MOLYBDENUM AS AN ESSENTIAL ELEMENT FOR HIGHER PLANTS

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(WITH ONE FIGURE)

The preliminary findings that molybdenum, in minute amounts, improved the growth of barley plants in a culture solution supplied with ammonium salts as the sole source of nitrogen (**1**), and that a group of seven heavy metals including molybdenum increased the growth of lettuce and asparagus (**2**), supported the view that the list of essential elements for higher plants is incomplete and suggested the desirability of determining whether or not molybdenum is essential in the nutrition of higher plants.

The essential nature of molybdenum for higher plants was established according to the criteria set up for other elements required by higher plants in minute quantity (**3**) as follows:

(A) When tomato plants were grown from the seedling stage in rigidly purified nutrient solutions (**13**) containing all of the eleven nutrient elements now regarded as essential (N, P, K, Ca, Mg, S, Fe, B, Mn, Zn, and Cu) characteristic deficiency symptoms became apparent in a few weeks. The lower leaves developed a distinct mottling different from any other deficiency symptom yet observed in the tomato (fig. 1A). In later stages necrosis at the margins and a characteristic involution of the laminae was evidenced (fig. 1 B). Almost all of the blossoms abscissed without setting fruit. These deficiency symptoms were produced in six successive experiments at various seasons extending over a period of a year and a half, using both purified and unpurified nutrient solutions; the results, however, were consistent only if the nutrient medium was rigidly purified by procedures efficacious in removing minute metal contaminants (**13**). Ordinary distilled water and C. P. chemicals contained molybdenum as a contaminant in amounts, adequate at times, to supply plant needs.

(B) The development of these deficiency symptoms was prevented by adding 1 part of molybdenum as molybdic acid to 100,000,000 parts of nutrient solution. This was effective whether added singly or jointly with 19 other elements,[1] none of which were capable of replacing molybdenum [The supplementary microelements' solutions B7 and C13 (**2**)].

(C) To test the direct effect of molybdenum on the plant as distinguished from its possible effect on the root environment, molybdenum-deficient plants were sprayed with a dilute solution of molybdic acid (0.05 p.p.m. Mo) so as to bring about absorption only through the aerial parts of the plant. Re-

[1] Ti, V, Cr, W, Co, Ni, Al, As, Cd, Sr, Hg, Pb, Li, Rb, Br, I, F, Se, Be.

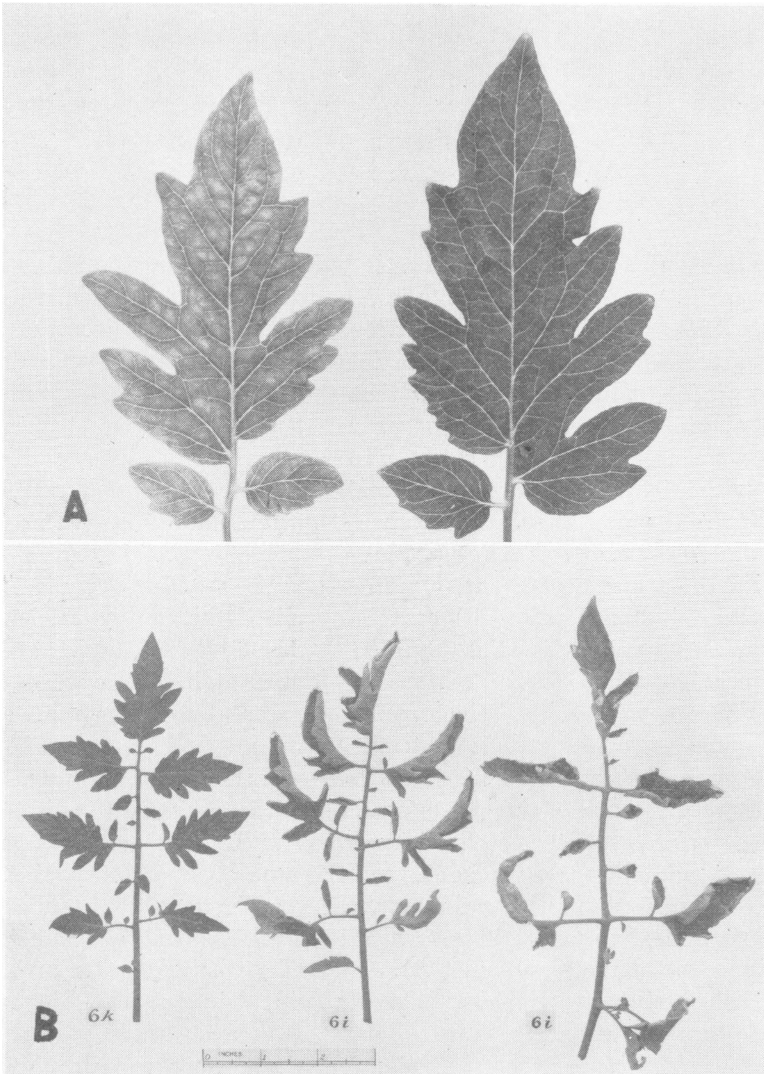

FIG. 1. Molybdenum deficiency symptoms.
A. Left, mottled appearance of foliage of a molybdenum-deficient plant; right, normal leaflet.
B. The two leaves on the right show curling and necrosis at the edges characteristic of an advanced stage of molybdenum deficiency; normal leaf at the left.

covery and resumption of normal growth with the disappearance of the molybdenum-deficiency symptoms took place.

Although but 0.01 p.p.m. was required to supply the needs of young tomato plants they tolerated relatively large concentrations of molybdenum in the nutrient solution, as distinct injury from excess was obtained only if concentrations exceeded 10 p.p.m. (2 mg. of molybdenum per plant).

In recent years the biological importance of molybdenum, particularly with reference to the nutrition of lower plant forms, has been recognized. STEINBERG (**11**) found that molybdenum is essential for the growth and sporulation of *Aspergillus niger* and that it has a relation, in that organism, to nitrogen metabolism (**12**). The relation of molybdenum to nitrogen fixation and growth of Azotobacter has recently received considerable attention (**4**, **6**, **9**). As for higher plants, the widespread distribution of molybdenum has been noted (**8**, **10**), and instances of improved growth as well as toxicity from adding molybdenum to the culture medium, have been reported (**5**, **14**, **7**).

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