Relation of Nitrogen Supply to the Molybdenum Requirement of Cauliflower Grown in Sand Culture

THE possible need for molybdenum by higher plants supplied with nitrogen in a form other than nitrate was first indicated by Arnon[1], who obtained improved growth of barley plants in the presence of a solution containing chromium, molybdenum and nickel with an ammonium nitrogen supply. Vanselow and Datta[2] and Hewitt[3] later showed the need of molybdenum by plants with adequate ammonium and nitrate nitrogen. Hewitt, however, has stated[3] that the absolute need for molybdenum for normal development when higher plants are supplied with ammonium nitrogen only still remains to be shown, and that the experimental difficulties of the use of ammonium compounds alone limit progress. Incorporation of solid calcium carbonate into ammonium nitrogen cultures, however, has been shown greatly to reduce the injury due to ammonium[4,5]. This device has been successfully applied to molybdenum-deficiency cultures using a purified source of calcium carbonate.

Cauliflower plants (var. Majestic) were grown in sand cultures at deficiency-levels of molybdenum of 0·00001 and of 0·00005 p.p.m., a normal level of 0·5 p.p.m. and an excess level of 50 p.p.m., with nitrogen at 10 m.M/lit. as follows: (i) nitrate without calcium carbonate, (ii) nitrate with calcium carbonate, (iii) nitrate with citric acid, (iv) ammonium sulphate with calcium carbonate, (v) ammonium citrate, (vi) ammonium nitrate, (vii) urea, and (viii) nitrite. Treatments with ammonium sulphate without calcium carbonate were included in the original scheme, but the plants did not make healthy growth and hence the effects of the treatments are not discussed in detail. Each compound was purified as previously described[6], and the analyses of dried foliage showed that molybdenum had been effectively removed for the deficiency-treatments.

Nitrate produced the best growth at the normal molybdenum level, but the plants with other treatments were sufficiently vigorous to show beyond reasonable doubt the effects of molybdenum-deficiency. The relative yields at 0·00001 p.p.m. molybdenum (approximately) as percentage of yields at 0·5 p.p.m. were (in the order given above): (i) 15·0, (ii) 15·2, (iii) 19·3, (iv) 36·3, (v) 24·8, (vi) 6·7, (vii), 21·4, (viii) 64·6. Leaf malformation and the bleaching and perforation of young leaves characteristic of whiptail[7,8] were observed at 0·00001 and 0·00005 p.p.m. molybdenum in all nitrogen treatments except nitrite. Typical advanced stages of whiptail in large plants[7] were characteristic of nitrate treatments and were accentuated by citric acid. Death of the growing point occurred with nitrate, ammonium nitrate, ammonium citrate and urea. 0·00005 p.p.m. molybdenum was sufficient to prevent any whiptail in the ammonium sulphate plus calcium carbonate treatment. Histological examination of some whiptail plants showed that the cells were not joined together and the middle lamella was almost invisible. This suggests that abnormal metabolism of pectic substances may be involved in the problem.

The ascorbic acid status was examined, and the effects reported previously[9,10] were confirmed. The relative ascorbic acid levels as percentage of the normal molybdenum levels at 0·00001 p.p.m. molybdenum were: (i) 58, (ii) 57, (iii) 79, (iv) 50, (v) 45, (vi) 58, (vii) 36, (viii) 67. Excess molybdenum did not further increase the ascorbic acid content over the normal treatment[9,10], and the molybdenum status did not materially affect the ratio of ascorbic to dehydroascorbic acid[10]. This and the overall response with different nitrogen sources support the suggestion of Hewitt *et al.*[9] that it may be in the synthesis of ascorbic acid or its precursors that molybdenum plays a part, rather than in its equilibrium in the oxidation-reduction systems.

Tests at intervals showed that nitrate was present in sand or accumulated in the foliage *only* when given in the treatment. This fact, and the characteristic appearance of plants grown with the other nitrogen sources, support the conclusion that the ammonium-, nitrite- and urea-nitrogen entered the plant without appreciable nitrification. Contrary to the effect of molybdenum deficiency on nitrate accumulation, no nitrite accumulated under similar conditions or in any other treatments. There was, on the other hand, a low concentration of ammonium-nitrogen present in the tissues of plants from all treatments.

Not only did the source of nitrogen interact with molybdenum at deficiency-levels, but the effects of the excess level also depended on the type of the nitrogen compound. Thus whereas with nitrate or ammonium nitrate and ammonium sulphate with calcium carbonate the toxicity effect was slight, injury was acute with ammonium citrate, urea or ammonium sulphate without calcium carbonate, the last treatment producing acute yellow intervenal chlorosis.

The effect of nitrite in relation to molybdenum deficiency was perhaps the most striking feature of these results, as this compound has shown the lowest molybdenum requirement so far with respect to growth, ascorbic acid status and freedom from whiptail. The implication of the results and a full account of the work described will be presented elsewhere.

The investigation was carried out under the guidance of Dr. E. J. Hewitt, to whom I am indebted for criticism and helpful suggestions.

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A Tea Root Disease New to South India

DURING a visit to some estates in Central Travancore in October 1951, my attention was directed to a small patch of unthrifty tea on one of the estates. The bushes appeared 'thin', with weak development of the branches and only a crown of unhealthy foliage. Examination of the aerial parts did not reveal any sign of insect damage or fungal attack. The roots, however, showed certain characteristic symptoms, namely, the entire absence of feeding roots and the presence of circular or slightly elongated and raised patches all over the bark of the tap and lateral roots (see photograph), and also extending to