Plant height of fennel was significantly influenced by different irrigation levels at all the stages of crop growth except at 40 DAS. Further, drip irrigation at 1.0 ETc gave highest plant height compared to all other irrigation levels but remained at par with 0.6 and 0.8 ETc. Thus, different levels of irrigation influenced the plant height significantly at later stages *i.e.* 70, 100 DAS and at harvest wherein the irrigation level of 1.0 ETc recorded the maximum plant height and was at par with 0.8 ETc and proved superior to 0.4 and 0.6 ETc. On pooled results basis, irrigation level 1.0 ETc gave higher dry matter accumulation at 40 DAS (3.41 g $plant^{-1}$) but it was statistically at par with irrigation level of 0.6 and 0.8 ETc and significantly superior to lower irrigation levels of 0.4 ETc. Further, in pooled basis, highest dry matter accumulation (*viz*. 14.93 and 50.28 g $plant^{-1}$) was recorded with drip irrigation at 1.0 ETc, which remained at par with irrigation levels 0.8 ETc (14.58 and 48.72 g $plant^{-1}$) at 70 DAS and harvest. At harvest dry matter production increased by 41.47, 16.60 and 3.20% in pooled basis at 1.0 ETc irrigation level over 0.4, 0.6 and 0.8 ETc irrigation levels, respectively. The highest chlorophyll a, b and total chlorophyll content in leaves was recorded with 1.0 ETc (1.43, 0.426 and 1.86 mg $g^{-1}$ fresh weight of leaves), which was at par with 0.8 ETc (1.42, 0.412 and 1.83 mg $g^{-1}$ fresh weight of leaves) at 75 DAS, but superior to irrigation at 0.4 and 0.6 ETc on pooled mean basis. Further, results revealed that increasing levels of irrigation up to 0.8 ETc significantly increased yield parameters viz., number of umbels $plant^{-1}$ and seed yield of fennel. It was seen that drip irrigation at 1.0 ETc recorded significantly maximum number of umbels $plant^{-1}$ (20.54, 20.88 and 20.71) and seed yield (1701, 1727 and 1714 kg $ha^{-1}$), which was at par with 0.8 ETc, but significantly higher than 0.4 and 0.6 ETc during both the years 2015-16, 2016-17 as well as on pooled results . Seed yield increased to the tune of 79.76, 14.92% in 2015-16, 76.30 and 6.09% in 2016-17 and 78.01 and 10.35% on pooled basis by 0.8 ETc over 0.4 and 0.6 ETc irrigation levels, respectively. Highest test weight (7.11, 7.30 and 7.21g) was recorded with irrigation level of 1.0 ETc during 2015-16, 2016-17 as well as on pooled basis. Further, on pooled basis drip irrigation at 0.8 (7.10 g) and 1.0 ETc (7.21 g) gave at par test weight. The 0.8 and 1.0 ETc irrigation levels by drip may have boosted plant height and yield qualities because they maintained soil moisture at field capacity and expanded the rhizosphere due to the increased water volume. As a result, plants take in a lot of moisture and nutrients from the soil, which is reflected in an increase in cell turgidity and elongation. This leads to improved plant growth and development, which in turn generates higher yield attributes and fennel seed production. The establishment of a water deficit in plant tissue and decreased nutrient availability resulted in decreased leaf water content and a drop in both cell volume and cell turgor were the causes of the decrease in plant height at 0.4 and 0.6 ETc irrigation levels. The reason for the yield increase in drip irrigation with higher ETc levels is that the crop did not experience moisture stress during the growth period because of the frequent higher volume of water application through drip irrigation, which created a favorable microclimate and kept soil moisture consistently closer to field capacity. Results of present study are closely related with the findings of Akash *et al.* (2023) and Devi *et al*. (2023) in fennel.

### Influence of Crop geometry

Pooled analysis of data presented in Table 1 showed that plant population at 30 DAS and harvest, plant height and dry matter accumulation at 40 DAS and total chlorophyll content was not influenced due to varying

crop geometry. Among different crop geometry, paired row sowing at 40 cm × 60 cm recorded highest plant height 14.80, 46.01, 85.24 and 117.4 cm over normal sowing at 50 cm row spacing and paired row sowing at 30 cm × 70 cm at 70, 100 DAS and harvest. The observed increase in plant height due to paired row sowing at 40 cm x 60 cm was of the order 3.84, 3.27 and 2.17% at 70, 100 DAS and harvest, respectively over normal sowing at 50 cm row spacing on pooled result basis. Further, paired row sowing at 40 cm x 60 cm significantly recorded higher dry matter of 13.25, 22.59 and 46.80 g plant$^{-1}$ over normal sowing at 50 cm (12.61, 21.68 and 44.32 g plant$^{-1}$) and paired row sowing of 30 cm x 70 cm (12.26, 21.02 and 42.13 g plant$^{-1}$) at 70, 100 DAS and harvest, respectively. In pooled data basis, chlorophyll content in leaves was not influenced significantly due to crop geometry. However, higher total chlorophyll content (1.73 mg g$^{-1}$ fresh leaves) was recorded under paired row sowing at 40 cm x 60 cm spacing at 75 DAS. On pooled basis, paired row sowing at 40 cm x 60 cm recorded significantly maximum number of umbels plant$^{-1}$ (19.05, 19.33 and 19.19), test weight (6.80 6.95 and 6.87 g) and seed yield (1510, 1550 and 1530 kg ha$^{-1}$) followed by normal sowing at 50 cm row spacing and paired row sowing at 30 cm x 70 cm during 2015-16, 2016-17 as well as on pooled mean basis. Proper paired row geometry facilitates sufficient interception of sunlight and satisfactory absorption of nutrients and water from the soil due to proper development of root system (Annadurai *et al*., 2009). The enhanced yield components might be due to the fact that in paired row (40 cm x 60 cm) planted crop received more irrigation water which led to increased photosynthetic area, higher photosynthetic rate and accumulation of more assimilates which in turn increased the seed yield and quality of produce. These results are in conformity with those of Devi *et al*. (2023) in fennel, Kumar *et al.* (2015) in fenugreek and Meena *et al*. (2015) in dill crop.

**Influence of Mulching**

A comprehensive analysis of data presented in Table 2 reveals that plant height was significantly affected by plastic mulch on pooled basis. The maximum plant height under plastic mulch was measured on a pooled basis at all observational stages, and it remained substantially higher than that of no mulch. On a pooled basis, plastic mulch significantly outperformed over no mulch treatment in terms of maximum plant height (45.35, 83.79, and 117.2 cm) and dry matter accumulation (13.17, 22.21, and 45.61 g plant-1) at 70, 100 DAS, and harvest, respectively. When plastic mulch was used instead of no mulch treatment, the maximum total chlorophyll content (1.73 mg g-1 fresh leaves) at 75 DAS was observed on a pooled basis. The amount of umbels plant-$^{1}$ (18.72, 19.27, and 18.99) and seed yield (1481, 1530, and 1505 kg ha-1) increased significantly with plastic mulch; the increases were 6.12, 6.23, and 6.15% and 5.26, 5.30, and 5.24% over the no mulch treatment. It is clear that using plastic mulch improves plant growth by modifying the microclimate, which in turn conserves more moisture by decreasing evaporation, changing the temperature of the soil, suppressing weeds, and using less irrigation water. Furthermore, as noted by Saren *et al.* (2008), plants that receive enough moisture experience full cell turgidity and eventually higher meristematic activity, which promotes more foliage development, a higher photosynthetic rate, improved plant growth, and a favourable effect on sink components.

**Interaction effect of drip irrigation levels and crop geometry**

Data in Table 3 show that interaction effect of drip irrigation levels and crop geometry significantly influenced the number of umbels plant$^{-1}$, test weight and seed yield. Data further highlighted that on pooled basis, irrigation at 1.0 ETc along with normal sowing at 50 cm row spacing gave maximum number of umbels plant$^{-1}$ (21.65), test weight (7.59 g) but it remained at par with 0.8 and 1.0 ETc along with paired row sowing of 40 cm × 60 cm. At same crop geometry, increasing levels of irrigation significantly increased the number of umbels plant$^{-1}$ up to 0.8 ETc level in pooled mean results. Further increase in irrigation level could not increase umbel plant$^{-1}$ significantly. Data reveals that paired row sowing at 40 cm × 60 cm with 0.8 ETc recorded significantly maximum test weight, which was comparable with 1.0 ETc on pooled result basis. Data further highlighted that on pooled basis, 0.8 ETc along with paired row sowing at 40 cm x 60 cm spacing recorded highest seed yield (1772 kg ha$^{-1}$), which was statistically at par with 1.0 ETc along with normal sowing at 50 cm row spacing and paired row sowing at

40 cm x 60 cm.

## Conclusion

It was concluded from the study that higher growth, yield attributes and seed yield of fennel crop can be obtained with drip irrigation scheduled at 0.8 ETc under paired row sowing of 40 cm x 60 cm and the magnitude was higher with use of plastic mulch over no mulch treatment. Therefore, for fennel cultivation in arid and semi-arid regions, integrated use of drip irrigation applied at 0.8 ETc and plastic mulch under paired row sowing are found more appropriate and effective over rest of the treatments.

**Authors Contribution**: Rupesh Kumar Meena is involved in overall formatting, conception, design and writing of the article. S.R. Bhunia is involved in overall idea, editing the article.

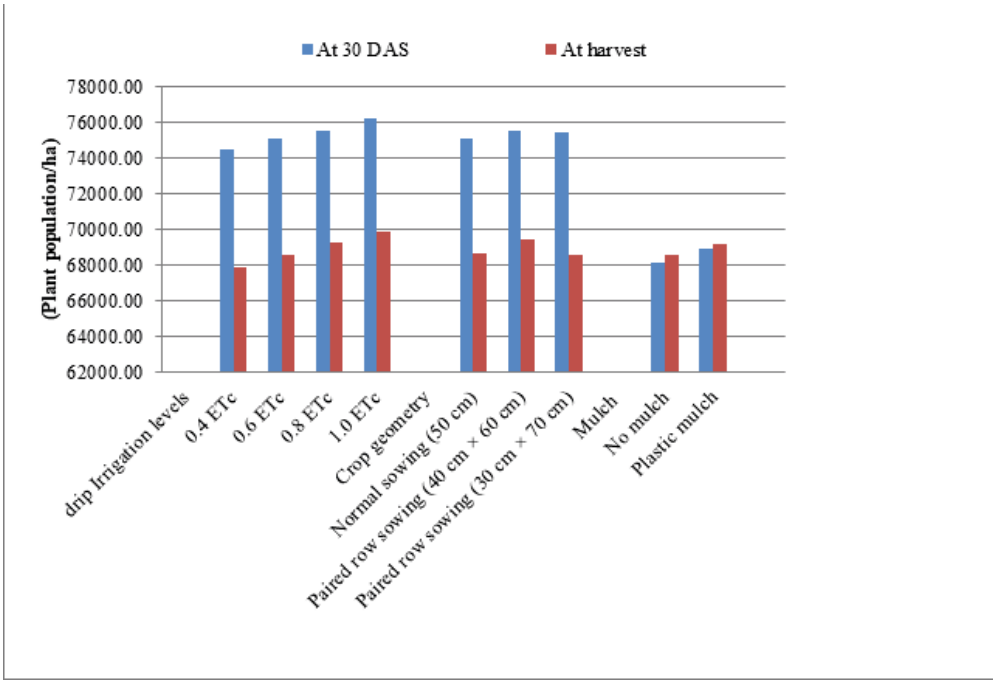


**Fig. 1** Effect of drip irrigation levels, crop geometry and mulch on plant population/ha

**Table 1:** Influence of drip irrigation levels, crop geometry and mulch on growth attributes of fennel (Pooled data of two years)

| Treatments | Plant height (cm) | | | | Dry matter accumulation (g plant$^{-1}$) | | | | Chlorophyll content (mg g$^{-1}$ of fresh leaves) at 75 DAS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 DAS | 70 DAS | 100 DAS | At harvest | 40 DAS | 70 DAS | 100 DAS | At harvest | Chlorophyll (a) | Chlorophyll (b) | Total chlorophyll |
| **Drip Irrigation levels (I)** | | | | | | | | | | | |
| $I_1$: 0.4 ETc | 14.23 | 36.37 | 64.87 | 109.9 | 3.22 | 8.98 | 17.22 | 35.54 | 1.17 | 0.294 | 1.47 |
| $I_2$: 0.6 ETc | 14.67 | 44.12 | 81.76 | 114.2 | 3.33 | 12.33 | 20.50 | 43.12 | 1.33 | 0.362 | 1.69 |
| $I_3$: 0.8 ETc | 14.89 | 48.72 | 91.04 | 117.8 | 3.38 | 14.58 | 24.22 | 48.72 | 1.42 | 0.412 | 1.83 |
| $I_4$: 1.0 ETc | 15.00 | 49.91 | 93.60 | 120.0 | 3.41 | 14.93 | 25.11 | 50.28 | 1.43 | 0.426 | 1.86 |
| SEm± | 0.15 | 0.41 | 0.89 | 1.04 | 0.05 | 0.18 | 0.22 | 0.57 | 0.02 | 0.007 | 0.02 |
| CD (P=0.05) | 0.46 | 1.25 | 2.69 | 3.14 | 0.14 | 0.55 | 0.66 | 1.71 | 0.05 | 0.021 | 0.05 |
| **Crop geometry (G)** | | | | | | | | | | | |
| G1: Normal sowing (50 cm) | 14.71 | 44.31 | 82.54 | 114.9 | 3.32 | 12.61 | 21.68 | 44.32 | 1.34 | 0.375 | 1.71 |
| G2: Paired row sowing (40 cm × 60 cm) | 14.80 | 46.01 | 85.24 | 117.4 | 3.39 | 13.25 | 22.59 | 46.80 | 1.35 | 0.382 | 1.73 |
| G3: Paired row sowing (30 cm × 70 cm) | 14.58 | 44.02 | 80.68 | 114.0 | 3.29 | 12.26 | 21.02 | 42.13 | 1.33 | 0.364 | 1.69 |
| SEm± | 0.13 | 0.31 | 0.58 | 0.56 | 0.04 | 0.13 | 0.15 | 0.49 | 0.01 | 0.006 | 0.01 |
| CD (P=0.05) | NS | 0.89 | 1.67 | 1.63 | NS | 0.38 | 0.43 | 1.40 | 0.03 | 0.018 | NS |
| **Mulch (M)** | | | | | | | | | | | |
| $M_0$: No mulch | 14.57 | 44.21 | 81.85 | 113.7 | 3.29 | 12.25 | 21.32 | 43.22 | 1.32 | 0.367 | 1.69 |
| $M_1$: Plastic mulch | 14.82 | 45.35 | 83.79 | 117.2 | 3.38 | 13.17 | 22.21 | 45.61 | 1.35 | 0.380 | 1.73 |
| SEm± | 0.07 | 0.20 | 0.40 | 0.42 | 0.03 | 0.10 | 0.11 | 0.36 | 0.01 | 0.004 | 0.01 |
| CD (P=0.05) | 0.21 | 0.57 | 1.14 | 1.19 | 0.08 | 0.29 | 0.32 | 1.01 | 0.03 | 0.01 | 0.03 |
| **Interaction (I x G)** | | | | | | | | | | | |
| SEm± | - | 0.62 | 1.16 | 1.1 | - | 0.26 | 0.30 | 0.97 | - | - | 0.03 |
| *CD (P=0.05) | - | 1.79 | 3.34 | 3.3 | - | 0.75 | 0.86 | 2.80 | - | - | 0.07 |

*CD at 5% for geometry at same level of irrigation

**Table 2: E**ffect of drip irrigation levels, crop geometry and mulch on number of umbels plant$^{-1}$, test weight and seed yield of fennel.

| Treatments | Number of umbels plant$^{-1}$ | | | Test weight (g) | | | Seed Yield (kg ha$^{-1}$ ) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled |
| **Drip irrigation levels (I)** | | | | | | | | | |
| $I_1$: 0.4 ETc | 13.97 | 14.69 | 14.33 | 5.46 | 5.61 | 5.54 | 934 | 958 | 946 |
| $I_2$: 0.6 ETc | 17.85 | 18.76 | 18.31 | 6.88 | 6.99 | 6.94 | 1461 | 1592 | 1526 |
| $I_3$: 0.8 ETc | 20.35 | 20.49 | 20.42 | 7.02 | 7.18 | 7.10 | 1679 | 1689 | 1684 |
| $I_4$: 1.0 ETc | 20.54 | 20.88 | 20.71 | 7.11 | 7.30 | 7.21 | 1701 | 1727 | 1714 |
| SEm± | 0.28 | 0.36 | 0.21 | 0.09 | 0.10 | 0.06 | 26 | 29 | 18 |
| CD (P=0.05) | 0.96 | 1.24 | 0.63 | 0.32 | 0.33 | 0.19 | 88 | 100 | 54 |
| **Crop geometry (G)** | | | | | | | | | |
| G1: Normal sowing (50 cm) | 17.97 | 18.55 | 18.26 | 6.62 | 6.83 | 6.73 | 1433 | 1480 | 1456 |
| G2: Paired row sowing (40 cm × 60 cm) | 19.05 | 19.33 | 19.19 | 6.80 | 6.95 | 6.87 | 1510 | 1550 | 1530 |
| G3: Paired row sowing (30 cm × 70 cm) | 17.53 | 18.24 | 17.88 | 6.43 | 6.53 | 6.48 | 1389 | 1443 | 1416 |
| SEm± | 0.19 | 0.22 | 0.15 | 0.07 | 0.07 | 0.05 | 18 | 19 | 13 |
| CD (P=0.05) | 0.58 | 0.66 | 0.44 | 0.22 | 0.22 | 0.16 | 55 | 57 | 38 |
| **Mulch (M)** | | | | | | | | | |
| $M_0$: No mulch | 17.64 | 18.14 | 17.89 | 6.59 | 6.70 | 6.64 | 1407 | 1453 | 1430 |
| $M_1$: Plastic mulch | 18.72 | 19.27 | 18.99 | 6.65 | 6.84 | 6.74 | 1481 | 1530 | 1505 |
| SEm± | 0.15 | 0.16 | 0.11 | 0.05 | 0.06 | 0.04 | 12 | 13 | 9 |
| CD (P=0.05) | 0.45 | 0.46 | 0.31 | NS | NS | NS | 35 | 37 | 25 |
| **Interaction (I x G)** | | | | | | | | | |
| SEm± | 0.38 | 0.44 | 0.30 | 0.15 | 0.15 | 0.11 | 37 | 38 | 27 |
| *CD (P=0.05) | 1.15 | 1.32 | 0.87 | 0.44 | 0.45 | 0.31 | 110 | 113 | 77 |

*CD at 5% for crop geometry at same level of drip irrigation

**Table 3:** Pooled interacted effect of drip irrigation levels and crop geometry on number of umbels plant$^{-1}$, test weight (g) and seed yield (kg ha$^{-1}$) of fennel

| Crop Geometry | Number of umbels plant$^{-1}$ | | | | test weight (g) | | | | Seed yield (kg ha$^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Drip irrigation levels | | | | | | | | | | | |
| | 0.4 ETc | 0.6 ETc | 0.8 ETc | 1.0 ETc | 0.4 ETc | 0.6 ETc | 0.8 ETc | 1.0 ETc | 0.4 ETc | 0.6 ETc | 0.8 ETc | 1.0 ETc |
| Normal sowing (50 cm) | 12.86 | 18.29 | 20.23 | 21.65 | 5.22 | 7.03 | 7.07 | 7.59 | 829 | 1550 | 1676 | 1771 |
| Paired row sowing (40 cm × 60 cm) | 14.63 | 19.64 | 21.23 | 21.25 | 5.32 | 7.21 | 7.56 | 7.41 | 986 | 1599 | 1772 | 1763 |
| Paired row sowing (30 cm × 70 cm) | 15.50 | 16.98 | 19.80 | 19.24 | 6.07 | 6.57 | 6.68 | 6.62 | 1023 | 1430 | 1604 | 1607 |
| SEm± | 0.30 | | | | 0.11 | | | | 27 | | | |
| *CD (P=0.05) | 0.87 | | | | 0.31 | | | | 77 | | | |
| SEm± | 0.32 | | | | 0.11 | | | | 28 | | | |
| **CD (P=0.05) | 0.95 | | | | 0.32 | | | | 83 | | | |

*CD at 5% for crop geometry at same level of drip irrigation

**CD at 5% for drip irrigation at same level or different level of crop geometry

**Conflict of Interest:** The authors declare no conflicts of interest.

## Reference


Akash, Ghiyal V., Malik, T.P., Yadav, P. Raa, V., Kumar, S. and Chaman. 2023. Effect of level of drip irrigation and nitrogen fertigation on yield parameters of fennel. *Int J Plant & Soil Sci.,* 35(22):373-381.

Annadurai, K., Puppala, N., Angadi, S. and Masilamani, P. 2009. Agronomic management for peanut production. *Agric Rev.,*30(4).

Devi, B., Bhunia, S.R., Sunita and Sarita, 2022. Effect of irrigation levels on yield, water use, water use efficiency and NPK uptake of fennel (*Foeniculum vulgare* Mill.) cultivars grown under drip system. *Pharm Innov.,*11(4):1994-1996.

Devi, B., Bhunia, S.R., Saini, A., and Meena, R.K. 2023. Effect of irrigation levels and crop geometry on growth, yield parameters and yield of fennel (*Foeniculum vulgare* Mill.) cultivar grown under drip System. *Biol Forum*, 15(2):698-701.

Hiscox, J.D. and Israelstem, G.F. 1979. A method for the extraction of chlorophyll from leaf tissue without maceration. *Can J Bot.,*57:1332-1334.

Jeelani, J., Katoch, K.K., Sanjeev, K.S. and Gupta, R.K. 2017. Effect of varying drip irrigation levels and different methods of NPK fertilizer application on soil water dynamics, water use efficiency and yield of broccoli (*Brassica oleracea* L. var. italica) in wet temperate zone of Himachal Pradesh. *Int J Pure App Biosci*, 5(1):210-220.

Kumar, R. and Kumar, M. 2020. Effect of drip irrigated mulch on soil properties and water use efficiency-A review. *J Soil Water Conserv*,19(3):300-309.

Kumar, S., Mehriya, M.L., Singh, U., Kumhar, S.R. and Sutaliya, R. 2023. Effect of Drip Irrigation Scheduling, Planting Methods and Mulches on Growth and Yield of Fennel (*Foeniculum vulgare* Mill.). *J Exp Agri Int,* 45(11):190-197.

Mahatma, M., Tripathi, K., Saxena, S. and Bhardwaj, V.

2024. Unveiling the nutraceutical potential of seed spices for multifaceted health effects. *Int J Seed Spices*, 12(1):13-33.

Meena, S.S., Mehta, R.S., Lal, G., Sharma, Y.K., Meena, R. D. and Kant, K. 2015. Effect of sowing dates and crop geometry on growth and seed yield of dill (*Anethum sowa* L). *Int J Seed Spices,* 5(1):79-82.

Meena, R.S., Lal, G., Saxena, S.N., Meena, N.K. and Meena, R.D. 2023.Ajmer Fennel-3: a high yielding and ramularia blight resistant fennel variety. *Int J Seed Spice*, 13(1&2):51-56

Panse, V.G. and Sukhatme, P.V. 1985. Statical Methods for Agricultural Workers, 4th Enlarged Edition, Indian Council of Agricultural Research Pub. New Delhi

Singh, R.B., Watanabe, S. and Isaza, A. 2021. Functional Foods and Nutraceuticals in Metabolic and Non-Communicable Diseases. Elsevier ISBN: 9780128198155

Saren, B.K., Mandal, K. and Bag, N. 2008. Effect of mulching and row spacing on growth, seed yield and oil yield of rainfed Niger (*Guizotiaabys sinica*) in red and lateritic acid belt of West Bengal. *Ind J Agric Sci.*, 78(6):557-559.

Singh, A., Narolia, R.K., Yadav, P.K., Shri Rakesh and Kumar, D. 2021. Performance of fennel (*Foeniculum vulgare* Mill.) Cultivars under different irrigation levels. *Pharm Innov J*, 10:1478-1481.

Spices board India, 2022-23. Statistics: Production of major Spices. Spices Board of India, Ministry of Commerce and Industry, Government of India, New Delhi. (http://www.indianspices.com).

Tamboli, Y.A., Amin, A.U., Patil, J.K.and Birla, J. 2020. Growth, yield attributes and yield of rabi fennel (*Foeniculum vulgare* Mill.) as influenced by different time of sowing, variety and spacing. *Int J Cur Microbiol App Sci*, 9(04):339-351.