The Relation of Manganese to Internal Bark Necrosis of Apple[1]

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The senior author in 1934 (*1*) suggested the name "internal bark necrosis" for a type of nonparasitic apple-bark disease occurring chiefly on the variety Red Delicious. In 1937 Young and Winter (*4*) stated that the disease apparently was caused by a deficiency of boron. Evidence supporting this view was presented in 1939 by Hildebrand (*3*). The writers have studied this disease intensively in West Virginia for the past six years and have been unable to produce any necrotic lesions or other symptoms typical of internal bark necrosis on the bark of Red Delicious trees grown in boron-free sand culture (*2*). Other symptoms of boron deficiency, such as stunting of the trees, procumbent growth of the twigs, and rosetting, were in evidence. The application of boron to the soil of diseased trees in orchards did not correct the disease.

During the progress of extensive boron analyses it was noted that the ash from diseased tissues (leaves and bark) was always dark, while ash from corresponding tissues of healthy specimens was much lighter in color. Investigation of the mineral constituents in diseased tissues revealed unusually high concentrations of both manganese and iron. The manganese content of severely diseased trees was sometimes 20 times as high as that of normal trees. The iron content, likewise, was usually much higher in the tissues of diseased trees. It was noted that the inner bark of diseased trees, in contrast to that of healthy trees, became discolored almost immediately when exposed to the air.

For a number of years the writers have noted that the disease is most prevalent on acid soils containing appreciable amounts of readily available manganese. In several cases where ammonium sulfate, a soil-acidifying fertilizer, was added to newly planted Red Delicious and Stayman Winesap trees, the trees became severely affected the first season, while the adjacent unfertilized trees showed no symptoms.

During the past six years large numbers of Red Delicious apple whips have been grown each season in the greenhouse in crocks (two-gallon, straight-sided, glazed earthenware jars with a side drainage hole flush with the bottom). One soil, designated as Soil A, was taken from an orchard where the disease is very prevalent. The percentage of trees that became diseased in the greenhouse in this soil varied from year to year. This agrees with the results obtained in parallel orchard experiments. Another soil, designated as Soil B, was taken from a location where the disease has never been known to occur, even though Red Delicious trees have been growing there for the past 20 years. When Red Delicious whips were planted in crocks in this soil, no symptoms of the disease appeared.

For the past three years extensive greenhouse and orchard experiments have been conducted to ascertain the role of manganese and iron in the development of the disease. On 1 June 1943, 54 Red Delicious apple whips were planted in crocks in Soil A and Soil B. All trees were watered with distilled water for the duration of the experiment. After the trees had become established, part in each soil were kept as controls and were not treated. The remaining trees in each soil were given for the season one application of manganese, iron, or a combination of iron and manganese. The iron (24–384 ppm) in the form of iron tartrate and manganese (24–384 ppm) in the form of manganous sulfate in solution were added to the soil. At the end of each growing season all unaffected trees were placed in cold storage for the winter. Each April the trees were returned to the greenhouse. In May 1944 and again in May 1945 each unaffected tree received an application of iron, manganese, or a combination of iron and manganese equal to that given the first season.

By the end of the third growing season (1945) 90.7 per cent of the treated trees and 58.3 per cent of the control trees in Soil A were diseased. On Soil B 54 per cent of the treated trees were diseased, while none of the control trees was diseased. Symptoms in all cases were identical with those observed in the orchard. It is evident that on Soil A the treatments greatly increased the number of trees that became diseased. It was noted also that the symptoms on the treated trees were more pronounced than those on untreated trees.

During the first year only 4.5 per cent of the treated trees, none of the controls on Soil A, and none of the trees on Soil B became affected. The greatest percentage of trees succumbed the second year, these being the trees which had been given the highest concentrations of salts.

The low percentage of diseased trees in Soil A during the first year is attributed to the fact that the experiment was set up too late in the season (1 June) and that the concentrations of iron and manganese applied were not sufficiently high. The writers have noted in both field experiments and greenhouse culture that a long season and ideal growing conditions are conducive to the development of the disease.

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It is significant also that the disease usually makes its appearance in late summer and early autumn, apparently at the period when there is an acceleration of food accumulation in the bark, and develops with great rapidity after the first symptoms become visible. It has been observed also that the trees most severely affected often have the most vigorous root systems.

In view of these experimental observations a much more extensive experiment using Soil A and Soil B was set up in the greenhouse on 4 April 1945. Fifty-four trees (32 treated; 22 controls) were planted in Soil A. Ninety trees (48 treated; 42 controls) were planted in Soil B. Greater concentrations of iron and of manganese were used (96–1,536 ppm) than in the previous experiment. At all times ideal moisture conditions were provided and as a result the trees made a much more vigorous growth than did those in the previous experiment, which were watered only intermittently so as to approximate orchard conditions.

By the end of the first growing season (1945) 75 per cent of the treated trees and 45.4 per cent of the controls in Soil A were diseased. In Soil B 31 per cent of the treated trees were diseased, and none of the controls was diseased.

From the results so far obtained it is quite apparent that excess manganese and perhaps iron are important factors in the development of the disease, but in order to evaluate the specific effect of manganese, iron, or combinations of manganese and iron, further experiments must be carried out, with trees grown in pure sand culture.

On 21 April 1945 such a preliminary experiment was begun. Red Delicious apple whips cut back to 10 inches were grown in acid-washed sand with the addition of varying amounts of manganese. The basic nutrient solution used was one which the authors have found well suited for the growth of apple trees.[2] For the first three weeks after the trees were planted all trees were supplied with the basic nutrients. Throughout the experiment the control trees received this nutrient solution. The manganese added to the treated trees was increased by doubling the concentrations in geometric progression from 0.5 to 128 ppm.

Within seven days after the manganese treatments were begun the new leaves of the trees began to manifest symptoms of manganese toxicity varying in intensity with the concentration used. At the end of the first growing season the disease developed on all four trees receiving the two highest concentrations of manganese, namely 64 and 128 ppm. In this experiment the disease was unusually severe and occurred both on the old growth and on that of the current season. It is noteworthy that the time of development of the disease in sand culture coincided with the appearance of the disease in other trees grown in crocks in Soil A, whether in the greenhouse or outside, and also with the time of its development in the orchard from which Soil A was taken.

During the last five years the writers have used lime in some field experiments. In April 1945 a greenhouse experiment was begun using Soil A, the soil in which some internal bark necrosis develops. Lime was added to eight crocks of this soil at planting time to decrease the acidity from pH 4.2 to pH 6.5. Of the eight trees grown, none developed the disease. Twenty-two control trees were grown in the same soil without addition of lime, 10 of these developing internal bark necrosis.

The above-described experiments indicate that manganese and perhaps iron are important factors in the development of internal bark necrosis. Further studies, however, are necessary in order to determine what specific role they play in causing this physiological disturbance.

[2] Basic nutrient solution: dihydrogen potassium phosphate, 0.0108 M; calcium nitrate, 0.0078 M; magnesium sulfate, 0.0020 M; ammonium sulfate, 0.0007 M; boron (as boric acid), 2.0 ppm; Fe (as iron tartrate), 6.0 ppm; Zn (as zinc sulfate), 0.2 ppm; Cu (as copper sulfate), 0.1 ppm; and Mn (as manganous sulfate), 0.5 ppm. Nutrients were renewed weekly. Nutrient solution was forced upward twice daily through the sand, allowed to stand 10 minutes in contact with the sand, and then allowed to drain. The trees were grown during the entire period in a greenhouse under whitewashed glass.

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Two New Effective Insect Repellents, NMRI-201 and NMRI-448[1]

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A survey of mosquito repellents at the Naval Medical Research Institute revealed two chemicals, 2-phenyl cyclohexanol and β-tetralol (2-naphthol,1,2,3,4-tetrahydro), which were unique because they lost only a relatively small percentage of their activity when applied to the sweating skin of test subjects. A mixture of these chemicals (NMRI-201), consisting of 70 per cent 2-phenyl cyclohexanol and 30 per cent β-tetralol (by volume), was found more effective than either of

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[2] The opinions and statements are those of the authors and not necessarily those of the Navy Department.