THE importance in plant growth of a number of elements other than the 10 usually considered necessary is now generally recognized. Boron, copper, and manganese are three of the most noteworthy of these so-called "minor" elements. A great number of investigations support the contention that green plants are unable to grow normally without them (38). The experiments described in this paper deal with the action of boron, copper, and manganese in promoting the growth and development of plants in the field and greenhouse.

REVIEW OF LITERATURE

Boron.—The essential nature of boron was demonstrated by Brenchley and Warington (6) for certain legumes; by Haas and Klotz (15) for citrus cuttings; by Johnston and Fisher (19) and Van Schreven (37) for tomatoes; by McHargue and Calfee (26) for lettuce; by Scharrer and Schrop (32) and Belousov (4) for sugar beets and turnips; by Martin (24) for sugar cane; and by Van Schreven (36) for tobacco. Agulhon (1), McMurtrey (28), and others have shown that addition of boron sometimes results in increased growth of a variety of crops in the field.

The symptoms of boron deficiency usually reported are depressed growth, distorted leaves, death of terminal buds, heart-rot in beets, a break down of the meristematic tissues, and an increase in starch and sugar in the leaves, presumably because disintegration of the phloem prevents translocation.

Copper.—Improvements in the productivity of peat and muck soils by the addition of copper have been reported in Florida by Allison, Bryan, and Hunter (2); in New York by Felix (12); in Michigan by Harmer (16); and in Indiana by Conner (9). Densch and Hunnius (11) found that copper fertilization increased the chlorophyll content of crops; Knott (20) reports that it improves the color and thickness of onion scales; Mader and Blodgett (23) state that copper sprays reduce potato scab; and Coleman and Ruprecht (8) agree with other investigators that it increases the copper content of the plants. The majority of the workers quoted found that the beneficial effect is obtained whether the copper salts are sprayed on the leaves or applied to the soil.

Sommer (35) and Lipman and MacKinney (22) found that, in solution cultures of highly purified material, minute amounts of copper are needed for the normal growth of a number of the crop plants. Anderssen (3) found from chemical analyses that chlorotic leaves of fruit trees grown on a sandy soil were low in copper. The application of copper to the soil or leaves of the trees cured the chlorosis.