RESEARCH ARTICLE

# EFFECT OF IRRIGATION LEVELS ON YIELD, WATER USE, WATER USE EFFICIENCY AND NPK UPTAKE OF FENNEL (*FOENICULUM VULGARE* MILL.) CULTIVARS GROWN UNDER DRIP SYSTEM

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**Abstract:** A field experiment was conducted at Instructional Farm, College of agriculture, Bikaner (Rajasthan) during *rabi* season to study the influence of drip irrigation levels on yield, water use efficiency and nutrient uptake of different cultivars of fennel. Results revealed that irrigation through drip at 1.0 PE recorded significantly highest number of umbels plant$^{-1}$ (30.90) and number of umbellate umbel$^{-1}$(20.04). Water use was higher when crop was irrigated at 1.0 PE, where as water use efficiency was found maximum (2.26 kg ha$^{-1}$ mm) with application of 0.85 PE drip irrigation. Significantly highest nutrient (NPK) uptake by seed and stover recorded with 1.0 PE level of irrigation but remained at par with 0.85 PE. Total nutrient uptake (seed and stover) increased significantly with increasing level of irrigation. Among the different cultivars RF-205 found superior over the RF-101, RF-125 and RF-143. Different cultivars could not influence nitrogen uptake and potassium uptake by seed. Test weight was not significantly influenced by both irrigation levels and cultivars.

**Keywords:** Cultivars, Irrigation, Growth, Yield

## INTRODUCTION

Fennel (*Foeniculum vulgare* Mill) is an important seed spice crop of arid and semi-arid region of India. It's fragrant seeds have an aromatic taste. Direct seeded fennel is a short duration crop, thus requires less water than transplanted crop and profitably raised as a winter crop. Its cultivation should be avoided in frost prone areas because it is susceptible to frost at flowering stage. Though during maturity, crop requires warm climate but high winds at the time of maturity can cause shattering of seed and very hot winds at flowering reduce seed setting. Dry as well as moderately cool weather conditions during seed formation stages increase seed yield as well as quality of the produce. A dry and cold weather favours higher seed production.

In India, fennel stands third in area and production among seed spices and mainly grown in Gujarat and Rajasthan and also to some extent in Karnataka, Maharashtra, Uttar Pradesh, Punjab and Bihar. Fennel crop occupied an area of about 239 thousand hectares with an annual production of 107 thousand tons and productivity of 22.33 q ha$^{-1}$. Rajasthan occupied an area of 30.67 thousand hectare with an annual production of 32.29 thousand tonnes, contributing 33% of total production in India.

For the optimal growth and development of any plants, balanced application of nutrients is highly essential. If any element is lacking in the soil it was not adequately balanced by other nutrient. But in reality uptake is influenced by many factors such as agro climatic conditions, soil type, method of application, mineral mobility and its accumulation sites. Untimely application of nutrients, following inappropriate method of application lead to severe loss of nutrients by leaching and fixation. But in reality uptake is influenced by many factors such as agro climatic conditions, soil type, method of application, mineral mobility and its accumulation sites (Harisha *et al*. 2017).

The PE approach allows the preparation of irrigation time table for different crops. PE based scheduling of irrigation is a proper approach for applying irrigation water through drip system for optimum yield potential of fennel crop as it includes all the environmental parameters. To reduce input cost, drip system is very useful for horticulture crop production in arid region (Kumar *et al*. 2016).

In arid and semiarid conditions of Rajasthan, availability of irrigation water is limited and therefore, it should be utilized most efficiently by adopting technologies like drip irrigation. Adoption of drip irrigation can not only reduce irrigation water requirement but also improve yield by maintaining moisture content at *Rhizisphere* in field capacity throughout the growing season. Scheduling of irrigation based on PE approach is considered most appropriate as PE is influenced by all climatic parameters. Thus proper irrigation scheduling through drip system may increase yield of the crop. Therefore, an experiment was undertaken to study the influence of different levels of irrigation through drip on growth, yield and water use efficiency of fennel.

## MATERIALS AND METHODS

A field experiment was conducted at Instructional Farm, College of Agriculture, S.K. Rajasthan Agricultural University, Bikaner (Rajasthan) during *rabi* seasons of 2019-20. The farm is located at about at 28º01'N latitude and 73º22'E longitudes with an average altitude of 234.70 meters above mean sea

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level under semi-arid tropic having an extreme of weather condition. The soil was loamy sand in texture and slightly alkaline in reaction (pH 8.5), poor in organic carbon (0.12 per cent), low in available nitrogen (117 kg $ha^{-1}$) but medium in available phosphorus (15.4 kg $ha^{-1}$) and potassium (172.7 kg $ha^{-1}$).

The experiment was laid out in Split Plot Design comprised of four irrigation levels viz., $I_1$:0.55PE, $I_2$:0.70 PE, $I_3$:0.85 PE and $I_4$:1PE through drip irrigation in main plot and four cultivars ($V_1$: RF-101, $V_2$: RF-125, $V_3$: RF-143 and $V_4$: RF-205) in sub plot and replicated thrice. Sowing was done by dibbling method using seed rate 10 kg $ha^{-1}$ at the depth of 2-3 cm. Recommended dose of N and $P_2O_5$ i.e. 90:40 Kg per ha was applied through urea and DAP, respectively. The whole amount of P and 30 kg N were applied as basal dressing prior to sowing. While remaining nitrogen was top dressed in two equal splits doses (45 DAS and at flowering). The scheduling of irrigation was done with 0.55, 0.70, 0.85 and 1.0 PE at alternate day irrigations were applied through drip. The irrigation water was calculated using pan evaporation data. Dripper discharge rate per hour and one dripper cover area per plot were calculated for applying irrigation water and then calculated amount of water (1mm) was applied in the field to operate drip system per hour. This calculated time was multiplied with evaporation data and converted according to PE levels viz., 0.55, 0.70, 0.85 and 1.0. Other package of practices was followed as per recommendations made for the crop in region. The uptake of nitrogen, phosphorus and potassium after harvesting of seed was estimated by using the following relationship:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient content in seed (\%)} \times \text{Seed yield (kg ha}^{-1}) + \text{Nutrient content in stover (\%)} \times \text{Stover yield (kg ha}^{-1})}{100}$$

The seed yield of respective plot was added to Stover yield to record biological yield per pIot and finally presented as kg $ha^{-1}$. One thousand seeds were counted from the sample drawn from finally winnowed and cleaned produce of each net plot and weight in grams was recorded separately for each net plot by electronic balance. It was calculated as the ratio of seed yield to total water used in the particular treatment and expressed in kg $ha^{-1}$ $mm^{-1}$.

$$\text{WUE (kg ha}^{-1}\,\text{mm}^{-1}) = \frac{\text{Seed yield (kg ha}^{-1})}{\text{Water used (mm)}}$$

## RESULTS AND DISCUSSION

### Number of umbels plant$^{-1}$, number of umbellate umbel$^{-1}$, test weight and biological yield

It is evident from the data (Table 3.1) that number of umbels plant$^{-1}$, number of umbellate umbel$^{-1}$ and biological yield of fennel were significantly influenced due to levels of irrigation and cultivars. Irrigation to the crop with 1.0 PE recorded significantly highest number of umbels plant$^{-1}$ (30.90) as compared to 0.55 PE and 0.70 PE and was statistically at par with 0.85 PE level of irrigation. Cultivar RF-205 was at par with RF -125 which recorded significantly maximum numbers of umbels plant$^{-1}$ (29.57) over RF - 101, RF -125 and RF - 143. Higher irrigation level (0.85 and 1.0 PE) helped to maintained stress free conditions for optimum plant growth. The result also confirmed the findings of Bhunia *et al*. (2015). Crop Irrigated with 1.0 PE recorded highest number of umbellate umbel$^{-1}$ (28.84) as compared to 0.55 PE and 0.70 PE and was statistically at par with 0.85 PE level of irrigation. Cultivar RF-205 at par with RF -125 recorded significantly maximum number of umbellate umbel$^{-1}$ (27.96) over RF - 101, RF -125 and RF – 143. Whereas, RF - 101, RF -125 and RF – 143 cultivars were remained at par to each other. Similar findings were also reported by Meena *et al*. (2017) who studied with five high yielding fennel varieties viz., RF-205, RF-125, RF-145, RF-178 and AF1. Highest yield, number of umbel plant$^{-1}$ was obtained from the AF1 followed by RF-205. Irrigation with 1.0 PE recorded highest biological yield (6567 kg $ha^{-1}$), which was statistically at par with 0.85 PE levels of irrigation. In case of cultivars highest biological yield (6195 kg $ha^{-1}$) was recorded in RF-205 as compared to RF - 101, RF -125 and RF – 143. The increased seed yield of fennel due to optimum moisture status in the root zone area throughout the crop growing periods which resulted higher relative leaf water, optimum growth, and increased yield attributes. Biological yield with increasing irrigation levels reported by Solanki *et al*. (2017) in fennel.

A critical examination of data presented in Table 3.1 stated that test weight of fennel was not influenced by different levels of irrigation. Irrigation with 1.0 PE recorded maximum test weight of fennel (7.48 g) as compared to other levels of irrigation. Test weight of fennel was not influenced by different cultivars of fennel (Table 3.1). Maximum test weight of fennel recorded in RF-205 as compared to RF - 101, RF - 125 and RF - 143. The result also confirmed the findings of Bhunia *et al*. (2015). Test weight was not

significantly affected by different irrigation levels and cultivars.

**Water use and water use efficiency**

Data presented in Table 3.1 showed that highest water use of 1138.50 mm was recorded with 1.0 PE and lowest water use of 660.11 mm was recorded at irrigation level of 0.55 PE, respectively. Further, data indicated that water use efficiency (2.26 kg $ha^{-1}$ $mm^{-1}$) was recorded maximum at 0.85 PE which was at par with 0.70 PE (2.20 kg $ha^{-1}$ $mm^{-1}$) and lowest with 0.55 PE (1.86 kg $ha^{-1}$ $mm^{-1}$) irrigation level. It was inferred from data (Table 3.1) that cultivars had significant effect on water use efficiency. However, highest water use efficiency (2.31 kg $ha^{-1}$ $mm^{-1}$) was recorded with RF - 205. Lowest water use efficiency of 1.99 kg $ha^{-1}$ $mm^{-1}$ was recorded with RF-143. Increase water in the soil resulted in decreased water use efficiency. Higher water in soil was not utilized by crop optimally. Most related result finding by Bhunia *et al*. (2005) observed that irrigating fennel at an IW/CPE ratio of 0.8 recorded significantly higher water use and water use efficiency over lower IW/CPE ratios, Most similar results also reported by Godara *et al*. (2013).

**Nitrogen uptake in seed, stover and total uptake**

It is apparent from the data (Table 3.2) that nitrogen uptake by fennel seed increased significantly with increasing levels of irrigation. Significantly highest nitrogen uptake (34.17 kg $ha^{-1}$) by seed recorded with 1.0 PE level of irrigation over 0.55 PE and 0.70 PE but remained at par with 0.85 PE (31.94 kg $ha^{-1}$) level of irrigation. The minimum nitrogen uptake (25.07 kg $ha^{-1}$) by seeds was observed under irrigation at 0.55 PE.

Data further showed that nitrogen uptake by seed was significantly influenced due to different cultivars of fennel (Table 3.2). Cultivar RF - 205 recorded significantly higher nitrogen uptake (29.55 kg $ha^{-1}$) as compared to cultivar RF - 101 (26.42 kg $ha^{-1}$), RF - 125 (26.32 kg $ha^{-1}$) and RF - 143 (25.50 kg $ha^{-1}$). The optimum soil moisture in soil also helped to increase availability of nutrient and translocation of food material which increased the vegetative growth of fennel plant. The enhanced N, P and K uptake by fennel crop might have ascribed to the cumulative effect for increased seed and stover yield. These results are in corroboration with Bhunia *et al*. (2005) and Jat *et al*. (2015) in fennel crop

It is clear from the data (Table 3.2) that nitrogen uptake by fennel stover increased significantly with increasing levels of irrigation and cultivars. Significantly highest nitrogen uptake (30.63 kg $ha^{-1}$) by stover recorded with 1.0 PE level of irrigation over 0.55 PE (19.36 kg $ha^{-1}$) and 0.70 PE (23.92 kg $ha^{-1}$) but remained at par with 0.85 PE (29.01 kg $ha^{-1}$) level of irrigation. Data presented in Table 4.8 that nitrogen uptake by stover was not influence due to different cultivars of fennel. Cultivar RF - 205 have higher nitrogen uptake (27.34 kg $ha^{-1}$) followed by cultivar RF - 125 (25.76 kg $ha^{-1}$), RF - 101 (25.41 kg $ha^{-1}$), and RF - 143 (24.41 kg $ha^{-1}$). The optimum soil moisture in soil also helped to increase availability of nutrient and translocation of food material which increased the vegetative growth of fennel plant. The enhance nitrogen uptake by fennel crop might have ascribed to the cumulative effect for increased seed and stover yield. These are in confirmation with Bhunia *et al*. (2005).

A perusal of data in table 3.2 revealed that total nitrogen uptake (Seed and Stover) increased significantly with increasing levels of irrigation. Significantly highest total nitrogen uptake (64.80 kg $ha^{-1}$) recorded with 1.0 PE level of irrigation over 0.55 PE (35.67 kg $ha^{-1}$) and 0.70 PE (48.99 kg $ha^{-1}$) but remained at par with 0.85 PE (60.94 kg $ha^{-1}$) level of irrigation. The minimum total nitrogen uptake (35.67 kg $ha^{-1}$) was observed under irrigation at 0.55 PE. Data (Table 3.2) showed that Cultivar RF - 205 gave significantly higher total nitrogen uptake (56.58 kg $ha^{-1}$) as compared to other fennel cultivars.

**Phosphorus uptake in seed, stover and total uptake**

A critical examination of data in table 3.2 indicated that phosphorus uptake by fennel seed increased significantly with increasing levels of irrigation and cultivars. Significantly highest phosphorus uptake by seed recorded with 1.0 PE level of irrigation (10.92 kg $ha^{-1}$) over 0.55 PE (4.74 kg $ha^{-1}$) and 0.70 PE (7.81 kg $ha^{-1}$) but remained at par with 0.85 PE (10.30 kg $ha^{-1}$) level of irrigation. Cultivar RF - 205 recorded significantly higher phosphorus uptake (9.23 kg $ha^{-1}$) as compared to cultivar RF - 101 (8.31 kg $ha^{-1}$), RF - 125 (8.30 kg $ha^{-1}$) and RF - 143 (7.93 kg $ha^{-1}$). The enhanced phosphorus uptake by fennel crop might have ascribed to the cumulative effect of increased seed and stover yield. These are in corroboration with Jat *et al*. (2015) in fennel crop. It is apparent from the data (Table 3.2) that phosphorus uptake by fennel stover increased significantly with increasing levels of irrigation and cultivars. Significantly highest phosphorus uptake by stover recorded with 1.0 PE level of irrigation (7.34 kg $ha^{-1}$) over 0.55 PE (4.38 kg $ha^{-1}$) and 0.70 PE (5.49 kg $ha^{-1}$) but remained at par with 0.85 PE (6.99 kg $ha^{-1}$) level of irrigation. Cultivar RF - 205 have higher phosphorus uptake (6.56 kg $ha^{-1}$) followed by cultivar RF -101 (5.88 kg $ha^{-1}$), RF -125 (6.12 kg $ha^{-1}$), and RF - 143 (5.64 kg $ha^{-1}$). It is evident from the data (Table 3.2) that total phosphorus uptake (Seed and Stover) increased significantly with increasing levels of irrigation and cultivar. Significantly highest total phosphorus uptake recorded with 1.0 PE level of irrigation (18.26 kg $ha^{-1}$) over 0.55 PE (9.12 kg $ha^{-1}$) and 0.70 PE (13.30 kg $ha^{-1}$) but remained at par with 0.85 PE (17.29 kg $ha^{-1}$) level of irrigation. Cultivar RF - 205 have significantly higher total phosphorus uptake (15.79 kg $ha^{-1}$) as compared to cultivar RF - 101 (14.20 kg $ha^{-1}$), RF - 125 (14.42 kg $ha^{-1}$) and RF - 143 (13.56 kg $ha^{-1}$). Enhanced phosphorus uptake by fennel crop might have

ascribed to the cumulative effect for increased seed and stover yield. These are in confirmation of Bhunia *et al.*(2005).

**Potassium uptake in seed, stover and total uptake**

A critical examination of data in Table 3.2 indicated that potassium uptake by fennel seed increased significantly with increasing levels of irrigation. Significantly highest potassium uptake by seed recorded with 1.0 PE level of irrigation (11.21 kg ha$^{-1}$) over 0.55 PE (5.60 kg ha$^{-1}$) and 0.70 PE (8.47 kg ha$^{-1}$) but remained at par with 0.85 PE (10.56 kg ha$^{-1}$) level of irrigation. Data (Table 4.10) further show that potassium uptake by seed did not influenced due to different cultivars of fennel. Cultivar RF - 205 has higher potassium uptake (9.79 kg ha$^{-1}$). The enhance potassium uptake by fennel crop might have ascribed to the cumulative effect for increased seed and stover yield. Equal result and reported by Bhunia *et al.* (2005).

It is evident from the data (Table 3.2) that potassium uptake by fennel stover increased significantly with increasing levels of irrigation and different cultivars. Significantly highest potassium uptake by stover recorded with 1.0 PE level of irrigation (67.82 kg ha$^{-1}$) over 0.55 PE (46.00 kg ha$^{-1}$) and 0.70 PE (54.30 kg ha$^{-1}$) but remained at par with 0.85 PE (64.47 kg ha$^{-1}$) level of irrigation. Cultivar RF - 205 have higher potassium uptake (64.64 kg ha$^{-1}$) as compared to cultivar RF - 101 (55.30 kg ha$^{-1}$), RF - 125 (57.05 kg ha$^{-1}$) and RF - 143 (55.59 kg ha$^{-1}$).

It is clear from the data (Table 3.2) that total potassium uptake (Seed and Stover) increased significantly with increasing levels of irrigation and cultivars. Significantly highest total potassium uptake recorded with 1.0 PE level of irrigation (79.03 kg ha$^{-1}$) over 0.55 PE (51.61 kg ha$^{-1}$) and 0.70 PE (62.77 kg ha$^{-1}$) but remained at par with 0.85 PE (75.03 kg ha$^{-1}$) level of irrigation. Data further showed that total potassium uptake (Seed and Stover) were significantly influenced due to different cultivars of fennel (Table 4.10). Cultivar RF - 205 have significantly higher total potassium uptake (74.43 kg ha-1) as compared to cultivar RF - 101 (63.88 kg ha-1), RF - 125 (66.02 kg ha-1) and RF - 143 (64.11 kg ha-1). The enhance total potassium uptake by fennel crop might have ascribed to the cumulative effect for increased seed and stover yield. Equal result and reported by Jat *et al.* (2015) in fennel crop.

**Table 1.** Effect of irrigation levels on number of umbels plant$^{-1}$, number of umbellate umble$^{-1}$, test weight, biological yield, water use and water use efficiency of fennel cultivars.

| Treatment | Number of umbels plant$^{-1}$ | Number of umbellate umble$^{-1}$ | Test weight (g) | Biological Yield (kg ha$^{-1}$) | Water use (mm) | Water use efficiency (kg ha$^{-1}$ mm) |
|---|---|---|---|---|---|---|
| **Irrigation levels** | | | | | | |
| 0.55 PE | 23.90 | 21.57 | 7.00 | 4302 | 660.11 | 1.86 |
| 0.70 PE | 27.73 | 25.97 | 7.10 | 5320 | 819.57 | 2.20 |
| 0.85 PE | 30.09 | 28.39 | 7.12 | 6412 | 979.04 | 2.26 |
| 1.00 PE | 30.90 | 28.84 | 7.48 | 6567 | 1138.50 | 2.02 |
| SEm± | 0.55 | 0.57 | 0.17 | 154 | - | 0.06 |
| CD at 5% | 1.90 | 1.98 | NS | 532 | - | 0.21 |
| **Cultivars** | | | | | | |
| RF -101 | 27.65 | 25.45 | 7.13 | 5438 | 899.31 | 2.00 |
| RF -125 | 28.66 | 26.76 | 7.18 | 5587 | 899.31 | 2.05 |
| RF -143 | 26.75 | 24.61 | 7.05 | 5381 | 899.31 | 1.99 |
| RF -205 | 29.57 | 27.96 | 7.35 | 6195 | 899.31 | 2.31 |
| SEm± | 0.50 | 0.64 | 0.18 | 115 | - | 0.04 |
| CD at 5% | 1.46 | 1.86 | NS | 336 | - | 0.13 |

**Tables 2.** Effect of irrigation levels on nutrient uptake of fennel cultivars in seed stover and total uptake of fennel cultivars.

| Treatments | Nitrogen uptake (kg ha$^{-1}$) | | | Phosphorus uptake (kg ha$^{-1}$) | | | Potassium uptake (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed | Stover | Total uptake | Seed | Stover | Total uptake | Seed | Stover | Total uptake |
| **Irrigation levels** | | | | | | | | | |
| 0.55 PE | 16.31 | 19.36 | 35.67 | 4.74 | 4.38 | 9.12 | 5.60 | 46.00 | 51.61 |
| 0.70 PE | 25.07 | 23.92 | 48.99 | 7.81 | 5.49 | 13.30 | 8.47 | 54.30 | 62.77 |
| 0.85 PE | 31.94 | 29.01 | 60.94 | 10.30 | 6.99 | 17.29 | 10.56 | 64.47 | 75.03 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.00 PE | 34.17 | 30.63 | 64.80 | 10.92 | 7.34 | 18.26 | 11.21 | 67.82 | 79.03 |
| SEm.± | 0.86 | 0.77 | 1.48 | 0.26 | 0.17 | 0.35 | 0.27 | 1.12 | 1.26 |
| CD at 5% | 2.98 | 2.67 | 5.11 | 0.91 | 0.60 | 1.21 | 0.95 | 3.87 | 4.36 |
| **Cultivars** | | | | | | | | | |
| RF -101 | 26.42 | 25.41 | 51.83 | 8.31 | 5.88 | 14.20 | 8.57 | 55.30 | 63.88 |
| RF -125 | 26.32 | 25.76 | 52.08 | 8.30 | 6.12 | 14.42 | 8.97 | 57.05 | 66.02 |
| RF -143 | 25.50 | 24.41 | 49.91 | 7.93 | 5.64 | 13.56 | 8.51 | 55.59 | 64.11 |
| RF -205 | 29.25 | 27.34 | 56.58 | 9.23 | 6.56 | 15.79 | 9.79 | 64.64 | 74.43 |
| SEm.± | 0.73 | 0.84 | 1.49 | 0.24 | 0.21 | 0.38 | 0.35 | 1.36 | 1.47 |
| CD at 5% | 2.14 | NS | 4.36 | 0.69 | 0.61 | 1.10 | NS | 3.98 | 4.29 |

## CONCLUSION

Results of the present investigation showed that the irrigation levels of 1.0 PE significantly enhanced the yield attributes over 0.55 and 0.70 PE levels but remained at par with 0.85 PE irrigation level. Water use efficiency was highest at 0.85 PE levels. Cultivar RF -205 showed highest yield attributes, NPK uptake followed by RF-125, RF-101 and RF-143 cultivars of fennel. Thus, it can be concluded that Cultivar RF -205 along with the irrigation level 1.0 PE perform better than the other with respect to the overall NPK uptake, yield and water use efficiency.

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