

Effect of nitrogen and irrigation on water use, moisture-extraction pattern, nutrient uptake and yield of fennel (*Foeniculum vulgare*)

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ABSTRACT

A field experiment was conducted during the winter seasons of 2001–03 at Agricultural Research Station, Sriganganagar, Rajasthan, to study the water use, nutrient uptake, yield and economics of fennel (*Foeniculum vulgare* Mill.) cultivars under various levels of nitrogen and irrigations. The highest yield (25.16 and 19.04 q/ha) and yield attributes were recorded with 80 kg N/ha. Net returns and gross returns and benefit : cost ratio were also the highest at 80 kg N/ha. Increasing levels of nitrogen also recorded higher consumptive use of water and significantly higher nutrients uptake. Higher level of nitrogen extracted more water from lower depth of rhizosphere than lower level of N. With an increase in irrigation frequency from IW : CPE ratio 0.4 to 0.8, yield and most of the yield attributes increased significantly. Similarly, water use and nutrients uptake were also higher with higher levels of irrigation. At lower irrigation level (IW : CPE ratio 0.4) more water was extracted from upper layers than higher irrigation level. Increasing levels of irrigation also recorded higher gross, net returns and benefit : cost ratio. Between the 2 varieties, 'RF 125' outperformed 'RF 101'.

Key words : Fennel, Nitrogen, Irrigation, Water-use efficiency, Moisture-extraction pattern, Nutrient uptake

Fennel is an important spice crop in India, having 15% of the countries total sown area and production in Rajasthan (Chaudhary, 2000). It is cultivated mainly as transplanted crop, although it can also be raised profitably as a winter direct-seeded crop (Mehta *et al.*, 1990). Direct-seeded fennel is very popular due to short duration than transplanted crop. Thus direct-seeded fennel is profitable than other common winter crops like mustard, chickpea and wheat. In spite of this fact, the productivity (1,200 kg/ha) of fennel is low compared to its potential yield (2,500 kg/ha). The reason for low productivity is due to lack of ideal agronomic practices for winter fennel including water and nitrogen management as well as non-adoption of suitable high-yielding varieties. With a view to find out an ideal combination of nitrogen and irrigation schedule and suitable variety to maximize production of winter fennel, present investigation was undertaken.

MATERIALS AND METHODS

The field experiment was conducted during the winter seasons of 2001–03 on sandy-loam soil at Agricultural Research Station (Rajasthan Agriculture University), Sriganganagar, in split-split plot design with 3 replications. The treatments comprised 3 nitrogen levels (40, 60 and 80 kg N/ha) in main plots, 3 levels of irrigation (IW : CPE ratio 0.4, 0.6 and 0.8) in subplots and 2 varieties

('RF 101' and 'RF 125') in sub-sub plots. A pre-sowing irrigation of 100 mm was applied for field preparation and to ensure germination and thereafter each irrigation of 60 mm depth was applied as per treatment. One common irrigation was applied 20 days after sowing for proper establishment of the crop. Nitrogen was applied as per treatment through urea in 3 equal splits—at sowing, at 1st and 2nd irrigation. Phosphorus 30 kg P_2O_5 was applied as basal through single superphosphate. The soil was sandy loam, having field capacity 16.2%, permanent wilting point 6.3%, bulk density 1.48 g/cc, pH (1:2) 8.1, electrical conductivity(1:2) 0.2 dS/m, organic carbon 0.28% and available P_2O_5 and K_2O 35 and 340 kg/ha, respectively. The crop was sown on 9 and 10 October in 2001–02 and 2002–03 respectively, with seed rate of 8 kg/ha and harvested on 8 and 25 April in both the years. Row-to-row spacing was 40 cm and intra-row spacing was 20 cm. The total crop-growing period was 198 days in both the years and pan evaporation was 667.6 mm and 518.5 mm in 2001–02 and 2002–03 respectively.

RESULTS AND DISCUSSION

Nitrogen

Nitrogen had significant effect on yield and yield attributes (Tables 1,2). The highest seed and stover yields were found with 80 kg N/ha, and these yields were at par

with the yields recorded with 60 kg N/ha. Both 60 and 80 kg N/ha recorded significantly higher seed and stover yields than 40 kg N/ha in both the years. Patel *et al.* (2000) recorded significantly higher yield of fennel with 90 kg N/ha over 60 kg N/ha. Harvest index was not influenced significantly by nitrogen levels and was the highest with 40 kg N/ha (27.4%) and 80 kg N/ha (23.9%) in 2001–02 and 2002–03 respectively. The highest gross and net returns and benefit : cost ratio were recorded with 80 g N/ha (Table 2). Water use increased with increasing levels of nitrogen (Table 5), being maximum with 80 kg N/ha and was followed by 60 kg N/ha. The highest water-use efficiency was recorded with 80 and 60 kg N/ha during 2001–

02 and 2002–03 respectively. The increasing levels of nitrogen increased the moisture extraction from lower layers. It may be owing to better development of roots with higher doses of nitrogen which helped in extracting more moisture from lower depth. Increase in nitrogen level significantly increased N, P and K uptake in both the years (Table 6). The highest N, P and K uptake was recorded with 80 kg N/ha followed by 60 and 40 kg N/ha.

Irrigation

The higher irrigation frequency with the increase in IW : CPE ratio from 0.4 to 0.8 significantly influenced the yield attributes (Table 1), seed and stover yields (Table 2).

Table 1. Effect of nitrogen and irrigation levels on yield attributes of fennel cultivars

Treatment	Height (cm)		Primary branches/		Secondary branches/		Umbles/plant		Umbles/umbl		Seeds/umbl		Test weight (g)	
	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03
<i>N (kg/ha)</i>														
40	117.5	112.0	5.6	5.6	16.2	16.0	40.2	18.8	19.4	22.3	262	312	7.2	8.4
60	122.6	117.3	5.9	6.1	18.7	17.3	44.3	19.9	23.2	23.3	312	327	7.3	8.9
80	125.4	118.6	6.0	6.2	19.9	18.0	45.5	20.5	24.1	23.3	314	329	7.3	9.0
CD (P=0.05)	1.4	3.4	NS	NS	1.0	1.4	4.1	NS	0.3	NS	6	11	0.1	0.2
<i>IW : CPE</i>														
0.4	109.4	1006.4	5.0	5.5	13.3	13.3	33.9	16.0	19.4	19.1	187	280	7.0	8.7
0.6	126.2	117.3	6.1	6.1	19.4	18.2	45.9	21.1	22.7	23.6	341	320	7.4	8.8
0.8	129.9	124.1	6.4	6.2	22.0	19.7	50.2	27.1	24.6	26.3	360	366	7.5	8.8
CD (P=0.05)	2.3	3.8	0.4	0.6	1.6	1.3	2.4	1.3	0.2	1.0	5	11	0.2	NS
<i>Varieties</i>														
'RF 101'	117.6	114.1	5.4	5.7	16.9	16.3	39.7	18.9	20.7	21.8	269	310	7.0	8.7
'RF 125'	126.0	117.8	6.2	6.3	19.6	17.9	46.9	20.6	23.7	24.2	323	335	7.5	8.7
CD (P=0.05)	7.7	1.9	0.6	NS	0.70	1.0	6.0	1.1	0.3	1.0	4	9	0.2	NS

Table 2. Effect of nitrogen and irrigation levels on yield, harvest index and monetary returns (mean) of fennel cultivars

Treatment	Seed yield (kg/ha)		Stover yield (kg/ha)		Harvest index (%)		Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit : cost ratio
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03				
<i>N levels (kg/ha)</i>										
40	20.97	16.75	55.54	55.82	27.4	23.1	9,067	33,948	24,881	3.74
60	24.01	18.33	68.62	58.78	25.9	23.7	9,260	38,106	28,846	4.12
80	25.16	19.04	71.31	60.45	26.1	23.9	9,454	39,780	30,326	4.21
CD (P=0.05)	1.91	1.49	6.93	2.67	NS	NS				
<i>IW : CPW ratio</i>										
0.4	16.76	14.78	40.07	36.42	29.5	28.8	9,015	28,386	19,371	3.15
0.6	24.25	18.32	69.09	63.53	26.0	22.4	9,225	38,313	29,088	4.15
0.8	29.13	21.03	86.34	75.07	25.2	21.9	9,540	45,144	35,604	4.73
CD (P=0.05)	1.15	2.27	7.00	2.87	3.1	3.2				
<i>Varieties</i>										
'RF 101'	19.73	15.43	52.48	55.45	27.3	21.7	9,260	31,644	22,384	3.41
'RF 125'	27.02	20.65	77.85	61.20	25.8	25.2	9,260	42,903	33,643	4.63
CD (P=0.05)	1.05	1.49	3.38	1.58	NS	NS				

Irrigation treatment of IW : CPE ratio of 0.8 significantly outyielded rest of irrigation levels. Higher irrigation frequency increased the availability of nutrients and thus enhanced the uptake of nutrients which in turn enhanced the meristematic activities and size of cells and formation and functioning of protoplasm which consequently improved the crop growth and yields. This results confirmed those of Ahmed *et al.* (1988). There was 73.81, 42.29 and 20.12, 14.79% higher seed yields at 0.8 IW : CPE over 0.4 and 0.6 IW : CPE ratio respectively. The highest yield obtained under IW : CPE ratio of 0.8 was evidently resulted from higher values of yield attributes. These findings are

Table 3. Interaction effect of nitrogen and irrigation on seed yield (q/ha) of fennel (2001–02)

Treatment	IW : CPE 0.4	IW : CPE 0.6	IW : CPE 0.8
<i>N</i> (kg/ha)			
40	14.62	22.43	25.86
60	17.84	23.40	30.79
80	17.81	26.91	30.75
CD (P=0.05)	2.00		

Table 4. Interaction effect of irrigation and variety on seed yield (kg/ha) of fennel (2001–02).

Treatment	RF 101	RF 125
<i>IW : CPE ratio</i>		
0.4	15.00	18.52
0.6	19.88	28.61
0.8	24.32	33.95
CD (P=0.05)	1.82	

in conformity with those of Patel *et al.* (1988), Sharma and Prasad (1998) and Patel *et al.* (2000). Increasing irrigation levels also increased gross return and benefit : cost ratio and all the values were the highest with IW : CPE ratio 0.8 (Table 2). Consumptive use was also higher with levels of irrigation (Table 5). More and more water was extracted from upper and middle layers when higher frequency of irrigation water was applied. It may be due to better proliferation of roots in upper and middle layers because of lower resistance of soil attributed by higher irrigation frequency. When the crop suffered from scarcity of water (IW : CPE 0.4) more water was extracted from lower layer in both the years.

Variety

Of the 2 varieties, 'RF 125' out-performed 'RF 101' for yield, yield attributes, water use, water-use efficiency, nutrients uptake, monetary return and benefit : cost ratio in both the years.

Nitrogen and irrigation and variety interaction

Interaction effect of nitrogen and irrigation and irrigation and variety were significant in 2001–02 (Table 3). Fennel yield was the highest with 60 kg N/ha and the irrigation level IW : CPE ratio 0.8. This yield was at par with the yield recorded with irrigation level of IW : CPE 0.8 and 80 kg N/ha. Variety and irrigation interaction also influenced the yield significantly (Table 4) in 2001–02. 'RF 125' variety gave significantly highest yield with irrigation level of 0.8 IW : CPE ratio. This variety also gave significantly higher seed yield with IW : CPE ratio 0.6 in comparison to 'RF 101' with 0.8 IW : CPE ratio.

Table 5. Effect of nitrogen and irrigation levels on consumptive use of water, water-use efficiency and moisture-extraction pattern (%) of fennel

Treatment	No. of irrigations		Water applied (mm)*		Consumptive use (mm)		Water use efficiency (kg/ha/mm)		Moisture-extraction pattern from different depth					
	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	2001–02	2002–03	0–30 cm		30–60 cm		60–90 cm	
									2001–02	2002–03	2001–02	2002–03	2001–02	2002–03
<i>N</i> (kg/ha)														
40	5.33	4	432.9	398.5	327.4	314.8	6.41	5.32	49.8	49.1	34.0	31.1	15.9	19.6
60	5.33	4	432.9	398.5	345.4	338.4	6.95	5.42	47.7	47.6	32.9	31.1	19.3	21.2
80	5.33	4	432.9	398.5	356.2	353.8	7.06	5.38	46.8	46.5	32.9	31.6	20.2	21.7
<i>IW : CPE ratio</i>														
0.4	4	3	352.9	338.5	272.1	297.7	6.16	4.96	46.2	46.8	34.2	29.8	19.4	23.3
0.6	5	4	412.9	398.5	322.1	339.7	7.53	5.39	47.9	48.5	33.4	31.2	18.6	20.2
0.8	7	5	532.9	458.5	434.9	369.6	6.70	5.69	50.2	49.6	32.3	32.5	17.4	19.8
<i>Variety</i>														
'RF 101'	5.33	4	432.9	398.5	334.0	337.4	5.91	4.57	48.6	48.1	33.3	31.3	17.9	20.5
'RF 125'	5.33	4	432.9	398.5	352.0	358.9	7.68	5.75	47.6	47.3	33.3	31.3	19.0	21.3

Including pre-sowing irrigation of 100 mm and rainfall of 12.9 mm and 58.5 mm in 2001–02 and 2002–03, respectively

Table 6. Effect of nitrogen and irrigation levels on nitrogen, phosphorus and potassium uptake (kg/ha) of fennel cultivars

Treatment	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
<i>N (kg/ha)</i>						
40	71.5	61.6	16.1	14.2	113.4	104.3
60	94.0	74.6	20.7	16.6	139.1	114.0
80	104.1	82.0	22.6	18.0	151.7	123.3
CD (P=0.05)	6.4	5.2	1.1	0.8	5.9	4.8
<i>IW : CPE ratio</i>						
0.4	54.5	48.5	11.8	12.4	78.7	70.6
0.6	96.3	77.9	23.2	17.4	139.4	118.9
0.8	121.3	93.8	27.2	21.4	194.8	158.6
CD (P=0.05)	5.9	1.9	1.0	1.7	4.9	12.5
<i>Variety</i>						
'RF 101'	72.8	63.2	16.3	14.6	109.5	103.4
'RF 125'	105.8	81.6	23.1	17.8	161.0	125.2
CD (P=0.05)	4.9	4.5	1.0	0.7	4.7	7.5

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