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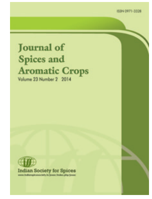

Response of fennel (*Foeniculum vulgare* Mill.) to phosphorus and zinc fertilization in a loamy sand soil

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Abstract

The field experiment was conducted with four levels of phosphorus (0, 20, 40, and 60 kg ha^{-1}) and four levels of $ZnSO_4$ (0, 15, 30 and 45 kg ha^{-1}) to study their effects on growth and yield of fennel. Application of P upto 40 kg ha^{-1} significantly increased days to 50% flowering, plant height, number of branches, number of umbels plant^{-1}, number of umbellets umbel^{-1}, seeds umbel^{-1}, seed and stover yield, net return and B:C ratio. The delay in 50% flowering, plant height, number of branches plant^{-1}, number of umbels plant^{-1}, number of umbellets umbel^{-1} and seeds per umbel^{-1}, seed and stover yield, net return and B:C ratio increased significantly upto 30 kg $ZnSO_4$ ha^{-1}. The combined application of P @ 40 kg ha^{-1} and Zn @ 30 kg $ZnSO_4$ ha^{-1} was significantly superior with respect to umbels plant^{-1}, seed and stover yield as compared to other combinations of P and $ZnSO_4$. The economic optimum dose of P and $ZnSO_4$ was computed as 53.85 kg ha^{-1} with response of 1245.66 kg ha^{-1} and 39.03 kg ha^{-1} with the response of 1255.94 kg ha^{-1}, respectively.

Keywords: fennel, *Foeniculum vulgare*, optimum dose, phosphorus, yield, zinc

Introduction

Fennel (*Foeniculum vulgare* Mill.) is one of the important seed spice cultivated throughout the temperate and sub-tropical regions of the world for its aromatic seeds which are used for culinary purpose. In India, it is mainly cultivated in the states of Gujarat and Rajasthan and to some extent in Uttar Pradesh, Bihar, Madhya Pradesh, Punjab and Haryana. Although this crop has a number of industrial and medicinal uses, it is not grown commercially due to the lack of information on its cultural requirements. Fennel responds well to fertilizers especially phosphorus (P) and zinc (Zn). P is critical in plant metabolism which plays an important role in cellular energy transfer, respiration, photosynthesis and it is a key structural component of nucleic acids, coenzymes, phosphoproteins and phospholipids. P fertilization is a major input in crop production (Tuncturk 2011). As a component of several dehydrogenase, proteinases and peptidases, Zn is also an essential nutrient required for proper growth of plant (Hamza & Sadanandan 2005). P and Zn interaction affects the availability and utilization of both the nutrients (Nayak & Gupta 1995). Therefore, keeping in view the importance of this crop, an experiment was conducted to study the effect of P and Zn application on growth and yield of fennel.

Material and methods

The experiment was laid during *rabi* 2012-13 at Agronomy farm, S.K.N. College of Agriculture, Jobner, Jaipur. The soil of the experimental field was loamy sand in texture, alkaline in reaction (pH 8.26), poor in organic carbon, low in available N (128 kg N ha^{-1}) and medium in P (16 kg P_2O_5 ha^{-1}), medium in K (161 kg K_2O ha^{-1}) and deficient in Zn (0.40 mg kg^{-1}). The experiment included 16 treatment combinations comprising four levels of P (0, 20, 40, and 60 kg ha^{-1}) and four levels of $ZnSO_4$ (0, 15, 30 and 45 kg ha^{-1}) laid out in a Factorial Randomized Block Design with three replications. The seed of fennel (Variety RF-101) was sown @ 10 kg ha^{-1} at depth of 2-3 cm on 14 November, 2012 by "kera" method in open furrows. Before sowing, the seed was treated with bavistin @ 3.0 g kg^{-1} seed to prevent seed born diseases. P was applied as per treatment through diammonium phosphate (DAP). The entire quantity of DAP was drilled in furrows 45 cm apart at a depth of 8-10 cm. Zn was supplied as per treatments through commercial grade $ZnSO_4.7H_2O$ at the time of sowing. In order to evaluate the economic feasibility of different treatments, the net return (Rs ha^{-1}), B:C ratio and optimum economic dose of P and Zn were worked out on the basis of prevailing market prices. The quadratic response function ($Y=a + bx + cx^2$) was fitted to seed yield data by the procedure described by Panse & Sukhatme (1985). After fitting the response curve, optimum dose of P and Zn was worked out with the help of the following formula:

$$P_2O_5 / Zn\ Opt. = (Q/p-b1) / (2\ b_2)$$

Where, P_2O_5/ Zn opt.=Optimum dose of P/ $ZnSO_4$ (kg ha^{-1}); P=Price of seed (Rs kg^{-1}); Q=cost of P / $ZnSO_4$ (Rs kg^{-1}); b_1 and b_2=coefficients of response equation.

Results and discussion

Effect of Phosphorus

Growth, yield attributes and yield

Application of graded levels of P @ 40 & 60 kg P_2O_5 ha^{-1} significantly increased the days to 50% flowering and increased the number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$ and seeds $umbel^{-1}$ (Table 1). Application of P might have resulted in increased carbohydrate accumulation and their remobilization to reproductive parts of the plants, resulting in increased flowering, fruiting and seed formation.

Table 1. Effect of phosphorus and zinc on growth and yield attributes of fennel

Treatment	Days to 50% flowering	Plant height (cm)	Number of branches $plant^{-1}$	No. of umbels $plant^{-1}$	No. of umbellets $umbel^{-1}$	Seeds $umbel^{-1}$	Test weight (g)
P levels (*kg P_2O_5 ha^{-1}*)							
P_0	102.88	89.0	9.7	20.8	12.1	149.2	3.08
P_{20}	108.46	103.9	11.4	22.6	13.2	165.2	3.33
P_{40}	113.23	113.0	12.7	24.3	14.1	175.1	3.53
P60	114.73	118.5	13.5	25.2	14.4	180.4	3.59
SEm±	0.88	2.8	0.4	0.5	0.2	2.7	0.09
CD ($P<0.05$)	2.54	8.2	1.2	1.3	0.6	7.9	NS
Zn levels (*kg $ZnSO_4$ ha^{-1}*)							
Zn_0	102.92	90.4	9.3	20.8	12.4	148.7	3.09
Zn_{15}	108.21	104.2	11.4	22.7	13.4	166.3	3.34
Zn_{30}	113.02	112.7	12.9	24.2	14.0	175.4	3.50
Zn_{45}	115.16	117.0	13.8	25.3	14.2	179.6	3.59
SEm±	0.88	2.8	0.4	0.5	0.2	2.7	0.09
CD ($P<0.05$)	2.54	8.2	1.2	1.3	0.6	7.9	NS

Significant increase in seed and stover yield was recorded by the application of 40 kg P_2O_5 ha^{-1} as compared to lower levels (Table 2), which was at par with 60 kg ha^{-1} also. This might be due to the concomitant increase in days to 50% flowering, plant height, number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$ and seeds $umbel^{-1}$ in this treatment. This might also be due the fact that excess assimilates stored in the leaves gets translocated into seeds at the time of senescence, leading to higher seed yield.

Highly significant and positive correlation existed between seed yield and yield attributes and nutrients uptake such as number of umbels $plant^{-1}$ (r=0.997**), number of umbellets $umbel^{-1}$ (r=0.982**), seeds $umbel^{-1}$ (r=0.993**) and test weight (r=0.988**) (Table 3). From regression studies, it was observed that a unit increase in number of umbels $plant^{-1}$, number of umbellets $umbel^{-1}$, seeds $umbel^{-1}$ and test weight increased the seed yield of fennel by 0.463, 2.458, 0.168 and 10.186 q ha^{-1}, respectively (Table 3).

Table 2. Interactive effect of phosphorus and zinc on seed and stover yield (q ha^{-1})

Treatments	Seed yield				
	P_0	P_{20}	P_{40}	P_{60}	Mean
Zn_0	5.23	6.99	8.28	8.53	7.26
Zn_{15}	7.57	10.10	11.97	12.33	10.50
Zn_{30}	8.76	11.69	13.86	14.27	12.14
Zn_{45}	9.03	12.06	14.29	14.71	12.52
Mean	7.65	10.21	12.10	12.46	
SEm±	0.33				
CD (P<0.05)	0.96				
	Stover yield				
Zn_0	16.86	23.08	27.43	28.52	23.97
Zn_{15}	23.28	31.85	37.86	39.37	33.09
Zn_{30}	27.49	37.63	44.72	46.50	39.09
Zn_{45}	28.53	39.04	46.40	47.25	40.56
Mean	24.04	32.90	39.10	40.66	
SEm±	1.10				
CD (P<0.05)	3.18				

Table 3. Correlation coefficient (r) and regression equation for seed and stover yield of fennel with various parameters

Independent variable (X)	Seed yield (Y)		Stover yield (Y)	
	Correlation (r)	Regression equation	Correlation (r)	Regression equation
Plant height (cm)	0.988**	Y= -9.133 + 0.186 X	0.993**	Y= -30.781 + 0.612 X
Number of branches $plant^{-1}$	0.985**	Y= -4.172 + 1.250 X	0.988**	Y= -14.295+ 4.101 X
Umbels $plant^{-1}$	0.997**	Y= 0.852 + 0.463 X		
Umbellets $umbel^{-1}$	0.982**	Y= -22.477 + 2.458 X		
Seeds $umbel^{-1}$	0.993**	Y= -17.540 + 0.168 X		
Test weight (g)	0.988**	Y= -23.857 + 10.186 X		

** Significant at P<0.01

Similar correlations between stover yield and growth attributes such as plant height (r=0.993**) and number of branches plant^{-1} (r=0.988**) also provided evidence on the positive effects of P application on yield. From regression studies it was observed that a unit increase in plant height and number of branches plant^{-1} increased stover yield by 0.612 and 4.101 q ha^{-1}, respectively. Similar results were also reported by Nath *et al.* (2008) in Ajwain and Mehta *et al.* (2010) in fenugreek.

Effect of zinc

Growth, yield attributes and yield

Days to 50% flowering, plant height, number of branches plant^{-1}, total number of umbels plant^{-1}, number of umbellets umbel^{-1} and number of seeds umbel^{-1} were significantly increased with application of $ZnSO_4$ upto 30 & 45 kg ha^{-1} whereas, test weight increased non significantly with increasing level of $ZnSO_4$ (Table 1). The seed and stover yield of fennel also increased significantly upto 30 kg $ZnSO_4$ ha^{-1} (Table 2), which was at par with 45 kg $ZnSO_4$ ha^{-1}. The favourable influence of applied $ZnSO_4$ on these characters may be ascribed to its catalytic or stimulatory effect on most of the physiological and metabolic processes of plant. Zn is also an essential component of enzymes responsible for assimilation of N, chlorophyll formation, regulating the auxin concentration in plants and increasing the cation exchange capacity of roots. The increase in the yield attributes might also be due to its role in biosynthesis of indole acetic acid (IAA) and initiation of primordia for reproductive parts and partitioning of photosynthates towards them which resulted in better flowering and fruiting. Similar results were reported by Hamza & Sadanandan (2005) in black pepper and Jakhar *et al*. (2013) in fenugreek.

The higher seed and stover yield arising from Zn application was further substantiated by the significant and positive correlation between seed yield and number of umbels plant^{-1} (r=0.997**), number of umbellets umbel^{-1} (r=0.982**), seeds umbel^{-1} (r=0.993**), test weight (r=0.988**), plant height (r=0.993**) and number of branches plant^{-1} (r=0.988**). The regression studies further revealed that a unit increase in number of umbels plant^{-1}, number of umbellets umbel^{-1}, seeds umbel^{-1} and test weight increased the seed yield by 0.463, 2.458, 0.168, 10.186, and 0.319 q ha^{-1}, respectively (Table 3). Further, the increased stover yield due to application of Zn is a manifestation of plant height and number of branches plant^{-1} as supported by the significant and positive correlation between stover yield and plant height (r=0.993**) and number of branches plant^{-1} (r=0.988**). The regression equation also revealed that a unit increase in plant height and number of branches plant^{-1} increased the stover yield of fennel by 0.612, 4.101, and 0.360 q ha^{-1} (Table 3).

Table 4. Effect of phosphorus and zinc on net returns and B:C ratio

Treatments	Net returns (Rs. ha^{-1})	B:C ratio
P levels (*kg P_2O_5 ha^{-1}*)		
P_0	21156	1.60
P_{20}	31605	2.21
P_{40}	38975	2.53
P_{60}	39529	2.39
SEm±	1596	0.10
CD (P<0.05)	4609	0.28
Zn levels (*kg $ZnSO_4$ ha^{-1}*)		
Zn_0	18792	1.34
Zn_{15}	32513	2.23
Zn_{30}	39410	2.59
Zn_{45}	40550	2.57
SEm±	1596	0.10
CD (P<0.05)	4609	0.28

Combined effect of phosphorus and zinc

The interactive effect of P and Zn on seed and stover yield (Table 2) indicated that the response of Zn varied with the dose of P application of 45 kg $ZnSO_4$ was significantly superior for seed and stover yield when it was combined with 40 kg P_2O_5 ha^{-1}. Combination of 45 kg $ZnSO_4$ with 60 kg P_2O_5 was significantly better than 30 kg $ZnSO_4$ ha^{-1} with 60 kg P_2O_5 ha^{-1} and 45 kg $ZnSO_4$ ha^{-1} with 40 kg P_2O_5 ha^{-1}. The favourable effect of optimum level of P-Zn combination might be because P fertilization is likely to make the crop more responsive to Zn by increasing the growth. Similar results were reported by Sammauria & Yadav (2008) in fenugreek.

Economics

Data presented in Table 4 indicated that the application of 60 kg P_2O_5 ha^{-1} recorded significantly higher net returns (Rs. 39,539 ha^{-1}) and was at par with 40 kg P_2O_5 ha^{-1} (Rs. 38,975 ha^{-1}) with higher B:C ratio (2.53). The application of 45 kg $ZnSO_4$ ha^{-1} recorded significantly higher net returns (Rs. 40,550 ha^{-1}) which was at par with 30 kg $ZnSO_4$ ha^{-1} (Rs. 39,410 ha^{-1}) with higher B:C ratio (2.59). This might be due to increase in seed yield in diminishing manner under increasing levels of Zn. These results corroborate the findings of Nair *et al.* (1992). The economic optimum dose of P and $ZnSO_4$ was computed as 53.875 kg ha^{-1} with response of 1245.66 kg ha^{-1} seed yield and 39.03 kg ha^{-1} with the response of 1255.94 kg ha^{-1} seed yield (Figs. 1 & 2), respectively.

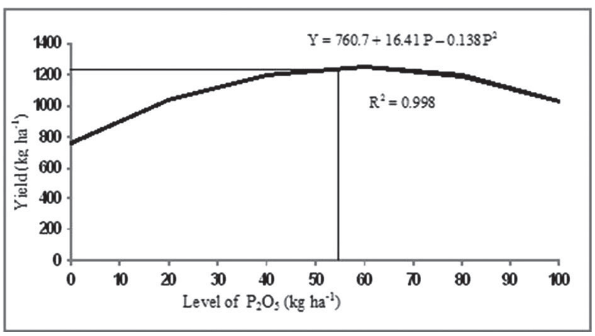

Fig. 1. Seed yield (Y) as a function of P fertilization

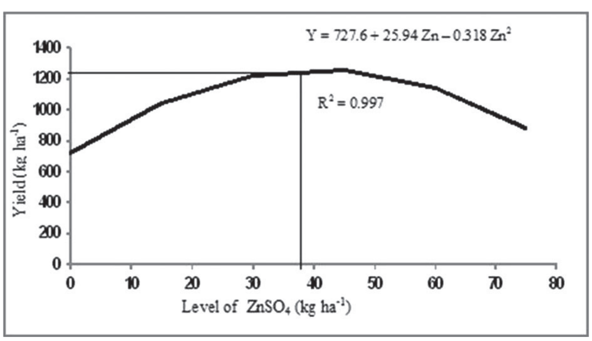

Fig. 2. Seed yield (Y) as a function of Zn fertilization

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