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Evaluation of Fennel (*Foeniculum vulgare* Mill.) and Fenugreek (*Trigonella foenumgraecum* L.) Intercropping System and Sulfur on Quality Parameters and Yield Advantages under Semi-Arid Region of Rajasthan

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Abstract The study was carried out during *rabi* season of 2013-14 to study the effect of different intercropping systems and sulfur levels on fennel (*Foeniculum vulgare* Mill.) and fenugreek (*Trigonella foenum-graecum* L.). The significantly lower seed, straw and biological yields of fennel and fenugreek were observed under intercropping system of 1 : 2 and 1 : 1 row ratio, respectively. The fennel grown in 1 : 2 row ratio, recorded significantly highest concentration of nitrogen, oil content in seed and sulfur concentration in seed and straw of fennel. However, the intercropping in 1: 1 row ratio recorded significantly lowest nitrogen concentration and protein content in seed and sulfur concentration in seed and straw of fenugreek as compared other cropping systems. Fennel and fenugreek recorded significantly lower total uptake of nitrogen and sulfur under intercropping in 1 : 2 and 1 : 1 row ratios, respectively as compared to all other cropping systems. The yield of both crops, nitrogen concentration in seed of fennel and seed and straw of fenugreek, sulfur concentration in straw of both crops, volatile oil content in seed and oil yield of fennel, protein content in seed of fenugreek and total uptake of nitrogen in both crops increased significantly upto 40 kg/ha. However, nitrogen concentration in straw of fennel significantly increased only upto 20 kg S/ha. The significant improvement in sulfur content in seed and total sulfur uptake by fennel and fenugreek were observed upto 60 kg/ S/ha. In the whole system, the intercropping in 1 : 1 row ratio gave significantly highest FEY (18.49 q/ha), LER (1.45), Monetary advantage (Rs 39,099.18/ha) and net returns (Rs 126,471/ha). Significantly higher fennel equivalent yield (15.00 q/ha), LER (1.20) and net returns (Rs 100,428/ha) were recorded with 40 kg S/ha over preceding levels.

Keywords : Intercropping, Fennel, Planting pattern, Fenugreek, Sulfur.

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Introduction

A spice is a dried seed, fruit root, bark or vegetative substance used in flavoring, seasoning and imparting aroma in variety of food items and beverages. In India, wide varieties of spices are grown and many of them are native to the subcontinent and also known as "Home of Spices". Besides importance in food industry, the spices have medicinal properties and thus are used in various pharmaceutical preparations and also in cosmetic industry. The usages of spices by consumers are increasing world-wide because they are completely natural rather than artificial additives for seasoning and flavoring of foods. Fennel (*Foeniculum vulgare* Mill.) plant is stout, aromatic annual herb (with potency of regeneration) which belongs to family Apiaceae. The bulb, foliage and seeds of the fennel plant are widely used in many of the culinary traditions of the world. Fenugreek (*Trigonella foenum-graecum* L.) popularly known by its vernacular name '*methi*' is an important vegetable and condiment crop grown in Northern India during *rabi* season for leaves, shoots and seeds. Fenugreek has three culinary uses ; as an herb (dried or fresh leaves),as a spice (seeds) and as a vegetable (fresh leaves, sprouts and micro greens). Fennel and fenugreek are the most important seed spice and legume crops grown in semi-arid areas of Rajasthan. The intercropping system aimed at increasing productivity per unit area, insurance against total crop failure under aberrant weather conditions. Therefore, integration of suitable vegetable crops with wide spaced seed spice crop is necessary. Among seed spices, fennel is a wide space crop best suited for intercropping with vegetable crops [1]. These crops require higher amount of sulfur as compare to cereals especially in low S soils of semi-arid region of Rajasthan, for augmenting the productivity and quality of both the components. Keeping this in view, present investigation was undertaken to find out the effect of different intercropping ratios and sulfur levels on yield and quality of fennel and fenugreek.

Materials and Methods

A field experiment was conducted during *rabi* season of 2013-14 at S. K. N.College of Agriculture, Jobner, Jaipur, comprising 16 treatment combinations of 4 intercropping systems viz., sole fennel RF-143, sole fenugreek RMt-305, fennel + fenugreek in 1 : 1 row ratio and fennel + fenugreek in 1 : 2 row ratio and 4 sulfur levels viz., 0, 20, 40 and 60 kg S/ha. Treatments were tested in randomized block design with three replications. The soil ofexperimental plots was loamy sand in texture, alkaline in reaction (pH 8.2), low in organic carbon (0.16%), available nitrogen (134.1 kg/ha), and available SO_4^{-2}-S (8.2 ppm) and medium in available phosphorus (17.1 kg P_2O_5/ha) and potassium (170.1 kg K_2O/ha) content. The experimental crops fennel and fenugreek were sown on 30 October and 18 November 2013 in lines 50 and 30 cm apart, keeping intra row spacing of 20 and 10 cm for sole, respectively. In fennel + fenugreek (1 : 1), the one row of fenugreek was planted in between two rows of fennel (additive series). Whereas, in 1 : 2 row ratio, two row of fenugreek were planted after replacing one row of fennel (replacement series). A uniform basal dose of 40 kg N + 45 kg P_2O_5/ha through urea and DAP was drilled prior to sowing and sulfur through gypsum was in corporate in the soil before sowing in respective plots as per treatments. The remaining 50 kg N/ha was given by side dressing through urea in rows of fennel at 40 DAS. Observations on yields of fennel and fenugreek were recorded from area of net plots harvested.

Results and Discussion

Effect of intercropping

The present findings pertaining to seed, straw and biological yields of fennel and fenugreek as influenced significantly by different intercropping systems are presented in Table 1. Among the cropping systems, fennel + fenugreek grown in 1 : 2 and 1 : 1 row proportion recorded significantly lower seed, straw and biological yields of fennel and fenugreek, respectively. The reduction in seed, straw and biological yields of both the crops in all intercropping systems over sole crops was primarily due to low plant population. Yield of main crop (fennel) on unit area basis was higher due to better yield attributes under intercropping systems as compared to sole fennel. Awasthi et al. [2] also showed that increased seed yield per unit area from mixed stand of fennel

Table 1. Effect of different intercropping systems and levels of sulfur on yield, nutrient content and quality of content of fennel and fenugreek.

Treatments	Fennel											
	Yield (q/ha)			Harvest index (%)	N content (%)		Total uptake of N (kg/ha)	S content (%)		Total uptake of S (kg/ha)	Oil content in seed (%)	Total oil yield (kg/ha)
	Seed	Straw	Biological		Seed	Straw		Seed	Straw			
Intercropping system												
Fennel	16.06	43.09	59.16	27.10	3.48	0.724	87.86	0.372	0.212	15.25	1.385	22.47
Fennel + fenugreek (1 : 1)	15.71	42.45	58.16	26.92	3.47	0.717	85.52	0.370	0.209	14.76	1.379	21.84
Fennel + fenugreek (1 : 2)	10.42	27.25	37.67	27.58	3.64	0.743	58.81	0.398	0.225	10.45	1.452	15.19
SEm ±	0.33	0.88	1.14	0.62	0.05	0.011	1.71	0.006	0.003	0.29	0.021	0.44
CD (p=0.05)	0.99	2.58	3.56	NS	0.15	NS	5.01	0.017	0.009	0.86	0.062	1.30
Sulfur (kg/ha)												
0	10.98	31.27	42.25	26.13	3.19	0.664	55.60	0.322	0.189	9.42	1.283	13.87
20	13.76	36.89	50.64	27.20	3.47	0.722	74.01	0.369	0.211	12.74	1.382	18.96
40	15.60	40.83	56.43	27.67	3.69	0.757	88.11	0.402	0.226	15.37	1.466	22.86
60	15.91	41.41	57.32	27.79	3.77	0.769	91.47	0.428	0.235	16.43	1.489	23.64
SEm±	0.39	1.01	1.40	0.72	0.06	0.013	1.97	0.007	0.004	0.33	0.025	0.51
CD (p=0.05)	1.15	2.98	4.11	NS	0.18	0.037	5.78	0.019	0.010	0.99	0.072	1.51

and chickpea as compared to their pure stands. The higher yield under pure stand was also reported by Kumar et al. [3] in mustard as compared to their yields under intercropping systems. However, reduction in yield of fenugreek (intercrop) might also be due to competition between the component crops for sharing of nutrients, light and water by main crop (fennel).

Intercropping systems differed in nitrogen and sulfur content in seed and straw, total uptake of nitrogen and sulfur, oil content in seed of fennel and protein content in seed of fenugreek (Tables 1 and 2). The fennel planting in 1 : 2 row ratio gave maximum and significantly higher nitrogen concentration in seed and sulfur concentration in seed and straw and volatile oil content in seed of fennel as compared to 1 : 1 row ratio and sole fennel. This might be due to complementary effect of intercropping. The greater availability of nitrogen owing to fixation by nodule bacteria in intercrop and other nutrients to the fennel crop resulted in higher absorption by plants which ultimately increased these parameters. A significant increase in nitrogen concentration and protein content in seed of fenugreek in 1 : 2 row ratio, being at par with sole fenugreek, was recorded as compared to 1 : 1 row ratio. The sole fenugreek remained at par with 1 : 2 row ratio, recorded significantly highest sulfur concentration in seed and straw of fenugreek as compared to 1 : 1 row ratio. This was probably due to comparatively greater availability of nutrients to the sole fenugreek as compared to intercropping where it was shared by both the crops. The results are in close conformity with those of Abraham et al. [4] and Tanwar et al. [5]. However, sole fennel, being on par with 1 : 1 row ratio, gave significantly highest total uptake of nitrogen, sulfur and volatile oil yield as compared to 1 : 2 row ratio. Sole fenugreek also gave significantly highest total uptake of nitrogen, sulfur. The higher total nitrogen and sulfur uptake under sole crops as compared to their intercropping systems was primarily due to increased seed yield under sole fennel and fenugreek as compared to yield obtained under intercropping. A significant effect of different cropping systems on fennel equivalent yield and competition function like land-equivalent ratio, relative crowding coefficient, competitive ratio, aggressivity and monetary advantage were observed (Table 3). Fennel and fenugreek 1 : 1 row ratio gave

Table 2. Effect of different intercropping systems and levels of sulfur on yield, nutrient content and quality of content of fennel and fenugreek.

Treatments	Fenugreek										
	Yield (q/ha)			Harvest index (%)	N content (%)		Total uptake of N (kg/ha)	S content (%)		Total uptake of S (kg/ha)	Protein content in seed (%)
	Seed	Straw	Biological		Seed	Straw		Seed	Straw		
Intercropping system											
Fennel	14.97	35.67	50.64	29.54	3.08	0.944	79.96	0.228	0.183	9.86	19.25
Fennel + fenugreek (1 : 1)	7.18	17.68	24.86	28.76	2.90	0.925	37.62	0.211	0.169	4.62	18.12
Fennel + fenugreek (1 : 2)	9.13	21.53	30.65	29.72	3.13	0.942	49.25	0.225	0.181	6.02	19.56
SEm±	0.24	0.56	0.81	0.69	0.04	0.015	1.28	0.003	0.003	0.14	0.27
CD (p=0.05)	0.71	1.62	2.40	NS	0.13	NS	3.74	0.010	0.008	0.41	0.79
Sulfur (kg/ha)											
0	8.59	21.48	30.07	28.43	2.80	0.819	42.00	0.176	0.148	4.79	17.47
20	10.31	24.68	34.99	29.39	2.99	0.915	53.52	0.214	0.175	6.56	18.66
40	11.32	26.73	38.05	29.70	3.15	0.988	62.15	0.239	0.191	7.67	19.66
60	11.49	26.94	38.43	29.83	3.22	1.027	64.76	0.256	0.198	8.32	20.10
SEm±	0.27	0.65	0.94	0.80	0.05	0.018	1.47	0.004	0.003	0.16	0.31
CD (p=0.05)	0.82	1.91	2.77	NS	0.15	0.052	4.32	0.011	0.009	0.48	0.92

significantly highest fennel equivalent yield (FEY) as compared to 1 : 2 row ratio and sole fennel and fenugreek. The higher equivalent yield of fennel under 1 : 1 row ratio planting might be due to higher production per unit area of fennel along with higher prices of produce. Similarly the highest LER were also found under 1 : 1 row ratio over sole crops and was comparable with 1 : 2 row ratio. Mehta et al. [6], while studying the coriander based intercropping system at Ajmer, also reported that the maximum coriander equivalent yield and LER were obtained under 1 : 1 row ratio than pure stands and other intercropping systems. The highest LER under intercropping might be due to biological efficiency of system in terms of yield per unit area. Similar results were also reported by Awasthi et al. [2]. The highest value of RCC was obtained under 1 : 1 row ratio (41.20) and lower under 1 : 2 row ratio (2.81). The higher RCC value in 1 : 1 row ratio indicates that the system in this row proportion had more yield than expected. This showed that fennel + fenugreek intercropping system in 1 : 1 row pattern should be preferred over fennel and fenugreek planting in 1 : 2 row ratio. In all the cropping system, RCC was high under main crop leading to dominance of fennel as main crop over fenugreek. Competition ratio is way to know the degree with which one crop competes with the intercrop. Higher competition ratio values for fennel than the fenugreek indicated that fennel (base crop) was more competitive than fenugreek when grown in association with each other in all intercropping systems (Table 2). Among intercropping systems, the competition ratio was higher for fennel (1.28) in 1 : 2 row ratio followed by 1 : 1 row ratio (1.22) of fennel and fenugreek compared to the minimum of 0.78 for fenugreek when grown in 1 : 2 row ratio, while fenugreek sown in 1 : 1 row ratio of fennel and fenugreek intermediated showing CR of 0.82. The data shown in Table 2 revealed that base crop did not compete equally. Fennel (base crop) indicated dominant behavior over the intercrop (fenugreek) as indicated by positive (+) sign against negative (–) sign for fenugreek. Aggressivity values was the highest (0.0028) for fennel + fenugreek in 1 : 2 row ratio compared to the minimum (0.0018) for fennel + fenugreek in 1 : 1 row ratio which indicated that fennel sown in 1 : 1 (fennel + fenugreek) intercropping system were the least competitive to fennel grown to 1 : 2 (fennel + fenugreek) intercropping system. Fennel proved the dominant com-

Table 3. Yield and monetary advantage and competition function in fennel and fenugreek intercropping.

Treatments	Fennel equivalent yield (q/ha)	Land equivalent ratio	Net returns (Rs/ha)	Relative crowding coefficient			Competition ratio		Agressivity		Monetary advantage (Rs/ha)
				FL	FK	Product	FL	FK	FL	FK	
				Intercropping system							
Fennel	16.06	1.0	109601	1	–	1	–	–	–	–	–
Fenugreek	5.82	1.0	24663	–	1	1	–	–	–	–	–
Fennel + fenugreek (1 : 1)	18.49	1.45	126471	26.93	1.53	41.20	1.22	0.82	0.0018	-0.0018	39099.18
Fennel + fenugreek (1 :2)	13.96	1.24	91129	2.21	1.30	2.87	1.28	0.78	0.0028	-0.0028	17785.87
SEm ±	0.39	0.02	3526	–	–	–	–	–	–	–	–
CD (p=0.05)	1.14	0.07	10183	–	–	–	–	–	–	–	–

panion to most intercrops, having higher competition ratio, which was further evident from positive aggressivity factor. Higher competitive ratio and positive aggressivity values of fennel in 1 : 2 and 1 : 1 row ratios of fenugreek indicated its dominance in the intercropping system.

The maximum monetary advantage was recorded in intercropping system under 1 : 1 row ratio (Rs 39,099.18/ha). Higher monetary advantage was evident with 1 : 1 row ratio of fennel + fenugreek, due to higher value of combined intercrops as compared to 1 : 2 row ratio (Rs 17,785.87/ha). The higher index value indicates better intercropping system. It was concluded that intercropping in one row fennel with one row of fenugreek is highly remunerative and more economically viable system in semi-arid area.

Effect of sulfur

Application of graded levels of sulfur from 0 to 60 kg S/ha significantly influenced the seed, straw and biological yields, nitrogen and sulfur concentration in seed and straw, total uptake of nitrogen and sulfur, volatile oil content in seed of fennel and protein content in seed of fenugreek over control (Tables 1 and 2). The significantly highest seed, straw and biological yields, sulfur content in straw, nitrogen content in seed, total uptake of nitrogen by fennel and fenugreek, volatile oil in seed of fennel and protein content in seed of fenugreek were obtained with increased application of sulfur upto 40 kg S/ha over 20 kg S/ha and control. However, sulfur content in seed and total uptake of sulfur by fennel and fenugreek were recorded significantly higher with increased application of sulfur upto 60 kg S/ha. The increase in yield under sulfur fertilization is obvious from the fact that application of sulfur improved overall nutritional environment of the rhizosphere as well as in the plant system, which inturn enhanced the plant metabolism and photosynthetic activity resulting into better growth and development of plants and ultimately the yields. Similar results were also reported by Kumawat et al. [7] and Bochalia et al. [8]. Based on the performance, it was concluded that intercropping of fennel and fenugreek in 1 : 1 row ratio gave significantly higher fennel equivalent yield (18.49 q/ha) and net returns (Rs 125,771/ha).

References

1. Mehta RS and Malhotra SK (2007) Seed spice based cropping system : In Malhotra S. K., Vashishtha B. B. (eds.) Production, development, quality and export of seed spices NRCSS, Ajmer (Raj), pp 181–189.
2. Awasthi UD, Tripathi AK, Dubey SD, Kumar S (2011) Effect of row ratio and fertility levels on growth, productivity, competition and economics in chickpea + fennel intercropping system under scarce moisture condition. J Food Leg 24 : 211—214.
3. Kumar S, Patal SK, Ghosh G (2013) Response of different boron and sulfur levels on chickpea based mustard intercropping system. Trends in Biosci 6 : 256—259.
4. Abraham T, Thenua OVS, Shivakumar BG (2010) Impact of levels of irrigation and fertility gradients on dry matter

production, nutrient uptake and yield of chickpea (*Cicer arietinum* L.) intercropping system. Leg Res 33 : 10—16.

5. Tanwar, SPS, Rokadia P, Singh AK (2011) Effect of row ratio and fertility levels on chickpea (*Cicer arietinum*) and linseed (*Linum usitatissimum*) intercropping system. Ind J Agron 56 : 217—222.
6. Mehta RS, Meena SS, Anwer MM (2010) Performance of coriander (*Coriandrum sativum*) based intercropping system. Ind J Agron 55 : 286—289.
7. Kumawat BL, Kumawat A, Kumawat S (2011) Response o f fenugreek to claying, irrigation and sulfur in loamy sands. In : Sastry EVD, Shekhawat KS (eds). Production and protection of seed spices. Avishkar Publ and Distributors, Jaipur, pp 150—160.
8. Bochalia GS, Tiwari RC, Ram B, Kantwa SR, Choudhari AC (2011) Response of fenugreek (*Trigonella foenum-graecum*) genotypes to planting geometry , agro-chemicals and sulfur levels. Ind J Agron 56 : 273—279.