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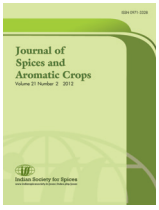

Sodicity affects growth, yield and cation composition of fennel (*Foeniculum vulgare* Mill.)

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Abstract

Field trials were conducted at Banthra, Lucknow, (Uttar Pradesh) to study the effect of sodicity on growth, yield and cation composition of fennel (*Foeniculum vulgare mill.*) grown in a Typic Natrustalf. The treatments included five exchangeable sodium percentage (ESP) levels (10, 20, 30, 40 & 50) and four genotypes *viz*., HF-107, NDF-9, Local BRS and NDF-7. An adverse effect of sodicity was observed on emergence of secondary branches and seed setting causing decrease in seed yield. The variety HF-107 produced the highest seed yield (1956 kg ha^{-1}) followed by Local BRS (1709 kg ha^{-1}), NDF-9 (1577 kg ha^{-1}) and NDF-7 (1078 kg ha^{-1}). The cation composition of stover revealed Na inclusion mechanism with narrow K/Na and Ca/Na ratios. The study further revealed that the crop can tolerate medium level of sodicity (ESP 30).

Keywords: cation concentration, fennel, *Foeniculum vulgare*, sodic soil, yield

Introduction

Fennel (*Foeniculum vulgare* Mill.) is an important crop of considerable medicinal value. Besides meeting home demands it is exported to earn foreign exchange. In India it is chiefly grown in the states of Rajasthan, Gujarat and Uttar Pradesh and one third area of these states is under salt affected soils. The utilization of salt affected wastelands can be promoted in view of the limited land resources by growing spice crops. In India, however, there are large tracts of salt affected soils (7.4 million ha) of which about 50.0% is adversely affected by sodicity (Tyagi & Minhas 1998). Recently, Garg (2011) reported that fennel has potential of growing in sodic soil without affecting its oil content. The present field study was thus under taken with the objectives of assessing the sodicity tolerance and response of fennel crop on growth, yield and cation composition.

Materials and methods

The study was conducted for two consecutive years (2001–02 to 2002–03) at Banthra Research Station of National Botanical Research Institute, Lucknow, India, located at 80°45'–80°53'E longitude and 26°40'–26°45' N latitude. The soil of the experimental plots was sandy loam in texture with pH 9.0, EC < 2 dSm^{-1}, exchangeable sodium percentage (ESP) 35, organic C 0.80%, available P 19 kg ha^{-1} and available K 694 kg ha^{-1}. The soil was a fine loamy

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mixed hyperthermic, Typic natrustalf. The soil chemical attributes of the experimental site are given in Table 1. Field trial with split plot design was laid out with five ESP levels 10, 20, 30, 40, & 50 as main plot treatments and four varieties such as HF-107, NDF-9, Local BRS and NDF-7 as sub plot treatments with three replications in plot size of 1 m × 1 m. Each plot was protected by one meter border so that neighbouring sodicity may not affect the treatments. The required ESP was created in the surface (0-15 cm) soil by adding gypsum/ sodium carbonate. The seeds of fennel were sown in the last week of October in 30 cm x 30 cm distance, at seed rate of 10 kg ha^{-1} fertilized with 80 kg N ha^{-1}, 40 kg P ha^{-1}, 25 kg K ha^{-1} + 20 t FYM ha^{-1} and the crop was harvested in the first week of April in each year. Observations were recorded on plant height, number of primary and secondary branches, umbel $plant^{-1}$, umbellate $umbel^{-1}$ and total seed yield $plot^{-1}$ at harvest. At the time of harvest samples of stover (leaf + shoot) were collected for cations analysis. One gram dry sample was digested in perchloric and nitric acid mixture (1:3) following wet digestion method. The contents of K, Na, and Ca were estimated by flame photometer. Magnesium content was determined by atomic absorption spectrophotometer (Richards 1954). The data recorded on different parameters for both the years were pooled and mean data over two years are presented after statistical analysis (Panse & Sukhatme 1961).

Table 1. Initial soil properties before sowing of fennel crop (mean of 2 years)

Treatments	pH 1:2 soil:water	EC (dSm^{-1})	OC (%)	Total N (%)	Av. P (kg ha^{-1})	Av K (kg ha^{-1})	ESP
ESP 10	8.15±0.06	1.14±0.12	0.94±0.08	0.17±0.008	25.91±5.99	653.30±135.72	13.90±0.54
ESP 20	8.40±0.29	1.11±0.41	1.26±0.03	0.17±0.02	32.77±6.24	834.85±101.61	19.32±3.02
ESP 30	8.90 ±0.14	0.62±0.07	0.71±0.14	0.16±0.031	20.51±2.59	925.28±52.98	27.26±6.12
ESP 40	9.18±0.13	0.66±0.05	0.53±0.08	0.13±0.12	7.30±1.16	660.40±196.37	38.19±6.02
ESP 50	9.67±0.02	0.78±0.05	0.35±0.03	0.12±0.014	5.22±0.79	463.67±7.48	55.29±2.30

Values indicate mean ± SD; EC=Electrical conductivity; OC=organic carbon; ESP=Exchangeable sodium percentage; Av=Available

Results and discussion

Germination and growth parameters

Results showed that germination occurred first on 10th day after sowing and ended within 30 days. It ranged from 90.0–93.0% in control (ESP 10) and 58.0–89.0% at the highest ESP. The study showed that increased sodicity caused a decrease in germination. The emergence among different varieties did not show any marked difference in timing of initiation and completion. Generally, fennel germinates within couple of weeks. Hence, delayed as well as reduction in sprouting was noticed with rise in soil ESP (Fig. 1). The varied response of germination in different varieties may be attributed to their genetic character besides lower osmotic potential of the soil. A decrease and delayed germination under salt affected soils have been reported in fennel and other spice crops (Garg & Malhotra 2008; Zaki *et al.* 2009).

Plant growth was observed to be higher in control and decreased with increasing soil ESP.

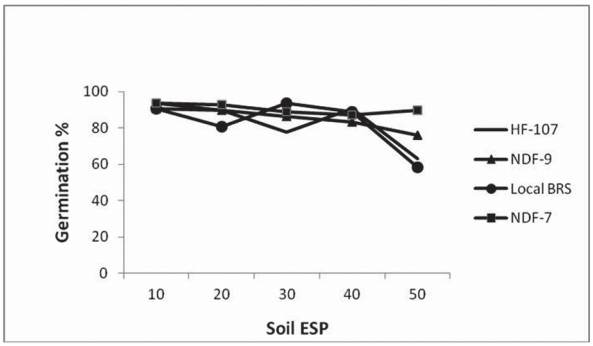

Fig 1. Germination (%) of different varieties of fennel grown at varying ESP levels

Mean plant height varied from 108.4 cm (Local BRS) to 134.6 cm (NDF-7) in control and from 69.3 cm (NDF-7) to 89.8 cm (NDF-9) at ESP 50. Plant height decreased significantly in all cultivars except in Local BRS due to rise in ESP levels. There was a maximum reduction of 48.5% in plant height of NDF-7 and minimum of 26.5% in Local BRS (Table 2). A general tendency of decline in plant growth caused by increasing salt stress has been observed in fennel and other crops (El-Wahab 2006; Garg & Lal Bahadur 2011). Influence of sodicity did not show any significant variation in emergence of primary branches across varieties even at highest sodicity level. However, secondary branching decreased significantly at ESP 30 and above indicating an adverse effect of sodicity (Table 2). This is in confirmation to the earlier report of Garg (2011). Probably osmotic potential of growth medium imbalances production of hormones in root and shoot. Besides increased respiration could cause reduction in photosynthetic products available for growth (Meiri & Shahavet 1973).

Yield parameters

Mean number of umbel plant^{-1} (2 years) showed that the effect of variety and ESP was significant but not their interaction (Table 3). It can be seen that mean number of umbel plant^{-1} formed was significantly more in variety NDF-9 followed by NDF-7, HF-107 and Local BRS. However, their count was significantly higher in control and decreased in all the varieties with increase in sodicity. It was found that their numbers reduced significantly from 30.4% to 51.6% at ESP 30 and above. The development of umbellate umbel^{-1} did not vary significantly amongst the varieties with variation in different ESP levels. Likewise, their interaction was not significant (Table 3). The data obtained for 1000 seed weight showed significant difference between the varieties due to effect of ESP and a decline of 8.7 to 17.5% was noticed at ESP 30

Table 2. Vegetative growth of different varieties grown at various levels of ESP (mean of 2 years)

Treatment	HF-107	NDF-9	Local BRS	NDF-7	CD(P=0.05)
		Plant height(cm)			
ESP 10	121.6	113.2	108.4	134.6	NS
ESP 20	106.7	110.0	105.3	109.0	NS
ESP 30	101.6	108.3	101.3	105.2	NS
ESP 40	91.8	106.8	90.0	98.8	NS
ESP 50	74.1	89.8	79.6	69.3	NS
CD (P<0.05)	19.62	13.76	29.85	37.93	
		Pr. branch plant^{-1}			
ESP 10	8.2	9.3	7.2	8.4	1.85
ESP 20	8.8	10.4	7.6	8.1	2.62
ESP 30	10.1	10.0	9.1	10.0	0.32
ESP 40	8.1	10.1	8.1	8.7	3.51
ESP 50	7.3	7.1	8.4	5.7	2.38
CD (P<0.05)	NS	NS	NS	2.94	
		Sec. branch plant^{-1}			
ESP 10	34.3	37.8	24.4	46.5	19.70
ESP 20	24.2	30.4	20.6	35.8	14.47
ESP 30	20.8	28.8	18.7	21.7	9.40
ESP 40	19.4	22.2	14.0	17.7	7.34
ESP 50	16.0	16.9	12.0	8.0	8.77
CD (P<0.05)	6.03	5.20	6.42	4.26	

Pr.=Primary; Sec.=Secondary; ESP=Exchangeable sodium percentage

Table 3. Effect of sodicity on yield parameters of fennel (mean of 2 years)

Variety	Umbel plant^{-1}	Umbellate umbel^{-1}	Seed yield (kg ha^{-1})	Test weight 1000^{-1} seed (g)
HF-107	43.12	24.20	1956.6	5.35
NDF-9	51.45	21.11	1577.3	5.23
Local BRS	35.02	17.84	170.94	5.25
NDF-7	46.20	17.16	1078.0	5.03
CD (P<0.05)	NS	NS	476.0	0.22
Treatment				
ESP 10	60.10	19.91	2316.6	5.76
ESP 20	50.89	18.14	2075.8	5.23
ESP 30	41.81	19.44	1587.5	5.26
ESP 40	37.84	18.89	1200.0	5.10
ESP 50	29.09	24.0	721.7	4.75
CD (P<0.05)	15.08	NS	469.0	0.64
Interaction (ESP × Variety)	27.53	19.85	1032.5	0.72

ESP=Exchangeable sodium percentage

and above. This showed that besides formation of umbel or umbellate, seed setting is an important factor under salt affected soils.

Seed yield

The effect of variety and ESP was significant but not their interaction (Table 3). Mean yield of seed was higher in control and decreased by 10.4–68.8% with rise in ESP. The decrease in seed yield may be attributed to general reduction in vegetative growth. Such an adverse effect on growth and seed yield has been reported in fennel grown in salt affected soil (Ashraf & Akhatar 2004). There was a drastic reduction in seed yield from 31.1–68.5% in all varieties at ESP 30. Assuming 50% decrease in seed yield from control to different grades of ESP as a criterion of sodicity tolerance, the present study showed seed yield of 2316.6 kg ha^{-1} in control and 1587.5 kg ha^{-1} at ESP 30 having <50% reduction indicating medium tolerance of fennel. In general, seed yield of fennel on normal soil varied from 1300 kg ha^{-1} to 2500 kg ha^{-1} depending on the variety, spacing, irrigation and use of fertilizers/ nutrients (Bhati 1990; Yadav *et al.* 1998; Pruthi 2001). In our study, seed yield observed at ESP 30 is at par with that of 1150–1300 kg ha^{-1} obtained in sodic soil (Rai *et al.* 2002; Garg *et al.* 2004) suggesting that this crop is able to withstand moderate degree of sodicity (ESP 30). On evaluating different varieties, HF-107 produced the highest seed yield of 1956 kg ha^{-1} followed by Local BRS (1709 kg ha^{-1}), NDF-9 (1577 kg ha^{-1}) and NDF-7 (1078 kg ha^{-1}). Thus, the best performing varieties were HF-107 and Local BRS.

Cation concentration

Mean concentration of Na in stover increased and that of K and Ca decreased significantly with rise of sodicity in all varieties. However, remarkable differences were evident at ESP 30 and above. The Mg concentration showed inconsistent variation. Results indicated that the plant is able to absorb higher amount of Na and store it in leaf. It was observed that salt tolerance in many crop plants depends on the efficiency of root system which regulates the excess of Na ions to reach the shoot (Khan *et al.* 1995). The study indicated that fennel is a good accumulator of Na without showing any deficiency/ toxicity during growth at ESP 30 (Table 3). Generally salt tolerant crop varieties have either selectivity /restriction (excluder) of Na absorption or faster rate of K accumulation. In the present study K/Na and Ca/Na ratios fluctuated within narrow limits i.e. less than

Table 4. Cation composition in fennel stover of different varieties grown at various levels of soil ESP (mean of 2 years)

Treatment	K	Ca	Mg	Na	K/Na	Ca/Na
			HF-107			
			($mg\ g^{-1}$)			
ESP 10	9.7	33.0	5.8	31.0	0.31	1.06
ESP 20	9.6	30.5	5.2	34.0	0.27	0.88
ESP 30	9.1	31.0	4.2	40.1	0.22	0.77
ESP 40	7.1	28.5	5.8	36.6	0.19	0.77
ESP 50	4.8	22.5	6.6	34.6	0.14	0.66
CD(P<0.05)	1.9	2.0	0.8	2.4		
			NDF-9			
ESP 10	17.0	33.0	7.0	28.0	0.60	1.17
ESP 20	13.0	31.0	8.0	35.0	0.37	0.88
ESP 30	8.0	29.0	7.0	38.0	0.21	0.76
ESP 40	8.0	28.0	4.0	37.0	0.20	0.75
ESP 50	6.0	26.0	2.0	41.0	0.14	0.63
CD(P<0.05)	3.1	2.7	2.3	4.4		
			Local BRS			
ESP 10	16.0	27.0	4.0	32.0	0.50	0.84
ESP 20	10.0	29.0	4.0	32.0	0.31	0.90
ESP 30	11.0	28.0	7.0	34.0	0.32	0.82
ESP 40	8.0	26.0	2.0	32.0	0.25	0.81
ESP 50	6.0	18.0	6.0	34.0	0.17	0.52
CD(P<0.05)	3.1	2.7	1.6	NS		
			NDF-7			
ESP 10	15.0	29.0	5.0	31.0	0.48	0.93
ESP 20	11.0	29.0	6.0	35.0	0.31	0.82
ESP 30	12.0	29.0	6.0	39.0	0.30	0.74
ESP 40	12.0	24.0	7.0	42.0	0.28	0.57
ESP 50	6.0	29.0	2.0	43.0	0.13	0.67
CD(P<0.05)	2.9	2.6	1.4	4.3		

ESP=Exchangeable sodium percentage

one (< 1) in all the varieties under sodic soil conditions reflecting salt inclusion mechanism. The study thus revealed that fennel can tolerate medium level of sodicity (ESP 30) and has Na inclusion mechanism.

The study indicated that sodicity affected emergence of secondary branches as well as seed setting resulting in decreased seed yield. The crop showed Na inclusion mechanism and was able to endure sodicity up to ESP 30.

Acknowledgment

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