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Impact of zinc and iron, their applicability techniques, and PGRs on yield of fennel (*Foeniculum vulgare*)

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Abstract

The experiment was conducted to find out the impact of zinc and iron, their applicability techniques, and PGRs on yield of fennel (*Foeniculum vulgare* Mill.) at Rajasthan Agricultural Research Institute, Durgapura, Jaipur. during 2020-21 and 2021-22. The experiment consisted of 25 treatment combinations with five levels of fertilization (control, soil application of $ZnSO_4$ @ 25 kg/ha, Soil application of $FeSO_4$ @ 50 kg/ha, foliar application of $ZnSO_4$ @ 0.5 % and foliar application of $FeSO_4$ @ 0.5 %) and five levels of plant growth regulators (control, GA_3 @ 50 ppm, GA_3 @ 100 ppm, NAA @ 25 ppm and NAA @ 50 ppm in a factorial randomized block design with three replications. The results revealed that integration of fertilization and plant growth regulators was more effective in increasing growth and yield of fennel. The application of application of $ZnSO_4$ @ 25 kg/ha significantly increased plant height (145.32 cm), number of primary branches per plant (7.08), number of secondary branches/plant (15.83), chlorophyll content (mg/g) at 75 DAS (1.82), seed yield (kg /ha) (1666) and stover yield (kg /ha) (2881) as compared to control. Similarly, plant growth regulators GA_3 @ 50 ppm also significantly increased the plant height (144.20 cm), Number of primary branches/plant (7.02), number of secondary branches/plant (15.72), chlorophyll content (mg/g) at 75 DAS (1.83), seed yield (kg /ha) (1648) and stover yield (kg /ha) (2867) as compared to the control.

Key words: $ZnSO_4$, Growth, Yield, PGRs, Seed yield, Chlorophyll content, Branches

Fennel (*Foeniculum vulgare* Mill.), belonging to the family Apiaceae, it is mainly cultivated in Gujarat, Rajasthan, and Uttar Pradesh. Rajasthan, it is mainly cultivated in Tonk, Jodhpur, Sirohi, Pali, Nagaur, and, to a limited extent, in Bharatpur, Kota, and Ajmer districts. It contributed 34,276 tonnes of production of fennel from a 31,622-ha area with a productivity of 1084 kg/ ha to the national pool (DASD, 2023). Zinc is the main nutrient in building blocks of some enzymes like alcohol dehydrogenase, carbonic anhydrase, superoxide dismutase, etc. and is needed for the formation of plant enzymes and many enzymatic reactions that become active with zinc (Pedler *et al.*, 2000). Similarly, iron is taken up by plants in the form of ferrous ions. Its concentration in the range of 100–500 mg/kg in mature leaf tissues is sufficient for optimum crop production. The (PGRs) are play an important role in mitigating stress and increasing flower seting. Exogenous application of PGR's has been reported to improves growth and yield of various crops (Bharud *et al.*, 1988). Hence an experiment was conducted to find out the effect of zinc, iron and PGR on fennel yield.

MATERIALS AND METHODS

The experiment was conducted at RARI, Durgapura, (Jaipur) during rabi season 2020-21 and 2021-22. This region falls under agroclimatic zone-IIIA (semi-arid eastern plains) in Rajasthan in India. It consisted of 25 treatment combinations with five levels of fertilization (control, soil application of $ZnSO_4$ @ 25 kg/ha, soil application of $FeSO_4$ @ 50 kg/ha, foliar application of $ZnSO_4$ @ 0.5 % and foliar application of $FeSO_4$ @ 0.5 %) and five levels of plant growth regulators (control, GA_3 @ 50 ppm, GA_3 @ 100 ppm, NAA @ 25 ppm and NAA @ 50 ppm in a factorial randomized block design with three replications.

The treatments were applied during October 2020-21 and 2021-22 after recording initial (base) yields attributing parameters of plants and observations were noted. Ferrous sulphate at 50 kg/ha and zinc sulphate at 25 kg/ha were applied as per treatment as basal. The required micronutrients for foliar spray were weighted and dissolved in water @ 500 l/ha. The $ZnSO_4$ @ 0.5% and $FeSO_4$ @ 0.5% were sprayed as per treatments. Sprays of NAA (25 and 50 ppm) and GA_3 (50 and 100 ppm) were administered as foliar sprays as per treatments. Before application, lime @ 2 g/litter of water was used to neutralize the solution of $ZnSO_4$ and $FeSO_4$. The plant height of plants was measured at harvesting from the base of plant to the top of the main shoot on a meter scale, and their mean was expressed as average plant height during both years.

Number of primary branches/plant, number of primary branches or plants was counted on five already selected and tagged plants in each plot at harvesting to compute the mean number of primary branches or plants during. Number of secondary branches/plant was counted on five already selected and tagged plants in each plot

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at harvest, and then mean was recorded. The fresh leaf samples were taken to determine the chlorophyll content of leaves at the flowering stage. These were washed with distilled water and dried with blotting paper. The total biomass harvested from each net plot was threshed and cleaned. The seeds so obtained were weighed in kg/plot and then converted into kg/ha and stover yield kg per plot was obtained by subtracting the seed yield/plot from the biological yield and then converting it into kg/ha.

The data were statistically analyzed as per Panse *et al.* (1995). The significance of treatments was tested through F test at 5 per cent level of significance. The critical difference CD was calculated to assess the significance of difference among the different treatments.

RESULTS AND DISCUSSION

Application of zinc had a significant effect on plant height at harvest during both years. The number of primary branches/plant increased significantly due to application of zinc and iron over the control. Soil application of $ZnSO_4$ @ 25 kg/ha produced higher number of primary branches per plant (7.08). The application of zinc and iron considerably enhanced the number of secondary branches/plant. The $ZnSO_4$ (25 kg/ha) resulted in significantly higher number of secondary branches (15.83). The chlorophyll content in leaves (7 DAS) and seed yield increased significantly due to application of iron and zinc treatments as compared to the control in both the years and in pooled analysis. The soil application of $ZnSO_4$ @ 25 kg/ha, closely followed by foliar application of $ZnSO_4$ @ 0.5% recorded maximum stover yield (2881 kg/ha) during both the years.

Application of GA_3 at 50 ppm (144.20 cm), being at par with GA_3 at 100 ppm produced higher plant height at harvesting (142.56 cm) as compared to the control. Higher number of primary branches to (7.02), was recorded with application of GA_3 at 50 ppm, was superior to rest of the treatments. The use of plant growth regulators resulted in significant difference in number of secondary branches. Application of GA_3 at 50 ppm (15.72) resulted the maximum increase in number of secondary branches and was significantly higher as compared to all other treatments. The chlorophyll content in leaves at 75 DAS. significantly enhanced due to plant growth regulators as compared to the control. Significantly maximum chlorophyll content (1.83 mg/g) was observed with application of GA_3 @ 50 ppm which was significantly higher as compared to all other remaining treatments except application of GA_3 @ 100 ppm (1.82 mg/g) which remained at par to it.

The seed yield was significantly influenced by different treatments of plant growth regulators as compared to the control. The maximum seed yield was recorded with the application of GA_3 @ 50 ppm (1648 kg/ha) which was remained at par with application of GA_3 @ 100 ppm (1628 kg/ha) and found superior over the control (1405 kg/ha). The application of plant growth regulators had a substantial impact on stover production of fennel when compared to the control. Higher stover yield of fennel was recorded with application of GA_3 @ 50 ppm (2867 kg/ha) which was significantly higher as compared to the control (2433 kg/ha).

The soil application of $ZnSO_4$ @ 25 kg/ha, being remained at par with foliar application of $ZnSO_4$ @ 0.5% and recorded significantly highest plant height, number of primary branches and number of secondary branches as compared to the control, soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5%. Further, the soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5% also gave higher values for above parameters over the control.

According to Gour *et al.* (2011), the maximum plant height was achieved with combined application of zinc sulphate and ferrous sulphate (as soil application at 5 kg/ha and 10 kg/ha + foliar application at 0.5% and 0.25%, respectively). When zinc was sprayed to fennel at a rate of 6 kg/ha, a notable rise in plant height was noted (Gupta, 2012). Kumawat et al. (2015) also observed maximum plant height with application of $ZnSO_4$ @ 30 kg/ha.

Singh *et al.* (2009) reported that application of zinc sulphate @ 20 kg/ha produced maximum number of primary and secondary branches. Mounika *et al.* (2018a) also reported that foliar application of zinc sulphate @ 0.5% recorded highest number of primary and secondary branches over the control. Our findings clearly stated that seed yield, stover yield and biological yield was significantly enhanced due to different treatments of zinc and iron over the control during both the years. The maximum values were obtained with soil application of $ZnSO_4$ @ 25 kg/ha which was significantly higher over control, soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5%. Further, analysis of data stated that soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5% remained at par to each other and recorded significantly higher seed, stover and biological yield of fennel as compared to the control. The increase in seed yield due to zinc and iron application may be attributed due to fact that initial status of available zinc and iron in soil was low (Table 3.2). Under such a situation an increase in the yield is quite natural. Further, increased seed yield is the manifestation of increase in yield attributes, *i.e.*, umbel/plant and number of seeds/umbellate.

The significantly maximum values were recorded with the application of GA_3 @ 50 ppm which was

Table 1: Effect of zinc and iron, their methods of application and plant growth regulators on chlorophyll content and days taken to maturity of fennel.

Treatments	Chlorophyll content (mg/g) at 75 DAS		
	2020-21	2021-22	Pooled
Control	1.65	1.72	1.68
Soil application of $ZnSO_4$ @ 25 kg/ha	1.70	1.79	1.74
Soil application of $FeSO_4$ @ 50 kg/ha	1.76	1.87	1.81
Foliar application of $ZnSO_4$ @ 0.5 %	1.75	1.86	1.80
Foliar application of $FeSO_4$ @ 0.5 %	1.77	1.88	1.82
SEm±	**0.02**	**0.02**	**0.01**
CD (P=0.05)	**0.04**	**0.05**	**0.03**
Control	1.64	1.75	1.70
GA_3 @ 50 ppm	1.78	1.88	1.83
GA_3 @ 100 ppm	1.77	1.87	1.82
NAA @ 25 ppm	1.71	1.80	1.76
NAA @ 50 ppm	1.72	1.81	1.76
SEm±	**0.02**	**0.02**	**0.01**
CD (P=0.05)	**0.04**	**0.05**	**0.03**

Table 2: Effect of zinc and iron, their methods of application and plant growth regulators on seed yield and stover yield of fennel

Treatments	Seed yield (kg /ha)			Stover yield (kg /ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertilization						
Control	1339	1431	1385	2408	2423	2415
Soil application of $ZnSO_4$ @ 25 kg/ha	1603	1730	1666	2917	2844	2881
Soil application of $FeSO_4$ @ 50 kg/ha	1477	1586	1532	2659	2648	2654
Foliar application of $ZnSO_4$ @ 0.5 %	1583	1692	1637	2868	2816	2842
Foliar application of $FeSO_4$ @ 0.5 %	1452	1544	1498	2625	2610	2618
SEm±	**23**	**26**	**17**	**54**	**52**	**37**
CD (P=0.05)	**66**	**73**	**49**	**154**	**148**	**105**
Plant Growth Regulators						
Control	1362	1447	1405	2440	2427	2433
GA_3 @ 50 ppm	1586	1709	1648	2883	2852	2867
GA_3 @ 100 ppm	1568	1688	1628	2861	2812	2837
NAA @ 25 ppm	1462	1557	1509	2632	2610	2621
NAA @ 50 ppm	1475	1582	1529	2661	2642	2652
SEm±	**23**	**26**	**17**	**54**	**52**	**37**
CD (P=0.05)	**66**	**73**	**49**	**154**	**148**	**105**
Interaction (F x P)			**Sig**			

remained at par with application of GA_3 @ 100 ppm and found superior over control, application of NAA @ 25 ppm and application of NAA @ 50 ppm. Maximum seed yield was produced may be due to GA_3 application. The increase in seed yield could be also attributed to increasing in number of umbels/plant, number of umbellets/umbel, number of seeds/umbel and test weight of fennel. Prajapat *et al.* (2015) recorded that seed yield of fennel significantly increased with the application of 100 ppm gibberellic acid over the control. Rathod *et al.* (2023) also recorded that the foliar application of GA_3 at 50 ppm resulted in significantly for seed yield. Higher stover yield is due to different plant growth regulators which initiate the physiological process to modify the morphological, biochemical and physiological changes in plants.

CONCLUSION

In our study application of $ZnSO_4$ @ 25 kg/ha in the soil, closely succeeded by a 0.5% foliar application, resulted in more yield, nutrient uptake, and net returns of fennel compared to the control. Applying 50 ppm of GA_3, which is equivalent to applying 100 ppm, resulted in more yield and nutrient uptake, as well as better net returns compared to other treatments.

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