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Study on the Effects of Increasing Manganese Concentrations in Nutrient Solutions for Tomato and corn under High Iron Levels

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In water culture experiments with tomato and corn plants the effect of different Mn-concentrations that cover the range between deficiency and toxicity under high Fe-level was studied.

From the data obtained, it was found that 0.5, 1.0, and 10 ppm Mn are the critical, safe and toxic levels in the hydroculture, however, they are 100, 160 and 1000 ppm Mn in toma to mature leaves, respectively.

Also, it was found that 2.5, 25 and 250 ppm Mn are the critical safe and toxic levels in the water culture, however, in corn mature leaves they were 100, 800 and 3500 ppm Mn, respectively.

The problem of micronutrients deficiency in agriculture has been receiving considerable attention, since a long time. The other side of this problem is the excess of these micronutrients particularly when they reach the toxic level. The importance of this work comes from the lack in the area of research work on toxicity problems. Some researchers may misinterprete the importance of the intergration between deficiency and toxicity. Of course, the plants which suffer from toxicity by one micronutrient may be tolerant to others. Interactions, or the balance of the elements within the plant, were given a considerable attention (Bingham, 1963; Dewit, Dihkshoorn and Noggle, 1963 and Emmert, 1961).

The work presented here is designed to elucidate the effect of different Mn-concentrations that cover the range between deficiency and toxicity on tomato and corn plants under high Fe-level in water culture.

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Material and Methods

Seeds of corn were germinated in quartz sand moistened with distilled water at 24°C. After 10 days, five homogeneous seedlings (percontainer) were transplanted to Hoagland solution in 4-liter containers. The same technique has been followed to obtain proper tomato seedlings, but after 10 days, the growth of seedlings was not vigorous enough to start with, therefore, these small seedlings were supported for another 10 days with a complete nutrient solution. The level of iron used was 25 times as high as the normal Fe-concentration in Hoagland solution.

Manganese concentrations used for tomato plants were : 0, 0.05, 0.25, 0.50, 1.00, 10.00, 25.00 and 50.00 ppm Mn, while for corn plants they were :

0, 0.05, 0.25, 0.50, 2.50, 25.00, 50.00 and 250.00 ppm Mn.

Chloride was added in the form of NaCl because $Mn\,Cl_2$ in Hoagland solution was substituted with $Mn\,So_4$ to avoid the side-effect of the high level of chloride as a complementary anion.

The nutrient solution was changed weekly and maintained at PH 5.8. Containers were arranged in the growth chamber where plants grown for 30 days at a day-night temprature of 24-15°C and a 14-hour photoperiod.

After 30 days, seedlings were harvested and separated into : Younger leaves, matture leaves, stems, and roots. All plant organs were rinsed more than three times in deionized water. Plants were dried at 70°C to constant weight, and handly groun in a porcelain morter to avoid any source of contamination. Samples were wet-ashed with a mixture of nitric, perchloric, and sulfuric acids (8 : 1 : 1). Micronutrients (Fe, Mn, Zn & Cu) in the digest were measured by atomic absorption spectrophotometer. Calcium and potassium were determined by flame photometer. Phosphorus was analysed by vanadomolybdophosphoric yellow colour method.

Results and Discussion

Tomato experiment

Data in table 1 show that roots have the highest concentrations of iron, manganese, zinc, Cu and phosphorus, while the low-

TABLE 1 : Effect of increasing manganses on the distribution of certain macro - and micronutrients (mean of five replicates) in different organs of tomato under high leavel of iron.

Mn-Conc. in Hydroculture (ppm Mn)	plant organ	Micronutrients (ppm)				Macronutrients (%)		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	younger leaves	186	9	33	18	1.13	4.64	1.09
	mature leaves	172	7	33	17	1.15	4.86	1.20
	stems	63	5	71	6	0.51	6.20	0.85
	roots	3380	9	136	120	3.30	4.67	0.67
0.05	younger leaves	530	26	33	11	0.96	4.60	0.71
	mature leaves	180	22	25	9	0.88	2.30	1.04
	stems	56	15	45	4	0.63	3.36	0.76
	roots	6360	92	163	101	2.50	5.80	0.72
0.25	younger leaves	426	41	35	13	1.00	4.46	0.86
	mature leaves	208	56	26	9	0.85	2.96	0.96
	stems	68	36	37	6	0.61	6.85	0.94
	roots	8800	159	155	90	2.27	2.58	0.86
0.50	yonuger leaves	364	74	32	10	0.91	4.40	0.80
	mature leaves	124	117	29	9	0.79	5.80	1.30
	stems	48	65	58	5	0.65	6.50	0.88
	roots	9480	263	179	77	2.50	2.84	0.72
1.00	younger leaves	432	86	34	13	1.03	4.04	0.80
	mature leaves	172	169	21	9	0.92	2.98	1.20
	stems	48	84	27	5	0.64	2.84	0.80
	roots	11460	460	136	66	2.00	4.88	0.67
10.00	younger leaves	400	540	30	11	1.00	4.04	0.80
	mature leaves	128	1300	24	8	0.83	2.42	1.00
	stems	42	500	43	5	0.60	2.38	0.88
	roots	10200	2290	167	86	2.00	5.00	0.80
25.00	younger leaves	272	1170	32	12	1.06	4.10	0.72
	mature leaves	160	1660	21	11	0.93	2.38	1.08
	stems	48	1170	63	4	0.72	3.10	0.69
	roots	9000	2430	174	104	2.07	2.92	0.60
50.00	younger leaves	354	1720	26	14	0.95	3.64	0.62
	mature leaves	110	2640	26	10	0.93	2.10	1.00
	stems	47	1690	93	5	0.73	2.14	0.60
	roots	7800	3210	207	146	2.24	3.44	0.52

est levels were observed in the stems. Hara and Sonoda (1979) found that manganese and zinc are translocated into all the plant organs, while Cu and Fe are accumulated in the roots. The concentration of iron within leaves was increased by increasing manganese concentration in the hydroculture. It is worthy herewith to mention that the increase in iron concentration was clearly observed with treatments receiving lower concentrations of manganese than those receiving higher ones. Moreover, the younger leaves had higher concentration of iron, zinc, and phosphorus than the mature ones. The stems had the highest concentration of zinc as compared to the other aerial plant organs.

Generally, potassium and calcium concentrations were not affected by Mn-concentration used in the hydroculture.

In case of high iron level, the obtained dry matter yield was increased by increasing Mn-concentration in the hydroculture upto 10 ppm and then decreased. It was found from results illustrated in table 2 & 3 that high iron level could protect tomato plants from manganese hazards, where the dry matter yield obtained from the treatment receiving 50 ppm Mn was higher than that of the control. Alvarez et al. (1980) studied iron-manganese interaction in tomato plants. They found that both deficient and normal Mn-levels antagonize iron absorption, but the reverse was true manganese reached toxic values; neverthless. manganese effect was always antagonistic on iron transport. Scherer and Hofner (1980) explained that in all other cases iron and manganese didn't interfer in the uptake of each other b ythe plants.

The data obtained indicate that the uptake of zinc, copper, phosphorus, potassium, and calcium by the aerial plant organs, and the uptake of iron and magnese by roots were parallel to the dry matter yield. On the other hand, magnese uptake by the aerial parts followed Mn-concentration in the hydroculture and not the dry matter yield because the high absorption resulting from the high Mn-concentration has overshadowed the effect of the dry matter yield. The copper uptake by roots was increased with the increase of manganese in the hydroculture, but only in case of the highest concentrations.

TABLE 2 : Effect of increasing manganese on the dry matter yield and uptake of certain macro - and micronutrients (mean of five replicates) by the aerial organs of tomato under high level of iron.

Mn-concentration in hydroculture (ppm Mn)	dry matter yield g/pot	uptake ug/pot				uptake mg/pot		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	1.42	225	11	56	22	15	71	16
0.05	4.64	940	98	142	38	39	133	44
0.25	5.12	1087	250	155	46	42	212	48
0.50	6.58	910	654	238	54	51	381	75
1.00	7.33	1201	1001	173	61	63	223	79
10.00	6.63	899	6483	200	50	52	173	62
25.00	5.54	910	8222	182	52	49	152	52
50.00	4.52	531	10369	199	41	40	102	39

TABLE 3 : Effect of increasing manganese on the dry matter yield and uptake of certain macro - and micronutrients (mean of five replicates) by the roots of tomato under high level of iron.

Mn-concentration in hydroculture (ppm Mn)	dry matter yield g/pot	uptake ug/pot				uptake mg/pot		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	0.34	1322	3	46	41	11	16	2
0.05	1.00	6360	92	163	101	25	58	7
0.25	1.12	9856	178	174	101	25	29	10
0.50	1.44	13651	379	258	111	36	41	10
1.00	1.53	17534	704	208	101	31	75	10
10.00	1.53	15606	3504	256	132	31	77	12
25.00	1.21	10890	2940	211	126	25	35	7
50.00	1.01	7878	3242	209	147	23	35	5

Visual symptoms :

Control treatment :

Shoot growth varies from normal to severe stunting; leaves near shoot tips are small, rolled forward, and somewhat, chlorotic; darkbrown spots along veins or distributed sporadically on younger leaves. The same visual symptoms were observed by schreiner and Dawson (1927) and Hambridge (1941).

Treatment received 0.05 ppm Mn :

Visual symptoms of Mn-deficiency were present only on the mature leaves, and the whole tomato plants were bigger than those of the control.

Treatment received 50 ppm Mn :

The abovementioned visual symptoms of Mn-deficiency shown on plants receiving 0.05 ppm Mn were again observed to a certain limit. However, the size of leaves and roots was normal.

Treatments received 0.50 and 1.00 ppm Mn :

No clear visual symptoms were observed, normal leaves and normal growth of roots were obtained.

Treatments received 10 and 25 ppm Mn :

Visual symptoms of Mn-toxicity started to be observed. Where the whole growth was reduced, Few and small brown spots were spread on the younger leaf surfaces.

Treatment received 0.25 ppm Mn :

Visual symptoms of Mn-toxicity were clear, significant reduction in leaves, roots and length of plants was noticed, brown spots were distributed on the surface of all leaves.

Diagnosis of Mn-concentration in hydroculture and its levels in mature leaves :

From the data obtained it could be concluded that 0.5, 1.0 and 10 ppm Mn are the critical, safe, and toxic levels in the hydroculture, however, in the mature leaves were 100, 160 and 1000 ppm Mn respectively. Ward (1977) stated that Mn-toxicity symptoms probably occurred on tomato plants between 450 and 500 ppm Mn for young top leaves and between 900 and 1000 ppm Mn for older lower leaves.

Table 4 shows that regardless the level of manganese in the hydroculture, most of the intercorrelation coefficients between the uptake of the different nutrients by the whole plant and Mn-concentration in the hydroculture were positive and highly significant except with calcium which exhibited a negative correlations. Alvarez et al. (1980) concluded that Mn-Fe interaction in the shoot of tomato plants is not related at all to plant growth. They added also that Mn-Fe interation, although it does exist, cannot be easily interpreted, and it is perhaps more than a simple antagonism.

TABLE 4 : Correlation coefficients between uptake of macro - and micronutrients by the whole plant of tomato under high level of iron within all levels manganese used in the hydroculture.

Elements	Mn	Zn	Cu	P	K	Co
Fe	0.6617**	0.9466**	0.9099**	0.8599**	0.5248*	-0.5525
Mn		0.5396**	0.6325**	0.4844**	0.2884	-0.1476
Zn			0.9482**	0.8674**	0.5693**	-0.6166**
Cu				0.9215**	0.5385**	-0.4757**
P					0.4189*	-0.4471*
K						-0.4222*

* at level of 0.05
** at level of 0.01

Corn experiment

Table 5 shows that roots had the highest concentrations of iron, copper, and phosphorus. Manganese accumulation in roots was clearly observed in treatments receiving 2.50 ppm Mn or more. The data also reveal that stems had the highest concentration of zinc, but the lowest of iron, manganese, and copper. For all treatments, concentration of phosphorus was higher in stems than both in younger and mature leaves, however, Zn-concentration in the younger leaves was higher than in the mature ones except for the control treatment. Clark (1970) in an interesting work found that the nutrient concentration of corn plants varied substantially as one nutrient was varied from deficiency to excess. Scherer and Hofner (1980) indicated that Fe-

TABLE 5 : **Effect of increasing manganese on the distribution of certain macro - and micronutrients (mean of five replicates) in different organs of corn nuder high level of iron.**

Mn-Conc. in hydroculture (ppm Mn)	plant organ	micronutrients (ppm)				Macronutrients (%)		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	younger leaves	191	11	39	8	1.52	3.82	0.28
	mature leaves	161	9	42	8	1.64	5.28	0.72
	stems	127	6	81	7	2.21	6.10	0.60
	roots	4980	10	46	30	1.87	5.44	0.40
0.05	younger leaves	212	31	28	8	1.39	3.48	0.28
	mature leaves	174	32	27	6	1.63	4.64	0.60
	stems	115	24	77	6	1.96	3.66	0.40
	roots	4540	29	50	30	1.96	3.28	0.36
0.25	younger leaves	247	38	25	6	1.09	4.08	0.30
	mature leaves	178	35	23	7	1.16	3.60	0.48
	stems	130	33	53	6	1.47	5.86	0.36
	roots	5760	39	47	29	1.56	5.24	0.40
0.50	younger leaves	255	76	22	5	0.76	4.74	0.28
	mature leaves	191	67	19	7	0.95	5.20	0.52
	stems	138	60	47	5	1.14	6.10	0.42
	roots	6700	66	47	26	1.59	5.86	0.52
2.50	younger leaves	164	83	27	6	0.90	5.16	0.24
	mature leaves	122	108	17	5	0.90	5.80	0.40
	stems	70	72	59	5	1.14	5.14	0.40
	roots	7880	411	54	22	1.51	4.36	0.64
25.00	younger leaves	166	380	28	7	0.90	3.26	0.24
	mature leaves	123	800	21	7	0.95	2.22	0.36
	stems	67	420	63	7	1.13	5.92	0.36
	roots	7050	2300	45	22	1.58	5.78	0.52
50.00	younger leaves	169	643	29	8	0.88	2.04	0.20
	mature leaves	127	1069	23	9	0.89	2.04	0.36
	stems	69	689	70	6	1.09	2.56	0.28
	roots	5990	3680	49	23	1.64	2.14	0.52
250.00	younger leaves	176	2800	27	10	0.92	1.92	0.16
	mature leaves	130	3520	26	9	0.83	1.80	0.24
	stems	81	3240	76	10	1.20	2.50	0.22
	roots	6730	5680	46	63	1.10	2.28	0.28

concentration in the nutrient medium led reduced Zn-concentration and total zinc amount in both upper parts and rocts of corn.

Results in tables 6 & 7 exhibit that the uptake of iron, zinc, phosphorus, and calcium by roots, and the uptake of zinc and copper by the aerial plant organs were parallel to the obtained dry matter.

TABLE 6 : Effect of increasing manganese on the dry matter yield and uptake of certain marco - and micronutrients (mean of five replicates) by the aerial organs of corn under high level of iron.

Mn-concentration in hydroculture (ppm Mn)	dry matter yield g/pot	uptake ug/pot				uptake mg/pot		
		Fe	Mn	Zn	Cu	P	K	Ca
0.0	2.90	490	27	132	23	48	139	15
0.05	5.78	987	172	244	37	97	235	27
0.25	11.04	2153	395	318	72	131	459	44
0.50	11.77	2318	796	300	71	111	620	51
2.50	13.29	1626	1252	373	70	126	731	48
25.00	13.87	1669	8820	427	97	135	440	47
50.00	14.41	1774	12924	489	118	134	310	45
250.00	9.38	1292	31338	352	92	90	191	20

TABLE 7 : Effect of increasing manganese on the dry matter yield and uptake of certain macro - and micronutrients (mean of five replicates) by the roots of corn under high level of iron.

Mn-concentration in hydroculture (ppm Mn)	dry matter yield g/pot	uptake ug/pot				uptake mg/pot		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	0.9°	4631	9	43	28	17	51	4
0.05	1.05	4767	30	53	32	21	34	4
0.25	2.91	16762	113	137	84	45	152	12
0.50	2.99	20033	197	141	78	48	175	16
2.50	3.07	24191	1262	166	68	46	134	20
25.00	2.99	21079	6877	135	66	47	173	16
50.00	2.89	17311	10635	142	66	47	62	15
250.00	2.03	13661	11530	93	124	22	46	6

On the other hand, the uptake of phosphorus, calcium and potassium by the aerial parts didn't follow the dry matter yield, and the lowest uptake was recorded for the control as well as 250 ppm Mn treatments. Results of Mn-uptake either by roots or by the aerial organs were parallel to the concentration of manganese in the hydroculture.

Visual symptoms

Control treatment

Plants were suffering from Mn-deficiency, yellow and green striping occurred, running along the leaf. The surface area of the leaves and the volume of roots were significantly reduced. The same symptoms have also been observed by Wallance (1951).

Treatment received 0.05 ppm Mn :

Visual symptoms of Mn-deficiency were observed, but were not as clear as in the control treatment.

Treatments received 0.25 and 0.50 ppm Mn :

No clear visual symptoms of manganese defeciency were noticed, the new leaves had pale green colour, normal growth for both aerial parts and roots was obtained.

Treatments received 2.5, 25 and 50 ppm Mn :

No visual symptoms for either Mn-deficiency or Mn-toxicity were noticed. Maximum growth for both aerial parts and roots was obtained.

Treatments received 250 ppm Mn :

Clear visual symptoms of Mn-toxicity were observed, particularly on the mature leaves as longitudinal distinct bright yellow stripes, reduction of root growth was also noticed. The plants started suffering from Mn-toxicity, but after 20 days might have been adapted to the toxic level of manganese.

TABLE 8 : Correlation coefficients between uptake of macro - and micronutrients by the whole plant of corn nuder high iron level within all levels of manganese used in the hydroculture.

Elements	Mn	Zn	Cu	P	K	Ca
Fe	0.6292**	0.1127	0.8884**	0.4932**	0.2038	0.1196
Mn		-0.4160*	0.6622**	0.2204	-0.0545	0.2112
Zn			-0.0264	0.5788**	0.2572	-0.0763
Cu				0.3124	0.1293	0.0958
P					0.4678**	0.4060*
K						0.6847**

* at level of 0.05

** at level of 0.01

Diagnosios of Mn-concentration either in hydroculture and its level in the mature leaves :

From the data obtained it could be concluded that 2.5, 25, and 250 ppm Mn are the critical, safe and toxic levels in the water culture however, in the mature leaves they were 100, 800 and 3500 ppm Mn, respectively. Benac (1976) recorded that no toxicity symptoms appeared on corn leaves at manganese content of approximately 1%.

Table 8 shows that the correlation coefficient between Mn-uptake and each of iron and copper uptake was positive and highly significant. On the other hand, the correlation coefficient between manganese and zinc uptake was significantly negative.

Interaction in the absorption and utilization of iron and manganese by plants has often been interpreted as a result of an antagonism between both micronutrients (Morris and Pierre, 1948; Alam et al., 1966 and Chiu, 1967).

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دراسة عن تأثير التركيزات المتزايدة من المنجنيز على نمو الطماطم والذرة فى مزارع مائية ذات مستوى عالى من الحـــديد .

انطون اميرجـــر
معهـــد بحوث تغـــذية النبـــات
كلية الزراعة ــ جامعة ميونخ التكنولوجيـــة
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المركز القـــومى للبحوث ــ الــدقى
جمهورية مصر العربيـــة

اجريت تجربة باستخدام نباتات الطماطم والذرة النامية فى المزارع المائية المحتـــوية على مستوى عـــالى من الحديد وتركيزات متصـــاعدة من عنصر المنجنيز تراوحت بين مستوى النقص وتجاوزت حدود السمية .

ــ اظهرت النتائج انه بالنسبة لنباتات الطماطم يمكن اعتبار :

ــ تركيز ٥ر٠ جزء فى المليون منجنيز فى المحلول الغذائى هو : الحد الحرج.

ــ تركيز ٠ر١ جزء فى المليون منجنيز فى المحلول الغذائى هـــو : حـــد الأمـــان .

ــ تركيز ٠ر١٠ جزء فى المليون منجنيز فى المحلول الغذائى هو : حد السمية.
وهذه التركيزات من عنصر المنجنيز تقابل التركيزات التالية فى الأوراق تامة النضـــج :

ــ تركيز ١٠٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : الحـــد الحـــرج .

ــ تركيز ١٦٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : حـــد الأمـــان .

ــ تركيز ١٠٠٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : حـــد السمـــية .

ــ اظهرت النتائج انه بالنسبة لنباتات الذرة يمكن اعتبار :

ــ تركيز ٥ر٢ جزء فى المليون منجنيز فى المحلول الغذائى هـــو : الحـــد الحـــرج .

ــ تركيز ٠ر٢٥ جزء فى المليون منجنيز فى المحلول الغذائى هو : حـــد الأمـــان .

ــ تركيز ٠ر٢٥٠ جزء فى المليون منجنيز فى المحلول الغذائى هو : حـــد السمـــية .

وهذه التركيزات من عنصر المنجنيز تقابل التركيزات التالية فى الأوراق تامة النضج :

— تركيز ١٠٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : الحد الحرج .

— تركيز ٨٠٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : حد الأمان .

— تركيز ٢٥٠٠ جزء فى المليون منجنيز فى الأوراق تامة النضج هو : حد السمية .