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# EXCESS TRACE METAL EFFECTS ON CALCIUM DISTRIBUTION IN PLANTS

KEY WORDS: Phytotoxicity, calcium, nickel, cadmium, lithium, manganese, vanadium, silver, molybdenum, metal interations

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## ABSTRACT

One of the most important roles of Ca in plants is that of protecting against toxicities of trace metals. Even though this is a function of Ca, at least some of the trace metals in excess do inhibit uptake and/or translocation of Ca. Managanese, when supplid at a very high level to bush beans (Phaseolus vulgaris L. cultivar Improved Tender-green) in solution culture, decreased Ca concentration in leaves, stems, and roots. The inhibition was pronounced for 10(E-3) and 10(E-2) M Mn. The decrease for the latter was 76% for leaves, 61% for stems, and 49% for roots. Molybdenum at 10(E-3) M decreased bush bean leaf, stem, and root concentrations of Ca by 38%, 24%, and 16%, respectively. Vanadate at 10(E-5) M decreased bush bean concentrations of Ca in leaves, stems, and roots by 37%, 50%, and 11%, respectively. Silver at 10(E-5) M decreased Ca in leaves by 67%. Cadmium at 10(E-4) M decreased leaf, stem, and root Ca by 76%, 28%, and 61%, respectively. Lithium at 50 ppm in soil decreased yields of bush beans by 75%, but had no effect on Ca in the shoots. In soil, 500 ppm Li decreased shoot yield of barley (Hordeum vulgare L. cultivar Atlas 57) by 66% and Ca concentration by 72%. Nickel (2 X 10(E-5) M) decreased Ca concentration in bush bean leaves by 45% at 10(E-4) M Ca, 42% at 10(E-3) M Ca, and 33% at 10(E-2) M Ca. In roots the reductions were 35%, 43%, and 44%, respectively. Decreased uptake of Ca caused by excess trace metals could increase their phytotoxicity.



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Calcium protects plants against imbalances and excesses of trace metals (4,7). Plants may even have a lower need for Ca if certain trace metals are present in low concentrations(5). The level of Ca needed for maximum growth may approach micronutrient levels under such conditions(2). The purpose of this paper is to show that excess trace metals can depress Ca uptake by plants. An implication is that if Ca is in low supply when excesses of some trace metals are present, phytotoxicity could be increased because of depressed Ca uptake resulting in an even lower Ca concentration in plants.

## MATERIALS AND METHODS

The data presented in this paper are largely a review of information published elsewhere(1). Experimental details are available there and are very briefly outlined with results. The plants were grown in solution culture in a glasshouse except for one experiment with Li which was in Yolo loam soil of pH 6. The pH of solutions was near 5. Mineral analyses of plants were made by emission spectrography. There were 4 replications for all treatments.

## RESULTS AND DISCUSSION

When bush bean plants were grown in 3700 ml nutrient solutions for 21 days with 10(E-5), 10(E-4), 10(E-3), and 10(E-2) M $MnSO_4$, yields were decreased for 10(E-3) and 10(E-2) M $MnSO_4$ Table 1). The Mn concentrations of plant parts were over 1% of dry

TABLE 1

Effect of $MnSO_4$ in solution culture on Mn and Ca Concentrations and yields for bush beans (dry weight basis).

| $MnSO_4$ | Yield | Mn | Ca | Yield | Mn | Ca |
|---|---|---|---|---|---|---|
| M | mg/plant | µg/g | % | mg/plant | µg/g | % |
| | Leaves | | | Roots | | |
| 10(E-5) | 1420 | 167 | 2.80 | 330 | 788 | 0.70 |
| 10(E-4) | 1175 | 993 | 2.55 | 292 | 1870 | 0.79 |
| 10(E-3) | 524 | 5140 | 1.88 | 156 | 7870 | 0.54 |
| 10(E-2) | 235 | 10790 | 0.68 | 39 | 11640 | 0.36 |
| LSD .05 | 180 | 2730 | 0.27 | 95 | 1734 | 0.13 |



wieght for the highest Mn level and this exceeded the Ca concentrations. The Ca concentrations in leaves, stems, and roots were depressed by Mn; at the highest Mn level the depressions were 76% for leaves, 61% for stems, and 49% for roots. Similar results, although not as great, were obtained for plants grown in soil.

When bush bean plants were grown for 14 days in 3700 ml nutrient solutions with levels of applied $H_2MoO_4$ at 0, 10(E-4), 2 X 10(E-4), and 10(E-3) M, yields were depressed for the applied Mo (Table 2) and Ca was depressed at the highest concentration of Mo by 38%, 24%, and 16% in leaves, stems, and roots, respectively.

When bush beans were grown in solution culture for 14 days with 0, 10(E-6), 10(E-5), and 10(E-4) M levels of applied $NH_4VO_3$, yields were depressed for the highest level of vanadate (Table 3) and Ca levels in leaves, stems, and roots were decreased 37%, 50%, and 11%, respectively.

When bush beans were grown in solution culture for 13 days with 0, 10(E-6), and 10E-5) M levels of applied $AgNO_3$, yields were depressed for both Ag rates and Ca was depressed in leaves by 67% at the high level (Table 4).

When bush beans were grown for 15 days in solution culture with 0, 10(E-6), and 10(E-4) M $CdSO_4$, yields were depressed

TABLE 2

Effect of $H_2MoO_4$ in solution culture

and Mo and Ca concentrations in bush bean plants.

| Mo | Yield | Mo | Ca | Yield | Mo | Ca |
|---|---|---|---|---|---|---|
| M | g/plant | µg/g | % | g/plant | µg/g | % |
| | Leaves | | | Roots | | |
| 0 | 2.28 | 0.2 | 2.04 | 0.44 | 3 | 0.64 |
| 10(E-4) | 1.48 | 189 | 2.48 | 0.39 | 3990 | 0.81 |
| 2X10(E-4) | 1.64 | 322 | 2.09 | 0.38 | 3250 | 0.74 |
| 10(E-3) | 0.42 | 710 | 1.26 | 0.10 | 5920 | 0.54 |
| LSD .05 | 0.35 | 133 | 0.30 | 0.10 | 2120 | 0.14 |

TABLE 3

Effects of $NH_4VO_3$ on yields and Mo and V concentrations of bush beans grown in solution culture (dry weight basis).

| $NH_4VO_3$ | Yield | V | Ca | Yield | V | Ca |
|---|---|---|---|---|---|---|
| M | g/plant | µg/g | % | g/plant | µg/g | % |
| | Leaves | | | Roots | | |
| 10(E-6) | 0.91 | 0 | 2.58 | 0.24 | 40 | 0.54 |
| 10(E-5) | 0.76 | 0 | 1.72 | 0.13 | 216 | 0.59 |
| 10(E-4) | 0.40 | 13 | 1.42 | 0.07 | 881 | 0.49 |
| LSD .05 | 0.20 | - | 0.33 | 0.06 | 24 | 0.17 |

TABLE 4

Effects of $AgNO_3$ on yields and Ag and Ca concentrations of bush beans grown in solution culture (dry weight basis).

| $AgNO_3$ | Vegetative | Ag in | Ca in | Ag in |
|---|---|---|---|---|
| M | yield | leaves | leaves | roots |
| | g/plant | µg/g | % | µg/g |
| 0 | 1.40 | 0.2 | 2.88 | 1 |
| 10(E-6) | 0.59 | 1.0 | 2.61 | 83 |
| 10(E-5) | 0.21 | 5.8 | 0.94 | 760 |
| LSD.05 | 0.09 | 1.8 | 0.39 | 14 |

strongly at the high level (Table 5) and Ca concentrations of leaves, stems, and roots by 76%, 28%, and 61%, respectively.

Barley plants were grown in Yolo loam soil for 10 days with 0, 500, and 1000 ug Li as Li oxalate per g soil. Yields and Ca concentrations of shoots were greatly depressed by high Li levels (66% and 72%, respectively for 500 ug Li per g soil) (Table 6).



TABLE 5

Effect of $CdSO_4$ on yields and Cd and Ca concentrations of bush beans grown in solution culture (dry weight basis).

| $CdSO_4$ | Yields | Cd | Ca | Yields | Cd | Ca |
|---|---|---|---|---|---|---|
| M | g/plant | µg/g | % | g/plant | µg/g | % |
| | Leaves | | | Roots | | |
| 0 | 1.75 | ND | 2.25 | 0.48 | 22 | 0.59 |
| 10(E-6) | 1.55 | ND | 1.96 | 0.44 | 136 | 0.58 |
| 10(E-4) | 0.11 | ND | 0.55 | 0.04 | 1190 | 0.23 |
| LSD .05 | 0.10 | - | 0.51 | 0.11 | 484 | 0.08 |

TABLE 6

Effect of Li oxalate on yields and Li and Ca in barley plants grown in Yolo loam soil (dry weight basis).

| Li | Shoot | Shoot | Shoot |
|---|---|---|---|
| | yield | Li | Ca |
| µg/g soil | g/plant | µg/g | % |
| 0 | 0.254 | 2 | 1.04 |
| 500 | 0.087 | 1131 | 0.29 |
| 1000 | 0.073 | 1733 | 0.20 |
| LSD .05 | 0.092 | 319 | 0.12 |

Bush beans were grown for 21 days in nutrient solution with varying levels of Ca and Ni (Table 7). Yields were depressed somewhat more by Ni at a low level of Ca than at a high level. A level of 2 X 10(E-5) M Ni depressed Ca in bush bean leaves by 45%, 42%, and 33%, respectively, for Ca levels of 10(E-4), 10(E-3), and 10(E-2) N. In roots the reductions were 33%, 43% and 44%. In

TABLE 7

Effects of Ni on yields and Ni and Ca concentrations of bush beans grown in solution culture (dry weight basis).

| Ca N | Ni M | Yield g/plant | Ni µg/g | Ca % | Yield g/plant | Ni µg/g | Ca. % |
|---|---|---|---|---|---|---|---|
| | | Leaves | | | Roots | | |
| (E-4) | 0 | 1.63 | 2 | 0.31 | 0.44 | 2 | 0.23 |
| | 2X10(E-5) | 0.52 | 95 | 0.17 | 0.08 | 531 | 0.15 |
| 10(E-3) | 0 | 1.96 | 2 | 1.09 | 0.44 | 2 | 0.30 |
| | 2X10(E-5) | 0.52 | 99 | 0.67 | 0.12 | 408 | 0.17 |
| 10(E-2) | 0 | 1.92 | 0 | 3.02 | 0.41 | 2 | 0.62 |
| | 2X10(E-5) | 0.98 | 45 | 2.03 | 0.21 | 4100 | 0.35 |
| LSD .05 | | 0.23 | 6 | 0.18 | 0.06 | 30 | 0.08 |

leaves the Ni depressed Ca less at the high level of Ca, than at the low, but this effect did not hold in roots. The results for leaves together with the greater yield decrease for the low Ca level indicate that a possible explanation for the interaction resulting in greater yield decrease at the low Ca level than at the high is the depressed Ca uptake in the presence of the high level of the trace metal Ni.

Since so many trace metals, when in excess, decreased Ca uptake, the result may be one of impaired membrane permeability resulting in leakiness. The results which were not specific, could be caused by a number of trace metals which could cause derangement of the membrane structure. In some cases, the levels of K and/or Mg are also decreased together with the Ca.

Since high levels of Ca are needed to ameliorate excesses of trace metals (4,5), the tendency of high levels of a number of trace metals to interfere with Ca uptake increases the phytotoxicities resulting from the trace metals.



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