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Effect of different levels of drip irrigation along with various fertigation levels on growth, yield and water use efficiency in fennel (*Foeniculum vulgare* Mill.)

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ABSTRACT : A field experiment was conducted to study the effect of different levels of drip irrigation along with various fertigation levels in fennel (*Foeniculum vulgare* Mill.) during *Rabi* season of 2010-11 at Swami Keshwanand Rajasthan Agricultural University, Bikaner. The experiment consisted of twenty one treatment combinations comprised of seven drip irrigation treatments (l 00: 100: 100 per cent ETc, 80:80:80 per cent ETc, 60:60:60 per cent ETc, 40:40:40 per cent ETc, 40:60:60 per cent ETc, 40:80:80 per cent ETc and 40: 100: 100 per cent ETc at three different development growth stages and three levels of fertigation (50, 75, 100 % recommended dose of N and P). The experiment was laid out in Split - Plot Design with three replications. Irrigation through drip was applied on the basis of ETc levels *i.e.* PE* Kp* Kc considering Kc values to be 0.70, 1.05 and 0.90 for initial (25 days), crop development (90 days) and final (35 days) stages, respectively. The fertigation was applied in six split doses at an interval of 15 days after sowing. Investigation results revealed that the the growth, flowering, yield and WUE of fennel significantly increased with different irrigation and fertigation levels. The maximum plant height (141.56 cm), number of branches per plant at 50 per cent flowering (39.22), diameter of main umbel (19.01 cm), dry matter of plant (34.46), biological yield (110.78) and test weight (8.58) were recorded under the treatment of 100 per cent Etc., whereas number of umbels per plant (21.40), number of umbellates per umbel (11.13), number of seeds per umbellate (10.63), seed yield (18.45 q ha^{-1}) and WUE (0.542 q ha^{-1} cm) were recorded maximum under the treatment of 80 per cent ETc. level. However, the 100 per cent fertigation level was recorded highest plant height (108.52 cm), number of branches per plant at 50 per cent flowering (29.10), number of umbels per plant (18.25), diameter of main umbel (14.65 cm), dry matter of plant (27.33), number of umbellates per umbel (8.34), number of seeds per umbellate (8.17), seed yield (14.39 q ha^{-1}), biological yield (62.50), test weight (7.83 g) and WUE (0.356 q ha^{-1} cm).

KEY WORDS : Drip irrigation, Fertigation, Water use efficiency, Growth stages, Fennel

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Fennel (*Foeniculum vulgare* Mill) commonly known as "saunf" belongs to the family Apiaceae (Umbelliferae) and is believed to be native of Southern Europe and Mediterranean region. It is widely cultivated throughout the temperate and subtropical region of the world. In India fennel is mainly grown in Gujarat and Rajasthan and to some extent in Utter Pradesh, Karnataka, Andhra Pradesh, Punjab, Madhya Pradesh, Bihar, Haryana and Jammu & Kashamir as a winter crop covering a total area of about 61 thousand ha with an annual production of 105 thousand tonne during 2010-11. In Rajasthan, it occupied an area of 9800 ha with an annual production of 8140 tonnes during 2010-11 (Anonymous, 2011). Fennel is mainly cultivated for its seeds (saunf) which have a pleasant fragrance and a pleasant aromatic taste and is the main constituent of different pickles (achar) and mouth freshener. It is also used in flavoured soup, fish dishes, bread rolls, pastries and confections.

The problem of high salinity has been observed in the

arid and semi-arid regions of Rajasthan. The ground water is the major sources of water in the state. The rainfall is scanty and evaportranspiration is very high. The only sources of water in these regions are highly saline ground water. The total of 10.67 million hectare area (about 31% of Rajasthan) comes under salt affected soil in the state out of which 8.87 million hectare area falls in western districts. Fertigation provides a variety of benefits to the users like high crop productivity and quality, resource use efficiency, environmental safety, flexibility in field operations, effective weed management and successful crop cultivation on fields with undulating topography. Fertigation is considered eco-friendly as it avoids the leaching of nutrients. Application of fertilizer in small quantities to the soil at any given time improves fertilizer use efficiency, helps to maintain nutritional balance and nutrient concentration at optimum level, saves energy and labour, provides opportunity to apply the nutrients at critical stage of crop growth and minimizes hazard of ground water pollution due to nitrate leaching as compared to conventional practice of fertilizer application. Fertigation through drip irrigation can increase yield and fertilizer savings in the range of 25 to 50%. It is particularly suitable for irrigation with water of poor quality (saline water) irrigating daily pushes the salt to the periphery of the moist zone: *i.e.* away from the root zone of the crop (Rathore and Gaur, 2010). The right combination of water and nutrients is the key for high yield and quality of produce. In fertigation, fertilizer application 25 to 40 per cent pressurized irrigation systems in the form of drip and sprinklers have positive significance not only in water saving but also in efficient energy, labour and fertilizer management system for crop production. In fertigation, fertilizer application is made in small and frequent doses that fit within scheduled irrigation intervals matching the plant water use of avoid leaching and other application losses. Although liquid fertilizers are most appropriate for use in fertigation, but in India the lack of availability and high cost of liquid fertilizers restrict their use for fertigation.

RESEARCH METHODS

The experiment was conducted at SKRAU, Bikaner which lies in Arid Partially Irrigated Western Plain (Zone Ic) of Rajasthan during *Rabi* season of 2010-11 on fennel variety RF-125. The experiment consisted of twenty one treatment combinations comprised of seven drip irrigation treatments (100: 100: 100 per cent ETc, 80:80:80 per cent ETc, 60:60:60 per cent ETc, 40:40:40 per cent ETc, 40:60:60 per cent ETc, 40:80:80 per cent, ETc and 40: 100: 100 per cent ETc at three different development growth stages *viz.*, initial¬25 days, crop development- 90 days and final stage- 35 days) and three levels of fertigation (50, 75, 100 per cent recommended dose of N and P). The experiment was laid out in split plot design with three replications. The irrigation treatment combinations in main plots were as follows :

Symbols	% ETc levels		
	Initial stage	Crop development stage	Maturity stage
T_1	100	100	100
T_2	80	80	80
T_3	60	60	60
T_4	40	40	40
T_5	40	60	60
T_6	40	80	80
T_7	40	100	100

The drip unit consisted of 63 mm 4 kg/cm PVC as main and sub main lines, 40 cm 4 lph inline laterals as water emitters and venturi as fertigation equipment. The water source for drip system was tubewell near the experimental site. The sowing was done manually and after that irrigation was applied through drip. Four rows were sown per lateral at row spacing of 15 cm. Inter cultural operations were carried out twice at 25 and 60 days after sowing and thinning at 35 days after sowing (DAS) to maintain plant spacing to be 40 cm. Thus the plant population was about 83000/ha.

The recommended fertilizer doses were adopted from the package of practices developed for Zone Ic *i.e.* nitrogen @ 90 kg/ha, phosphorus @ 40 kg/ha. and FYM @ 5 tonnes per ha. Nitrogen was applied through urea and phosphorus by phosphoric acid. The quantity of fertilizers to be applied per split as fertigation was calculated after inclusion of the correction factor 1.1 for nitrogenous and 1.6 for phosphatic fertilizers.

Fertigation levels in sub plots were as follows:		
Treatments	Dose	Symbol
100 % Recommended Dose	(N 90 kg +40 kg P_2O_5)	F_1
75 % Recommended Dose	(N 65 kg +30 kg P_2O_5)	F_2
50 % Recommended Dose	(N 45 kg +20 kg P_2O_5)	F_3

Irrigation through drip was applied on the basis of ETc levels *i.e.* PE Kp Kc considering Kc values to be 0.70, 1.05 and 0.90 for initial, crop development and final stages, respectively. The total volume of water required per plot was calculated on the basis of area to be irrigated and wetting fraction (0.9). Time of irrigation was decided on the basis of total volume of water required per plot and number of drippers per lateral and discharge per dripper. The fertigation was applied in six split doses at an interval of 15 days after sowing.

To assess the impact of various treatments on plant height, number of branches per plant at 50 per cent flowering, days taken to 50 per cent flowering, number of umbels per plant, diameter of main umbel, dry matter of plant, number of umbellates per umbel, number of seeds per umbellate,

seed yield, biological yield and test weight of fennel. The mean plot data recorded on five randomly selected plants on growth and flowering traits were subjected to statistical analysis (Panse and Sukhatme, 1967). Water use efficiency (WUE) for seed yield was calculated using the relationship.

$$\text{WUE (q/ha/cm)} = \frac{\text{Seed yield (q ha}^{-1}\text{)}}{\text{Total water applied (cm)}}$$

RESEARCH FINDINGS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarised under following heads:

Growth attributes:

Data revealed that the maximum plant height at harvest and number of branches per plant at 50 per cent flowering (141.56 cm and 39.22, respectively) were recorded under the treatment 100 per cent ETc (Table 1). Whereas, the treatment 40 per cent drip irrigation recorded minimum plant height (64.22 cm) and number of branches per plant (17.22). It is well known fact that sufficient soil moisture for progressive plant growth is maintained by drip irrigation, which leads to better development of photosynthetic area and accelerate photosynthetic rate. Another reason for this is that growth and development phases in fennel is synchronized under well watered and nutritional conditions, more of photosynthetic is diverted toward vegetative growth rather than fruiting parts. According to Radin *et al.* (1989) the poor ability of the fennel crop to absorb the nutrients during reproductive growth compared to vegetative phase is responsible for reduced water uptake by the plants resulting in the deterioration of the root zone system when assimilate supplied are diverted to the fruiting parts.

The plant height and number of branches per plant of fennel varied significantly with different fertigation levels. The highest plant height at harvest (108.52 cm) and number of branches per plant at 50 per cent flowering (29.10) were recorded in 100 per cent. This might be due to better nutritional environment in the root zone for the growth and development of the plant as N and P are considered as one of the major nutrients required for proper growth and development of the plant. Beside this, nitrogen is main constituent of protoplasm, cell nucleus, amino acids, chlorophyll and many other metabolic processes like transpiration. Phosphorus is a constituent of nucleic acids, phytin and phospholipids. The increasing levels of N and P through drip restricted fertilizers to the wetted zone of soil where the active roots are concentrated thus, leads to better utilization of nutrients, their uptake and enhanced vegetative growth. The similar results were obtained by Ram Pratap (2010).

Flowering attributes :

A critical examination of data revealed that the minimum days taken to 50% flowering (83.78) was recorded under the treatment of 40 per cent ETc (Table 1). Whereas, the treatment 100 per cent drip irrigation recorded maximum days taken to 50% flowering (101.33). This might be due to the fact that 80 per cent ETc level of drip irrigation at three growth stage resulted in better vegetative growth and

Table 1 : Effect of different levels of drip irrigation along with various fertigation levels on growth, yield and water use efficiency in fennel

Treatments	Plant height (cm)	No. of branches at 50% flowering	Days to 50% flowering	No. of umbels per plant	Diameter of main umbel	No. of umbellates per umbel	No. of seeds per umbellate	Dry matter of plant	Yield (qt^{-1})	Biological yield	Test weight (g)	WUE (q ha^{-1} cm)
Drip irrigation levels												
T_1	141.56	39.22	83.78	20.29	19.01	10.59	10.23	34.46	18.32	110.78	8.58	0.457
T_2	129.67	33.78	85.44	21.40	16.71	11.13	10.63	33.66	18.45	105.06	8.04	0.542
T_3	112.67	26.33	90.33	17.52	14.82	8.38	8.50	27.39	13.46	70.33	7.42	0.494
T_4	64.22	17.22	101.33	14.12	12.06	5.09	5.54	20.34	7.97	14.89	7.16	0.385
T_5	76.44	21.56	97.00	15.41	11.81	5.51	5.84	21.98	9.93	30.72	7.31	0.380
T_6	89.78	27.11	86.33	16.48	12.47	6.04	6.83	23.27	13.37	41.78	7.59	0.424
T_7	111.56	29.00	86.00	19.33	13.52	7.92	7.27	26.12	16.37	53.89	8.17	0.443
S.E. ±	0.862	0.409	0.403	0.111	0.085	0.118	0.092	0.093	0.043	0.340	0.031	0.004
C.D. (P=0.05)	2.656	1.256	1.242	0.343	0.261	0.364	0.285	0.286	0.134	1.048	0.096	0.012
Fertigation level												
F_1	108.52	29.10	90.62	18.25	14.65	8.34	8.17	27.33	14.39	62.50	7.83	0.356
F_2	103.62	27.90	90.00	17.96	14.41	7.85	7.84	26.70	13.97	60.90	7.79	0.346
F_3	98.95	26.24	89.48	17.17	13.97	7.24	7.50	26.20	13.58	59.79	7.64	0.336
S.E. ±	0.530	0.173	0.253	0.069	0.048	0.062	0.035	0.051	0.048	0.173	0.027	0.004
C.D. (P=0.05)	1.534	0.501	0.732	0.201	0.140	0.179	0.102	0.146	0.139	0.500	0.078	NS

carbohydrate accumulation which influenced early flowering and fruiting as assisted by more availability of sunlight and optimum availability of water. Whereas, higher moisture, enhanced vegetative growth and leaf area which limited radiant fluxes into the canopy and might be responsible for delayed flowering and fruiting behaviour. Another reason for this variation is that growth and development phases in fennel are synchronized under well watered and nutritional conditions, more of the photosynthates is diverted towards vegetative growth rather than fruiting parts. These findings are similar to the findings of Patel *et al.* (2007).

The days to 50% flowering of fennel varied significantly decreased with different fertigation levels. The minimum days to 50% flowering (89.48) was recorded in 50 per cent recommended dose of N and P which was at par to 75 per cent recommended dose of N and P. Lower doses of N and P could not meet out the nutritional requirement of plant for better root growth and vegetative growth which ultimately resulted in reduced growth, early accumulation of photosynthates and ultimately early flowering and fruiting. Whereas, optimum dose (75 % RDF) maintained the proper nutritional environment in the root zone, balanced the physiological processes and could helped in proper utilization and uptake of nutrients resulted in better vegetative growth which delayed the flowering and fruiting but helped in proper development of seed by maintaining source to sink relationship and ultimately resulted in early and prolonged harvesting as compared to 50 per cent (F_3) RDF (Imamsaheb *et al.,* 2011).

Yield attributes :

The result indicated that the number of umbels per plant (21.40), number of umbellate per umbel (11.13), number of seeds per umbellate (10.63), seed yield per hectare (18.45 q) were recorded under the treatment 80 per cent ETc. whereas, the treatment 40 per cent drip irrigation recorded minimum number of umbels per plant, number of umbellate per umbel number of seeds per umbellate and seed yield per hectare were 14.12, 5.09, 5.54, 7.97 q, respectively (Table 1). Therefore, the diameter of main umbel (19.01), dry matter of plant (34.46), biological yield (110.78 g/plant) and test weight (8.58 g) were recorded significantly higher in T_1 whereas, the minimum dry matter of plant (20.34), biological yield (14.89 g/plant) and test weight (7.16 g) were observed in T_4 treatment 40 per cent drip irrigation recorded minimum. This might be due to better water utilization and uptake of nutrients and excellent soil-water air relationship with higher oxygen concentration in the root zone. It may also be due to the optimum moisture conditions in the entire root zone of the crop which reflected in better physiological activities of plants resulting into increased dry matter accumulation and thereby increased. The frequent application of water, maintained the soil moisture almost near the field capacity, thereby crop did not experience moisture stress during the growth period. Similar results were reported by Bafna *et al.* (1993) and Raina *et al.* (1999).

All yield attributes of fennel significantly increased with different fertigation levels. The maximum number of umbels/ plant (18.25), diameter of main umbel (14.65 cm), number of umbellate per umbel (8.34), number of seeds per umbellate (8.17), dry matter of plant (27.33), seed yield (14.39 q/ha), biological yield (62.50 g/plant) and test weight (7.83 g) were recorded in 100 per cent recommended dose of N and P. The minimum value of all yield attributes of fennel was observed with 50 per cent recommended dose. Restriction of fertilizers to the wetted zone of soil where active roots are concentrated leads to better utilizations of nutrients might probable be the reason of higher yield (Hebber *et al.,* 2005). The appropriate and sufficient fertilizer application through fertigation makes it possible to meet out the crop nutrient requirement at various growth stages with minimum leaching beyond the root zone resulting in improved growth and yield characteristics. Broadcasting of fertilizers, generally tends to cause uneven distribution of fertilizers in the root zone. Alternatively, soluble N and P fertilizer can be applied via fertigation through drip system, to obtain proper distribution in soil. This is the evidence for the longer activity in fertigation where nutrients were applied to match the nutrient uptake by the crop. This enhanced the current photosynthesis for seed development leading to the development of good quality with appropriate size and producing more number of seed per umbel and seed weight in fertigation treatments compared to soil application treatments. Similar findings were observed by Shedeed *et al*. (2009), Badra and Yazied (2010) and Brahma *et al.* (2010).

Water use efficiency (WUE) of fennel:

The maximum water use efficiency (0.542 q ha^{-1} cm) was recorded under the treatment 80 per cent ETc which was significantly higher over all other drip irrigation treatments. The treatment 40:60:60 per cent drip irrigation recorded minimum WUE (0.380 q ha^{-1} cm). The water use efficiency under 80 per cent was 0.542 and 0.494 q ha^{-1} cm per cent more than 100 and 60 per cent ETc, respectively. The water use efficiency of fennel had no significant variation because of fertigation levels.

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