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Soil Fertility and Micronutrient Uptake by Fennel (*Foeniculum vulgare* Mill.) as Influenced by Micronutrients Fertilization

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Abstract A field experiment was conducted on fennel, a important seed spice crop of arid and semi arid region of India to study the effect of micronutrient application by different methods on biomass production and micronutrient dynamics in fennel (Foeniculum vulgare Mill.). Results revealed that uptake of iron was highest in T_2 (4.54 kg/ha), manganese its uptake was highest in T_3 (2.42 kg/ha) Cu uptake was highest in T_4 (0.43 kg/ha) where the soil was fertilized with Fe 10 kg ha^{-1}, Mn 10 kg ha^{-1} and cu 5 kg ha^{-1} respectively. In case of zinc fennel removed highest zinc from T_{11} (0.76 kg/ha) where crop was fertilized by 0.5% $ZnSO_4$ as a foliar spray. Similarly highest biron uptake was observed in foliar spray of boron 0.25% (0.46 kg/ha). Average uptake of micronutrients by fennel is Fe-1982.6 ha^{-1}, Mn-1465.7 g ha^{-1}, Cu-33.8 g ha^{-1}, Zn-443.3 g ha^{-1} and B-336.6 g ha^{-1}. It clearly shows that all applied micronutrients by all the three methods are utilized by crop in higher quantity as compared to its non application treatments.

Keywords Micronutrient, Uptake, Iron, Fennel, Balance sheet.

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Introduction

Fennel is important major seed spice crop of india particularly semi arid region of Rajasthan, Gujarat, Madhya Pradesh and other states like Karnataka, Tamil Nadu and Andhra Pradesh. Fennel is the one of the most biomass yielding crop and demands more nutrients than any other seed spices. more over fennel is a long duration crop and matures in 210—240 days. Long duration nature of crop demands continuous availability and uptake of nutrientsalong with irrigations. For the optimal growth and development of any plants, balanced application of nutrients is highly essential. If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result [1]. In recent days excessive use of non micronutrient fertilizers and less or no use of organic manure leads to micronutrients disorder in crop plants particularly in arid and semi arid regions of India where soils are poor structured and low in native nutrient status. Application of nutrients utimely, following inappropriate method of application leads to severe loss of nutrients by leaching and fixation. But in reality uptake is influenced by many factors such as agro climatic conditions, soil type, method of application, mineral mobility and its accumulation sites [2]. With this context an eperiment was conducted in fennel, an important seed spice crop of semi arid regions of India to study the effect of various micronutruents on micronutrient content in the whole plant, nutrient uptake, and soil fertility status after harvest and thereby to prepare a balance sheet of the moicronutrients.

Materials and Methods

The present study was carried out at the ICAR-National Research centre on Seed Spices, Tabiji, Ajmer (Rajasthan) during rabi season of 2014-15, to find out the impact of micronutrients such as iron, manganese, zinc, copper and boron on growth and yield of fennel. The soil of the experimental field was sandy loam having 4.32 mg kg^{-1} DTPA extractable iron, 8.77 mg kg^{-1} DTPA extractable manganese, 0.78 mg kg^{-1} DTPA extractable copper, 0.96 mg kg^{-1} DTPA extractable manganese, 0.78 mg kg^{-1} DTPA extractable copper, 0.96 mg kg^{-1} DTPA extractable zinc and 0.43 mg kg^{-1} hot water extractable boron. The study was carried out by three methods such as soil application, foliar spray and seed priming. The soil application treatments includes T_1-control, T_2-Fe 10 kg ha^{-1}, T_3-Mn 10 kg ha^{-1}, T_4-Cu 5 kg ha^{-1},T_5-Zn 5 kg ha^{-1} and T_6-boron 2.5 kg ha^{-1} through Ferrous Sulphate ($FeSO_4.7H_2O$), Manganese Sulphate ($MgSO_4.H_2O$), Copper sulphate ($CuSO_4.\%H_2O$), Zinc Sulphate ($ZnSO_47H_2O$) and Borax Power (Di-Sodium tetra borate) ($NaB_4O_7.10H_2O$) respectively. All the themicronutrient fertilizers are applied to soil by incorporating in soil just before sowing. In foliar spray treatments the micronutrients such as T_7-water spray, T_8 $FeSO_4$0.5%, T_9-$MnSO_4$0.5%, T_{10} -$CuSO_4$0.5%, T_{11}-$ZnSO_4$0.5% and T_{12}-Borax 0.25% are sprayed at 45 and 90 DAS by mixing with sticker at the rate of one ml per litre of spray solution. Spraying was carried out using 5.0 litre capacity hand sprayer. In seed treatments T_{13}-Water soaking, T_{14}-iron 500ppm, T_{15}-Manganese 500ppm, T_{16}-Copper 500ppm, T_{17} Zinc 500ppm and T_{18}-Boron 250ppm solutions were prepared and seeds were soaked for 12 hours, surface washed by water to remove surface nutrients and shade dried for 24 hours to bring the seed moisture to its original status. Experiment was laid out in RBD and the plot size was 3.5 m ×3m (10.5 m) with three replications. The soil samples were collected before and after the cropping season to assess the nutrient uptake by the crop and to prepare balance sheet. The plant samples were collected at physiological maturity to analyse plant nutrient status of fennel. Soil samples were collected from the surface (0-15 cm depth) before sowing seed of both year crops. samples were air dried and powdered with wooden mortar and passed through a 2 mm stainless steel sieve. Soil samples were extracted formicronutrients using 0.005m DTPA and analyzed using atomic absorption spectrophotometer. The plant samples were collected at the time of physiological maturity. Plant samples were successively washed with tape water, 0.1 M HCl and distilled water and dried at 70°C. After proper drying samples were powdered in wily mill and passed through the 20 mesh steal sieve. The samples were digested in nitric acid and perchloric acid mixture (10 : 4) and digested samples were analyzed using atomic absorption spectrophotometer.

Results and Discussion

Results pertaining to soil fertility ststus, nutrient uptake and balance of nutrients were discussed here under. It shows demarked unfluence on soil fertilty ststus after harvest of the fennel crop and also nutrient utilization.

Nutrient uptake

Uptake of iron by fennel crop was highest in T_2 (4.54 kg/ha) followed by T_8 (3.47 kg/ha) and T_{14} (2.9 kg/ha). (Table 1). In case of manganese its uptake was highest in T_3 (2.42 kg/ha) followed byT_3 (2.10 kg/ha) and T_{15} (1.87 kg/ha). Cu uptake was highest in T_4 (0.43 kg/ha) followed by T_{10} (0.42 kg/ha) and T_{16} (0.40 kg/ha). In case of zinc fennel removed highest zinc from T_{11} (0.76 kg/ha) where crop was fertilized by 0.5% $ZnSO_4$ foliar spray. The same was reported in corn that broadcast and incorporation of fine powder or liquid micronutrients resulting in uptake efficiencies of 0.8 to 8.5% of applied Zn [3]. similarly highest boron uptake was observed in foliar spray of boron 0.25% T_{12} (0.46 kg/ha). It clearly shows that all applied micronutrients by all the three methods are utilized by crop in hifgher quantity as compared to its non application treatments. In case of iron soil was defit in intial status and when supplied as soil application crop reoved higher amount as compared to foliar and seed treatment.

Soil fertility after the harvest

After application of micronutrient fertilizers through soil, foliar and seed, the expected and actual balance

Table 1. Initial soil micronutrient status and addition of micronutrient to fennel crop. * Data not analyzed statisically.

Treat-ments	Initial nutrient status of soil (kg/ha) 1					Addition of nutrients (kg/ha) 2					Total nutrient added to crop (kg/ha) 3=2+1				
	Fe	Mn	Cu	Zn	B	Fe	Mn	Cu	Zn	B	Fe	Mn	Cu	Zn	B
T_1	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0	9.7	15.16	2.20	2.15	0.94
T_2	9.7	2.20	15.16	2.15	0.94	10	0	0	0	0	19.7	15.16	2.20	2.15	0.94
T_3	9.7	2.20	15.16	2.15	0.94	0	10	0	0	0	9.7	25.16	2.20	2.15	0.94
T_4	9.7	2.20	15.16	2.15	0.94	0	0	5	0	0	9.7	15.16	7.20	2.15	0.94
T_5	9.7	2.20	15.16	2.15	0.94	0	0	0	5	0	9.7	15.16	2.20	7.15	0.94
T_6	9.7	2.20	15.16	2.15	0.94	0	0	0	5	2.5	9.7	15.16	2.20	2.20	3.44
T_7	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0	9.7	15.16	2.20	2.15	0.94
T_8	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0	10.58	15.16	2.20	2.15	0.94
T_9	9.7	2.20	15.16	2.15	0.94	0.9	1.5	0	0	0	9.7	15.16	2.20	2.15	0.94
T_{10}	9.7	2.20	15.16	2.15	0.94	0	0	1.2	0	0	9.7	16.66	2.20	2.15	0.94
T_{11}	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0	9.7	15.16	3.40	2.15	0.94
T_{12}	9.7	2.20	15.16	2.15	0.94	0	0	0	1.1	0.3	9.7	15.16	2.20	3.25	0.94
T_{13}	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0	9.7	15.16	2.20	2.15	1.24
T_{14}	9.7	2.20	15.16	2.15	0.94	0.05	0	0	0	0	9.7	15.16	2.20	2.15	0.94
T_{15}	9.7	2.20	15.16	2.15	0.94	0	0.03	0	0	0	9.73	15.16	2.20	2.15	0.94
T_{16}	9.7	2.20	15.16	2.15	0.94	0	0	0.04	0	0	9.7	15.20	2.20	2.15	0.94
T_{17}	9.7	2.20	15.16	2.15	0.94	0	0	0	0.03	0	9.7	15.16	2.24	2.15	0.94
T_{18}	9.7	2.20	15.16	2.15	0.94	0	0	0	0	0.04	9.7	15.16	2.20	2.18	0.94

of micronutrients in the soil was worked out. It was found that actual balance was higher in case of DTPA extractable iron content in the soil of all the treatments except T_2 (10.7 kg ha^{-1}) where soil was fertilized with iron 10kg ha^{-1}. This may be due to higher dose of iron which was applied and interaction of iron with other elements such as manganese. In case of DTPA extractable manganese content in soil after harvest of crop was noticed that all the treatments were less in residual manganese as compared to expected balance. This may bedue to availability of sufficient manganese in soil and process of ion exchange mechanism might have responsible for lower amount of DTPA extractable Mn in the soil. In the same way copper content was found higher actual balance than the expected balance in the soil except soil application of copper 5 kg ha and all the seed treatments. Zinc application to the soil 5 kg ha has leads heavy loss in the final status of soil as compared to all other treatments where fertility status of DTPA extractable zinc was higher than the expected. Same was reported that the residual effect of copper, zinc are strongly affected by cultivation practices, which breaks up and mixes the residual copper and zinc throughout the soil increasing its uptake by the subsequent crops [4]. Boron content was also showed similar trend of zinc and found higher expected balance than actual status of boron in the soil after the crop harvest. In all the cases soil application of fertilizers was shown lower fertility status as compared to other treatments. This may be due to use of water soluble fertilizers for soil application might have lead to leaching and fixation in soil. but incase of foliar and seed treatments fertilizers were applied directly to crop so that crop used the nutrients directly from spry solution rather than from soil. this might have contributed to the higher balance in the final status of nutrients in other treatments as compared soil application. It is also reported in Japanese mint that soil applied nutrients will undergo many chemical and physical reaction which leads to fixation, leaching and convention to unavailable forms. however some portion of nutrients will be absorbed by crop and weed also. This makes the applied micronutrients to remain highest and lowest in the soil [5].

Balance of micronutrients

The results presented in Table 2 on net gain or loss

Table 2. Micronutrient uptake, residue of micronutrients and balance of nutrients after the harvest of fennel crop. * Data not analyzed statistically.

Treatments	Removal of nutrients plants (kg/ha)* 4					Expected balance (kg/ha)* 5=3-4				
	Fe	Mn	Cu	Zn	B	Fe	Mn	Cu	Zn	B
T_1	1.39	1.07	0.25	0.40	0.37	8.29	14.1	1.95	1.75	0.57
T_2	4.54	1.75	0.37	0.51	0.34	15.1	13.4	1.82	1.64	0.60
T_3	1.63	2.42	0.38	0.55	0.28	8.04	22.7	1.78	1.60	0.66
T_4	1.62	1.46	0.42	0.41	0.26	8.05	13.7	6.78	1.74	0.68
T_5	1.69	1.43	0.30	0.54	0.31	7.98	13.7	1.90	6.61	0.63
T_6	1.67	1.28	0.31	0.41	0.41	8.00	13.8	1.89	1.74	3.03
T_7	1.61	1.14	0.31	0.38	0.29	8.07	14.0	1.88	1.77	0.65
T_8	3.47	1.49	0.39	0.56	0.40	7.11	13.6	1.77	1.59	0.54
T_9	2.14	2.10	0.35	0.52	0.36	7.53	14.5	1.85	1.63	0.58
T_{10}	1.71	1.65	0.41	0.49	.029	7.97	13.5	2.98	1.66	0.65
T_{11}	2.42	1.29	0.37	0.76	0.33	7.25	13.8	1.83	2.49	0.61
T_{12}	1.47	1.28	0.25	0.39	0.46	8.21	13.8	1.95	1.76	0.78
T_{13}	1.23	1.11	0.27	0.34	0.33	8.45	14.0	1.92	1.81	0.61
T_{14}	2.90	1.37	0.35	0.40	0.32	6.82	13.8	1.80	1.75	0.62
T_{15}	1.59	1.87	0.37	0.32	0.34	8.08	13.3	1.83	1.83	0.60
T_{16}	1.46	1.38	0.40	0.35	0.30	8.22	13.7	1.88	1.80	0.64
T_{17}	1.49	1.14	0.32	0.34	0.26	8.19	14.0	1.88	1.84	0.68
T_{18}	1.64	1.16	0.33	0.31	0.38	8.03	14.0	1.86	1.84	0.60

Table 2. Continuted.

Treatments	Actual balance (kg/ha)* 6					% Net gain (+) or loss (-)* 7=5-6				
	Fe	Mn	Cu	Zn	B	Fe	Mn	Cu	Zn	B
T_1	8.76	9.97	2.37	1.64	1.03	5.38	-41.41	18.06	-6.98	44.50
T_2	10.7	8.71	2.24	2.02	0.87	-41.36	-53.97	18.59	18.81	31.74
T_3	8.94	12.6	2.31	1.93	0.96	9.99	-80.66	22.75	17.01	31.70
T_4	9.00	10.1	3.14	1.75	1.12	10.56	-35.33	-116.1	0.37	39.08
T_5	9.03	9.52	2.31	2.40	1.14	11.55	-44.31	17.66	17.66	45.05
T_6	8.89	10.6	2.35	1.95	1.97	10.00	-30.18	19.68	10.58	-53.76
T_7	8.89	9.74	2.13	1.79	0.87	9.25	-43.91	11.43	1.00	26.02
T_8	8.51	9.65	2.4	1.90	0.92	16.52	-41.62	13.41	16.40	41.22
T_9	8.44	9.56	2.17	1.95	1.03	10.78	-52.37	14.99	16.11	43.45
T_{10}	8.92	10.7	2.49	1.86	1.05	10.60	-25.98	-19.89	10.62	38.20
T_{11}	8.76	10.8	2.08	1.79	0.96	17.19	-27.98	12.37	-38.84	36.54
T_{12}	8.96	9.95	2.08	1.86	1.05	8.36	-39.63	6.40	5.34	26.20
T_{13}	8.80	9.63	2.17	1.55	1.08	4.02	-45.92	11.47	-16.98	43.60
T_{14}	8.58	10.7	2.24	1.75	0.99	20.48	-28.87	19.82	-0.12	37.01
T_{15}	9.18	10.3	2.28	1.57	1.16	11.98	-28.81	20.02	-16.78	48.47
T_{16}	9.36	9.77	2.20	1.81	1.19	12.22	-41.15	14.18	0.61	46.33
T_{17}	9.12	9.56	2.13	1.68	0.99	10.21	-46.63	11.79	-9.72	31.40
T_{18}	8.76	9.74	2.37	1.84	1.12	8.29	-43.77	21.57	-0.02	46.19

indicates that percentage gain or loss of micronutrients in the soil after the crop harvest. After comparing expected balance and actual balance of micronutriens in the soil, percent gain or loss of each micronutrients showed clear variations by methods of application. In case of iron 41.36% was lost or became unavailable form in soil application of Fe 10 kg ha (T_2) and highest percent gain (20.48) was observed in seed treatment Fe 500ppm (T_3). It is reported that the residual effects of Fe and Mn fall to

below 50% of the initial yield response within one year for fe and 6 years for Mn [6]. Copper was found a net loss of 116.1% in soil application of copper 5 kg ha. Incase of zinc and boron also in soil application found highest loss of 175.6 and 53.76% respectively. Among all these elements manganese found net loss in all the treatments it is less than the expected balance even though it was in normal range in the soil. From this it can be concluded that in the process of cation exchange iron and manganese might have exchanged between soil complex and soil solution. Hence the net gain of iron and net loss of manganese has been observed. Zinc status in case of seed treatments found net loss than expected balance in the soil. Boron was observed net gain in all the treatments. It clearly indicates the fixation of these metals in soil clay complex and absorption on organic matter and subsequent exchange mechanisms made these elements to vary in the soil after the harvest of fennel crop. Even though utilization of applied micronutrients is highest in soil application but eventually all micronutrients are get fixed.

From study it can be concluded that deficiency of element play major role in uptake and utilization. Iron is deficit element in the present study showed the higher biomass production. Micronutrient metals such as Mn and Zn was removed in greater extent than other elements. In case of all micronutrient elements external application by soil leads to net loss of nutrients. It clearly indicates the fixation of these metals ions on soil clay complex and absorption on organic matter and leaching of metal ions.

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