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Response of foliar application of macro and micro nutrients on growth, yield and economics of fennel (*Foeniculum vulgare* Mill.)

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Abstract
Crop nutrients are essential elements required for producing healthy, vigorous plants, as they drive all the key processes involved in crop growth and development. Throughout its life cycle, a plant requires a continuous supply of these nutrients. Since nutrient absorption through the leaf stomata is more efficient than through the roots, foliar fertilization serves as an effective method to quickly enhance plant growth. It is a vital agricultural practice that supports sustainable and productive crop management. This technique offers multiple benefits, including improved nutrient uptake efficiency, reduced soil contamination, higher crop yields, and lower overall production costs. However, the effectiveness of foliar application depends on several factors, such as the plant species, type of fertilizer used, its concentration, the frequency of spraying, and the plant's stage of growth. Therefore, the present study was conducted to assess the impacts of foliar fertilization of nutrients namely $MgSO_4$ (T_1), Ca (NO_3) (T_2), Sulphur (T_3), $MnSO_4$ (T_4), Boron (T_5), ZnO (T_6), $FeSO_4$ (T_7) and Control (T_8) on fennel. Foliar application of nutrients @ 0.5% each were applied at 45 and 90 days after sowing in RBD Design with three replications at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, RVSKVV, Mandsaur, (M.P.) during the Rabi season of 2020-2021. Treatment T_6 was recorded highest plant height, primary branches, secondary branches, fresh weight, dry weight at 60, 90, 120 days after sowing and at harvest. Similarly, treatment T_6 was registered the highest value of number offumbels plant^{-1}, number of umbellates umbel^{-1}, number offseeds umbel^{-1},test weight, seed yield and harvest index as compared to control.

Keywords: *Foeniculum vulgare*, foliar spray, growth, nutrients, phenology and yield

Introduction

Fennel (*Foeniculum vulgare* Mill.) is a perennial plant of the Apiaceae family grown for its edible shoots, leaves and seeds. It is a cool season crop mainly grown during the winter season in northern India. In India it commonly occurs in the states of Gujarat and Rajasthan and in some cases in Andhra Pradesh Karnataka, Madhya Pradesh and Punjab. Fennel seeds, leaves and roots have medicinal properties. The seeds are fragrant, stimulant and carminative. They are used for diseases such as cholera, bile, nervous breakdown, cough and cold, constipation, dysentery and diarrhea, as well as in diseases affecting chest, lung, spleen and kidneys (Singh *et al.*, 2007) [25]. A balanced supply of essential nutrients is crucial for maximizing crop yield, quality, and profitability. These nutrients play a vital role in plant growth and development; however, their proper management is equally important. Nutrient management involves the efficient use and balanced application of nutrients for sustained productivity (Waraich *et al.*, 2011) [26]. The primary goal of nutrient management is to ensure that plants receive the right amount of nutrients at the right time to enhance crop performance. Nutrients can be supplied either through soil or foliar application, but foliar application is often preferred due to its higher effectiveness (Ballabh *et al.*, 2013) [3]. In this method, nutrients are directly delivered to plants in liquid form through their leaves, which readily absorb them via stomata and the epidermis. The nutrients are applied as a spray on the foliage, hence the term "foliar spray" (Noreen *et al.*, 2018) [17]. This approach is advantageous because it requires a smaller quantity of fertilizer compared to soil application. Foliar feeding allows for rapid and efficient nutrient uptake, minimizes losses from leaching and fixation, and helps regulate nutrient absorption by the plant (Manonmani and Srimathi,

2009) [12]. It is particularly effective when roots cannot absorb enough nutrients from the soil. Therefore, foliar nutrition is considered an essential technique in modern agriculture, offering an efficient way to utilize nutrients and quickly correct deficiencies. In this context, the present study was conducted to evaluate the effect of foliar application of macro-and micronutrients on the growth and yield of fennel.

Materials and Methods

The experiment was carried out with eight treatments in Randomized Block Design and replicated three times at Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Mandsaur, (M.P.) during the Rabi season of 2020-2021. The treatments accompanied with foliar application of MgSO4 (T_1), $Ca(NO_3)$ (T_2), Sulphur (T_3), $MnSO_4$ (T_4), Boron (T_5), ZnO (T_6), $FeSO_4$(T_7) and Control (T_8). Foliar application of macro and micronutrients @ 0.5% each were applied at 45 and 90 days after sowing. All the parameters were noted at 60, 90 and 120 days after sowing (DAS) and at harvest. Site of the experiment is located in the Malwa plateau in the western part of Madhya Pradesh and belongs to sub-tropical and semi-arid climatic conditions. The experimental data recorded were subjected to statistical analysis using analysis of variance technique suggested by Panse and Sukhatme (1985).

Results and Discussion

Phenological parameters

Data pertaining to phenology are diagrammatically illustrated in Figure 1. The foliar spray treatments have been found non significant with each other. Treatment T_6 had early 50% flowering (96.00) followed by T_7 (97.00) and T_4 (98.33). The late flowering was seen in T_8 (103.67). However days taken to maturity differed significantly among treatments. Treatment T_6 was observed earliest maturity (176.33 days) followed by T_7 (178.00) which was at par with T_4 (180.00) but significantly early over the remaining treatments. The maximum days to maturity was taken by T_8 (184.00). The assumption seems to be justify that foliar applications of micronutrient have been effective and especially significance in case of rapid absorption of the required nutrients which synchronized to the demand for early maturity in fennel crop (Savithri *et al.*, 1999) [21]. The foliar application of zinc micronutrients might have increased the absorption and uptake of NPK and also triggered the defense mechanism of plants and ultimately enhanced plant growth and development (Anuprita *et al.*, 2005) [2].

Morphological parameters

The morphological parameters are presented in Table 1 and 2. The significantly highest plant height was observed in treatment T_6 (38.53 cm) which was at parwith treatment T_7 (37.67 cm), T_4 (37.53 cm), T_5 (36.87 cm) and T_3 (36.40 cm) but significantly maximum with the remaining treatments at 60 DAS. The treatment T_6 attained maximum plant height (107.93 cm) which was at parwith treatment T_7 (104.27 cm) and T_4 (103.93 cm) but significantly higher with the remaining treatments at 90 DAS. Result revealed maximum plant height (164.60 cm) under treatmentT_6 followed by T_7 (163.00 cm) which were at parwith treatment T_4 (161.53 cm) and T_5 (158.53 cm) but they were significantly higher over rest of the treatments at 120 DAS. Treatment T_6 was observed maximum plant height (205.30 cm) followed by T_7 (201.70 cm) which were at parwith treatment T_4 (200.57 cm) and T_5 (200.30 cm) but they were statistically superior with the remaining treatments at harvest. Among the micronutrients, zinc is an essential nutrient for the standard and healthy growth and development of plants (Cakmak *et al.*, 1998) [5]. In the grand growth phase, Zn is essential for tryptophan synthesis (Castillo-González *et al.*, 2018) [6], which is responsible for the production of enzymes that promote cell elongation and growth (Taiz *et al.*, 2017; Marangoni *et al.*, 2019 and Marschner, 2012) [28, 13, 14]. The Zn fertilizer has a role in various physiological processes, *i.e.*, chlorophyll formation, activation of enzymes, stomatal regulation, etc., which increased the plant height (Yassen *et al.*, 2010; Oosterhuis and Weir, 2010 and Habib, 2009) [27, 18, 10].

The number of primary and secondary branches plant^{-1} were significantly influenced by foliar application in macro and micro-nutrients during the different intervals of plant growth. The treatment T_6 had accumulated highest number of primary branches plant^{-1} (7.57) followed by T_7 (7.57) which were at parwith treatment T_4 (7.47), T_5 (7.47) and T_3 (7.20) but they were significantly superior over rest of the treatments at 60 DAS. The T_6observed higher number of primary branches plant^{-1} (10.53) followed by T_7 (10.42) which were at par with treatment T_4 (10.20) and T_5 (9.60) but they were significantly maximum over rest of the treatments at 90 DAS. Among the treatments, T_6 had attended maximum number of primary branches plant^{-1} (11.83) which was at par with T_7 (11.73), T_4 (11.67) and T_5 (11.20) but appreciably higher over the remaining treatments at 120 DAS. The treatment T_6 was registered maximum number of primary branches plant^{-1}(13.80) followed by T_7 (13.40) which were at par with treatment T_4 (12.90), T_5 (12.60) and T_3 (12.47) but they were significantly superior with the remaining treatments at harvest. The treatment T_6 had accumulated highest number of secondary branches plant^{-1} (13.67) followed by T_7 (13.53) which were at par with treatment T_4 (13.20), T_5 (13.20) and T_3 (13.00) but they were significantly superior over rest of the treatments at 60 DAS. The treatment T_6 (18.40) was recorded maximum number of secondary branches which was on at par with T_7 (17.80), T_4 (17.00) and T_5 (16.93) but significantly higher over rest of the treatment at 90 DAS. Similarly the treatment T_6 was registered significantly maximum number of secondary branches plant^{-1} (22.00) followed by T_7 (21.73) at 120 DAS. The treatment T_6had the highest number of secondary branches plant^{-1} (24.17) at harvest. Increase in branches per plant with foliar application of Zn might be due to Zn role in tryptophan formation, required for auxin synthesis and plant growth (Mallick and Muthukrishnan, 1980) [11]. Besides, the increase in the biosynthesis of auxin, Zn also promotes nutrient uptake (Cakmak, 1999) [4] that ultimately increase vegetative growth. Nasri *et al.* (2011) [16] showed that foliar application of zinc significantly improved number of branches in *Phaseolous vulgaris*. Foliar application of macro and micro-nutrients were significantly influenced the fresh and dry weight during the different intervals of plant growth. The fresh and dry weight were recorded significantly highest (269.60 g plant^{-1} and 109.91 g plant^{-1}) under the treatment T_6 at harvest.

Yield and its components

The significant differences were indicated among the yield and yield attributing traits and data is represented in Table 3. The maximum number of umbels plant^{-1} (38.00), number of umbellate umbel^{-1} (36.00),number of seeds umbel^{-1} (575.33), test weight (8.44 g), seed yield plant^{-1} (17.00 g), seed yield plot^{-1} (1.22 kg), seed yield ha^{-1} (19.39 q) and harvest index (41.25 %) were found in treatment T_6. However, minimum number of umbels plant^{-1}, number of umbellate umbel^{-1},number of seeds umbel^{-1}, test weight, seed yield plant^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and harvest index were found in treatment T_8. The Increase in yield in treatment T_6 may be attributed to increased plant height, maximum number of primary and secondary branches, and maximum number of umbels and umbellets. Romheld and Marschner (1991) [19] and McCauley *et al.* (2009) [15] reported that increase in the grain yield was attributable to the improved physiology of plants with the added Zn. The positive influence of foliar application of ZnO @ 5% on fennel crop growth may be due to the improved ability of the crop to absorb nutrients to photosynthesize and better sink source relationship. The foliar application of zinc oxide might have caused to increase the number of fruits plant^{-1} by increasing IAA synthesis (Shnain *et al.*, 2014) [23] as well as carbohydrates translocation (Singh and Tiwari, 2013) [24]. The foliar application of ZnO also might have caused to increase the photosynthates translocation to the fruit and decrease in flowers and fruits abscission (Graham *et al.*, 2000; Ruby *et al.*, 2001; Ali *et al.*, 2008) [8, 20, 1].

Economics of the treatments

The result revealed from Table 4 that, treatment T_6 had the highest net returns of Rs. 126320 with B: C ratio 4.3:1. It might be because of a large increase in production owing to a greater supply of accessible zinc to the crop and correction of hidden zinc deficiency in plants, or improved crop nutrition with foliar application of these micro nutrients Choudhary *et al.* (2015) [7]. The comparable findings were also recorded by Gupta (2012) [9] and Sharma (2006) [22].

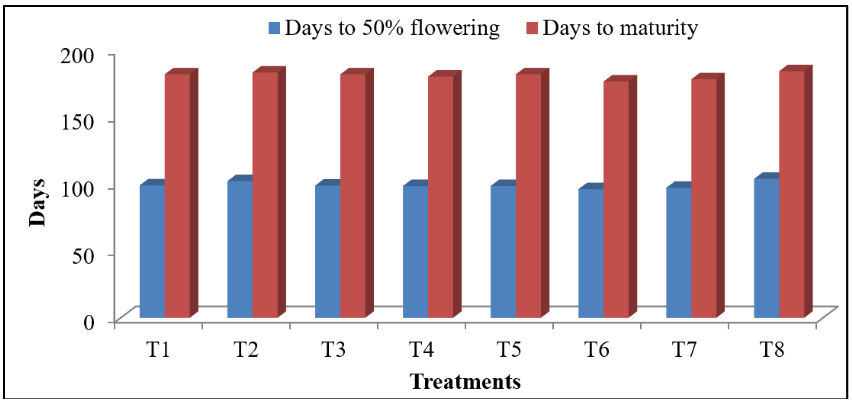

Fig 1: Effect of foliar application of macro and micro-nutrients on phenological parameters of fennel

Table 1: Effect of foliar application of macro and micro nutrients on plant height, number of primary and secondary branches of fennel

Treatments		Plant height (cm)				Number of primary branches plant^{-1}				Number of secondary branches plant^{-1}			
		60 DAS	90 DAS	120 DAS	At harvest	60 DAS	90 DAS	120 DAS	At harvest	60 DAS	90 DAS	120 DAS	At harvest
T_1	$MgSO_4$	35.60	100.00	151.27	193.48	6.73	8.47	10.40	11.93	12.47	16.20	19.40	21.13
T_2	$Ca(NO_3)$	35.00	98.53	151.07	192.00	6.50	8.33	9.83	11.30	12.33	15.93	18.73	20.00
T_3	Sulphur	36.40	100.53	152.27	193.40	7.20	9.13	10.80	12.47	13.00	16.33	20.87	21.20
T_4	$MnSO_4$	37.53	103.93	161.53	200.57	7.47	10.20	11.67	12.90	13.20	17.00	21.17	22.83
T_5	Boron	36.87	103.33	158.53	200.30	7.47	9.60	11.20	12.60	13.20	16.93	21.00	22.47
T_6	ZnO	38.53	107.93	164.60	205.30	7.57	10.53	11.83	13.80	13.67	18.40	22.00	24.17
T_7	$FeSO_4$	37.67	104.27	163.00	201.70	7.57	10.42	11.73	13.40	13.53	17.80	21.73	23.57
T_8	Control	31.33	94.33	147.60	188.40	5.40	8.27	9.10	11.10	11.80	13.47	17.00	19.00
S.Em. ±		0.76	1.41	2.22	2.02	0.25	0.33	0.32	0.33	0.22	0.51	0.50	0.58
C.D. at 5%		2.29	4.27	6.74	6.13	0.76	0.99	0.98	1.00	0.67	1.55	1.51	1.77

Table 2: Effect of foliar application of macro and micro nutrients on fresh and dry weight of fennel

Treatments		Fresh weight (g plant^{-1})				Dry weight (g plant^{-1})			
		60 DAS	90 DAS	120 DAS	At harvest	60 DAS	90 DAS	120 DAS	At harvest
T_1	$MgSO_4$	39.00	182.91	231.69	240.08	14.01	61.00	77.63	100.63
T_2	$Ca(NO_3)$	38.30	180.91	230.55	239.90	13.50	60.30	77.05	100.02
T_3	Sulphur	39.74	185.59	235.19	245.60	14.13	62.91	79.53	101.73
T_4	$MnSO_4$	40.20	197.37	246.93	258.30	14.47	65.86	82.44	106.11
T_5	Boron	39.93	197.05	246.60	256.00	14.38	65.72	82.33	105.33
T_6	ZnO	43.52	210.37	260.32	269.60	15.00	68.97	85.91	109.91
T_7	$FeSO_4$	42.51	200.50	250.19	260.50	14.90	66.83	83.53	106.53
T_8	Control	33.51	166.18	215.73	225.10	13.30	55.46	72.04	95.04
S.Em. ±		1.04	4.55	4.70	5.20	0.21	1.32	1.35	1.61
C.D. at 5%		3.14	13.81	14.27	15.78	0.64	4.01	4.09	4.88

Table 3: Effect of foliar application of macro and micro nutrients on yield and yield attributes of fennel

Treatments		Number of umbels (plant^{-1})	Number of umbellates (umbel^{-1})	Number of seeds (umbel^{-1})	Test weight (g)	Seed yield (g plant^{-1})	Seed yield (kg plot^{-1})	Seed yield (q ha^{-1})	Harvest index (%)
T_1	$MgSO_4$	35.47	33.93	508.40	8.08	13.99	0.98	15.54	36.91
T_2	$Ca(NO_3)$	34.40	33.20	455.93	8.03	13.69	0.96	15.21	36.71
T_3	Sulphur	35.87	34.07	519.73	8.13	14.25	1.00	15.84	37.44
T_4	$MnSO_4$	36.67	34.93	523.00	8.23	16.02	1.11	17.59	38.49
T_5	Boron	36.47	34.60	520.60	8.18	15.50	1.03	16.35	38.19
T_6	ZnO	38.00	36.00	575.33	8.44	17.00	1.22	19.39	41.25
T_7	$FeSO_4$	37.80	35.40	547.20	8.37	16.89	1.18	18.76	40.44
T_8	Control	32.20	31.67	449.80	7.98	12.87	0.90	14.30	36.65
S.Em. ±		0.65	0.45	12.55	0.12	0.50	0.04	0.53	0.86
C.D. at 5%		1.96	1.38	38.05	0.36	1.52	0.12	1.60	2.61

Table 4: Effect of different levels of major nutrients and organic manure on economics of fennel

Treatments		Total cost (₹)	Gross return (₹)	Net profit (₹)	B:C ratio (₹)
T_1	$MgSO_4$	28500	124320	95820	3.3:1
T_2	$Ca(NO_3)$	28400	121680	93280	3.2:1
T_3	Sulphur	28500	126720	98220	3.4:1
T_4	$MnSO_4$	28600	140720	112120	3.9:1
T_5	Boron	28500	130800	102300	3.5:1
T_6	ZnO	28800	155120	126320	4.3:1
T_7	$FeSO_4$	28600	150080	121480	4.2:1
T_8	Control	28000	114400	86400	3.0:1

Conclusions

On the basis of research and the results reported, it could be concluded that the foliar spray of zinc at 0.5% can be suggested for fennel, as they gave more seed yield, net yield and B: C ratio in fennel.

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