International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(4): 881-884

Received: 19-05-2019
Accepted: 21-06-2019

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Effect of nitrogen and sulphur levels on yield attributes, yield and quality of fennel (*Foeniculum vulgare* Mill.)

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Abstract
A field experiment was conducted on fennel (*Foeniculum vulgare* Mill.) during *Rabi* season of 2016-17 at the College of Agriculture, Junagadh Agricultural University, and Junagadh on medium black clayey soil. The treatments comprised all possible combinations of four levels of nitrogen viz., 0, 60, 90 and 120 kg ha^{-1} and three levels of sulphur viz., 0, 20 and 40 kg ha^{-1} were evaluated in FRBD with three replications. Application of 120 kg nitrogen ha^{-1} was observed superior over rest of the levels of N in increasing plant height, number of branches per plant, number of umbels per plant, number of umbellate per umbel, number of seeds per umbellates, weight of 1000 seed, protein content, seed yield and stover yield. Application of 40 kg sulphur ha^{-1} significantly increased plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel, number of seeds per umbellates, weight of 1000 seed, seed yield and stover yield. While, protein content in seed did not influenced by S application. Interaction effect of nitrogen and sulphur was found significant with respect to umbellates per umbel, seed yield and stover yield. Combined application of 90 kg N ha^{-1} along with 40 kg S ha^{-1} recorded significantly higher number of umbellates per umbel, seed yield and stover yield than rest of the treatment combination.

Keywords: Fennel, nitrogen, sulphur, yield attributes, yield and protein

Introduction
Fennel, *Foeniculum vulgare* (family *Apiaceae*), a native of southern Europe and Mediterranean area, is an important seed spice. India is worlds the largest producer, consumer and exporter of the spices and among all spices, fennel is one of the most important spice. It is commonly known as '*Saunf*' or '*Badi saunf*' and in Gujarat it is locally known as '*Variari'*. The plant is pleasantly aromatic and is used as a pot herb. The seeds are aromatic, stimulant and carminative. They are useful in diseases of chest, spleen and kidney.

Among the various nutrients, nitrogen is primary essential element required to increase agricultural production. It has the quickest and the most pronounced effect on plant growth and development and ultimately on crop yield. It plays an important role in synthesis of chlorophyll and amino acids that contribute to the building unit of protein and thus growth of plants. An adequate supply of this element is associated with vigorous vegetative growth and dark green colour. Nitrogen (N) is the most recognized in plants for its presence in the structure of the protein molecule. Accordingly, nitrogen plays an important role in the synthesis of the plant constituents through the action of different enzymes (Jones *et al.,* 1991). In Fennel, sulphur is the fourth major plant nutrient after nitrogen, phosphorus and potassium. Sulphur is essential for synthesis of amino acids, proteins, oils and component of vitamin A. Sulphur is also a component of key enzymes and vitamins in the plant and is necessary for the formation of chlorophyll. The need for sulphur fertilization has also been identified because of the increased use of S-free fertilizers and higher productivity of crops associated with greater uptake of sulphur (Ponkia *et al*. 2018) [8].

Materials and Methods
A field experiment was conducted on fennel (var. Gujarat Fennel-11) at instructional farm, Junagadh Agricultural University, during *Rabi* seasons of 2016-17. The soil was medium clayey in texture and slightly alkaline in reaction with pH (8.06) and EC (0.41 dS m^{-1}), medium in available nitrogen (262 kg ha^{-1}), phosphorus (29 kg P_2O_5 ha^{-1}), potassium (218 kg K_2O ha^{-1}), sulphur (10.64 mg kg^{-1}), iron (5.24 mg kg^{-1}), zinc (0.74 mg kg^{-1}), high in manganese(15.84 mg kg^{-1}) and copper (1.40 mg kg^{-1}) content.

The experiment were laid out in factorial randomized block design with three replications and consisting all possible combinations of four levels of nitrogen *viz*., 0, 60, 90 and 120 kg ha^{-1} and three levels of sulphur *viz*., 0, 20 and 40 kg ha^{-1}. Recommended dose of fertilizers was applied at the time of sowing.

Results and Discussion

Effect of nitrogen

Growth, yield attributes, yield and quality

An assessment of data (Table-1and 3) indicated that application of nitrogen brought about significant variation in growth parameters *viz*., plant height and number of branches per plant, yield attributes *viz*., number of umbels per plant, number of umbellates per umbel, number of seeds per umbellates (Table-1), quality parameters *viz*., 1000 seed weight and protein content and seed and stover yield (Table-3). Fertilize the crop with 120 kg N ha^{-1} produced remarkably higher plant height (131 cm), no. of branches per plant (8.85), number of umbels per plant (18.62), number of umbellates per umbel (32.51), number of seeds per umbellates (34.37) seed yield (1826 kg ha^{-1}), stover yield (3583 kg ha^{-1}), 1000 seed weight (7.29 g) and protein content (17.42 %) in seed. However, it was remain statistically at par with 90 kg N ha^{-1} with respect to all these parameters, except protein content.

Nitrogen is considered to be a vitally important plant nutrient. In addition to its role in the formation of proteins, nitrogen is an integral part of chlorophyll which is the primary absorber of light energy needed for photosynthesis. Thus, greater availability of photosynthates, metabolites and nutrients to develop reproductive structures (Giaquinta and Quebedeaux, 1980) [2] seems to have resulted in increased growth, yield attributes, yield and protein content with nitrogen levels of 120 kg N ha^{-1}. As these growth and yield attributes evidently resulted in higher yields under higher nitrogen level. Significant increase in seed yield and stover yield under these nitrogen levels were because of formation of strong sinks and source activity. The higher seed yield of fennel may be attributed to improved growth parameters and yield components, which ultimately resulted in higher yield and also due to growth and yield attributes showed significantly positive correlation with seed yield evidently, resulted in higher yield. The present findings are in close agreement with the results obtained by Patel *et al.* (2000) [6], Pratap *et al.* (2003) [9], Bhardwaj and Kumar (2016) [1] and Meena *et al.* (2017) [4].

Effect of sulphur

Growth, yield attributes, yield and quality

Application of sulphur levels significantly influenced growth parameters, yield attributes, quality parameters and seed and stover yield (Table-1 and 2) except protein content. Significantly the higher plant height (130 cm), no. of branches per plant (8.84), number of umbels per plant (18.14), number of umbellates per umbel (34.13), number of seeds per umbellates (31.94) (Table -1), seed yield (1949 kg ha^{-1}), stover yield (3751 kg ha^{-1}) and 1000 seed weight (7.26 g) (Table-2) were found with application of 40 kg S ha^{-1}. This increase in seed yield with increasing levels of sulphur which increased sulphur content in plant and helped in better development and thickening of xylem, collenchyma's tissue and such favourable effects might have resulted in stronger stem and increasing photosynthetic as well as meristem tic activities which might have promoted vegetative growth and consequently yield. Application of sulphur might be attributed to increased availability of nutrients owing to favourable environment created by sulphur and also it plays a significant role in overall biosynthesis process. These results of the investigation are in close conformity with Pratap *et al.* (2003) [9] and Patel (2005) in fennel.

Interaction effect of nitrogen and sulphur

The data regarding interaction between nitrogen and sulphur application on seed and stover yield was found significant (Table-2 & 4). Combined application of 90 kg N ha^{-1} along with 40 kg S ha^{-1} ($N_{90}S_{40}$) recorded significantly higher number of umbellates per umbel (37.37), seed (2158 kg ha^{-1}) and stover (4194 kg ha^{-1}) yield than rest of the treatment combination. However, it was statistically comparable with treatment combinations $N_{60}S_{40}$ and $N_{120}S_{40}$. Nitrogen and sulphur play important role in synthesis of essential amino acids like cysteine, methionine, and certain vitamin like biotine, thymine and Vitamin B_1 containing plants. The present findings are in close agreement with the results obtained by Pratap *et al.* (2003) [9] in fennel, Ruveyde *et al.* (2011) in fenugreek, Patel *et al.* (2013) [7] and Yousuf *et al.* (2014) [11] in coriander.

Conclusion

Based on the experimental results, it can be concluded that among the different rates of nitrogen and sulphur, 120 kg N ha^{-1} and 40 kg S ha^{-1} performed better in terms of growth parameters, yield attributes, quality parameters. These levels of nitrogen and sulphur also gave maximum seed and stover yield of fennel, further its combination 90 kg N ha^{-1} along with 40 kg S ha^{-1} produced higher seed and stover yield. Thus proper rate of nitrogen with combination of sulphur increased the growth and development of crops and also increased the economical yield of crops.

Table 1: Effect of different levels of nitrogen and sulphur on growth and yield attributes of fennel

Treatments	Plant height (cm)	Number of branches per plant	Number of umbels per plant	Number of umbellates per umbel	Number of seeds per umbellates
Nitrogen levels (kg N ha^{-1})					
N_0-Control	116	7.51	14.63	25.59	26.51
N_1-60	126	8.17	17.05	29.85	28.91
N_2-90	129	8.72	17.83	31.72	31.80
N_3-120	131	8.85	18.62	32.51	34.37
S. Em±	3	0.22	0.49	0.66	0.88
C.D. at 5%	8	0.64	1.42	1.92	2.57
Sulphur levels (kg S ha^{-1})					
S_0-Control	121	7.75	15.84	26.42	29.15
S_1-20	125	8.34	17.12	29.19	30.11
S_2-40	130	8.84	18.14	34.13	31.94

S.Em±	2	0.19	0.42	0.57	0.76
C.D. at 5%	7	0.55	1.23	1.66	2.23
Interaction (NXS)					
S.Em.±	4	0.38	0.84	1.13	1.52
C.D. at 5%	NS	NS	NS	3.33	NS
C.V.%	6.2	7.9	8.60	6.60	8.70

Table 2: Interaction effect of nitrogen and sulphur on number of umbellates per umbel

Levels of Nitrogen	**Levels of sulphur**			
	S_0	**S_{20}**	**S_{40}**	**Mean**
N_0	24.40	25.23	27.12	25.59
N_{60}	25.02	28.87	35.65	29.85
N_{90}	27.06	30.73	37.37	31.72
N_{120}	29.19	31.93	36.40	32.51
Mean	26.42	29.19	34.13	
S.Em±	1.13			
C.D. at 5%	3.33			

Table 3: Effect of different levels of nitrogen and sulphur on yield and quality of fennel

Treatments	**Seed yield (kg ha^{-1})**	**Stover yield (kg ha^{-1})**	**1000 seed weight (g)**	**Protein content (%)**
Nitrogen levels (kg N ha^{-1})				
N_0 – Control	1400	2738	7.00	11.48
N_1 – 60	1666	3288	7.04	14.13
N_2 – 90	1774	3481	7.20	16.06
N_3 – 120	1826	3583	7.29	17.42
S.Em±	45	84	0.07	0.41
C.D. at 5%	131	248	0.20	1.21
Sulphur levels (kg S ha^{-1})				
S_0 – Control	1443	2898	7.02	14.52
S_1 – 20	1607	3169	7.12	14.94
S_2 – 40	1949	3751	7.26	14.86
S.Em±	39	73	0.06	0.36
C.D. at 5%	114	214	0.17	NS
Interaction (NXS)				
S.Em.±	77	146	0.12	0.71
C.D. at 5%	227	429	NS	NS
C.V.%	8.10	7.70	2.86	8.36

Table 4: Interaction effect of nitrogen and sulphur on seed and stover yield of fennel

Levels of Nitrogen	**Levels of sulphur**							
	Seed yield (kg ha^{-1})				**Stover yield (kg ha^{-1})**			
	S_0	**S_{20}**	**S_{40}**	**Mean**	**S_0**	**S_{20}**	**S_{40}**	**Mean**
N_0	1332	1382	1487	1400	2614	2808	2794	2738
N_{60}	1362	1619	2017	1666	2792	3148	3925	3288
N_{90}	1488	1675	2158	1774	2975	3276	4194	3481
N_{120}	1591	1754	2132	1826	3211	3444	4093	3583
Mean	1443	1607	1949		2898	3169	3751	
S.Em±	77				146			
C.D. at 5%	227				429			

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