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## To study the interaction effect of Fe×Mn on yield, chemical composition and nutrient uptake at various cuttings of spinach plants and grain, straw at maturity

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### Abstract

A pot experiment was conducted at pot culture yard in Department of Agricultural Chemistry and Soil Science, R.B.S. College Bichpuri, Agra (UP). To study the interaction effect of (Fe × Mn) on yields, chemical composition of plants at different growth stages and uptake of nutrients by grain and the straw at maturity by spinach crop. Four levels (0, 5, 10, 20 ppm) of each iron and manganese were evaluated in factorial design with three replications. The results indicated that the interaction of effect of (Fe × Mn) on yields was found to be significant. The maximum values (19.5, 49.0 mg/pot) of green foliage and dry matter (2.4, 5.6 mg/pot) were noted under 10 ppm Fe + 10 ppm manganese dose. The highest dose (20 ppm iron and 20 ppm manganese) reduce the yields upto minimum levels. Nutrient composition of spinach plants grain and straw in respect of N, P, Fe, Mn content was consistently increase up to (10 ppm) dose of iron and manganese level. Thereafter, a deduction was noted with higher dose (20 ppm) iron and manganese. Similar trend was noted in case of nutrients uptake by spinach plants. It is concluded from the results that (Fe × Mn) with dose of 10 ppm was found to significantly superior over rest of the combinations. Investigations also revealed that Fe and Mn has antagonistic relation in respect their content and uptake in all the growth stages of spinach plants.

**Keywords:** Interaction, Fe×Mn, chemical composition, spinach, maturity

### Introduction

In order to boost up crop production per unit area per unit time, increasing emphasis is being laid on cultivation of high yielding varieties of crops intensive cropping heavy fertilization and modern techniques of cultivation. In this context, importance of micronutrients can hardly be over emphasized as in many areas their supply in soil may become a limiting factor in obtaining maximum levels of crop yields. In several parts of the country micronutrients disorders have been recognised as major cause of crop failure and poor productivity (Takkar and Randhawa, 1978) [1]. Substantial improvement in the performance of crop have been reported as a result of micronutrient supplement of soil for crop from different parts of country (Kanwar and Randhawa, 1974, Katyal, 1986) [5, 6]. Thus the need for knowledge of micronutrients status of soil assumes still greater importance in view of increased hectare yields. Among various micronutrients, manganese is especially important owing to its typical and complex behaviour in soils besides, its vital and indispensable role in plant growth. Manganese functions in the activation of numerous enzymes concerned with carbohydrate metabolism, phosphorylation reactions and the citric acid cycle and with other metal in the activation of such enzymes as arginase, cystein, desulphydnase, deoxyribonuclease and yeast phosphatase. Apparently it is specific activator of the enzymes prolidase and glutomyl transferase. Antagonist relationship between Fe and Mn has been reported in soils and plants (Pathak *et al.*, 1979) and likewise they influence yield of crop differently. Basen and Saxena (1970) [2] and Jain (1973) obtained increased rice yield by the application of Fe and Mn. Ratios of Fe and Mn either in soil and plant have no significant impact on crop yield, only their addition in optimum concentration is of great significance (Agarwala and Associates, 1964) [1].

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Such information available in this respect, so far is rather meagre in soils of Agra. Hence the study is being undertaken with a view to study the Fe and Mn interaction of yield, their content and uptake by Spinach crop.

### Materials and Methods

A pot culture experiment was carried out using spinach crop in pot culture yard in the department of soil science and agriculture chemistry RBS College Bichpuri, Agra. The experimental soil was collected from research farm of RBS college the experimental soil was sandy loam in texture alkaline on reaction (pH 8.0) with organic carbon content 3.4 kg per hectare, available N 160 kg per hectare, available phosphorus 8.4 kg per hectare, available potassium 115 kg per hectare, total Fe extracted with HClO<sub>4</sub> (1.8%), available Fe-DTPA (4.5 ppm), total Mn (350 ppm), determined by methods of Willard and Greathouse (1917)<sup>[12]</sup>, available Mn (7.0ppm) extracted with DPTA and determined colorimetrically by Willard and Greathouse (1917)<sup>[12]</sup>. The experiment comprising four levels (0, 5, 10, 20 ppm) of iron and four levels (0, 5, 10, 20 ppm) of manganese was conducted in a factorial randomised block design with three replications in 48 pots. Forty eight earthen pots of similar size and shape were selected clean and lined with polythene sheets after mixing the soil lot thoroughly 6kg of soil was filled in each pot iron manganese were applied through ferrous sulphate and manganese sulphate respectively. The Basal doses of nitrogen Phosphorus and potassium were applied through urea single super phosphate and muriate of potash

respectively at the time of sowing. The crop was raised with recommended agronomic practices. First cutting of spinach was done after 15 days of sowing followed by second cutting 20 days after first cutting. The yield data in regard to green foliage and dry matter were recorded at first and second cuttings. The samples were analysed for nitrogen content by modified Kjeldahl method (Jakson 1973). Phosphorus in di-acid (HNO<sub>3</sub>: HClO<sub>4</sub>) digest were determined by vanadomolybdate yellow colour method and flame photometre respectively. Iron and Mn in di-acid digest were determined on atomic absorption spectrophotometer uptake of nutrients was calculated by multiplying nutrient content with their respective dry matter yield.

### Results and Discussion

#### Yield

The interaction effect of Mn×Fe on yields was found to be significant. An analysis of data given in table 1 reveals that the green foliage and dry matter yields at both cuttings and grains and straw yields of spinach at maturity were increased consistently with applied manganese under lower levels of iron. The yields of spinach were reduced under 20 ppm Mn in the absence and presence of iron. The minimum yields of spinach at different stages of growth were recorded under 20 ppm Mn and 20 ppm Fe treatment. The maximum green foliage and dry matter yields at both cuttings and grains and straw yields at maturity were noted under 10 ppm Fe and 10 ppm Mn treatment. Similar results were reported by Swarup and Mishra (1972)<sup>[10]</sup>.

**Table 1:** Green foliage, dry matter, straw yield and grain yield of spinach (g pot<sup>-1</sup>) as influenced by Fe×Mn interaction at different stages of growth and maturity

Fe levels (ppm)	Mn levels (ppm)				Mn levels (ppm)			
	0	5	10	20	0	5	10	20
<b>First cutting</b>								
	<b>Green foliage yield</b>				<b>Dry matter yield</b>			
0	16.0	16.5	16.9	15.5	1.3	1.5	1.6	1.8
5	16.6	17.6	18.0	17.6	1.5	1.8	2.0	1.8
10	17.4	19.5	20.0	17.6	1.8	2.3	2.4	1.8
20	18.4	18.8	17.0	14.5	1.8	2.0	1.7	1.0
CD @ (P=0.05)	0.49				0.148			
<b>Second cutting</b>								
	<b>Green foliage yield</b>				<b>Dry matter yield</b>			
0	40	44	50	30	4.0	4.8	5.5	4.0
5	44	46	47	35	4.7	5.1	5.5	3.9
10	46	48	49	37	4.8	5.2	5.6	3.8
20	44	44	44	35	4.5	4.6	4.5	3.5
CD @ (P=0.05)	1.42				0.152			
<b>Maturity</b>								
	<b>Straw yield</b>				<b>Grain yield</b>			
0	4.0	4.8	5.5	4.0	1.5	1.7	2.0	1.3
5	4.7	5.1	5.6	3.9	1.8	2.1	2.0	1.5
10	4.8	5.2	5.4	3.8	1.9	2.0	2.0	1.5
20	4.5	4.6	4.5	3.5	1.8	1.8	1.6	1.3
CD @ (P=0.05)	0.152				0.166			

### Chemical composition of plants at various cuttings

It is clear from the data given in table-2 that N content in plants was increased significantly with every increase in the Mn level under all the Fe levels indicating synergistic relationship between Mn and Fe in respect of N content. The maximum N content in spinach plants at all stages of growth was recorded under 20 ppm Mn and 20 ppm Fe treatment. The interaction effect of Mn×Fe on nitrogen content in spinach plants at various growth stages was found to be significant. While, the Fe×Mn interaction did not have any

significant effect on P content at all stages of growth of spinach plants. Singh and Singh (1975)<sup>[9]</sup> also reported similar findings. It is evident from the data presented in table-2 that application of iron significantly increased the iron content in spinach plants at various cuttings under all the levels of manganese. But Mn addition tended to decrease the concentration of iron in the presence or absence of iron levels. The lowest level of iron was recorded under 20 ppm Mn + 0 ppm Fe treatment indicating an antagonistic effect of Mn on iron absorption by plants at various stages of growth. The data

of table-2 reveals that Fe addition reduced the Mn content significantly under all the levels of Mn indicating an antagonistic relationship between these two elements. The adverse effect of iron on Mn content was much more pronounced in the absence of Mn addition. The lowest concentration of Mn in spinach plants at various cuttings were

noted under 0 ppm Mn + 20 ppm Fe treatment. Manganese addition on the other hand, increased its content significantly and maximum values were noted under 20 ppm Mn + 0 ppm Fe treatment. The highest levels of Mn improved its content in the presence of 20 ppm Fe dose over control but lower level of Mn (5 PPM) failed to do so.

**Table 2:** Interaction effect of Fe x Mn on chemical composition of spinach plants at various cuttings and maturity

Fe levels (ppm)	Mn levels (ppm)				Mn levels (ppm)			
	0	5	10	20	0	5	10	20
	Nitrogen (%)							
	First cutting				Second cutting			
0	2.30	2.35	2.92	2.50	1.90	1.90	1.96	2.04
5	2.32	2.35	2.46	2.55	1.90	1.90	2.00	2.04
10	2.38	2.39	2.48	2.55	1.96	1.98	2.02	2.06
20	2.40	2.45	2.52	2.57	1.98	2.06	2.07	2.10
CD @ (P=0.05)	0.02				0.025			
	Iron (ppm)							
	First cutting				Second cutting			
0	388	378	365	406	406	400	385	375
5	418	410	396	380	436	427	410	400
10	452	443	430	420	475	468	445	436
20	468	457	445	438	500	488	465	452
CD @ (P=0.05)	1.61				1.456			
	Manganese (ppm)							
	First cutting				Second cutting			
0	170	136	210	240	156	168	200	225
5	156	168	196	220	140	156	180	200
10	144	160	186	205	132	145	160	182
20	128	140	160	185	116	128	140	175
CD @ (P=0.05)	1.537				1.518			

### Chemical composition of nutrients at maturity

It is evident from data given in table-3 that nitrogen content in straw and grain increase with every increase in Mn level under all the Fe level indicating synergistic relation between Mn and Fe in respect of N content. A further study of data presented in table-3 show that applications of iron significantly increased the iron content in straw and grain at maturity under all the levels of manganese. But Mn addition caused decrement in the content of iron in presence or absence of iron levels. The lowest value of iron concentration

was noted with 20 ppm Mn + 0 ppm iron levels showing antagonistic effect of Mn on iron in straw and grain respectively. Similar trend is observed in Mn content of straw and grain that Mn concentration decrease as application of iron level increases. Minimum Mn concentration in grain and straw was recorded with 20 ppm Fe and 0 ppm Mn levels. Similar results were reported by Gangwar (1986)<sup>[3]</sup> (Lal *et al.* 2012 and Lal *et al.* 2016)<sup>[7, 8]</sup> that wheat crop responded to lower levels of iron and manganese applications. The application of iron reduced Mn content and vice versa.

**Table 3:** Nutrients content in straw and grain of spinach plants as affected by Fe x Mn interaction at maturity of crop

Fe levels (ppm)	Mn levels (ppm)				Mn levels (ppm)			
	0	5	10	20	0	5	10	20
	Nitrogen (%)							
	Straw				Grain			
0	0.75	0.75	0.80	0.80	2.15	2.15	2.20	2.32
5	0.76	0.78	0.80	0.82	2.15	2.14	2.20	2.27
10	0.78	0.80	0.80	0.84	2.20	2.20	2.24	2.28
20	0.80	0.80	0.85	0.88	2.23	2.27	2.30	2.35
CD @ (P=0.05)	0.017				0.017			
	Iron (ppm)							
	Straw				Grain			
0	396	388	375	369	275	268	252	240
5	425	418	404	390	296	290	275	265
10	460	450	433	425	230	222	208	295
20	475	467	450	440	260	250	240	230
CD @ (P=0.05)	1.345				1.415			
	Manganese (ppm)							
	Straw				Grain			
0	90	110	136	168	132	148	172	195
5	78	100	120	142	115	130	155	180
10	65	80	100	125	92	112	138	157
20	60	72	105	105	88	102	118	136
CD @ (P=0.05)	1.463				0.148			

### Nutrients uptake

The interaction effect of Fe×Mn as reflected from the data given in table 4 that an uptake in grain and straw of spinach plants increased consistently with 5 and 10 ppm Fe application in presence or absence of applied Mn. The highest level of Fe (20 ppm) failed to improve the N utilisation over 10 ppm Fe level under all the levels of manganese. Similarly Mn application also enhanced the utilisation of nitrogen. The maximum values of N uptake in straw and grain of spinach were recorded under 10 ppm Fe and 10 ppm Mn treatment. The higher levels of Fe and Mn were found to have an antagonistic effect on the utilisation of nitrogen. The interaction effect of Fe×Mn on Fe uptake as seen from table-4 that 5 and 10 ppm Mn levels increased the uptake of Fe when applied with 5 and 10 ppm Fe level in grain and straw of spinach crop. Mn application @ 20 ppm showed an adverse effect on Fe uptake by spinach grain and straw. The minimum uptake of Fe was noted under 20 ppm Mn+ 20 ppm Fe treatment. In respect of manganese it is evident from the data given in table 4 that application of 5 ppm Fe increased the uptake of Mn by spinach grain under all levels of manganese. But all the levels of iron reduced the uptake of Mn by straw in presence or absence of manganese. The higher levels of iron (10 and 20 ppm) caused a significant reduction in manganese uptake indicating and antagonistic effect. The adverse effect of higher levels of iron on Mn uptake was much more pronounced in the presence of higher levels of manganese. The lowest value of Mn uptake by spinach grain was recorded under 20 ppm Mn and 20 ppm Fe treatment. But in case of straw, the lowest value of Mn uptake was noted under 20 ppm Fe + 0 ppm Mn treatment. (Lal *et al.* 2012 and Lal *et al.* 2016)<sup>[7, 8]</sup>.

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**Table 4:** Effect of Fe and Mn interaction on the uptake of nutrients (mg pot<sup>-1</sup>) by spinach crop at maturity

Fe levels (ppm)	Mn levels (ppm)				Mn levels (ppm)			
	0	5	10	20	0	5	10	20
<b>Nitrogen</b>								
	<b>Straw</b>				<b>Grain</b>			
0	30.0	36.0	40.0	32.0	27.9	32.2	34.0	27.8
5	35.2	39.8	44.1	32.0	38.7	38.5	43.9	40.9
10	37.5	41.6	43.3	31.9	39.6	50.5	53.8	41.1
20	36.0	36.8	38.3	30.8	40.1	44.4	39.1	23.5
CD @ (P=0.05)	1.743				3.170			
<b>Iron</b>								
	<b>Straw</b>				<b>Grain</b>			
0	0.16	0.18	0.21	0.17	0.36	0.41	0.41	0.30
5	1.20	0.22	0.22	0.15	0.44	0.53	0.55	0.49
10	0.23	0.24	0.23	0.16	0.42	0.52	0.51	0.50
20	0.22	0.22	0.21	0.15	0.47	0.51	0.41	0.23
CD @ (P=0.05)	0.015				0.037			
<b>Manganese</b>								
	<b>Straw</b>				<b>Grain</b>			
0	0.36	0.53	0.75	0.64	0.17	0.22	0.28	0.24
5	0.37	0.51	0.66	0.56	0.18	0.23	0.32	0.33
10	0.32	0.42	0.54	0.48	0.17	0.26	0.34	0.28
20	0.27	0.34	0.41	0.37	0.16	0.21	0.21	0.14
CD @ (P=0.05)	0.016				0.016			

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