Original Research Article

Effect of Drip Irrigation Scheduling, Planting Methods and Mulches on Growth and Yield of Fennel (*Foeniculum vulgare* Mill.)

Abstract

The present field experiment was conducted to study the effect of planting methods, mulches and drip irrigation scheduling on fennel during *Rabi* season of 2020-21 and 2021-22 at the Instructional Farm, College of Agriculture, Jodhpur. The field experiment was laid out in split plot design comprised of four levels of drip irrigation *i.e.* 1.0, 0.8, 0.6 and 0.4 PEF (Pan Evaporation Fraction) in main plot, two planting methods (direct sowing and transplanting) in sub plot and three mulches (no mulch, straw mulch and plastic mulch) in sub-sub plot. The results revealed that increasing levels of drip irrigation from 0.4 to 1.0 PEF significantly enhanced crop growth and yield in both the seasons of experimentation. Among planting methods, transplanting surpassed direct sowing. Moreover, use of straw mulch was found significantly superior over plastic mulch and no mulch.

Keywords : Drip irrigation, transplanting, Direct sowing, Mulch, PEF (pan evaporation fraction)

Introduction

Agricultural sustainability and productivity hinge on the judicious use of resources and the adoption of optimal cultivation practices. Water availability for agriculture sector is under challenge in the world as well as in arid lands. Today, it is more important to use water resources wisely and to irrigate intelligently by using modern irrigation system (Jeelani et al., 2017). The significance of this truth is amplified in the context of crops like fennel (*Foeniculumvulgare* Mill.), which holds a prominent place in various industries due to its medicinal, culinary, and aromatic properties. Fennel (*Foeniculum vulgare* Mill.) commonly known as 'saunf', is one of the most important spices and aromatic plant. The *Foeniculum* (fennel) plant belongs to the Apiaceae family, and the center of origin is South Europe and Mediterranean region. Fennel is a cross-pollinated crop and has the somatic chromosome number n = 22. As the global demand for fennel continues to rise, there is a growing necessity to investigate and implement the most effective agronomic practices to enhance its production. Christen *et al*., (2006) reported that drip irrigation is an efficient water delivery system that provides water directly to the root zone of the plant. This system allows water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. It can result in both water conservation and improved crop yields. As a method of precise water delivery, is known for its potential in enhancing water use efficiency and nutrient uptake. The choice of planting method in fennel cultivation holds significant importance as it directly influences various aspects of plant growth, development, and overall crop productivity. Mulching offers a wide range of benefits that play a significant role in enhancing the growth and yield of the fennel crop. By minimizing evaporation from the soil surface, mulch aids in the preservation of soil moisture - an element of paramount importance for the optimal growth of fennel, especially during periods of drought. Mulching reduces the requirement for labor-intensive weeding, promoting healthier and more robust crops. Beyond these benefits, mulch is instrumental in maintaining soil temperature and conserving soil moisture, creating an environment conducive to the growth of fennel. Hanada (1991) also reported that the mulching with appropriate material had number of effects, such as conserved soil moisture, reduced weed invasion, pests and diseases. The use of organic mulches goes a step further by enriching soil fertility, contributing to improved plant growth and superior yield. Additionally, mulches can prevent soil compaction and erosion, improving the physical structure of the soil and promoting better root development. As such, mulching is a beneficial, multipurpose tool in the cultivation of fennel, playing a vital role in the plant's overall health and productivity. Keeping in view of the importance of irrigation, planting methods, soil and moisture conservation to enhance the yield and quality of fennel, the present investigation was carried out.

Materials and methods

The field experiment was conducted at Instructional Farm, College of Agriculture, Jodhpur. The field experiment was laid out in Split Plot Design with three replications and comprised 24 treatment combinations with four levels of drip irrigation *i.e.* 1.0, 0.8, 0.6 and 0.4 PEF (Pan Evaporation Fraction) in main plot, two planting methods (direct sowing and transplanting) in sub plot and three mulches (no mulch, straw mulch and plastic mulch) in sub-sub plot during *Rabi* season of 2020-21 and 2021-22. Both the direct sowing and transplanting of fennel (variety RF-205) were conducted on November 1, 2020, and 2021. For direct sowing, the seeds were placed using the *'Kera'* method at a spacing of 50 cm × 20 cm and a sowing depth of 2 to 3 cm. During the transplanting process, healthy and uniform seedlings aged approximately 40 days were carefully transplanted into the main field maintaining a spacing of 50 cm × 20 cm between each seedling and biometric observation for both were recorded at same interval after direct sowing and transplanting of fennel. The crop was irrigated just after sowing and transplanting with common drip irrigation (50 mm) was applied to ensure uniform germination and establishment of crop. Subsequent irrigations in each treatment were administered through the drip irrigation system with the measured amount of water provided based on the Pan Evaporation fraction (PEF) value. Mulching was done at 20 DAS in treatments. Straw mulch was applied with non-edible mustard straw at the rate of 5 t/ha between row and plant in treatment plots. Plastic mulch was done with white on black polyethylene films with the thickness 25 micron and width of 1 m was spread over plots and holes of 5 cm diameter were made on plastic mulch at a distance of 20 cm in each row which were made 50 cm apart.

Crop growth rate

Crop growth rate was calculated between 35 to 70 DAS, 70 to 105 DAS and 105 DAS to harvest (physiological maturity) of crop stages by using the formula (Enyi, 1962):

$$\text{Crop growth rate (g/m}^2\text{/day)} = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

Where,

W_1 = Total dry matter of plant at time t_1

W_2 = Total dry matter of plant at time t_2

t_1 = Time of first observation

t_2 = Time of second observation

P = Land area over which the dry matter was recorded in m^2

Relative growth rate

Relative growth rate was calculated between 35 to 70 DAS, 70 to 105 DAS and 105 DAS to harvest of crop stages by using the formula

$$\text{Relative Growth Rate (g/g/day)} = \frac{\text{Log}_e W_2 - \text{Log}_e W_1}{T_2 - T_1}$$

Results

Crop growth rate

Crop growth rate was significantly influenced at various growth stages due to varying levels of drip irrigation in both the seasons (2020-21 and 2021-22) and on pooled basis (Table 2). On an average, crop growth rate progressively increases with the intensification of drip irrigation levels (from 0.4 to 1.0 PEF) at all growth stages. Pooled data demonstrate that application of drip irrigation at 1.0 PEF during crop period of 35-70 DAS resulted in significantly enhanced mean crop growth rate (2.72 g/m^2/day) to the order of 12.86, 24.77 and 48.63 percent compared to 0.8, 0.6 and 0.4 PEF, respectively. The corresponding enhancement at 70-105 DAS was to the magnitude of 17.34, 33.28 and 61.19 percent and at 105 DAS – harvest was to the tune of 20.55, 43.14 and 79.51 percent.

Planting methods had prominent effect on crop growth rate up to 105 DAS of crop period during across the years 2020-21 and 2021-22 and on pooled basis. Pooled data indicate that transplanting recorded significantly higher mean crop growth rate (2.51 g/m^2/day) by 21.84 percent over direct sowing at 35-70 DAScrop period. The corresponding increase at 70-105 DAS stage was 8.25 percent. Further, at 105 DAS- harvest stage, crop growth rate was not significantly affected due to planting methods.

Moreover, mulches also had significant impact on crop growth rate in both the years and on pooled basis. The application of straw and plastic mulches considerably improved crop growth rate over no mulch on both the years and on pooled basis. On an average, use of straw mulch (2.43 g/m^2/day) resulted in significantly higher mean crop growth rate at 35- 70 DAS over plastic mulch and no mulch to the extent of 6.11 and 13.55 percent, respectively.The corresponding improvements in crop growth rate at 70-105 DAS due to straw mulch was to the order of 13.42 and 12.06 percent. At 105 DAS- harvest, application of plastic and straw mulches significantly increased crop growth rate to the order of 13.06 and 12.63 percent compared to no mulch (4.67 g/m^2/day), respectively. However, there was no significant difference observed between straw and plastic mulches at this stage in this respect.

Relative growth rate

A meticulous analysis of data in table 2 indicated that varying levels of drip irrigation significantly affected relative growth rate at 35-70 DAS period in both the seasons (2020-21 and 2021-22) and on pooled basis. On an average, drip irrigation applied at 1.0 PEF at this stage significantly enhanced mean relative growth rate over 0.8 (50.91 mg/g/day), 0.6 (48.96 mg/g/day) and 0.4 PEF (44.99 mg/g/day) to the order of 4.63, 8.80 and 18.40 percent, respectively. However, at later growth stage, it was not significantly influenced due to varying levels of drip irrigation.

Among planting methods, transplanting resulted to significantly higher mean relative growth rate by 7.13 percent compared to direct sowing (47.83 mg/g/day) at 35-70 DAS. Whereas, at 70-105 DAS, direct sowing led to significant enhance in mean relative growth rate compared to transplanting (35.74 mg/g/day) and increase being 5.96 percent.

Moreover, Application of straw mulch recorded significantly higher mean relative growth rate to the extent of 2.07 and 5.55 percent over plastic mulch (49.74 mg/g/day) and no mulch (48.10 mg/g/day), respectively at 35-70 DAS. However, at 105 DAS – harvest stage, relative growth rate was not significantly impacted due to varying levels of drip irrigation, planting methods and mulches in both the years (2020-21 and 2021-22) and on pooled basis.

Seed yield

A comprehensive analysis of data presented in table 2illustrated the seed yield of fennel was significantly affected due to varying levels of drip irrigation, planting methods and mulches in both the seasons (2020-21 and 2021-22) and on pooled basis. On pooled basis, the gradual increase in moisture stress from 1.0 to 0.4 PEF tended to significantly decrease seed yield of fennel. Application of drip irrigation at 1.0 PEF significantly increased seed yield (2482 kg/ha) to the magnitude of 13.23, 32.09 and 79.85 percent over 0.8, 0.6 and 0.4 PEF and increase due to drip irrigation scheduled at 0.8 PEF was 16.66 and 58.84 percent over 0.6 and 0.4 PEF, respectively

Further, transplanting method outperformed direct sowing led to significantly enhanced mean seed yield by 17.36 percent over direct sowing method (1825 kg/ha).Moreover, application of straw mulch significantly improved mean seed yield over plastic mulch (2131 kg/ha) and no mulch (1585 kg/ha) by 4.79 and 40.88 percent, respectively and the enhancement in mean seed yield due to plastic mulch was 34.45 percent over no mulch.

Discussion

Theincrease in growth and yield with increasing levels of drip irrigation might be due to favourable moisture status in the root zone throughout the crop growing period which resulted in higher relative leaf water content, better growth and development of plant and thus increased growth parameters, dry matter production and subsequently in development of yield attributes enhanced seed yield of fennel. Chetti *et al.* (1997) revealed that the relative water content of leaf decreases with declining in soil moisture and increases in leaf temperature and consequently reduction in source capacity, which results in increased photorespiration, decreased net photosynthesis. Jat*et al.* (2015) in also revealed that fennel recorded highestgrowth and yield attributes and seed yield, stalk yield and biological yield with irrigation at drip irrigation at 1.0 and 0.8 IW/CPE ratios with paired row planting. Similar results were also obtained by Solanki *et al.* (2017) in fennel.Reproduction and seed development are seriously affected by moisture deficit in fennel. The most critical period with respect to water stress begins with the appearance of pollen mother cell, which decides the number of seed setting in umbels. The damage occurred to reproductive stage due to water deficiency may not recover with supply of water at another stage of crop. In fact seed yield is the function of several yield components, which are depended on complementary interaction between vegetative and reproductive growth of crop. Findings of present study are in line with those of Patel *et al.* (2000), Bhunia *et al.* (2005) in fennel, Rao *et al.* (2010) and Kunapara*et al.*(2016) in cumin.

Transplanting displayed a clear advantage in fennel cultivation, manifesting in significantly higher growth parameters compared to direct sowing. Transplanting might allow for a more robust and expansive root system early on. A well-established root system can access nutrients more efficiently, leading to enhanced dry matter accumulation ultimately crop growth rate and relative growth rate.By beginning their growth in a controlled environment and being transplanted at an optimal time, fennel plants might experience minimized transplant shock. This could lead to a more continuous and efficient nutrient uptake and assimilation contributed to more formation of yield attributes ultimately resulted in higher seed yield with higher transplanting. Yadav and Khurana (1999) observed that the transplanted fennel recorded significantly higher dry matter accumulation, seed yield and biological yield compared to direct sown fennel.Similar finding was also reported by Abou El-Magd *et al.* (2010).

Dry matter accumulation is an important and first pre requisite parameter for crop growth and higher yield. The total yield will therefore be the total amount of dry matter produced and less the photosynthates used in respiration. This might be due to higher plant height, number of branches, total chlorophyll content, relative water content and other growth characters were significantly higher with the application of mulches which might be resulted in higher dry matter accumulation.Meena *et al.* (2014) reported that the application of straw mulch in fennel significantly increasedplant height, number of branches/plant, and dry matter accumulationbut remained at par with plastic mulch. It is obvious that use of mulches lead to better plant growth by changing the micro-climate by conserving more moisture through reducing evaporation, altering soil temperature, controlling weeds and thus, economizing the use of irrigation water. Moreover, adequate availability of moisture to plants results in full cell turgidity and eventually higher meristematic activity, leading to more foliage development, greater photosynthetic rate, better plant growth and consequently favourable effect on sink components as reported by Saren *et al*. (2008) and Yadav *et al*. (2006).

Conclusion

In conclusion, the study's findings collectively highlight the intricate relationship between drip irrigation, planting methods, and mulches in fennel cultivation. The study revealed that the combination of drip irrigation applied at 1.0 PEF superimposed with transplanting method and straw mulch was found superior over rest of the treatment.

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Table 1: Effectsof levels of drip irrigation, planting methods and mulches on crop growth rate of fennel

Treatments	**Crop growth rate (g/m^2/day)**								
	35-70 DAS			**70-105 DAS**			**105 DAS – At harvest**		
Levels of drip irrigation	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
I_1 : 1.0 PEF	2.21	3.24	2.72	8.33	9.54	8.93	6.33	6.80	6.57
I_2 : 0.8 PEF	1.98	2.84	2.41	7.17	8.05	7.61	5.24	5.67	5.45
I_3 : 0.6 PEF	1.83	2.53	2.18	6.32	7.09	6.70	4.61	4.57	4.59
I_4 : 0.4 PEF	1.48	2.18	1.83	5.18	5.89	5.54	3.53	3.79	3.66
SEm ±	0.05	0.07	0.04	0.20	0.22	0.15	0.31	0.38	0.25
CD (P = 0.05)	0.17	0.23	0.13	0.69	0.78	0.46	1.07	1.32	0.76
Planting methods									
P_1 : Direct sowing	1.69	2.44	2.06	6.42	7.39	6.91	4.83	5.01	4.92
P_2 : Transplanting	2.06	2.95	2.51	7.07	7.89	7.48	5.02	5.41	5.22
SEm ±	0.03	0.04	0.02	0.11	0.14	0.09	0.14	0.14	0.10
CD (P = 0.05)	0.09	0.13	0.07	0.35	0.45	0.26	NS	NS	NS
Mulches									
M_1 : No mulch	1.73	2.54	2.14	6.18	7.08	6.63	4.46	4.87	4.67
M_2 : Straw mulch	2.01	2.84	2.43	7.07	7.97	7.52	5.15	5.37	5.26
M_3 : Plastic mulch	1.89	2.70	2.29	6.99	7.87	7.43	5.16	5.39	5.28
SEm ±	0.03	0.04	0.02	0.11	0.14	0.09	0.13	0.15	0.10
CD (P = 0.05)	0.08	0.11	0.06	0.31	0.40	0.25	0.37	0.42	0.27
Interaction (I × P)									
SEm ±	0.06	0.08	0.05	0.21	0.28	0.17	0.28	0.28	0.20
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (I × M)									
SEm ±	0.05	0.07	0.05	0.22	0.28	0.18	0.26	0.29	0.19
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (P × M)									
SEm ±	0.04	0.05	0.03	0.15	0.20	0.12	0.18	0.21	0.14
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (I × P × M)									
SEm ±	0.08	0.10	0.06	0.31	0.39	0.25	0.36	0.41	0.27
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effectsof levels of drip irrigation, planting methods and mulches on relative growth rate and seed yield of fennel

Treatments	Relative growth rate (mg/g/day)									Seed yield (kg/ha)		
	35-70 DAS			70-105 DAS			105 DAS – At harvest					
Levels of drip irrigation	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**	**2020-21**	**2021-22**	**Pooled**
I_1 : 1.0 PEF	50.57	55.98	53.27	40.61	36.14	38.37	18.44	16.86	17.65	2340	2624	2482
I_2 : 0.8 PEF	48.70	53.13	50.91	39.30	34.86	37.08	17.73	16.42	17.07	2117	2267	2192
I_3 : 0.6 PEF	47.29	50.64	48.96	38.14	34.37	36.26	17.47	15.34	16.41	1767	1990	1879
I_4 : 0.4 PEF	42.80	47.18	44.99	37.61	33.38	35.50	16.53	15.01	15.77	1299	1461	1380
SEm ±	0.95	0.86	0.64	0.93	0.76	0.60	1.10	1.20	0.82	41	49	32
CD (P = 0.05)	3.28	2.99	1.98	NS	NS	NS	NS	NS	NS	140	168	98
Planting methods												
P_1 : Direct sowing	45.57	50.09	47.83	39.81	35.93	37.87	18.07	16.01	17.04	1722	1929	1825
P_2 : Transplanting	49.11	53.38	51.24	38.03	33.45	35.74	17.01	15.80	16.41	2039	2242	2141
SEm ±	0.45	0.50	0.33	0.43	0.48	0.32	0.45	0.43	0.31	22	25	17
CD (P = 0.05)	1.46	1.62	1.00	1.41	1.57	0.97	NS	NS	NS	71	83	50
Mulches												
M_1 : No mulch	45.46	50.73	48.09	38.38	34.24	36.31	17.32	15.72	16.52	1530	1641	1585
M_2 : Straw mulch	48.75	52.79	50.77	38.74	34.55	36.64	17.53	15.94	16.74	2102	2364	2233
M_3 : Plastic mulch	47.81	51.67	49.74	39.64	35.28	37.46	17.77	16.06	16.91	2010	2251	2131
SEm ±	0.45	0.42	0.31	0.46	0.48	0.33	0.38	0.38	0.27	19	23	15
CD (P = 0.05)	1.29	1.22	0.87	NS	NS	NS	NS	NS	NS	56	65	42
Interaction (I × P)												
SEm ±	0.90	0.99	0.67	0.87	0.96	0.65	0.90	0.86	0.62	43	51	33
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	141	166	100
Interaction (I × M)												
SEm ±	0.90	0.84	0.62	0.92	0.97	0.67	0.77	0.76	0.54	39	45	30
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	112	131	84
Interaction (P × M)												
SEm ±	0.64	0.60	0.44	0.65	0.68	0.47	0.54	0.53	0.38	28	32	21
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	79	92	60
Interaction (I × P × M)												
SEm ±	1.27	1.19	0.87	1.31	1.37	0.95	1.08	1.07	0.76	55	64	42
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	159	185	119