4 *Egypt. J. Agron. Vol. 13, No. 1,2, PP. 41-60 (1988)*

# Distribution Pattern of Certain Macro- and Micronutrients in Different Organs of Soybean, Tomato and Corn in Relation to Different Mn-Concentrations in the Nutrient Solution

**A. Amberger, M. Yousry**
*Institute of Plant Nutrition, Withenstephan, Freising, F. R. G. and Soils and Water Use Laboratory, National Research Centre, Dokki, Cairo, Egypt.*

IN water culture experiments with soybean, tomato and corn plants the distribution pattern of certain nutrients within their different organs, in relation to different Mn-concentrations has been studied.

Correlation coefficent calculated between uptake of nutrients by the whole soybean plant indicated that there is a highly and negative correlations between Zn and each of the three elements : Fe, Cu and P.

However, within the whole tomato plants, the highly significant and negative correlation coefficients were obtained between calcium and each of the elements Fe, Mn, Zn and Cu.

Chemical analysis and visual symptoms observed during the growth of corn plants confirmed the idea that it is to be considered as a Mn-tolerant plant which could eliminate the direct effect of high Mn-concentration by an efficient and quick change and redistribution of nutrients in the different organs.

Determination of the distribution pettern of Fe, Zn, Cu, P, K, and Ca as affected by varying levels of manganese might probably explain how maganese induces a disturbance in the nutritional balance. This holds also for the lacations where manganese is located or accumulated in the plants. Plant species and varieties differ in their tolerance to excess maganese (Hewitt, 1948; Foy et al., 1967 and Loneragan, 1975). Jones (1972) recommended that there is need to describe the sufficiency concentration range, particularly at the excessive toxic levels. He also added that the distribution of a micronutrient among or between

---

This work was financed by a grant from Alexander von Humboldt Foundation, F. R. G.

various plant parts may be more useful than a single analysis.

The objective of the study reported here was to determine the effect of Mn-levels in the nutrient solution on the growth and the distribution pattern of certain elements within the plant organs of soybean, tomato and corn.

## Materials and Methods

Seeds of soybean and corn were germinated on quartz and moistened with distilled water. After ten days, homogeneous seedlings 8 cm height were transplanted into a 4 liter pots. Seeds of tomato were germinated according to the same method, but after 10 days the growth was not ready for transplanting, therefore, nutrient solution was applied to the moistened quartz sand for another 10 days to obtain the proper and homogeneous seed lings which also were transplanted in a 4 liter pots.

Hoagland solution with 8 successive Mn-concentrations were used (Table, 1). Five seedlings were transplanted in each pot and five replications of the treatments were used. The conditions in the growth chamber were :

| | |
|---|---|
| day temprature | : 24°C |
| night temprature | : 15°C |
| day humidity | : 60% |
| night humidity | : 80% |
| photoperiod | : 14 h |

After 30 days all pots were sampled. Each time a distinction was made between 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 spectrophotometer. Calcium and potassium were measured by flame photometer. Phosphorus was analysed by the vanadomolybdo phosphoric acid yellow colour method.

TABLE 1 : Manganese concentrations used in the nutrient solution for soybean, tomato and corn.

| ppm Mn | | |
|---|---|---|
| Soybean | Tomato | Corn |
| 0 | 0 | 0 |
| 0.05 | 0.05 | 0.05 |
| 0.25 | 0.25 | 0.25 |
| 0.50 | 0.50 | 0.50 |
| 1.00 | 1.00 | 2.50 |
| 5.00 | 10.00 | 25.00 |
| 10.00 | 25.00 | 50.00 |
| 25.00 | 50.00 | 250.00 |

## Results and Discussion

*Soybean experiment*

Results obtained (Table. 2) indicate that concentration of both macro-and micronutrients in the different plant organs varied for each organ. It is worth mentioning that numerous investigators have chosen one plant organ to represent the level of such element within the whole plant. Therefore, it is essential when collecting plant tissue samples that the time of sampling is known, as well as stage of growth prior to sampling. These data should be considered when interpreting the plant analysis result.

In fact, roots had the highest concentrations of iron, copper, phosphorus and potassium. Accumulation of iron was observed in the control treatment and also in the treatment receiving more than 1 ppm Mn. On the other hand, roots contained the lowest concentration of zinc. The calcium concentration was nearly the same for all treatments. Generally, manganese concentration of both roots and uper parts has followed the concentration of. manganese used in the hydroculture.

Brown and Jones (1977) studied manganese and iron toxi-

**TABLE 2 : Effect of increasing manganese on the distribution of certain macro-and micronutrients (mean of five replicates) in different organs of soybean.**

| Mn-conc. in hydroculture (ppm) | plant organ | Micronutrients (ppm) | | | | Macronutrients(%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Zn | Cu | P | K | Ca |
| | younger leaves | 156 | 8 | 105 | 8 | 1.25 | 2.55 | 0.18 |
| 0.00 | mature leaves | 126 | 13 | 98 | 7 | 2.07 | 3.20 | 0.80 |
| | stems | 42 | 7 | 107 | 11 | 1.27 | 4.52 | 0.58 |
| | roots | 3870 | 6 | 64 | 78 | 3.98 | 5.64 | 0.52 |
| | younger leaves | 106 | 38 | 93 | 9 | 1.24 | 3.21 | 0.37 |
| 0.05 | mature leaves | 201 | 47 | 106 | 8 | 1.95 | 3.18 | 0.94 |
| | stems | 45 | 18 | 86 | 10 | 1.15 | 4.40 | 0.69 |
| | roots | 2580 | 113 | 72 | 124 | 3.84 | 5.86 | 0.64 |
| | younger leaves | 211 | 81 | 109 | 9 | 1.30 | 3.17 | 0.33 |
| 0.25 | mature leaves | 217 | 136 | 106 | 8 | 1.96 | 1.92 | 0.70 |
| | stems | 56 | 31 | 105 | 11 | 1.16 | 3.68 | 0.45 |
| | roots | 2240 | 357 | 66 | 64 | 3.70 | 3.42 | 0.54 |
| | pounger leaves | 170 | 83 | 74 | 8 | 1.12 | 2.93 | 0.23 |
| 0.50 | mature leaves | 198 | 155 | 94 | 7 | 1.47 | 1.34 | 0.60 |
| | stems | 83 | 34 | 78 | 9 | 0.90 | 3.62 | 0.52 |
| | roots | 2302 | 421 | 82 | 58 | 2.94 | 3.16 | 0.50 |
| | younger leaves | 102 | 231 | 90 | 10 | 1.30 | 2.97 | 0.17 |
| 1.00 | mature leaves | 263 | 304 | 117 | 8 | 1.96 | 3.20 | 0.95 |
| | stems | 43 | 48 | 81 | 10 | 1.22 | 1.50 | 0.48 |
| | roots | 1980 | 590 | 71 | 76 | 3.48 | 4.40 | 0.57 |
| | younger leaves | 83 | 472 | 90 | 8 | 1.17 | 3.47 | 0.39 |
| 5.00 | mature leaves | 152 | 700 | 85 | 7 | 1.49 | 1.84 | 0.69 |
| | stems | 42 | 172 | 91 | 12 | 1.09 | 4.20 | 0.56 |
| | roots | 2340 | 1180 | 73 | 78 | 3.38 | 2.00 | 0.52 |
| | younger leaves | 125 | 790 | 83 | 10 | 1.26 | 3.16 | 0.35 |
| 10.00 | mature leaves | 217 | 1600 | 130 | 9 | 1.74 | 3.00 | 0.98 |
| | stems | 62 | 630 | 110 | 12 | 1.20 | 4.12 | 0.64 |
| | roots | 2140 | 1620 | 60 | 72 | 3.66 | 5.48 | 0.53 |
| | younger leaves | 105 | 1607 | 136 | 10 | 1.35 | 3.51 | 1.68 |
| 25.00 | mature leaves | 71 | 2400 | 111 | 9 | 1.63 | 2.16 | 1.40 |
| | stems | 54 | 1290 | 154 | 13 | 1.39 | 1.68 | 1.03 |
| | roots | 2480 | 2440 | 54 | 72 | 2.92 | 2.16 | 0.67 |

cities in function of the soybean variety. They found that tops of both Mn-intolerant and tolerant cultivars had similar manganese content, but manganese tolerant cultivar tops contained more potassium. The roots contained less iron than in the Mn-intolerant tops and roots.

Stems had the lowest concentration of iron, manganese and copper, while the concentration of zinc, phosphorus, potassium and calcium was nearly the same as well as in leaves. An exception is to notify for the calcium concentration which was higher in the stems than in the younger leaves. Younger leaves had lower concentration of iron, manganese. phosphorus and calcium than that of the mature ones. On the other hand, contration of zinc, copper and potassium was higher than that of the mature leaves in most of the treatments.

The uptake of macro-and micronutrients either by aerial organc or by roots (Tables, 3 and 4) was decreased when Mn-concentration in the hydroculture was increased except for the control treatment. It could be attributed to the decreased in the dry matter yield as a result of the consecutive manganese concentration being used in the water culture.

**TABLE 3 : 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 soybean.**

| 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 | 2.94 | 303 | 31 | 298 | 25 | 50 | 101 | 19 |
| 0.05 | 6.10 | 922 | 233 | 606 | 52 | 103 | 215 | 51 |
| 0.25 | 5.73 | 976 | 590 | 605 | 51 | 97 | 143 | 35 |
| 0.50 | 5.19 | 842 | 597 | 458 | 40 | 66 | 109 | 29 |
| 1.00 | 4.53 | 859 | 1023 | 475 | 39 | 77 | 122 | 35 |
| 5.00 | 3.95 | 438 | 2018 | 345 | 34 | 53 | 108 | 25 |
| 10.00 | 2.22 | 344 | 2632 | 262 | 23 | 34 | 75 | 18 |
| 25.00 | 1.61 | 111 | 3020 | 210 | 17 | 24 | 35 | 21 |

TABLE 4 : Effect of increasing manganese on the dry matter yield and uptake of certain macro - and micronutrients (mean of five replicates) by the roots of soybean.

| 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 | 0.72 | 2796 | 4 | 46 | 56 | 29 | 41 | 4 |
| 0.05 | 1.40 | 3612 | 158 | 101 | 174 | 49 | 82 | 9 |
| 0.25 | 1.32 | 2957 | 471 | 87 | 84 | 49 | 45 | 7 |
| 0.50 | 1.30 | 2993 | 547 | 107 | 75 | 38 | 41 | 7 |
| 1.00 | 1.03 | 2039 | 607 | 73 | 78 | 36 | 45 | 6 |
| 5.00 | 0.90 | 2106 | 1062 | 66 | 70 | 30 | 18 | 5 |
| 10.00 | 0.69 | 1477 | 1118 | 41 | 50 | 25 | 38 | 4 |
| 25.00 | 0.50 | 1240 | 1220 | 27 | 36 | 15 | 11 | 3 |

No definite information is available concerning the early stages of Mn-toxicity in plants. However, it has been observed by many research workers that too much available manganese in the soil or in the sand or in the water cultures harms plant growth (Jones, 1972).

*Visual symptoms :*

*Control treatment :*

Plants were suffering from Mn-deficiency, visual symptoms appeared after 11 days. The leaves were smaller than the normal ones. Branching was delayed and very limited, normal growth of roots and the length of plants was shorter than the normal ones.

*Treatments received 0.05, 0.05. 0.05 and 1.00 ppm Mn :*

No visual symptoms were observed. It means a normal growth of roots. The branching started normally after 11 days.

The length of the plants was normal, and the surface area of leaves was also normal.

*Treatment receiving 5 ppm Mn :*

Visual symptoms of Mn-toxicity appeared to one could observe twisted leaves, and few brown spots spreaded on younger leaf surfaces. The leaves were smaller than the normal one but the volume of the roots was normal.

*Treatment receiving 10 ppm Mn :*

Visual symptoms of Mn-taxicity were obvious. Twisted leaves, brown spots spreaded on younger leaf surfaces were observed. Branching started after 6 days, and narrow and small leaves were noticed. The leaf surface and growth of roots was decreased.

*Treatment receiving 25 ppm Mn :*

Visual symptoms of Mn-toxicity were very clear. Brown spots covering the whole younger leaf area were observed. Clear depression in the growth of roots, twistd and very narrow and small leaves were noticed. Branching started after 3 days.

*Diagnosis of Mn - concentrations either in hydroculture or in mature leaves :*

The critical, safe and toxic concentrations were 0.05, 0.25 and more than 1.00 ppm Mn in the water culture respectively, while in the mature leaves they were 46, 85 and more than 200 ppm Mn. Somers and Shive (1942) recorded that visual deficiency symptoms were observed on soybean plants grown in water culture when Mn-concentration ranges between 2-11 and 17-19 ppm Mn in leaves and roots respectively. They added also that visual Mn-toxicity symptoms appeared on soybean plants when Mn-concentration in leaves ranges between 173 — 999 ppm Mn.

Table 5 shows the correlation coeffcients calculated between uptake of macro-and micronutrients by the whole plant. The highly significant and negative correlations were obtained between zinc and each of the elements iron, copper and phosphorus.

TABLE 5 : Correlation coefficients bteween the uptake of macro - and micronutrients by the whole soybean plant of for all levels of manganese used in the hydroculture.

| Elements | Mn | Zn | Cu | P | K | Ca |
|---|---|---|---|---|---|---|
| Fe | 0.1456 | –0.6583** | 0.9546** | 0.7630** | 0.5652** | –0.3858** |
| Mn | | –0.0181 | 0.1474 | 0.4720** | –0.0138** | 0.4026** |
| Zn | | | –0.6878** | –0.4958** | –0.3957* | 0.5487** |
| Cu | | | | 0.7678** | 0.5886** | –0.4105* |
| P | | | | | 0.2317 | –0.0200 |
| K | | | | | | –0.3118 |

* at level of 0.05
** at level of 0.01

On the other hand, significantly positive correlations were obtained between : (a) manganese and each of The elements phosphorus and calcium (b) iron and each of the elemnts copper, phosphorus and potassium. c) copper and each of the elements phosphorus and potassium.

Data in table (6) indicate that iron is accumulated in the roots approximately 20 times more than in the other plant organs. In fact, roots contain the highest concentration of iron, magnases, zinc, copper and phosphorus and lowest concentration of calcium. Among the deficient Mn-treatments and also the toxic ones potassium concentration of roots was higher than the other plant organs compared to the normal Mn-treatments.

Resukts of leaf analysis indicated that toxic Mn-concentration of the hydroculture (more than 1 ppm Mn) was accompanied with a decrease of Fe-concentration either in the younger or in the mature leaf samples. Alvarez et al. (1980) concluded that Mn/Fe in the shoot of tomato plants is not related at all with plant growth. Manganese concentration of younger leaves was lower than that of the mature ones in all treatments. Vlamis (1967) found that the recommended Mn-concentration in Hoagland solution was toxic to barley, slightly toxic to lettuce and non toxic to tomato. It is worth mentioning that dry matter yield obtained from the highest Mn-treatment (50 ppm Mn) was

**TABLE 6 : Effect of increasing manganese on the distribution of certain macro - and micronutrients (mean of five replicates) in different organs of tomato.**

| Mn-conc. in hydroculture (ppm Mn) | plant organ | Micronutrients (ppm) | | | | Macronutrients(%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Zn | Cu | P | K | Ca |
| 0.00 | younger leaves | 152 | 9 | 40 | 21 | 0.68 | 2.22 | 0.96 |
| | mature leaves | 124 | 8 | 39 | 20 | 0.94 | 1.98 | 0.95 |
| | stems | 72 | 6 | 102 | 7 | 0.46 | 1.68 | 0.92 |
| | roots | 3900 | 11 | 264 | 164 | 1.81 | 4.04 | 0.61 |
| 0.05 | younger leaves | 102 | 43 | 30 | 14 | 0.96 | 4.00 | 1.08 |
| | mature leaves | 71 | 47 | 28 | 10 | 0.84 | 2.16 | 0.92 |
| | stems | 26 | 30 | 75 | 7 | 0.49 | 5.00 | 1.06 |
| | roots | 3120 | 41 | 260 | 107 | 1.14 | 4.40 | 0.44 |
| 0.25 | younger leaves | 85 | 84 | 29 | 13 | 0.75 | 4.12 | 0.99 |
| | mature leaves | 83 | 140 | 28 | 10 | 0.77 | 2.20 | 0.98 |
| | stems | 30 | 71 | 62 | 6 | 0.50 | 4.06 | 1.04 |
| | roots | 3000 | 400 | 219 | 95 | 1.32 | 2.30 | 0.56 |
| 0.50 | younger leves | 103 | 150 | 33 | 14 | 1.01 | 2.24 | 1.10 |
| | mature leves | 104 | 230 | 29 | 11 | 0.87 | 2.20 | 1.04 |
| | stems | 30 | 119 | 82 | 6 | 0.58 | 2.00 | 1.00 |
| | roots | 3300 | 688 | 260 | 150 | 1.50 | 2.06 | 0.57 |
| 1.00 | younger leaves | 83 | 192 | 31 | 16 | 0.80 | 4.40 | 1.04 |
| | mature leaves | 85 | 360 | 24 | 11 | 0.91 | 2.76 | 1.15 |
| | stems | 26 | 159 | 72 | 7 | 0.48 | 2.36 | 0.96 |
| | roots | 2720 | 1080 | 193 | 187 | 1.14 | 3.14 | 0.49 |
| 10.00 | younger leaves | 59 | 790 | 26 | 14 | 0.96 | 2.18 | 0.84 |
| | mature leaves | 59 | 1130 | 30 | 14 | 1.13 | 3.00 | 1.14 |
| | stems | 23 | 630 | 97 | 7 | 0.68 | 2.48 | 0.92 |
| | roots | 2380 | 2950 | 245 | 209 | 1.44 | 5.32 | 0.42 |
| 25.00 | younger leaves | 67 | 1230 | 30 | 17 | 0.85 | 4.20 | 0.96 |
| | mature leaves | 56 | 1650 | 45 | 25 | 1.36 | 3.26 | 1.08 |
| | stems | 12 | 900 | 183 | 8 | 0.68 | 4.96 | 0.84 |
| | roots | 3000 | 3700 | 300 | 321 | 1.54 | 5.84 | 0.45 |
| 50.00 | younger leaves | | | | | | | |
| | mature leaves | | | | | | | |
| | stems | | | | | | | |
| | roots | | | | | | | |

not enough to carry out the required analysis. Walace (1951) and Sherman (1957) considered tomato as a sensitive plant to manganese excess.

Samples repesenting young and mature leaves had the lowest Zn-concentration, while the younger leaves contained higher copper concentration than the mature ones except for the treatment receiving 25 ppm Mn.

In general, the phosphorus and calcium concentration of both younger and mature leaves increased when Mn-concentration of the water culture increased, while no clear trend was observed for the K-concentration.

Stems contained the lowesr concentration of iron, manganese, copper and phosphorus throughout all treatments. However, the Zn-concentration was more than that presented in leaf samples. Negative relationship was recorded between the Ca-concentration and the Mn-concentration of the water culture except for the control treatment, however, potassium didn't follow any clear trend.

The total iron uptake by the upper plant parts increased for the treatments receiving 0.0 — 0.5 ppm Mn, then it decreased with the increase of Mn-concentration in the water culture. The increase may be due to the direct effect of Mn-concentration on Fe-uptake. However, the decrease can be attributed to the decrease of dry matter yield (Table 7).

Results of Mn-uptake has followed the Mn-concentration of the hydroculture except treatment received 25 ppm Mn. This is due to the acute depression of dry matter yield. Table (8) shows the uptake of macro-and micronutrients by roots. Iron uptake by roots five times more than the uptaken by the aerial plant organs. The trend observed here showed that the increase of Fe-uptake by the upper parts was parallelled by that of the roots.

Values of Mn-uptake revealed that the increase of Mn-uptake followed the increase of Mn-concentration of the water-culture. In addition, Zn, cu, F, and Ca-uptake either by aerial parts or by roots was parallelld to the dry matter yield.

**TABLE 7 : 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.**

| 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 | 4.24 | 518 | 33 | 221 | 75 | 33 | 85 | 40 |
| 0.05 | 8.50 | 559 | 358 | 340 | 85 | 66 | 273 | 84 |
| 0.25 | 8.25 | 578 | 925 | 304 | 79 | 58 | 250 | 82 |
| 0.50 | 7.25 | 617 | 1368 | 313 | 74 | 59 | 156 | 75 |
| 1.00 | 6.16 | 433 | 1683 | 229 | 69 | 48 | 187 | 66 |
| 10.00 | 3.25 | 166 | 3002 | 143 | 40 | 32 | 87 | 33 |
| 25.00 | 1.98 | 103 | 2666 | 129 | 37 | 20 | 78 | 20 |
| 50.00 | 0.42 | | | | | | | |

**TABLE 8 : 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.**

| Mn concentration in hyroculture (ppm Mn) | dry matter yield g/pot | uptake ug/pot | | | | uptake mg/pot | | |
|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Zn | Cu | P | K | Ca |
| 0.00 | 0.68 | 2652 | 7 | 180 | 112 | 12 | 27 | 4 |
| 0.05 | 1.72 | 5366 | 71 | 447 | 184 | 20 | 76 | 8 |
| 0.25 | 1.46 | 4380 | 584 | 320 | 139 | 19 | 34 | 8 |
| 0.50 | 1.49 | 4917 | 1025 | 387 | 224 | 22 | 31 | 8 |
| 1.00 | 1.19 | 3237 | 1285 | 230 | 222 | 14 | 37 | 6 |
| 10.00 | 0.60 | 1428 | 1770 | 147 | 125 | 9 | 32 | 3 |
| 25.00 | 0.50 | 1500 | 1850 | 150 | 160 | 8 | 29 | 2 |
| 50.00 | 0.14 | | | | | | | |

*Visual symptoms*

*Control treatment*

Visual symptoms of Mn-deficiency were very clear. Pale yellow spots were distributed in a reticulate pattern on the leaf surfaces. Growth of roots and size of leaves were smaller than normal.

*Treatments receiving 0.05, 0.25 and 0.05 ppm Mn :*

No visual symptoms were observed. A normal growth and normal size of leaves were observed.

*Treatment receiving 1 ppm Mn :*

No clear visual symptoms were noticed, but generally, the whole growth of plants was smaller than normal.

*Treatment receiving 10 ppm Mn :*

Toxicity symptoms started as a gradual reduction in the leaf surface area which was yellowish (pale) green in colour. Erkama (1950) stated that excess manganese may induce Fe-deficiency in addition to producing direct toxic effects similar to Mn-deficiency.

*Treatment receaiving 25 ppm Mn :*

Plants were nearly about half the size compared to those of treatment received 10 ppm Mn. Plants were suffering from Mn-toxicity. Toxicity symptoms appeared as a reduction of the whole growth.

*Treatment receiving 50 ppm Mn :*

Toxicity symptoms were very acute, plants wlre very small. The colour of leaves was pale yellow, and the size of plants was the half of those receiving a treatment of 25 ppm Mn. The yellow colour has started from the leaf edge to the middle. The growth of roots was very limited. The yield of dry matter obtained was not enough to do the required analysis.

*Diagnosis of Mn - concentration either in hydroculture or in mature leaves*

The critical, safe and toxic concentration were 0.05, 0.25, and more than 0.50 ppm Mn in the water culture respectively while in the mature leaves they were 47, 95 and more than 250 ppm Mn. Lyon et al. (1943) and Nicholas (1946) found already deficiency symptoms on tomato plants grown in water culture when Mn-concentration in leaves was 5 - 7 ppm Mn. 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 (9) illustrates correlation coefficients calculated between uptake of macro-and micronutrients by the whole plant. Highly significant and positive correlation coefficients were obtainted between :

a) manganese and each of the elements iron, zinc, copper and phosphorus,

b) iron and each of the elements zinc, copper and phosphosrus. On the other hand, highly significant and negative correlation were obtained between calcium and each of the elements iron, manganese, zinc and copper.

*Experiment of corn*

Table (10) shows that iron, manganese, and copper concentration of roots was the highest compared to upper plant organs. It can be concluded that iron being accumulated in roots. It was about 40 times more than the aerial parts. Alvarez et al. (1980) reported that Mn/Fe interaction, although it does exist, in praxis cannot be easily put forward. It is perhaps more than a simple antagonism. Phosphorus concentration of roots was higher than other parts of the plant except for the control treatment. However, potassium concentration was lower in he roots than in the aerial organs. Results of calcium concentration has not yielded a clear **trend.**

Data on iron concentration of leaf samples showed similar values for younger and mature leaves. Proportionally, the Fe-content in the control treatment was the highest, while the treat-

TABLE 9 : Correlation coefficients between uptake of macro - and micronutrients by the whole tomato plant for all levels of manganese used in the hydroculture.

| Elements | Mn | Zn | Cu | P | K | Ca |
|---|---|---|---|---|---|---|
| Fe | 0.7040** | 0.9410** | 0.9015** | 0.5028** | 0.3423 | -0.8096** |
| Mn | | 0.6812** | 0.9198** | 0.6875** | 0.2885 | -0.6163** |
| Zn | | | 0.8527** | 0.3672* | 0.4419* | -0.7506** |
| Cu | | | | 0.6254** | 0.3515* | -0.8106** |
| P | | | | | -0.0745 | -0.3394 |
| K | | | | | | -0.2587 |

* at level of 0.05.
** at level of 0.01.

ment received 25 ppm Mn-had the lowest Fe-concentration. Mature leaf samples had higher Mn-concentration than the younger ones, but in both leaf samples Mn-concentration.

Increased in a parallel was as the increase of Mn-concentration used in the water culture. Results of the copper analysis indicate that both mature and younger leaves had approximately the same lecel of concentration. However, Zn-concentration was the lowest in leaf samples compared to the other organs. The younger leaves had a higher phosphorus concentration than the mature ones except for the control treatment. In general, calcium and potassium concentration was decreased when manganese concentration of the water culture was increased.

The lowest concentration of iron and manganese was observed in stem samples, however, it had the highest concentration of zinc and potassium. Results of copper and calcium indicated that stems had nearly the same concentration as well as in leaf samples.

It is well known that the corn plant is considered as a tolerant plant for high Mn-concentration. Several investigators have

TABLE 10 : **Effect of increasing manganese on the distribution of certain macro - and micrountrients (mean of five replicates) in the fifferent organs of corn.**

| Mn-conc. in hydroculture (ppm Mn) | plant organ | Micronutrients (ppm) | | | | Macronutrients(%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Zn | Cu | P | K | Ca |
| 0.00 | younger leaves | 126 | 11 | 39 | 12 | 1.16 | 3.98 | 0.20 |
| | mature leaves | 117 | 11 | 38 | 12 | 1.22 | 5.86 | 0.50 |
| | stems | 56 | 8 | 140 | 10 | 1.73 | 6.42 | 0.48 |
| | roots | 3220 | 10 | 105 | 62 | 1.10 | 5.28 | 0.36 |
| 0.05 | younger leaves | 70 | 29 | 36 | 11 | 0.89 | 5.64 | 0.26 |
| | mature leaves | 85 | 39 | 44 | 9 | 0.66 | 4.88 | 0.38 |
| | stems | 25 | 19 | 120 | 11 | 1.12 | 4.80 | 0.40 |
| | roots | 2340 | 37 | 104 | 57 | 1.14 | 4.88 | 0.96 |
| 0.25 | younger leaves | 69 | 53 | 41 | 10 | 0.91 | 3.42 | 0.24 |
| | mature leaves | 81 | 52 | 47 | 10 | 0.75 | 2.00 | 0.36 |
| | stems | 27 | 36 | 116 | 10 | 1.03 | 5.50 | 0.24 |
| | roots | 2680 | 135 | 109 | 60 | 1.21 | 2.98 | 0.40 |
| 0.50 | younger leaves | 79 | 66 | 42 | 8 | 0.74 | 2.30 | 0.24 |
| | mature leaves | 84 | 61 | 38 | 9 | 0.63 | 3.32 | 0.42 |
| | stems | 29 | 43 | 151 | 8 | 0.92 | 5.10 | 0.32 |
| | roots | 2480 | 410 | 137 | 48 | 1.40 | 2.30 | 0.46 |
| 2.50 | younger leaves | 54 | 117 | 38 | 10 | 0.84 | 4.52 | 0.24 |
| | mature leaves | 79 | 167 | 38 | 9 | 0.69 | 4.08 | 0.50 |
| | stems | 22 | 62 | 101 | 9 | 0.87 | 3.14 | 0.32 |
| | roots | 1960 | 1020 | 95 | 52 | 1.03 | 1.92 | 0.66 |
| 25.00 | younger leaves | 55 | 420 | 43 | 10 | 0.85 | 1.60 | 0.24 |
| | mature leaves | 59 | 653 | 37 | 8 | 0.54 | 1.52 | 0.24 |
| | stems | 18 | 371 | 140 | 10 | 0.97 | 2.44 | 0.24 |
| | roots | 2100 | 2740 | 84 | 54 | 1.29 | 2.82 | 0.80 |
| 50.00 | younger leaves | 67 | 680 | 37 | 8 | 0.87 | 2.54 | 0.22 |
| | mature leaves | 72 | 1036 | 32 | 7 | 0.36 | 2.04 | 0.28 |
| | stems | 23 | 718 | 117 | 8 | 1.02 | 2.56 | 0.26 |
| | roots | 2280 | 5140 | 95 | 51 | 1.38 | 2.00 | 0.44 |
| 250.00 | younger leaves | 61 | 2080 | 40 | 10 | 0.91 | 1.84 | 0.16 |
| | mature leaves | 92 | 2430 | 41 | 11 | 0.71 | 2.10 | 0.24 |
| | stems | 26 | 2190 | 144 | 11 | 1.06 | 3.98 | 0.16 |
| | roots | 2880 | 7720 | 116 | 80 | 1.54 | 1.78 | 0.22 |

reported that Mn-tolerance is associated with a reduced Mn-uptake and/or transport to plant tops (Ouellette and Dessureaux, 1958; and Andrew and Hegarty. 1969.

Table 11 shows that the positive effect of the Mn-concentration used in the water culture was efficient till 2.50 ppm Mn. The dry matter yield was decreased among the treatment receiving more than 2.50 ppm Mn, but it was alawys more than that obtained from the control. Again, in spite of the decrease of dry matter yield among treatments receiving high Mn-concentration the uptake of iron, copper, and phosphorus was increased. On the other hand, the lower the uptake of potassium the higher the concentration of manganese was in the water culture. It can be suggested that the Mn-uptake, either by the aerial plant organs or by roots is an indicator of the Mn-concentration used in the hudroculture.

Table 12 illustrates the uptake of macro-and micronutrients by the roots. It can be concluded that the uptake of iron, zinc, and copper follows the dry matter yield.

**TABLE 11 : 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.**

| Mn concentration in hydroculture (ppm Mn) | dry matter yield g/pot | uptake ug/pot | | | | uptake mg/pot | | |
|---|---|---|---|---|---|---|---|---|
| | | Fe | Mn | Zn | Cu | P | K | Co |
| 0.00 | 7.04 | 775 | 74 | 387 | 82 | 90 | 375 | 22 |
| 0.05 | 10.37 | 719 | 334 | 572 | 104 | 85 | 530 | 33 |
| 0.25 | 11.75 | 813 | 583 | 668 | 118 | 98 | 344 | 38 |
| 0.50 | 13.33 | 962 | 782 | 811 | 115 | 95 | 458 | 44 |
| 2.50 | 15.31 | 947 | 2056 | 752 | 142 | 117 | 618 | 68 |
| 25.00 | 14.64 | 723 | 7944 | 859 | 130 | 102 | 252 | 35 |
| 50.00 | 14.63 | 895 | 12696 | 727 | 110 | 114 | 335 | 37 |
| 250.00 | 11.45 | 846 | 26300 | 633 | 123 | 93 | 262 | 28 |

**TABLE 12 : 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.**

| 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 | 1.43 | 4605 | 14 | 150 | 89 | 16 | 76 | 5 |
| 0.05 | 2.00 | 4680 | 74 | 208 | 114 | 23 | 98 | 19 |
| 0.25 | 2.73 | 7316 | 261 | 298 | 164 | 33 | 81 | 11 |
| 0.50 | 3.33 | 8258 | 1365 | 456 | 160 | 47 | 77 | 15 |
| 2.50 | 3.49 | 6840 | 3560 | 332 | 181 | 36 | 67 | 23 |
| 25.00 | 3.96 | 8316 | 10850 | 333 | 214 | 51 | 112 | 32 |
| 50.00 | 3.07 | 7000 | 15780 | 292 | 157 | 42 | 61 | 14 |
| 250.00 | 2.20 | 6336 | 16984 | 255 | 176 | 34 | 39 | 5 |

*Visual symptoms*

*Control treatment*

Visual symptoms of Mn-deficiency were observed as yellow stripes on the leaf surface. The leaf area and the volume of the roots were significantly reduced through the Mn-deficiency.

*Treatments receiving 0.05, 0.25 and 0.50 ppm Mn*

No clear visual symptoms of Mn-deficiency could be observed, the new leaves were pale green. The leaf area and volume of the roots were larger than those of the control.

*Treatments receiving 2.5 and 25 ppm Mn*

No clear visual symptoms could be observed either on the side of the Mn-deficiency or on side of the toxicity. The growth of leaves and roots reached a maximum.

*Treatments receiving 50 and 250 ppm Mn*

Visual symptoms of Mn-toxicity were noticed as a longtudi-

TABLE 13 : Correlation coefficients between uptake of Macro - and micronutrients by the whole plant of corn for all levels of manganese used in the hydroculture.

| Elements | Mn | Zn | Cu | P | K | Ca |
|---|---|---|---|---|---|---|
| Fe | 0.5309** | 0.6673** | 0.9880** | 0.4460* | -0.1889 | 0.4137* |
| Mn | | 0.0638 | 0.5974** | 0.2167 | -0.0481 | 0.2392 |
| Zn | | | 0.6672** | 0.6613** | -0.0838 | 0.2960 |
| Cu | | | | 0.5022** | -0.1424 | 0.4261* |
| P | | | | | 0.2938 | 0.0464 |
| K | | | | | | -0.0748 |

* at level of 0.05
** at level of 0.01

nal distinct bright yellow stripes along the surface. The surface area of The Leaves and size root were also significantly reduced.

*Diagnosis of Mn-concentration either in hydroculture or in mature leaves*

The critical, safe and toxic concentrations were 2.5, 5.0 and 50 ppm Mn in the water culture respectively, while in the mature leaves they were 160, 400 and 1300 ppm Mn. Benac (1976) recorder that no toxicity symptoms appeared on corn leaves at Mn-content of approximately 1%.

Table 13 illustrates the correlation coefficients calculated between uptake of macro-and micronutrients by the whole plant. Significant and positive correlations were obtained between : a) Fe-uptake and the other elements under investigation except potassium, b) P-uptake and each of the elements Fe, Zn and copper. Manganese uptake was significantly correlated with the copper, content.

It can be concluded that Mn-tolerant plants can eliminate the direct effect of the high Mn-concentration by an efficient and quick change of the nutrient balance.

## References

Alvarez-Rinaut, M. C.; A. Leal and L. Realde Martinez (1980) Iron-manganese interation and its relation to boron levels in tomato plants. Plant and Soil 55, 377-388.

Andrew, C. S. and M. P. Hegarty (1969) Comparative responses to manganese excess in eight tropical and four temperate pasture legume species. Aust. J. Agric. Res. 20, 687-696.

Benac, R. (1976) Response of sensitive (Arachis hypogaea) and a tolerant (Zea mays) species to different concentrations of manganese in the environment. Cahiers ORSTOM 11, 43-51. c. f. Soils and fertilizers 40, 2084. 1977.

Brown, J. C. and W. E. Jones (1977) Manganese and iron toxicities dependent on soybean variety. Communications in Soil Sci. and Plant Analysis 8, 1-15.

Erkama, J. (1950) The effect of copper and manganese on the iron status, of higher plants. In Trace elements in plant physiology, P. 53-62. Frans Verdoorn (ed.). Pub. by the Chronica Botanica Company, Waltham, Massachusetts.

FOY, C. D.; A. L. FLEMING; G. R. Burns and W. H. Armiger (1967) Characterization of diffrential aluminum tolerance tolerance among varieties of wheat and barley. Soil Sci. Soc. Amer. Proc. 31, 513-521.

Hewitt, E. J. (1948) Relation of manganese and some other metals to the iron status of plants. Nature 161, 489-490.

Jackson, W. A. (1967) Phsiological effects of soil acidity. In : R. W. Pearson and F. Adams (ed.) Soil Acidity and Liming. Agronomy 12. 43-124.

Jones, J. B. (1972) Plant tissue analysis for micronutrients P. 319-345. In : J. Mortvedt; P. M. Giordano and Lindsay (ed.) Micronutrients In Agriculture. Soil Sci. Soc. Amer. Inc. Madison, Wisconsin, USA.

Lockard, R. G. (1959) Bull. 108 Dept. Agric. Malaya F. M. S. P. 148. c. f. J. Mertvedt; P. M. Giordano and L. Lindsay (ed.). Micrountrients In Agriculture. In Agriculture. Soil Sci. Soc. Amer. Inc. Madison, Wisconsin, USA.

Loneragan, J. F. (1975) The avilability and absorption of trace elements in soil-plant systems and their relation to the movement and concentrations of trace elements in plants. Trace Elements In Photosynthesis (ed.) D. J. D. Nicholas and A. R. Egan P. 109-134. Academic, New York.

Lyon, C. B.; K. C. Beeson and C. H. Ellis (1943) Effects of micronurient dificiencies on growth and vitamin content of the tomato. Bot. Gaz. 104, 495-514.

Nicholas, D. J. D. (1946) Detection of manganese deficiency in plant tissue tests, using tetramethly diamino diphenyl methane. Nature, 157 : 696.

Sherman, G. D. (1957) Manganese and soil fertility. In : "Soil" P. 135-139. U. S. Agric. Yearbook.

Somers, I. I. and J. W. Shive (1942) The iron- manganese relation in plant metabolism. Plant Physiol. 17, 582-602.

Ouellettte, G. J. and L. Dessureaux (1958) Chemical composition of alfalfa as related to degree of tolerance to manganese and aluminum. Canad. J. Plant Sci. 38, 206-214.

Vlamis, J. and D. E. Williams (1967) Manganese and silicon interactions in the gramineae. Plant and Soil 27, 131-140.

Wallace, T. (1951) "The Diagnosis of Mineral Deficiencies in Plants by Visual Symptoms". (2nd edition) H. M. Stationery Office, London.

Ward, G. M. (1977) Manganese deficiency and toxicity in greenhouse tomato. Canad. J. Plant Sci. 57, 107-115.

Received in 26/1/1987
in revised form 25/12/1988)

# نظام توزيع بعض العناصر المغذية الكبرى والصغرى فى مختلف اعضاء نباتات فول الصويا والطماطم والذرة تحت ظروف التركيزات المختلفة من عنصر المنجنيز فى المحلول الغذائى

**انطون امبرجر**
معهد بحوث تغذية النبات
جامعة ميونيخ التكنولوجية
جمهورية المانيا الاتحادية

**محمد يسرى**
قسم الأراضى واستغلال المياه
المركز القومى للبحوث
الدقى — القاهرة — جمهورية مصر العربية

تمت دراسة نظام توزيع بعض العناصر المغذية الكبرى والصغرى فى مختلف أعضاء نباتات فول الصويا والطماطم والذرة النامية فى مزرعة مائية تحت ظروف تركيزات مختلفة من عنصر المنجنيز تراوحت بين مستوى النقص فى العنصر ومستوى السمية .

أظهرت النتائج وجود ارتباطات سالبة ومعنوية بين الزنك وكل من الحديد والنحاس والفوسفور .

فى حالة نبات الطماطم ( كوحدة متكاملة ) أظهرت النتائج وجود ارتباط سالب عالى المعنوية بين الكالسيوم وكل من الحديد والمنجنيز والزنك والنحاس .

تمت متابعة أغراض النقص والسمية على النباتات النامية فى المزارع المائية وذلك بالعين المجردة ومن خلال التحليلات الكيمائية التى اكدت ان النباتات المقاومة للتركيزات العالية من المنجنيز هى التى يمكنها تلافى الاثر المباشر للتركيز العالى من العنصر وذلك بسرعة توزيعه على على مختلف أعضاء النبات .