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Effect of different levels of nitrogen and potassium on growth and flowering behaviour of fennel (*Foeniculum vulgare* Mill.)

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Abstract
A field experiment was carried out during *rabi* 2018-2019, with 4 levels of nitrogen (60 kg ha^{-1}, 80 kg ha^{-1}, 100 kg ha^{-1} and 120 kg ha^{-1}) and 3 levels of potassium (40 kg ha^{-1}, 60 kg ha^{-1} and 80 kg ha^{-1}) in Factorial Randomized Block Design (FRBD), with 3 replications and 12 treatment combinations. An application of nitrogen at N_4 i.e. 120 kg N ha^{-1} was found to exhibit significantly superior performance in respect of growth parameters. While, earliness in terms of flowering exhibited by the treatment N_1 (60 kg N ha^{-1}). In respect of influence of potassium levels, K_2 (60 kg K ha^{-1}) was found significantly superior for plant height (181.93 cm), number of primary branches per plant (10.86), number of secondary branches per plant (23.81), early flowering (66.80 days) and days required for 50% flowering (86.08) at 120 DAS. The interaction effect of N_4 x K_2 (N_4-120 N kg ha^{-1} and K_2-60 K kg ha^{-1}) found superior for growth parameters.

Keywords: Fennel, nitrogen level, potassium level, growth parameters and flowering behaviour

Introduction
Fennel (*Foeniculum vulgare* Mill.) locally called 'saunf' is an important seed spice belongs to family Apiaceae. It is also used in preparation of various value-added products *viz*., spice oils, oleoresins and spices powder. Seed spices also have industrial importance and are used in various pharmaceutical preparations and medicines. Fennel is a well-known aromatic medicinal plant used in traditional medicine and also as spice and substrate for different industrial purpose (Telci *et al*., 2009) [19]. It is widely used in traditional Arabian medicine as diuretic appetizer and digestive (Karnick, 1994) [8]. Fennel's therapeutic uses have been introduced and integrated in to many other systems of traditional medicine, including Ayurvedic, Chinese and Japanese (Wichtel and Bisset, 1994) [21]. Plant nutrition is one of the key factors influences the growth and yield of crop plants. Nitrogen is one of the most important nutrients in crop production because it affects photosynthetic efficiency and leaf development, which leads to dry matter production (Dordas and Sioulas, 2008) [6]. Moniruzzaman *et al*. (2005) [13] reported that, days to flowering were increased with the increased levels of nitrogen application in coriander. Oliveira *et al*. (2003) [14] reported that plant height of coriander increased linearly in proportion to the increase in the dose of nitrogen. Altering the soil nutrients and fertility status by providing balanced and adequate nutrients as per the crop requirement is one of the ways to boost the crop productivity of fennel.

Materials and Methods
Field experiment was conducted at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *rabi* season of 2018-19. The experiment was laid out in Factorial Randomized Block Design (FRBD) with 4 levels of nitrogen (60 kg ha^{-1}, 80 kg ha^{-1}, 100 kg ha^{-1} and 120 kg ha^{-1}) and 3 levels of potassium (40 kg ha^{-1}, 60 kg ha^{-1} and 80 kg ha^{-1}) thus making twelve treatment combinations with replicated three times. As per the initial soil samples available nitrogen, phosphorus and potash were 215.12, 13.65 and 293.34 kg ha^{-1} respectively. Fennel seed was sown on 28th October, 2018 with spacing of 45 × 30 cm. Urea and MOP fertilizers were applied to all the plots for supply of N and K. Half a dose of N and full doses of K were applied as basal application.

The crop was top dressed with the remaining half dose of N was applied at 30 days after sowing. The observations on growth and flowering parameters were recorded from five randomly selected plants and the data were statistically analysed for level of significance. The data obtained on various characters were statistically analysed as suggested by Panse and Sukhatme (1985) [15].

Results and Discussion
Effect of nitrogen
Growth parameters
The effect of varying nitrogen doses on the plant height, number of primary and secondary branches of fennel was significant. Significantly higher plant height (189.49 cm), primary and secondary branches per plant (11.53 and 23.73 respectively) were recorded as a result of higher levels of nitrogen (N_4-120 kg ha^{-1}). Increased level of nitrogen in plant by virtue of its increased availability in the soil and thereafter efficient absorption and translocation in growth by way of active cell division and elongation resulting in greater plant height (Clarkson and Hanson, 1980) [3]. In our study, higher nitrogen doses yielded higher plant heights. The results of present investigation are in agreement with the finding of Diwan *et al.* (2018) [5] in coriander. Each increase in nitrogen level significantly increased primary and secondary branches per plant. Nitrogen is a constituting of enzyme, protein and chlorophyll which result increased the branches per plant (Sharma *et al*., 2016) [17]. This is in conformity with the results found by Pratap *et al*. (2003) [16] in fennel. Increased nitrogen doses are beneficial in encouraging vegetative development and secondary branch formation. Our findings are in agreement with those of Meena *et al*. (2016) [10], Waskela *et al*. (2017) [20] and Singh *et al.* (2018) [18] in fennel.

Flowering behaviour
The data revealed that significantly, the early flowering (61.17 days) was observed in N_1-60 kg ha^{-1}. Whereas, the maximum days required for first flowering (73.57 days) was recorded in the treatment N_4-120 kg ha^{-1}. Optimum role of nitrogen increases photosynthetic rate, leaf area production as well as net assimilation rate and is associated with high photosynthetic activity leading to vigorous vegetative growth and ultimately delayed flowering in fennel (Farooq *et al*., 2009) [7]. This is in accordance with Waskela *et al*. (2017) [20] and Meena *et al*. (2016) [10] in fennel. Significantly minimum days required for 50% flowering (81.64) was observed in N_1-60 kg ha^{-1}. Whereas, the maximum days required for 50% flowering (91) was recorded in treatment N_4-120 kg ha^{-1}. The period for 50% flowering was significantly delayed with an increasing level of nitrogen. It corroborates with the findings of Lokhande *et al*. (2015) [9] in fennel.

Effect of potassium
Growth parameters
Under the effect of potassium fertilization, application of potassium significantly increased plant height, primary and secondary branches per plant throughout the growth period. The plant height was increased significantly with increasing K levels up to 60 kg ha^{-1}. The treatment K_2 i.e. 60 kg ha^{-1} recorded significantly maximum plant height (181.93 cm) at 120 DAS. Potassium is directly involved in enzyme activation, maintenance of water status, energy relations, and translocation of assimilates and protein synthesis thus, potassium is an essential nutrient element for plant growth. These findings were also supported by Bhardwaj (2016) [2] in fennel. It is elucidated with the data presented in Table 1 indicate that, significantly the maximum number of primary branches (10.86) at 120 DAS was recorded in K_2 treatment i.e. 60 kg ha^{-1}. Potassium (K) is an essential nutrient element for plant growth and taken up from the soil solution by the plant roots in the form of potassium ion (K^+). Significantly maximum number of secondary branches per plant (23.81) at 120 DAS was observed in treatment K_2-60 kg ha^{-1}. Potassium is very mobile within the plant and essential for photosynthesis and for starch formation and it translocate from upward to downward which helps to increase the branches per plant (Mengel *et al.*, 2001) [11]. The findings of this investigation are in close conformity with those of Mishra *et al.* (2016) [12] and Davara *et al.* (2019) [4] in coriander.

Flowering behaviour
The early flowering and days required to 50% flowering data are presented in Tables 3. Early flowering and days required to 50% flowering were early by the application of K_2-60 kg ha^{-1}. Early flowering (66.80 days) was observed in K_2-60 kg ha^{-1}. However, the maximum days required for first flowering (68.50 days) was recorded in treatment K_1-40 kg ha^{-1}. K as a plant nutrient improved plant-water relation, raised photosynthetic activity and translocation of sugar. This is in accordance with experiments conducted by Ali *et al*. (2015) [1] in black cumin. Minimum days required to 50% flowering (86.08) was observed in K_2-60 kg ha^{-1}. Whereas, the maximum days required for 50% flowering (86.86) was recorded in treatment K_1-40 kg ha^{-1}. Present findings are supported with Waskela *et al*. (2017) [20] in fennel.

Interaction effect of nitrogen and potassium
The data showed that, the interaction effect due to the different levels of nitrogen and potassium was found to be the significant. Treatment combination ($N_4 \times K_2$) i.e., N 120 kg ha^{-1} and 60 kg ha^{-1} recorded significantly maximum plant height (191.21 cm) and number of primary branches per plant (12.53) at 120 DAS. Whereas number of secondary branches per plant (24.46) was significantly maximum under the treatment combination ($N_4 \times K_2$), which was significantly at par (24.33) under treatment combination T_8 i.e., $N_3 \times K_2$. The interacting effect between nitrogen and potassium in respect of flowering behaviour was recorded significant result. The $N_1 \times K_2$ interaction was recorded for early flowering (61.06 days) followed by T_1 i.e. N_1K_1 (61.33) and T_3 i.e. N_1K_3 (61.13) which were statistically at par with each other and superior over rest of the treatments. The $N_1 \times K_3$ interaction recorded the minimum days required for 50% flowering (81.40) followed by T_1 (82.00) and T_2 (81.53) which were statistically at par with each other and superior over rest of the treatments.

Table 1: Effect of different levels of nitrogen and potassium on Plant height (cm), Primary branches per plant and number of secondary branches per plant

Treatments	Plant height (cm)	Primary branches per plant	Secondary branches per plant
	120 DAS	120 DAS	120 DAS
Factor A - Nitrogen levels (kg ha^{-1})			
N_1(80 kg ha^{-1})	166.48	8.40	21.88
N_2(80 kg ha^{-1})	182.60	9.55	22.71
N_3(100 kg ha^{-1})	184.83	10.68	22.73
N_4(100 kg ha^{-1})	189.49	11.53	23.73
SE(m)±	0.11	0.09	0.07
CD at 5%	0.33	0.27	0.22
Factor B- Potassium levels (kg ha^{-1})			
K_1(40 kg ha^{-1})	179.63	9.30	21.68
K_2 (60 kg ha^{-1})	181.93	10.86	23.81
K_3 (80 kg ha^{-1})	180.99	9.96	22.80
SE(m)±	0.09	0.08	0.06
CD at 5%	0.28	0.24	0.22
Interaction (A x B)			
SE(m)±	0.19	0.16	0.13
CD at 5%	0.57	0.48	0.39

Table 2: Interaction effects of different levels of nitrogen and potassium on plant height (cm), Primary branches per plant, and Secondary branches per plant

Treatment combinations	Plant height (cm)	Primary branches per plant	Secondary branches per plant
N_1 K_1	165.70	8.33	20.86
N_1 K_2	167.42	8.66	22.86
N_1 K_3	166.33	8.20	21.93
N_2 K_1	181.51	8.66	21.86
N_2 K_2	183.76	10.46	22.86
N_2 K_3	182.54	9.53	22.66
N_3 K_1	184.60	9.60	21.06
N_3 K_2	185.33	11.80	24.33
N_3 K_3	184.56	10.66	22.80
N_4 K_1	186.72	10.60	22.93
N_4 K_2	191.21	12.53	24.46
N_4 K_3	190.54	11.46	23.80
Interaction (A x B)			
SE(m)±	0.19	0.16	0.13
CD at 5%	0.57	0.48	0.39

Table 3: Effect of different levels of nitrogen and potassium on days required for first flowering and days required for 50% flowering

Treatments	Days required for 1st flowering			Days required for 50% flowering		
	Potassium levels			Potassium levels		
Nitrogen levels (kg ha^{-1})	K_1 (40 kg ha^{-1})	K_2 (60 kg ha^{-1})	K_3 (80 kg ha^{-1})	K_1 (40 kg ha^{-1})	K_2 (60 kg ha^{-1})	K_3 (80 kg ha^{-1})
N_1(80 kg ha^{-1})	61.33	61.06	61.13	82.00	81.53	81.40
N_2(80 kg ha^{-1})	66.26	63.86	66.80	86.26	83.53	85.63
N_3(100 kg ha^{-1})	72.46	68.93	71.00	88.40	87.53	90.00
N_4(100 kg ha^{-1})	73.93	73.33	73.46	90.80	91.73	90.26
Interaction (A x B)						
SE(m)±	0.27	0.23	0.47	0.14	0.12	0.25
CD at 5%	0.80	0.70	1.40	0.43	0.37	0.75

Conclusion

Based on the results, it can be concluded that the application of nitrogen i.e. N_4-120 kg ha^{-1} enhanced growth parameters of fennel. The application of K_2-60 kg ha^{-1} significantly superior in respect of growth parameters and flowering behaviour of fennel. The combined application of N_4-120 kg ha^{-1} and K_2-60 kg ha^{-1} was registered highest growth in fennel.

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