252

13

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Integrated study about Deficiency and Toxicity of Manganese and Critical Levels Manganese in the Nutrient Solution for corn Grown under high Levels of zinc and Copper.

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An integrated study about deficiency and toxicity of manganese, and critical levels of manganese in the nutrient solution for corn grown nuder high levels of zinc and copper have been carried out. The role of zinc and copper in the nutritional balance and redistribution of certain nutrients in the different plant organs was also examined.

Under high Zn-level there was no significant correlation between both iron and manganses uptake, while highly significant and positive correlations were obtained between manganese and zinc and the other macro - and micronutrients.

Under high Cu-levels the highly significant and positive correlations were obtained between Mn-uptake on one hand and on the other hand of zinc and copper uptake. The same was true for the correlation and between P-uptake and both iron and copper. In addition, a significant positive and significant correlation between iron and manganese uptake was also found.

Various plant species may behave entirely differently in the same environment making it necessary to study each in detail before attempting a conclusion regarding nutritional problems. The toxicity of heavy metals to crop plants varies from one metal to another (Chino and Kitagishi, 1966) and from one crop to another (Osawa and Ikeda, 1971; and Tanaka et al., 1975). It has been observed that plants within the same species will vary in their ability to absorb micronutrients (Gorsline et al., 1968; and Munson, 1969).

The corn plant is considered to the a manganese-tolerant plant. In the literature there is no clear information concerning

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either toxic Mn-concentrations for tolerant plants or the interaction between consecutive Mn-concentration, and high level of zinc and copper.

Therefore, the present study gives information on the integration between Mn-deficiency and Mn-toxicity for crop plant when high level of zinc and copper are present. It also explains the role of zinc and copper in the nutritional balance and the redistribution of certain nutrients in the different plant organs.

Material and Methods

Seeds of corn were germinated in quartz sand moistened with distilled water. After 10 days five homogeneous seedlings were transplanted into 4 liter pots containing Hoagland solution. The concentrations used for manganese were 0, 0.5, 0.25, 2.50, 2.50, 25.00, 50.00, and 250.00 ppm. The first experiment has been carried out under high level of zinc which was 25 times as high as in the normal Hoagland solution. The second experiment was conducted under high level of copper which was also 25 times as high as in the normal Hoagland solution.

The culture solution was aereated for 1 hour every 8 hours, renewed once a week, and maitained at PH 5.8. Pots were arranged in the growth chamber where plants were grown for 30 days at a daynight temprature of 24 — 150°C at a 14-hour photoperiodicity. Each treatment has been replicated five times.

After 30 days all pots were sampled. Each time the distinction was made with ,respect to younger leaves, mature leaves stems, and roots. All the samples were rinsed more than three times with deionized water, dried at 70°C, weighed, milled by hand in a porcelain morter to avoid any source of contamination, and kept for chemical analysis. An aliquot of the milled samples was digested with nitric-perchloric-sulfuric (8 : 1 : 1) acids mixture. Iron, manganese, zinc, and copper in the digested solution were determined by atomic absorption spectro-photometer. Calcium and potassium were measured by flame photometer. Phosphorus was analysed by vanadomolybdophosphoric yellow colour method.

Results and Discussion

Experiment done under high zinc level

Results in table 1 show that roots had the highest concentration of iron, manganese, and copper, while the lowest ones were observed in the stems. Hara and Sonoda (1979) found that iron is absorbed by plants but very badly translocated. They added also that copper and iron are accumlated in the roots.

TABLE 1 : Effect of increasing manganese on the distribution of certain macro - and micronutrients (mean of five replicates) in different organs of corn grown in the presence of a high zinc level.

Mn-conc. in hydroculture (ppm Mn)	plant organ	Micronutrients (ppm)				Macronutrients(%)		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	younger leaves	115	11	78	13	1.25	5.92	0.24
	mature leaves	112	9	135	13	1.43	4.22	0.60
	stems	43	6	544	11	1.52	6.28	0.52
	roots	2300	12	714	42	1.55	5.04	0.40
0.05	younger leaves	87	20	84	11	0.96	5.72	0.22
	mature leaves	86	17	109	12	1.06	5.16	0.48
	stems	30	9	540	10	1.21	5.80	0.28
	roots	1560	29	751	38	1.31	5.64	0.28
0.25	younger leaves	82	42	95	8	0.82	4.94	0.24
	mature leaves	89	39	117	10	0.73	5.30	0.52
	stems	29	23	553	7	0.83	6.40	0.34
	roots	1760	56	855	33	1.23	4.35	0.48
0.50	younger leaves	90	45	98	8	0.73	4.74	0.24
	mature leaves	88	48	126	8	0.73	3.48	0.46
	stems	30	26	562	6	0.76	5.64	0.32
	roots	1370	67	882	26	1.05	4.24	0.40
2.50	younger leaves	43	116	129	7	0.75	4.52	0.28
	mature leaves	69	141	206	10	0.69	4.92	0.42
	stems	15	119	823	6	0.77	5.44	0.36
	roots	550	373	966	28	1.07	4.86	0.44
25.00	younger leaves	39	387	177	7	0.84	4.68	0.32
	mature leaves	62	639	255	9	0.75	5.38	0.48
	stems	13	352	734	7	0.76	6.40	0.32
	roots	608	2320	1036	39	1.23	5.02	0.54
50.00	younger leaves	49	744	113	6	0.74	2.56	0.20
	mature leaves	67	1180	207	11	0.71	4.18	0.42
	stems	16	553	711	6	0.76	6.67	0.28
	roots	1320	3860	958	28	1.80	4.74	0.68
250.00	younger leaves	67	2440	87	8	0.77	4.83	0.14
	mature leaves	87	3780	105	11	0.72	5.30	0.28
	stems	25	2310	579	8	1.00	6.25	0.24
	roots	1850	5460	811	51	2.08	5.22	0.28

Concentration of zinc and phosphorus were higher in stems than in either younger or mature leaves. Moreover, roots had the highest concentration of phosphorus particularly in control plants and treatments that received 50 and 250 ppm Mn. Therefore, it could be concluded that either under a deficient or a toxic level of manganese phosphorus has been accumulated in roots.

Generally, the increase in zinc concentration is parallelled to the increase of manganese in the hydroculture. The highest concentration of copper is observed in roots of plants that received 50 ppm Mn. Scherer and Hofner (1980) studied the interactions of into, manganese, and zinc during uptake and transport by corn, in water culture experiments. They found that in aerial patrs of corn the iron and zinc concentrations were lowered by increasing Mn-concentrations of the nutrienty solution, but the iron and zinc concentrations of the roots were increased under the same conditions. Rahimi and Bussler (1975) found that increasing Zn-concentration in the nutrient solution decreased the contents of P, Fe, Mn, and Cu in corn plants.

Data in tables 2 and 3 indicate that manganese uptake either by roots or by aerial plant organs was parallelled to its concentration in the water culture and didn't follow the dry matter yield. There was no relation between iron uptake by roots among treatment receiving more than 0.5 ppm Mn and the dry matter yield, while iron uptake by the aerial parts depended mainly its dry matter yield.

In general, uptake of zinc, copper, phosphorus, and calcium by the aerial organs has followed the dry matter yield obtained. The distributtion of a micronutrient among or between various plant parts may be more useful than a single analysis (Jones, 1972).

Visual symptoms

Control treatment o

Plants suffering from Mn-deficiency, are showing visual symptoms as pale yellow stripes on the leaf surface. Surface area

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 corn grown in the presence of high zinc level. ... ...

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	5.54	478	42	738	58	63	227	22
0.05	12.37	962	205	2078	142	131	667	48
0.25	16.79	1283	567	3229	152	129	911	72
0.50	18.24	1403	783	3761	139	134	769	70
2.50	18.84	1020	2476	5368	163	135	924	71
25.00	15.87	753	8302	5028	129	123	853	65
50.00	15.40	801	14337	4350	132	112	654	52
250.00	13.42	987	43229	2153	132	103	712	31

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 corn grown in the presence of a high zinc level. ... ...

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	0.99	2277	12	707	42	15	50	4
0.25	2.95	5192	165	2522	97	36	128	14
0.05	2.19	3416	64	1645	83	29	124	6
0.50	3.89	4329	261	3431	101	41	165	16
2.50	3.33	1831	1242	3216	93	36	162	15
25.00	3.44	2092	7981	3564	134	42	173	19
50.00	3.35	4422	12931	3209	94	60	159	23
250.00	2.83	5235	15452	2295	144	59	148	8

of the leaves and the volume of roots were reduced as a result of Mn-deficiency and high Zn-level.

Treatment receiving 0.05 ppm Mn

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

Treatment receiving 0.25 ppm Mn :

No clear visual symptoms were noticed, only the new leaves were pale-green in colour. All plants had normal growth either the aerial parts or the roots.

Tr3atments receiving 0.5 and 2.5 ppm Mn :

No visual symptoms of deficiency or toxicity were observed, the growth of the plants reached a maximum.

Treatments receiving 25 and 50 ppm Mn :

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

Treatmentd receiving 250 ppm Mn :

Cleat visual symptoms of Mn-toxicity as distinct yellow strips were noticed, particularly on the mature leaves. The plants were suffering from Mn-toxicity within the first two weeks, but after that they might have been adapted to the high manganese concentration.

Diagnosis of Mn-concentration either in the hydrocultuse or in mature leaves :

The critical, safe and toxic levels were 0.50, 2.50, and 250

TABLE 4 : Correlation coefficients between uptake of macro - and micronutrients by the whole plant of corn grown nuder a high zinc level for all levels of manganese used in the hydroculture.

Elements	Mn	Zn	Cu	P	K	Ca
Fe	0.2751	0.6597**	0.9300**	0.5234**	0.0457	0.3511*
Mn		0.4800**	0.5123**	0.6058**	0.5514**	0.6866**
Zn			0.7229**	0.5649**	0.5165**	0.5608**
Cu				0.6864**	0.1975**	0.4804**
P					0.1886	0.4243*
K						0.4226*

* at level of 0.05
** at level of 0.01

ppm Mn in the water culture, while in mature leaves they were 48, 200, 3700 ppm Mn respectively.

Table 4 shows the correlation coefficients obtained between uptake of macro-and micronutrients by the whole plant within all levels of manganese used in the hydroculture. There was no significant correlation between both iron and manganese uptake, while highly significant and positive correlations were obtained between manganese and zinc and the other macro-and micronutrients.

Experiment under high level of copper :

Data in table 5 show that the concentration of iron in leaves was increased with the increase of manganese in the water culture, however, mature leaves had higher iron concentration than the younger ones. The lowest concentration of iron and the highest concentration of zinc and potassium were observed in the stems.

In all treatments, concentration of manganese was gradually increased as a result of the consecutive manganese concentration of the hydroculture. For all treatments similar values of copper and phosphorus concentrations were noticed in the aerial plant organs among all treatments.

Results in table 6 show that the total uptake of iron, zinc, copper phosphorus, and potassium by the aerial plant organs were parallelled to the dry matter yields of these organs. Increasing the manganese concentration in the water culture between 0.5 and 50 ppm Mn didn't affect the dry matter yield, but the uptake of iron, copper and phosphorus were gradually decreased. On the other hand, increasing the concentrations of manganese within the abovementioned range has increased the uptake of zinc. Manganese uptake either by roots or aerial parts was increased according to the increase of manganese concentration in the nutrient solution.

The uptake of zinc, copper, and phosphorus by roots had approximately the same values among all treatments except for the control. It was also noticed that the uptake of iron and potas-

TABLE 5 : Effect of increasing manganese on the distribution of certain macro - and micronutrients (mean of five replicates) in different organs of corn grown under a high copper level.

Mn- conc. in hydroculture (ppm Mn)	plant organ	Micronutrients (ppm)				Macronutrients (%)		
		Fe	Mn	Zn	Cu	P	K	Ca
0.00	younger leaves	43	11	46	21	1.07	5.62	0.31
	mature leaves	49	10	48	23	1.21	4.36	0.80
	stems	15	8	78	26	1.32	6.48	0.56
	roots	1520	10	47	1420	1.52	4.22	0.43
0.05	younger leaves	42	35	37	14	0.96	5.12	0.36
	mature leaves	40	31	34	17	0.71	6.44	0.68
	stems	16	18	58	15	0.80	6.33	0.51
	roots	920	27	47	1300	1.43	5.22	0.36
0.25	yiunger leaves	42	89	34	16	0.80	5.16	0.37
	mature leaves	39	63	35	16	0.67	6.44	0.68
	stems	15	26	56	17	0.71	6.80	0.56
	roots	1030	71	48	1010	1.21	5.22	0.36
0.50	younger leaves	47	95	35	16	0.76	4.80	0.34
	mature leaves	38	88	37	16	0.68	5.45	0.61
	stems	16	39	56	16	0.85	6.16	0.56
	roots	1360	99	44	1220	1.35	5.20	0.37
2.50	younger leaves	41	164	39	16	0.72	5.08	0.32
	mature leaves	40	214	46	16	0.65	5.30	0.68
	stems	15	69	59	15	0.78	6.48	0.48
	roots	1130	243	40	1060	1.26	3.68	0.39
25.00	younger leaves	29	360	39	12	0.79	4.54	0.32
	mature leaves	37	675	54	15	0.63	5.60	0.64
	stems	14	405	59	12	0.73	6.52	0.44
	roots	544	1320	59	1080	1.11	4.36	0.40
50.00	younger leaves	30	540	40	12	0.71	4.80	0.24
	mature leaves	38	1080	55	15	0.63	5.30	0.53
	stems	14	735	65	14	0.66	6.76	0.43
	roots	517	2090	59	1250	1.03	4.88	0.40
250.00	younger leaves	32	1420	38	13	0.77	4.88	0.28
	mature leaves	40	2270	55	16	0.71	2.84	0.44
	stems	17	1680	62	17	0.92	5.88	0.28
	roots	1150	5560	63	1530	1.22	4.66	0.27

TABLE 6 : 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 corn grown nuder a high copper level.

Mn concentration in hydroculture	dry matter yield	uptake up/pot				uptake mg/pot		
(ppm Mn)	g/pot	Fe	Mn	Zn	Cu	P	K	Ca
0.00	4.48	196	46	225	101	53	223	28
0.05	11.20	417	339	426	179	82	681	65
0.25	11.83	430	772	446	191	85	724	68
0.50	12.59	476	1050	492	201	92	678	66
2.50	12.01	438	2123	551	190	83	650	65
25.00	12.26	382	6564	626	169	84	673	65
50.00	12.51	402	10923	652	175	82	672	54
250.00	7:98	273	15177	400	120	61	314	29

sium by roots didn't follow neither the dry matter yield nor the concentrations of manganese in the hydroculture Table 7.

Visual symphoms

Control Treatment

Plants were suffering from either Mn-deficiency or the high copper concentration. All plants were yellow in colour, the growth was depressed under these two abnormal conditins. The leaf surface area and growth of roots were reduced during the whole period of the experiment and all leaves were twisted.

Treatment receiving 0.05 ppm Mn :

Visual symptoms of Mn-deficiency have been masked by the effect of the high copper concentration. Hera and Sonoda (1979) stated that toxicity of copper is exceptionally strong although it is a needed micro-element for the higher plants is well known. The twisted and yellow leaves were present during the first 20 days of the experiment. Chlorosis and twisted leaves were the main visual symptoms. Plants might have been adapted to the high copper level after 20 days.

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 grown under a high copper level.

Mn concentration in hudroculture	dry matter yield	uptake ug/pot				uptake mg/pot		
(ppm Mn)	g/pot	Fe	Mn	Zn	Cu	P	K	Ca
0.00	1.06	1611	11	50	1505	16	45	5
0.05	2.20	2024	59	103	2860	31	115	8
0.25	3.31	3409	235	159	3343	40	173	12
0.50	3.00	4080	297	132	3660	41	156	11
2.50	3.11	3514	755	124	3297	39	114	12
25.00	2.93	1594	3868	173	3164	33	128	12
50.00	2.63	1357	5497	155	3288	27	128	11
250.00	1.97	2266	10953	124	3014	24	92	5

Treatments receiving 0.25, 0.50, 2.50 and 25 ppm Mn

The main visual symptoms were chlorosis and twisted leaves. Plants might have been adapted to the high copper concentration after 15 days. By the end of the experiment the chlorosis was completely vanished. The plants had a normal growth both the aerial organs and the roots.

Treatment recdeiving 50 ppm Mn

The abovementioned visual symptoms have been also observed in addition to the Mn-toxicity symptoms which started as clear yellow stripes covering the whole leaf. Manganese toxicity symptoms were obvious from the first day of the experiment.

Treatment receiving 250 ppm Mn

Manganese toxicity symptoms were very clear besides the abovementioned symptoms resulting from the high copper concentration. The growth of roots was also the least as compared to other treatments. Blaschke (1977) has studied the effects of high rates of copper on pea plants. He found that root growth was markedly reduced by 1 ppm Cu in water culture; higher ra-

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

Elements	Mn	Zn	Cu	P	K	Ca
Fe	0.4034*	0.2551	0.9255**	0.7013**	0.1844	–0.2004
Mn		0.6849**	0.5482**	0.3270	–0.0241	0.1757
Zn			0.2646	0.0884	–0.0676	0.2353
Cu				0.7926**	0.1234	–0.1469
P					–0.1069	–0.2139
K						0.1683

* at level of 0.05

** at level of 0.01

tes led to complete inhibition of elongation, and shoot growth was also inhibited.

Diagnosis of Mn-cncentrations in the hydroculture or in the mature leaves : Treatment receiving 250 ppm Mn :

The critical, safe, and toxic concentrations were 0.50, 1.00 and 50 ppm Mn in the water culture, while in the mature leaves they were 88, 150, and 1100 ppm Mn respectively.

Table 8 presents the correlation coefficients between the uptake of macro-and micronutrients by the whole plant within all levels of manganese and under a high copper concentration. It is worthy to mention here that a high copper level may disturb the relations among most of the nutrients under investigation. Highly significant and positive correlation coefficients were obtained between Mn-uptake and both the zinc and copper uptake. The same was true between the phosphorus uptake and both amounts of iron and copper. In addition, a significant positive correlation coefficient between iron and manganese uptake was also obtained.

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● دراسة متكاملة عن النقص والتسمم بعنصر المنجنيز والمستويات الحرجة لتركيز العنصر فى المحلول الغذائى بالنسبة لنبات الذرة تحت مستوى عالى من الزنك وتحت مستوى عالى من النحاس ٠

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اجريت دراسة متكاملة للتعرف على مستويات النقص والسمية بعنصر المنجنيز لنبات الذرة ، وذلك باستخدام المزارع المائية ، تارة تحت مستوى عالى من الزنك وتارة أخرى تحت مستوى عالى من النحاس ٠

تحت المستوى العالى من الزنك لم تظهر أى ارتباطات معنوية بين الحديد الممتص والمنجنيز الممتص بينما وجدت ارتباطات موجبة عالية المعنوية بين المنجنيز الممتص والزنك الممتص وبعض العناصر الكبرى والصغرى تحت الدراسة ٠

تحت المستوى العالى من النحاس امكن الحصول على ارتباط موجب عالى المعنوية بين المنجنيز الممتص وكل من الزنك الممتص والنحاس الممتص وكذلك بين الفوسفور الممتص وكل من الحديد الممتص والنحاس الممتص كما اظهرت النتائج وجود ارتباط موجب ومعنوى بين الحديد الممتص والمنجنيز الممتص ٠