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A Comparative Analysis of Levels of Drip Irrigation, Planting Methods and Mulches on the Growth and Yield of Fennel

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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, Agriculture University, 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 study found that drip irrigation level significantly influenced the final plant population, dry matter accumulation, and seed yield per plant. The drip irrigation scheduled at 1.0 PEF recorded significantly higher plant population, dry matter accumulation and seed yield per plant. Among planting method, Direct sowing led to a higher plant population, while transplanting resulted in increased dry matter accumulation and seed yield per plant. Further, application of straw mulch also improves dry matter accumulation and seed yield per plant compared to no mulch and plastic mulch.

Keywords Drip irrigation, Pan evaporation fraction, Transplanting, Straw, Plastic mulch.

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 (*Foeniculum vulgare* Mill.), which holds a prominent place in various industries due to its medicinal, culinary, and aromatic properties. Fennel (*Foeniculum vulgare*

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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 2n = 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) 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 the Instructional Farm, College of Agriculture, Agriculture University, 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.

RESULTS

Plant population

A perusal of data (Fig. 1) showed that the varying drip irrigation level and mulches failed to brings perceptible variation in initial plant population during both the seasons. However, final plant population was significantly influenced by various drip irrigation

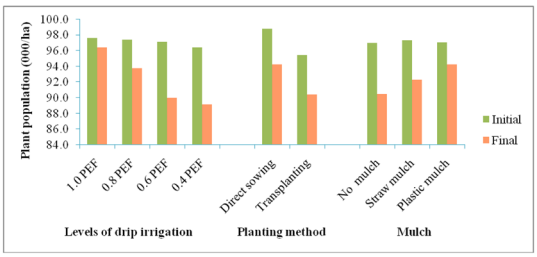

Fig. 1. Effects of levels of drip irrigation, planting methods and mulches on plant population (000/ha).

level during both season of 2020-21 and 2021-22. Further on pooled basis, it was noticed that the significantly maximum number of plant survived under drip irrigation at 1.0 PEF over 0.6 and 0.4 PEF but, found at par with 0.8 PEF. Among planting method, a close examination of data show that direct sowing of crop recorded significantly highest initial and final plant population compared transplanting. Further, significantly highest plant population was observed with the application of plastic mulch compared to no mulch and straw mulch. Mortality of weaker seedlings due to moisture stress in lower irrigation levels have been reason of lower plant density at harvest.

Dry matter accumulation

The dry matter accumulation (g/plant) at harvest was significantly affected by various drip irrigation level in both the seasons (Table 1). It was noticed that the applying drip irrigation at 1.0 PEF significantly increased dry matter accumulation to tune of 17.76, 35.56 and 65.29% over 0.8, 0.6 and 0.4 PEF, respectively on pooled basis of data. Dry matter accumulation was also significantly enhanced due to drip irrigation scheduled at 0.8 PEF over 0.6 and 0.4 and the increases were 15.11 and 40.36%, respectively on pooled basis. Application of both plastic and straw mulches significantly enhanced dry matter accumulation compared to no mulch plots. The increases were to the tune of 11.56% for plastic mulch and 12.81% for straw mulch.

Interaction effect

Levels of drip irrigation × planting methods

Data in Table 2 shows that the interactive effect of levels of drip irrigation and planting methods in each season as well as in pooled analysis significantly

Table 1. Effects of levels of drip irrigation, planting methods and mulch on dry matter accumulation and seed yield/plant of fennel.

Treatments	Dry matter accumulation (g/plant) At harvest			Seed yield/plant (g)		
Levels of drip irrigation	2021	2022	Pooled	2021	2022	Pooled
I_1 : 1.0 PEF	73.24	83.98	78.61	27.21	32.56	29.89
I_2 : 0.8 PEF	62.38	71.13	66.76	24.80	27.81	26.31
I_3 : 0.6 PEF	55.38	60.60	57.99	20.87	23.51	22.19
I_4 : 0.4 PEF	44.22	50.91	47.56	15.63	17.55	16.59
SEm ±	1.34	1.54	1.02	0.49	0.61	0.39
CD (p = 0.05)	4.63	5.35	3.15	1.71	2.11	1.21
Planting methods						
P_1 : Direct sowing	56.45	63.71	60.08	19.40	22.64	21.02
P_2 : Transplanting	61.16	69.61	65.38	24.86	28.08	26.47
SEm ±	0.79	0.85	0.58	0.29	0.32	0.22
CD (p = 0.05)	2.58	2.77	1.74	0.95	1.05	0.65
Mulch						
M_1 : No mulch	53.77	62.27	58.02	18.60	21.06	19.83
M_2 : Straw mulch	61.66	69.24	65.45	24.62	28.89	26.76
M_3 : Plastic mulch	60.99	68.46	64.73	23.18	26.13	24.65
SEm ±	0.66	0.79	0.52	0.28	0.33	0.22
CD (p = 0.05)	1.91	2.29	1.46	0.81	0.94	0.61
Interaction (I × P)						
SEm ±	1.58	1.70	1.16	0.58	0.64	0.43

Table 1. Continued.

Treatments	Dry matter accumulation (g/plant) At harvest			Seed yield/plant (g)		
Levels of drip irrigation	2021	2022	Pooled	2021	2022	Pooled
CD (p = 0.05)	5.16	5.54	3.48	1.89	2.09	1.30
Interaction (I × M)						
SEm ±	1.33	1.59	1.03	0.56	0.65	0.43
CD (p = 0.05)	NS	NS	NS	1.62	1.88	1.22
Interaction (P × M)						
SEm ±	0.94	1.12	0.73	0.40	0.46	0.30
CD (p = 0.05)	NS	NS	NS	NS	NS	NS
Interaction (I × P × M)						
SEm ±	1.87	2.24	1.46	0.80	0.92	0.61
CD (p = 0.05)	NS	NS	NS	NS	NS	NS

influenced dry matter accumulation of fennel. It was noticed that the combination of drip irrigation at 1.0 PEF and transplanting produced significantly higher dry matter per plant over other combination of drip irrigation and planting method.

Seed yield/plant

Data presented in Table 1 revealed marked effect of varying levels of drip irrigation on seed yield/plant of fennel during both years of experimentation. Data further showed that the increasing moisture stress in crop significantly decreased seed yield/plant. It was noticed that the significantly higher seed yield/plant was observed under drip irrigation at 1.0 PEF over 0.8, 0.6 and 0.4 PEF during both the seasons. Seed yield/plant increased to the tune of 13.61, 34.70 and 80.17% by drip irrigation at 1.0 PEF over 0.8, 0.6 and 0.4 PEF on pooled basis of data. However, seed yield/plant was also significantly enhanced due to drip irrigation at 0.8 PEF over 0.6 and 0.4 PEF by 18.57 and 58.59%, respectively on pooled basis of data. Among planting method, transplanting of fennel gave significantly higher seed yield per plant by 25.93% over direct sowing on pooled basis of data. Furthermore, application of straw mulch also significantly improves seed yield per plant. The pooled data showed that the increases were 34.94 and 8.60% over no mulch and plastic mulch.

Interaction effect

Levels of drip irrigation × planting methods

Data in Table 3 show that the interactive effect between levels of drip irrigation and planting methods

Table 2. Interaction effects of levels of drip irrigation and planting methods on dry matter accumulation (g/plant) at harvest of fennel.

Irrigation × Planting methods	2021			2022			Pooled		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
I_1 : 1.0 PEF	66.8	79.7	73.2	78.4	89.6	84.0	72.6	84.6	78.6
I_2 : 0.8 PEF	60.9	63.8	62.4	66.1	76.2	71.1	63.5	70.0	66.8
I_3 : 0.6 PEF	54.5	56.3	55.4	59.7	61.5	60.6	57.1	58.9	58.0
I_4 : 0.4 PEF	43.6	44.8	44.2	50.7	51.2	50.9	47.2	48.0	47.6
Mean	56.5	61.2		63.7	69.6		60.1	65.4	
SEm ±		1.58			1.70			1.16	
*CD (p = 0.05)		5.16			5.54			3.48	
SEm ±		2.47			2.77			1.85	
**CD (p = 0.05)		8.05			9.02			5.56	

*CD at 5 % for planting methods at same levels of drip irrigation.
**CD at 5 % for drip irrigation at same or different planting methods .

Table 3. Interaction effects of levels of drip irrigation and planting methods on seed yield/plant (g) of fennel.

Irrigation × Planting method	2021			2022			Pooled		
	P_1	P_2	Mean	P_1	P_2	Mean	P_1	P_2	Mean
I_1 : 1.0 PEF	25.11	29.32	27.21	30.05	35.07	32.56	27.58	32.20	29.89
I_2 : 0.8 PEF	21.66	27.94	24.80	24.51	31.12	27.81	23.08	29.53	26.31
I_3 : 0.6 PEF	16.75	25.00	20.87	19.72	27.31	23.51	18.23	26.16	22.19
I_4 : 0.4 PEF	14.09	17.18	15.63	16.28	18.83	17.55	15.18	18.00	16.59
Mean	19.40	24.86		22.64	28.08		21.02	26.47	
SEm ±		0.58			0.64			0.43	
*CD (p = 0.05)		1.89			2.09			1.30	
SEm ±		0.91			1.08			0.70	
**CD (p = 0.05)		2.96			3.51			2.11	

*CD at 5 % for planting methods at same levels of drip irrigation.
**CD at 5 % for drip irrigation at same or different planting methods.

Table 4. Interaction effects of levels of drip irrigation and mulch on seed yield/plant (g) of fennel.

Irrigation × Mulch	2021				2022				Pooled			
	M1	M2	M3	Mean	M1	M2	M3	Mean	M1	M2	M3	Mean
I_1 : 1.0 PEF	21.84	30.19	29.61	27.21	25.87	36.26	35.55	32.56	23.86	33.22	32.58	29.89
I_2 : 0.8 PEF	20.76	27.63	26.01	24.80	22.96	32.37	28.12	27.81	21.86	30.00	27.06	26.31
I_3 : 0.6 PEF	18.23	23.75	20.64	20.87	19.93	27.20	23.41	23.51	19.08	25.48	22.03	22.19
I_4 : 0.4 PEF	13.56	16.91	16.44	15.63	15.49	19.75	17.43	17.55	14.52	18.33	16.93	16.59
Mean	18.60	24.62	23.18		21.06	28.89	26.13		19.83	26.76	24.65	
SEm ±		0.56				0.65				0.43		
*CD (p = 0.05)		1.62				1.88				1.22		
SEm ±		0.95				1.15				0.66		
**CD (p = 0.05)		2.75				3.30				1.86		

*CD at 5 % mulch at same levels of drip irrigation.
**CD at 5 % for drip irrigation at same or different level of mulch.

on seed yield per plant in both season as well as pooled analysis significantly impacted the seed yield per plant. It was observed that drip irrigation at 1.0 PEF with transplanting gave significantly higher seed yield/plant on pooled basis over other combination of drip irrigation and planting methods. However, transplanting method found superior over direct sowing at varying drip irrigation level (0.4 to 1.0 PEF) on pooled basis of data.

Levels of drip irrigation × mulch

Data (Table 4) indicated that the interaction effect of levels of drip irrigation and mulch on seed yield/plant was found significant during both the season as well as on pooled basis. The combination of drip irrigation at 1.0 PEF with straw found superior in producing significantly higher seed yield/plant over rest of the combination but found at par with the combination of 1.0 PEF with plastic mulch on pooled basis of data.

DISCUSSION

The results demonstrate that moisture stress significantly affects growth and yield of fennel crop, and increasing levels of irrigation positively influence growth attributes and seed yield per plant. The results suggest that maintaining higher soil moisture helps the fennel plants to thrive and produce more seeds per plant. Additionally, the study shows that even the transition from 0.4 PEF to 0.8 PEF leads to notable improvements in growth and yield fennel. This might be associated with availability of moisture for the plants to perform photosynthesis effectively, enhancing nutrient uptake, creating the energy they need to grow and ensuring the plants are well-nourished. It helps to maintain the structure of the plant and assists in temperature regulation, both of which are

essential for healthy growth. The observed increase in yield production could potentially be attributed to a proper balance of soil moisture in the plants, which creates ideal conditions for metabolite translocation (Farag *et al.* 2016). Another possibility is that adequate soil-available water facilitated an enhanced rate of vegetative growth, leading to increased yields (Farag *et al.* 2014). Seed yield of a crop is the result genetic traits of the crop, soil characteristics, and environmental conditions that influence its growth and development. Similarly, different sowing methods, such as direct seeding or transplanting, can affect the establishment and early growth stages of the crop, influencing its yield potential (Mahmood *et al.* 2012). The growth and yield of fennel is also likely influenced by the type of mulching. Application of straw mulch improves soil quality and moisture retention, which can result in larger, healthier plants, and subsequently higher growth and yield. Similar finding were also reported by Meena *et al.* (2014). The application of plastic mulch was also improves growth and yield of fennel over no mulch. This might be due to the pronounced impact of polyethylene mulch on plant growth could be attributed to its role in maximizing nutrient availability and maintaining soil moisture over a longer duration, creating a conducive environment for plant growth. In contrast, the absence of mulch tends to yield minimal results due to lower soil moisture regimes and increased weed infestation, leading to greater water loss from the soil surface. Similar finding were also reported by Yadav and Bhati (2013), Meena *et al.* (2020).

CONCLUSION

The obtained results highlight that drip irrigation at 1.0 PEF, adopting transplanting as a planting method, and using straw mulch are all highly effective strategies for enhancing dry matter accumulation and seed yield in fennel cultivation.

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