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Purpose of Bulletin

THE purpose of this bulletin is to make available in one place the results of studies on the relationship of Internal Bark Necrosis to manganese toxicity and to present the detailed data from which conclusions reported here were reached. The methods used, and the materials employed in carrying out the different studies, together with the discussion of the results of these studies in relation to published information are given.

Internal Bark Necrosis in Relation to Other Apple Bark Diseases

Much interest and considerable confusion has existed among horticulturists and orchard owners who have been faced with a variety of somewhat similar apple bark diseases. The first workers to describe one of these diseases in detail were Hewitt and Truax (17) who applied the name Apple Measles to a pimpled or blistered and often reddish discoloration of young bark. Such symptoms may later develop into a roughening of the older bark and sometimes they precede canker development. To this whole syndrome of frequently diverse successive symptoms, the term Apple Measles has been applied.

Berg, in 1934, made a thorough study of the measles complex as it occurs in West Virginia and he delimited three distinct diseases within the "measles" complex (2). One was caused by the fungus *Helminthosporium papulosum*. This disease Berg named Black Pox. He gave the name Internal Bark Necrosis to another disease which was characterized by the presence of groups of dead cells within the living bark. This disease was associated particularly with the variety Delicious. The third type of bark condition, found most often on the York variety in West Virginia, most closely approximates the original description of Apple Measles.

Internal Bark Necrosis was considered to be caused by boron deficiency by Young and Winter (31) and by Hildebrand (18). In 1946,

[1]The manuscript was edited by R. P. True, Plant Pathologist, Department of Plant Pathology, Bacteriology, and Entomology, West Virginia University Agricultural Experiment Station.

Berg and Clulo, using sand cultures in the greenhouse, showed that the disease resulted from manganese toxicity (4, 5). Berg and Clulo (3) were unable to confirm the relationship of Internal Bark Necrosis to boron deficiency in West Virginia. Later, Clulo and Berg (9) published the results of investigations in which they used boron in sand culture studies. These showed that Internal Bark Necrosis was not related to the concentration of boron.

Meanwhile, Dunegan and Isely (11) showed what they consider to be the original disease described by Hewitt and Truax to be caused by the deposition of the winter eggs of the white apple leaf hopper, *Typhlocyba pomaria* McAtee. Crawford (10), in a study of Apple Measles in New Mexico, produced the symptoms on Jonathan apple in high concentrations of soluble salts, largely sodium chloride and sodium nitrate, which are commonly present in the alkaline soils of that state. Other similar but still undelimited symptomatic diseases have been reported (17, 22, 23), and in England a disease of apparently similar nature has been ascribed to the bacterium *Pseudomonas papulans* by Lacy and Dowson (20).

Economic Importance

This bulletin deals with Internal Bark Necrosis, a disease which appeared in West Virginia simultaneously with the introduction of the apple variety Delicious. The disease is principally confined to this variety and its sports, though it occurs occasionally on other varieties. The popularity of Delicious has led to its extensive planting throughout the nation, and Internal Bark Necrosis has been found wherever this variety has been planted on highly acid manganiferous soils. Although most of our commercial varieties are somewhat more resistant to manganese toxicity than Delicious, the disease has been reported occasionally on Golden Delicious, Grimes, Jonathan, McIntosh, Rome, Northwestern Greening, Stayman, York, and King David. Rhodes (22), in a study of the susceptibility of Missouri apple varieties to Apple Measles, found only the latter two severely affected. Concentrations of manganese which affected Delicious and Blaxstayman failed, in greenhouse tests in West Virginia, to induce symptoms in the other varieties listed here. Diseased trees are unthrifty and branches or sometimes the whole tree may die. Losses in individual instances have been so considerable that young plantings of Delicious have been pulled and replaced by other varieties.

Symptoms

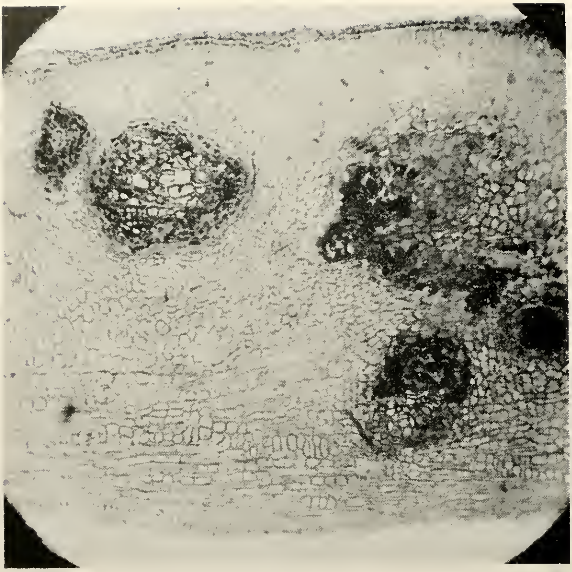
Characteristic symptoms of Internal Bark Necrosis appear on the bark of stems but have not been found on roots. The lower portion of diseased stems, the trunks and lower branches, and the leaves borne on these branches are, under orchard conditions, most likely to be severely affected. Bark symptoms may develop more severely on only one side of a diseased tree, or all sides may be affected equally. The leaves of diseased trees or affected branches may be small, and show a yellow discoloration sometimes as intervenal chlorosis and sometimes as large or small yellow areas. These yellow areas may appear in combination with green portions of the leaf, which sometimes have a distinctly purplish tint. Affected leaves are likely to be shed prematurely.

Three types of stem lesions have been observed—the pimply, the oedematous, and the minute superficial lesions. Of these, pimply lesions are the most common. They are found in association with the other two types when they appear.

Pimply lesions develop from small necrotic areas which originate deep in the cortex and pericycle. At first, such lesions may be surrounded by apparently normal healthy tissues (Figure 1, a). Later, these groups of necrotic cells may become encysted within the bark by the development of an enclosing layer of suberized cells (Figure 1, b). The first externally visible indications of this condition are raised points that appear on the epidermal surface (Figure 2, a). These localized swellings are due to the hyperplasia that occurs in living tissues bordering the groups of necrotic cells. These elevations of the epidermis are usually larger, and present more variation in size and shape than those that characterize the "measles" disease of Hewitt and Truax. In severely diseased trees necrotic areas may develop in any parenchymatous tissue, even in wood parenchyma (8).

Where the pockets of dead tissue in the bark are comparatively small and isolated, the external elevations develop into more or less hemispherical papules. However, in cases where they are larger, irregular in shape, or closely aggregated, the bark becomes unevenly elevated into undulating ridges, the contour of which may gradually change, since the upheaval of the bark often continues for more than one year (Figure 2, b). The periderm covering the papules of ridged areas may remain smooth and apparently normal throughout the first season, or it may assume a reddish, or dark-brown pigmentation. In other cases, dead, slightly sunken patches appear on the summit of some of the ridged areas with the periderm turning light brown and beginning to check and scale by the end of the first season.

In the course of time the number of such dead areas increases. The radial development of the bark is retarded, and numerous short, irregular cracks appear. The checking of the bark and scaling of the periderm may continue for several years until the bark on severely affected limbs and branches assumes a characteristic scaly, cracked and



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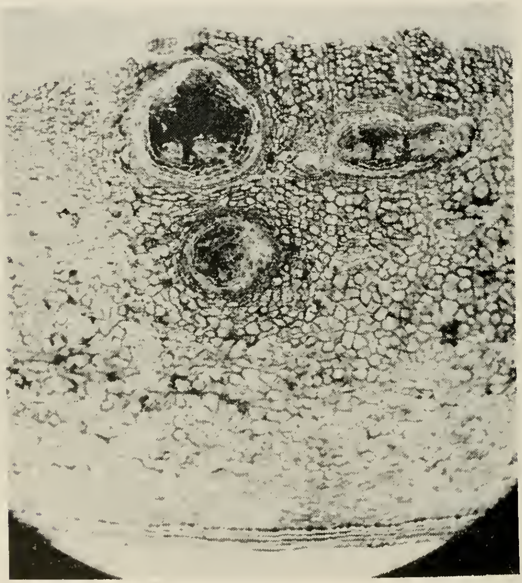

b

FIGURE 1. Sections through the cortex and phloem of apple twigs affected with Internal Bark Necrosis. (a) Necrotic areas in the cortex not yet walled off from adjacent tissues. (b) Necrotic areas involving the inner cortex and outer phloem which have been surrounded and walled off from the living tissue by layers of pathological cork cells.

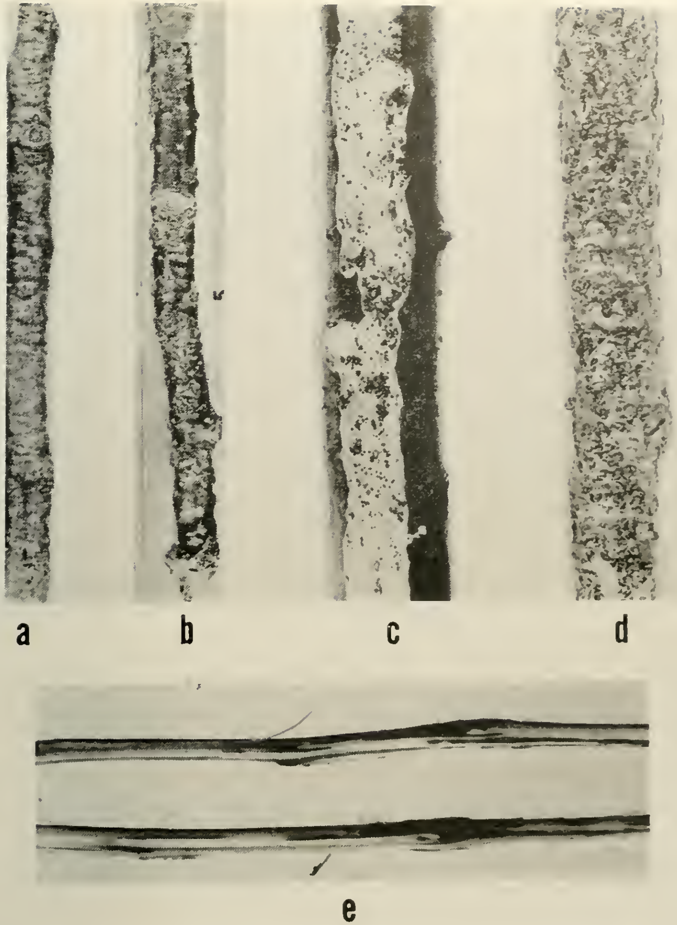

FIGURE 2. Symptoms of Internal Bark Necrosis. (a) Early symptoms, raised points that appear on the epidermal surface of affected twigs. (b) Larger, irregularly-shaped papules and uneven undulating ridges that may develop where epidermal elevations continue to swell or are closely aggregated. (c) Irregularly-circular areas of dead cells are visible within the cortex and living phloem when exposed by slicing off the outer surface layers of affected twigs and branches. (d) Roughened bark may become irregularly-cracked and scaly if the condition persists for several years. (e) Short dark streaks that may be visible at the cambium layer when affected bark is removed from diseased twigs.

oughened appearance (Figure 2, d). These necrotic areas are surround-ed by a halo of light-green tissue that appears to be water-soaked. Upon utting deeper into the bark, larger and more irregular areas of dead ells are noted (Figure 2, c). Sometimes narrow black streaks, one centi-neter or more in length, of discolored pericyclic fibers together with other ells adjacent to them will be disclosed. Such strands are often completely surrounded by a phellogen (Figure 1, b). In some instances the internal necrotic areas extend inward to the cambium, and corresponding darkened streaks may appear in the wood internal to necrotic bark streaks or lesions (Figure 2, e).

Oedematous and also minute superficial lesions can be distinguished from the pimple-type lesions described above, but some pimply lesions are found wherever lesions of these other types are present; and all are considered symptoms of Internal Bark Necrosis.

Oedematous lesions most commonly occur at the base of the tree or in isolated areas of limited extent higher on the main stem. Only rarely are they found on the bark of stems less than one year old. They generally appear in greenhouse-grown trees in early August of the year following their planting into toxic soil. The bark of the oedematous lesions swells conspicuously and has a water-soaked appearance. The outer periderm over these swellings splits parallel to the axis of the stem and becomes loose over the swollen area so that it appears as a series of tan papery sheets covering the unruptured portions of the swelling. Directly below the layered periderm the cells are usually bright green, large, and have a mealy texture. Within two weeks after oedematous lesions have split open, the underlying tissues turn brown and collapse. The wood under oedematous lesions is frequently discolored. Orange or dark-brown patches, or occasionally black streaks, may develop there.

Minute superficial lesions are caused by the localized stimulation of the normal periderm to increased activity. They are clearly visible under the hand lens as darkened points, are perceptible to the touch, and are confined to the terminal portion of the current season's matured growth.

Earlier Studies on the Nature of Internal Bark Necrosis

Some early investigators concluded that Internal Bark Necrosis, as described by Berg (2), was due to boron deficiency (18, 31). Recently, Shannon (26) concluded from sand-culture studies that manganese toxicity was more active than boron deficiency or toxicity of iron or aluminum in inducing symptoms that he considered those of Internal Bark Necrosis. However, the symptoms Shannon obtained when boron was deficient were typical of boron deficiency rather than of Internal Bark Necrosis as described here. Berg and Clulo (3) showed in both field and greenhouse experiments that Internal Bark Necrosis was not related to boron concentration. In the course of more extensive studies Clulo and Berg (9) noted during their analysis of boron in the leaves and bark that the ash from diseased trees was always dark in comparison with the ash from corresponding tissues of healthy trees. They also noted that when the inner bark of diseased trees was exposed to air browning due to oxidation took place almost immediately. Investigation showed that the tissues from diseased trees were usually high in manganese, in some cases 20 times as high as those of healthy trees.

These observations led to a long series of experiments with manganese, carried out under controlled conditions. Apple trees were grown for several years in the greenhouse in two different orchard soils, in only one of which the disease developed naturally, and in sand cultures to which in all cases varying amounts of manganese were supplied. The results of these studies proved that Internal Bark Necrosis develops when, under certain conditions, the trees take up excessive quantities of manganese from the soil (7). Studies have also been made of the varietal reactions to different soil treatments (21), and of the effects of manganese toxicity on affected cells and tissues of the apple tree. The manganese content of the orchard soils has been studied in relation to the development of Internal Bark Necrosis. Results of studies of the pathological anatomy of apple trees affected by Internal Bark Necrosis have been reported briefly (8).

Chemical Methods Used in Analyses

The manganese content of the samples of apple leaves and bark was determined by a periodate method based on the work of Willard and Greathouse (30). The samples were dried at 100° C. before being pulverized in a mortar. Duplicate 1-gram samples were used for each analysis. The results reported in the tables are the average of two separate analyses. The manganese content is reported as ppm Mn (μg/gm; mg/kg). The active manganese in soil samples was determined by the method of Sherman, McHargue and Hodgkiss (27), using 1 *N* ammonium acetate containing 0.2 per cent hydroquinone as the leaching agent.

RESULTS OF EXPERIMENTS

(1) *The addition of various quantities of $MnSO_4$ to balanced nutrient solutions suppied to one-year old apple whips grown in sand culture showed that an increase in the quantity of manganese supplied resulted in an increased manganese content within the tissues of experimental plants. Trees taking up large quantities of manganese developed symptoms of Internal Bark Necrosis.*

One-year old whips of uniform size were cut back to 11 inches and planted in the greenhouse in acid-washed sand in heavily glazed 2-gallon earthenware crocks with stoppered drainage openings flush with the bottom. Two trees received each treatment. The crocks were covered with oil cloth cut to fit the trees. A nutrient solution,[2] made up each week, was changed twice daily following a flushing out of the sand with double-distilled water. The pH of the culture solution after passing through the sand was 4.6. Manganese sulfate was added to the basic nutrient solution in quantities which supplied from 0.5 to 128 parts per million (ppm of Mn^{++}). The results, given in Table 1, show clearly

TABLE 1. EFFECT OF INCREASING CONCENTRATION OF MANGANESE ADDED AS $MnSO_4$ TO THE NUTRIENT SOLUTION ON THE MANGANESE CONTENT AND SYMPTOM EXPRESSION IN DELICIOUS APPLE GROWN IN SAND CULTURE—1945.*

MANGANESE ADDED TO BASIC NUTRIENT (ppm)	AVERAGE MANGANESE CONTENT OF TISSUES		SYMPTOM EXPRESSION **
	1945 LEAVES (ppm)	1945 BARK† (ppm)	
0.5	54	42	NONE
1.0	66	64	NONE
2.0	106	77	NONE
4.0	155	107	NONE
8.0	193	107	NONE
16.0	291	209	NONE
32.0	532	330	SLIGHT
64.0	832	543	SEVERE
128.0	1034	764	SEVERE

* Results based on average for two trees receiving each treatment.
† Indicates bark removed from stem elongations produced in 1945.
** Categories of symptom severity used were: None, Slight, Moderate and Severe.

that there was a progessive intake of manganese reflected in increasing manganese concentrations in both bark and leaves, positively correlated with the dosage of manganese sulfate. By the end of the first growing season only one tree treated with 32 ppm of manganese (in addition to the 0.5 ppm furnished in the basic nutrient) developed the disease on the current season's bark. With the 64- and 128-ppm treatments, Internal Bark Necrosis developed with severe symptoms shown on the bark of both the current and the previous season's growth. A similar experiment carried out in 1947, using three manganese concentrations on treatment groups of ten trees each, gave similar results. These are shown in Table 2.

(2) *The addition of various quantities of $MnSO_4$ and of iron tartrate alone and together to soil taken from a healthy orchard* (or to crocks of washed sand as in Experiment 1) *in which apple whips were*

[2] Basic nutrient solution: KH_2PO_4, 0.0108 M. (Molar concentration); $CaNO_3$, 0.0780 M.; $MnSO_4$, 0.0020 M.; $(NH_4)_2SO_4$, 0.0007 M.; boron as boric acid, 2 ppm (parts per million); iron, as iron tartrate 6 ppm; zinc, as $ZnSo_4$, 0.2 ppm; copper as $CuSO_4$, 0.1 ppm; and manganese, as $MnSO_4$, 0.5 ppm per liter of solution.

TABLE 2. EFFECT OF MANGANESE ADDED AS $MnSO_4$ TO THE NUTRIENT SOLUTION ON MANGANESE CONTENT AND SYMPTOM EXPRESSION IN DELICIOUS APPLE GROWN IN SAND CULTURE—1947.*

Manganese Added To Basic Nutrient (ppm)	Average Manganese Content of Tissues				Symptom Expression
	Top Leaves (ppm)	Basal Leaves (ppm)	1947 Bark (ppm)	1946 Bark (ppm)	
0.5	116	183	71	94	NONE
8.0	317	264	180	224	NONE
64.0	1290	500	657	862	SEVERE

* Results based on average for 10 trees receiving each treatment.

grown in the greenhouse showed that incidence and severity of symptoms increased with the addition of manganese, either alone or with iron, but that the addition of iron alone failed to induce Internal Bark Necrosis.

While it was proved that an excessive dosage of manganese will produce Internal Bark Necrosis, it had been observed also that the disease was often associated with soils high in iron compounds. Since manganese and iron are generally associated in our soils it seemed necessary to test both elements in relationship to this disease.

Apple whips headed to 10 inches were planted in glazed crocks in the greenhouse on April 18, 1947 in soil taken from an orchard near Morgantown where the disease does not occur naturally.[3] On the same date iron tartrate was added at rates which supplied 96 to 768 ppm iron to one treatment block; magnanese sulfate was added at the same rates to a third treatment block; and manganese sulfate and iron tartrate were added in inverse ratio to trees in a fourth block. The trees were held over in this same soil to the second year at the end of which period analyses were made with results shown in Table 3.

The data show that where iron tartrate alone was supplied, Internal Bark Necrosis failed to develop. Where manganese sulfate was added in sufficiently high concentration, either alone or in various combinations with iron tartrate, the disease was produced.

Additional studies of the effect of iron were carried out by the addition of iron, as tartrate, to a balanced nutrient solution supplied to Delicious apple growing in sand culture as in Experiment No. 1.

Thirty-two Red Delicious apple whips were cut back to 10 inches and planted in crocks in acid-washed sand. The trees were supplied with the basic nutrient solution for three weeks after planting. Throughout

[3] The soil was taken from the Husten property near Morgantown where Red Delicious apples had grown for 20 years without developing symptoms of Internal Bark Necrosis.

Table 3. Effects of Manganese Added as $MnSO_4$ and Iron Added as Iron Tartrate Upon Manganese Content and Symptom Expression by Delicious Apple When Applied Both Alone and Together in Various Concentrations and Combinations to Potting Soil Obtained from a Healthy Orchard.*

Treatments Concentrations		First Season Results Manganese Content		Symptom Expression on Current Season's Growth	Second Season Results		Soil pH at End of 2nd Season
Iron (ppm)	Manganese (ppm)	Leaves (ppm)	Bark (ppm)		Manganese Content Leaves (ppm)	Symptom Expression on Current Season's Growth	
96	NONE	138	64	NONE	——	NONE	4.92
192	NONE	176	138	NONE	393	NONE	4.92
384	NONE	158	108	NONE	384	NONE	4.86
768	NONE	132	135	NONE	226	NONE	4.76
NONE	96	164	155	NONE	372	NONE	4.83
NONE	192	1026	328	SLIGHT	750	SLIGHT	4.86
NONE	384	337	262	SLIGHT	761	MODERATE	4.88
NONE	768	1242	440	SLIGHT	1090	SEVERE	4.90
96	96	396	190	NONE	343	NONE	4.76
192	192	615	314	SLIGHT	615	NONE	4.73
384	384	908	346	SEVERE	902	MODERATE	4.76
768	768	1172	390	SEVERE	1277	SEVERE	4.66
96	768	762	322	SEVERE	785	SLIGHT	4.83
192	384	1348	272	SEVERE	996	SLIGHT	4.88
384	192	308	240	SLIGHT	375	NONE	4.92
768	96	565	204	SLIGHT	545	NONE	4.84

* Figures are based upon the individual responses of 16 trees, each of which received one of the treatments listed in the left-hand column of the table. The treatments listed were added to 15 pounds of air-dried potting soil.

the experiment, four control trees received this nutrient solution alone. The remaining trees were divided into groups of four per treatment and iron was supplied in the form of iron tartrate, the concentration of which was increased by doubling in geometric progression from 12 to 768 ppm. All trees were supplied with 0.5 ppm manganese in the form of manganese sulfate in the basic nutrient. The four trees given 768 ppm Fe died during the first week of treatment. The control trees as well as the remaining treated trees grew well but none became diseased. These results further substantiate the conclusion that iron is not directly concerned with the development of Internal Bark Necrosis.

(3) *Treatments that acidified manganiferous soils, lowering their pH, caused an increase in the incidence and severity of Internal Bark Necrosis in Delicious apple grown in treated soils in the greenhouse. Such treatments included the addition of $(NH_4)_2SO_4$, sulfur, and of H_2SO_4 to naturally manganiferous soil.*[4]

[4] The soil was obtained from the Huxham orchard near Huntington where Internal Bark Necrosis has frequently appeared and sometimes caused severe injury.

(a) *Ammonium sulfate* was applied to Delicious apple whips cut back to 14 inches planted May 23, 1946 in a uniform manganiferous soil contained in glazed crocks with bottom drainage. Ammonium sulfate at the rate of 15 gm per 15 lbs of air-dried soil was added to 10 trees on July 9. Thirty trees were reserved as untreated checks. The trees were taken down September 6th and analyses made of the leaves and bark with the results shown in Table 4.

It is to be noted that all trees receiving ammonium sulfate treatment became diseased, while 53.3 per cent of the checks remained healthy. While the soil of both treated and check pots had a uniform pH when trees were planted, the addition of the ammonium sulfate increased the acidity by 0.30 pH unit. The manganese content of the bark appears to be a more reliable index of the occurrence and severity of manganese toxicity than the quantity of manganese found in the leaves.

(b) *Sulfur* was applied in three different concentrations, in each case throughly mixed with a highly manganiferous orchard soil. Trees were planted in these soils in the greenhouse in the spring of 1946. Trees which showed no symptoms of Internal Bark Necrosis at the end of that season were carried over winter in cold storage and grown for a second season in the same soil. The results are shown in Table 5. It is clear that the addition of sulfur caused an increase in the incidence and severity of Internal Bark Necrosis and in the manganese content of the trees in treated soils. As expected, the soil pH was found to decrease as a result

Table 4. Effect of $(NH_4)_2SO_4$ Added to a Naturally Maganiferous Soil* on the pH of the Soil, Manganese Content, and Incidence and Severity of Internal Bark Necrosis in Delicious Apple in the Greenhouse.

Treatment	Symptoms	Number of Affected Trees	Average Manganese Content† 1947 Leaves (ppm)	Average Manganese Content† 1947 Bark (ppm)	Soil pH at End of Experiment**
NH_4SO_4 - 15gm per 15 lbs. of soil	NONE	0	——	——	
	SLIGHT	5	1305	571	4.64
	MODERATE	3	1452	638	4.58
	SEVERE	2	1398	655	4.57
Controls	NONE	16	993	407	4.88
	SLIGHT	12	1180	470	4.87
	MODERATE	2	1620	628	4.94

* The soil was obtained from the Huxham orchard near Huntington where Internal Bark Necrosis has frequently appeared and sometimes caused severe injury.

† Figures given represent manganese content at the end of the experiment. Experimental trees were obtained from a single nursery and consistently had low and rather uniform content of manganese when tested.

** The soil pH at planting time was 5.18.

TABLE 5. EFFECT OF THE ADDITION OF SULFUR TO A HIGHLY MANGANIFEROUS ORCHARD SOIL ON THE MANGANESE CONTENT AND THE INCIDENCE AND SEVERITY OF INTERNAL BARK NECROSIS IN DELICIOUS APPLE GROWN IN THE GREENHOUSE.*

SOIL TREATMENT	NUMBER OF TREES TREATED	AVERAGE MANGANESE CONTENT BEFORE TREATMENT (BARK ONLY) (ppm)	SYMPTOMS (1946)	AVERAGE MANGANESE CONTENT END OF 1946		SYMPTOMS (1947)	AVERAGE MANGANESE CONTENT END OF 1947	
				LEAVES (ppm)	BARK (ppm)		LEAVES (ppm)	BARK (ppm)
Sulfur 1.7 gm per 15 lbs of soil	4	108	NONE	1414	639	MODERATE	1395	608
Sulfur 3.4 gm per 15 lbs of soil	4	124	SEVERE	2064	775	——	——	——
Sulfur 6.8 gm per 15 lbs of soil	3	62	SEVERE	2280	1003	——	——	——
Untreated Controls	21	87	NONE	516	249	NONE†	455	174

* The pH of untreated soil was 5.66. At the end of the experiment the pH of several crocks of soil measured ranged from 4.32 to 4.67, averaging pH 4.64.

† Two of the 21 check trees died in winter storage. Eighteen showed no symptoms and gave the average manganese content figures shown in the table. One check tree in the untreated manganiferous soil obtained from the Huxham orchard near Huntington showed moderate symptoms of Internal Bark Necrosis the second year. The manganese content of the bark of this tree was initially 161 ppm but by the end of the second year had risen to 522 ppm.

of the addition of sulfur. Manganese is known to be made more readily available in soils of high acidity (16). Fujimoto and Sherman (14) found that the addition of sulfur to soil increased the absorption of manganese from it by plants.

(c) *Sulfuric acid,* the third soil-acidifying agent used, was likewise added in three different extreme dilutions to glazed crocks of highly manganiferous soil on April 19, 1946. Whips of Delicious apple were planted in these crocks of treated soil May 4.

There was a progressive increase in the manganese content of leaves and bark correlated with the dosage of sulfuric acid applied (Table 6), but little significant increase in the severity of symptoms beyond that attained by the addition of the smallest quantity of sulfuric acid (2.8 gm./15 lb. of soil).

(4) *Treatments that neutralized highly manganiferous orchard soil, lowering its acidity as indicated by increasing pH measurements, caused incidence and severity of Internal Bark Necrosis to decrease. Such treatments included the addition of Ca $(OH)_2$, $CaCO_3$, $MgCO_3$, MgO, and $NaCO_3$ to highly manganiferous orchard soils.*

The neutralizing compounds were added at planting time to 15 lbs. of air-dried soil which was placed in each of several glazed crocks with bottom drainage into which Delicious apple whips were planted. The experiments extended over a period of three years with the results shown in Table 7.

All of these neutralizing compounds decreased the soil acidity and prevented the development of manganese toxicity. Fujimoto and Sherman

TABLE 6. EFFECT OF THE ADDITION OF VARYING QUANTITIES OF SULFURIC ACID TO A HIGHLY MANGANIFEROUS ORCHARD SOIL ON THE MANGANESE CONTENT AND THE INCIDENCE AND SEVERITY OF INTERNAL BARK NECROSIS IN DELICIOUS APPLE GROWN IN THE GREENHOUSE.

SOIL TEATMENT	NUMBER OF TREES TREATED	AVERAGE MANGANESE CONTENT OF BARK BEFORE TREATMENT (ppm)	AVERAGE SOIL pH* AFTER TREATMENT (pH)	SYMPTOMS (1946)	AVERAGE MANGANESE CONTENT AFTER TREATMENT			
					LEAVES	STEM BARK		ROOT BARK
					(1946) (ppm)	(1946) (ppm)	(1945) (ppm)	(ppm)
H_2SO_4, 2.8 gm per 15 lbs of soil	4	64	4.95	MODERATE	1468	758	785	832
H_2SO_4, 5.6 gm per 15 lbs of soil	4	59	4.50	SEVERE	2872	957	1253	988
H_2SO_4, 11.2 gm per 15 lbs of soil	4	63	4.47	SEVERE	5206	1823	3091	1570
Untreated Checks	21	87	——	NONE	516	249	181	87

* Soil pH was initially 5.66.

Table 7. Effect of the Addition of Neutralizing Compounds to a Highly Manganiferous Orchard Soil on the Manganese Content and the Incidence and Severity of Internal Bark Necrosis in Delicious Apple Grown in the Greenhouse.

Soil Treatment All Dosages Added to 15 lbs. Air Dried Soil	Number of Trees Treated	Symptoms	Average Manganese Content			
			At Beginning of This Experiment (Bark Only) (ppm)	At End of The Experiment		Soil pH At Conclusion of Experiment*
				Bark (ppm)	Leaves (ppm)	
$Ca(OH)_2$, 6.8 gm	10	NONE	91	109	324	5.68
$Ca(OH)_2$, 13.6 gm	10	NONE	80	107	201	6.62
$CaCO_3$, 18.4 gm	8	NONE	—	74	424	6.71
$MgCO_3$, 16.7 gm	5	NONE	—	—	236	6.25
MgO, 7.3 gm	5	NONE	—	—	539	6.44
Na_2CO_3, 9.7 gm	10	NONE	92	139	272	7.50
Untreated controls	16	NONE	87†	407	993	4.88
Untreated controls	14	MODERATE	87	491	1244	4.88

* Soil pH of one lot of soil tested at initiation of experiment was 4.80.

† Average figures for both sets of checks in regard to average manganese content at the beginning of the experiment are based on all 30 checks taken together rather than being based on the lots of symptomatic and non-symptomatic controls considered separately, as is true also for the soil pH figures at the end of the experiment.

(13) found that plant absorption of manganese was decreased by the addition of either calcium carbonate or dolomitic-limestone soil. Berger and Gerloff (6) worked on a potato disease known as "Stem Streak Necrosis" which is caused by too much manganese in the soil. This disease occurs only on highly acid soil. It has been observed at a pH of 4.7, and has been much more serious at a still more acid reaction of pH 4.5. It was shown that Stem Streak Necrosis could be prevented by giving the highly acid fields a light application of lime so as to bring about a less acid reaction of about pH 5.2.

It is to be noted that 53.3 per cent of the control trees remained healthy and had a smaller amount of manganese in the leaves as compared with the control trees which developed the Internal Bark Necrosis. It is also to be noted that the pH values of the soil of the two check groups is the same throughout. It is evident that the difference in tolerance to manganese is not wholly a matter of pH but is due to other factors, some of which may be inherent in the trees which were whips of the Delicious variety scions bud-grafted onto Delicious or other seedling stocks.

(5) *Treatment with $NaNO_3$ seems to increase manganese uptake and increase Internal Bark Necrosis symptoms as well but does so without lowering the pH of the treated soil as $(NH)_2SO_4$ does.*

The sodium nitrate was applied to nine Delicious apple whips planted simultaneously in the same soil and under the same conditions as described for ammonium sulfate. The amount of sodium nitrate applied was computed on the basis of the amount of nitrogen used in the ammonium sulfate treatment. The trees were taken down September 6, 1946 and analyses made with results shown in Table 8.

TABLE 8. THE EFFECT OF THE ADDITION OF $NaNO_3$ TO A HIGHLY MANGANIFEROUS ORCHARD SOIL ON MANGANESE UPTAKE AND ON INCIDENCE AND SEVERITY OF INTERNAL BARK NECROSIS IN DELICIOUS APPLE GROWN IN THE GREENHOUSE.

SOIL TREATMENT	SYMPTOMS	NUMBER OF AFFECTED TREES*	AVERAGE MANGANESE CONTENT AT END OF EXPERIMENT		SOIL pH AT END OF EXPERIMENT†
			BARK (ppm)	LEAVES (ppm)	
$NaNO_3$	SLIGHT	6	639	1653	4.86
19.3 gm.	MODERATE	1	642	2297	4.92
per 15 lbs of soil	SEVERE	2	545	2335	5.01
Untreated	NONE	16	407	993	4.88
Controls	SLIGHT	12	470	1180	4.87
	MODERATE	2	628	1620	4.94

* Grouped by symptom-severity classes.
† Soil pH at planting time was 5.18.

The leaves of trees treated with sodium nitrate contained significantly more manganese than those treated with ammonium sulfate, while the manganese content of the bark was less than that in the ammonium sulfate-treated trees, though this difference was not considered significant.

It has been suggested by Arnon's work (1) that nitrate nitrogen is more active in bringing about the absorption of manganese than is the ammonium nitrogen. It is to be noted also that the soil treated with sodium nitrate attained a soil pH of 4.93, while the final pH of soil that received ammonium sulfate treatments was 4.59.

(6) *Differences in uptake of manganese by ten commercial apple varieties grown in the greenhouse in untreated uniform manganiferous soil were found to be considerable. Only Blaxstayman took up more manganese from this soil than did Delicious. Only one of the Blaxstayman trees (the one showing the highest uptake) showed any symptoms of Internal Bark Necrosis although several trees of the Delicious variety did so despite their lower rate of manganese uptake.*

Delicious, like Blaxstayman, is a comparatively heavy feeder on manganese, as shown in Table 9, but unlike Blaxstayman, Delicious seems to have a low manganese tolerance. The combination in Delicious of a

TABLE 9. AVERAGE MANGANESE CONTENT OF LEAVES AND THE BARK OF THE CURRENT SEASON'S SHOOTS OF TEN COMMERCIAL APPLE VARIETIES GROWN IN A UNIFORM UNTREATED HIGHLY MANGANIFEROUS SOIL IN THE GREENHOUSE.*

Variety	Number of Trees Tested	Manganese Content at the End of the Experiment†			
		Leaves		Bark of Current Season Shoots	
		Range (ppm)	Average (ppm)	Range (ppm)	Average (ppm)
Rome	23	199-1195	558	105-495	202
Stayman	5	659-915	837	176-270	228
Blaxstayman	5	1280-3809	2669	440-1108	819
Grimes	5	401-686	545	113-155	135
Lodi	5	445-689	537	155-211	182
Yellow Transparent	5	422-466	449	135-164	151
Turley	5	360-472	435	132-188	163
Yellow Delicious	5	440-648	516	126-205	160
York	5	422-604	544	255-413	314
Delicious	30	691-2068	1110	272-798	446

* The soil pH was 4.80 at the beginning of the experiment.

† In regard to symptom production in relation to manganese uptake, it can be reported that among the five Blaxstaymen trees tested only the tree which took up the largest quantity of manganese (1108 ppm in the bark) showed slight symptoms of Internal Bark Necrosis. Of the 30 Delicious trees, 14 showed symptoms and had manganese contents of the bark ranging from 372 to 798 ppm. The 16 Delicious trees which showed no symptoms had a manganese content of the bark ranging from 272 to 535 ppm.

high rate of uptake and a low tolerance results in this commercial variety suffering the most from manganese toxicity. Low rates of manganese absorption and a high level of tolerance may combine to make other varieties suffer less injury from manganese.

(7) *A comparison of the ranges of manganese content found among healthy and diseased Delicious apple trees grown in a uniform soil without treatment shows that the average manganese content for healthy trees was lower than that for diseased trees, but that the extremely high figures for manganese content of some healthy trees was higher than the extremely low figures shown by some diseased trees. The overlapping of manganese-content ranges of healthy and diseased groups was considerable.*

It will be noted, in the data already presented, that individual trees show fluctuations of two sorts: (1) rather extreme variations in the manganese content of the leaves and bark, and (2) variations in tolerance to manganese as reflected in differences in the severity of the development of Internal Bark Necrosis. Table 10 shows the range of manganese intake by the variety Delicious over a period of four years. The extremes for leaves vary from 249 ppm manganese for healthy trees to

TABLE 10. RANGES IN MANGANESE CONTENT AND AVERAGES FOR DELICIOUS APPLE GROWN IN UNTREATED UNIFORM HIGHLY MANGANIFEROUS SOIL IN THE GREENHOUSE IN RELATION TO THE PRESENCE OR ABSENCE OF SYMPTOMS OF INTERNAL BARK NECROSIS.

Year of Experiment	Condition of Trees	Number of Trees Observed	Range of Manganese Content		Average Manganese Content		Soil pH*
			Leaves (ppm)	Bark of Current Shoots (ppm)	Leaves (ppm)	Bark (ppm)	
1945	Healthy	7	264-806	—	537	—	4.86
1945	Diseased	10	718-1875	—	1379	—	4.77
1946	Healthy	20	249-824	144-422	489	234	—
1946	Diseased	1	1055	539	1055	539	4.78
1947	Healthy	16	691-1465	272-535	993	407	4.88
1947	Diseased	14	850-2068	372-798	1244	491	4.88
1948	Healthy	10	431-703	170-316	548	223	—
For all years	Healthy	53	249-1465	144-535	655	291	4.87
	Diseased	25	718-2068	372-798	1290	494	4.83

* The pH values were determined at the beginning of the experiment.

2068 ppm in diseased trees. The maximum for leaves of the health trees averages higher (950 ppm) than the minimum for diseased trees (874 ppm). However, the average of the manganese content of leave from healthy trees was lower than that of leaves from diseased trees. Th same is true of the manganese content of the bark.

It is evident from the variation in manganese content of individua trees receiving the same treatment that other factors in addition to th manganese content of leaves and bark are concerned with the develop ment of Internal Bark Necrosis. We can only suggest that two o these factors are probably inherent, being existing differences amon trees in regard to their intake and tolerance of manganese.

(8) *Minimum and average manganese content for leaves and bar of Delicious apple showing Internal Bark Necrosis when grown i manganiferous soil treated with* $(NH_4)_2SO_4$, *Sulfur, and* H_2SO_4 *whic lower soil pH, and with* $NaNO_3$, *which does not, were comparable. Thi indicates that* $NaNO_3$ *stimulates the uptake of manganese in a differen manner than other compounds which appear to have this effect throug their influence on soil acidity.*

When a manganiferous soil is treated with chemicals which increas the acidity, the induction of Internal Bark Necrosis is rapidly increase Increased manganese absorption also occurs when sodium nitrate i applied to such soils in which susceptible apple varieties are plante Table 11 shows the lowest and the average quantities of manganese foun in the leaves and bark of Delicious apple trees treated with chemical which induce Internal Bark Necrosis. It appears that the average De licious tree will develop Internal Bark Necrosis when the bark contain about 600 ppm of manganese, but some trees will tolerate considerabl more and some are less tolerant. Of special interest is the developmen of Internal Bark Necrosis in one tree containing 357 ppm manganese i

TABLE 11. THE LOWEST AND THE AVERAGE MANGANESE CONTENTS A WHICH INTERNAL BARK NECROSIS WAS PRODUCED ON DELICIOUS APPL GROWING IN SOILS TREATED WITH $(NH_4)_2SO_4$, SULFUR, H_2SO_4 AND $NaNO$

Soil Treatment	Manganese Content				Soil pH at End of Experiment* (pH)
	Leaves		Bark of Current Shoots		
	Minimum (ppm)	Average (ppm)	Minimum (ppm)	Average (ppm)	
$(NH_4)_2SO_4$	984	1367	425	608	4.60
Sulfur	1069	1395	357	608	4.64
H_2SO_4	1861	2085	428	682	4.53
$NaNO_3$	1113	2095	498	609	4.90

* Soil pH was 4.80 at the beginning of the experiment.

the bark. This is the lowest amount found in the bark of hundreds of affected trees which have been analyzed for manganese content.

The soil treatment with sodium nitrate, a common source of nitrogen used in orchards and on many other crops, produced unexpected results. Its use tended to increase both pH and the production of Internal Bark Necrosis. These results are seemingly contradictory because an increase of the soil pH usually tends to decrease the solubility of manganese and so to reduce the likelihood that Internal Bark Necrosis will develop. Funchess (15) in the Alabama Agricultural Experiment Station found that manganese toxicity developed in several crops grown on soils high in nitrates but did not appear in plots of low nitrate content. Friedricksen (12) found the manganese content of leaves was less in cultures supplied with ammonia as a source of nitrogen than in cultures containing nitrates as the nitrogen source. Sidiris, Young and Krauss (29) showed experimentally that the change of pH during a two-week interval between renewal of the nutrient solutions was from 6.6 to 4.4 for ammonia nitrogen and from 4.4 to 6.8 for nitrate nitrogen. Sidiris and Young (28) later found that the concentration of both manganese and iron increased in plant tissues in proportion to the amounts of nitrate nitrogen in the nutrient solution. Our results with sodium nitrate appear to substantiate the findings of these investigators.

(9) *Variations exist between the manganese contents of different parts of the same tree as well as between individual Delicious trees and among different commercial varieties tested.*

Sometimes the symptoms of Internal Bark Necrosis are rather uniformly distributed on the main stem and branches but they may be found to be more pronounced on or confined to one side of the trunk and to one or more of the branches. This uneven symptom distribution was considered to be associated with variable soil conditions surrounding the roots and perhaps also due to a difference between the absorptive capacity of different roots. In the greenhouse experiments carried out in uniform soils, the irregular distribution of the symptoms is not especially apparent, yet on careful inspection certain twigs of the young trees show variation in the number and distribution of the necrotic areas in the bark. The twigs of each of two trees in the 1946 experiment, growing in soil treated with 2.8 gm sulfuric acid per 15 lbs soil, were analyzed separately with results shown in Table 12. In Tree 72, with symptoms of uniform moderate severity, the manganese content of the bark varied directly with the extent to which symptoms were shown by the individual twigs. In the case of Tree 74 the bark of visibly affected twigs was found to contain more manganese than the bark of twigs showing little or no symptoms of Internal Bark Necrosis. The bark of the 1945 wood of

Table 12. Manganese Content of Individual Twigs of Two Deliciou
Apple Trees Grown in the Greenhouse in Highly Manganiferou
Soil Treated with H_2SO_4 in 1946.

Tree Number	Twig Number	Symptom Severity	Percentage of Twig Length Visably Affected	Manganese Content: Leaves (ppm)	Manganese Content: Bark of 1946 Shoot Growt (ppm)
72	1	Moderate	43	1793	390
	2	Moderate	79	1934	442
	3	Moderate	100	1858	498
74	1	Moderate	70	2473	615
	2	Moderate	25	2168	621
	3	Slight	—	—*	651
	4	Trace	—	—	453
	5	None	—	—	468

* Average manganese content for leaves of twigs 3, 4, and 5 taken together was 22
ppm.

Tree 74 contained on the average 654 ppm manganese and the root ba
674 ppm manganese. The average manganese content for the 1945 ba
of Tree 72 was 454 ppm and the root bark averaged 516 ppm mangane
In both cases, the root bark contained more manganese than the ste
bark even though necrotic lesions have never been noted in roots
diseased trees.[5] The soil had a pH of 4.78 at the end of the experimen

(10) *The exchangeable and readily reducible manganese content
six West Virginia orchard soils, taken in most cases from beneath bo
naturally diseased and healthy trees, showed in all cases manganese qua
tities ample for normal growth and in most cases sufficient to indu
Internal Bark Necrosis, provided that the soils were made sufficient
acid to make the manganese available in toxic concentrations.*

The manganese content of several orchard soils was determined
the method described by Sherman, McHargue and Hodgkiss (27). Th
soil samples were brought to the laboratory, air dried, pulverized, scree
ed through a 20-mesh sieve, and stored in air-tight glass containers un
they could be analyzed. No attempt was made to determine separate
the water-soluble manganese since it is assumed that the very sma
amount of this form present would be included in the exchangeab
manganese.

From the Huxham orchard near Huntington, in which Intern
Bark Necrosis was frequently observed, soil samples were taken at i
tervals over a period of one year from one small plot in the open whe
young trees showing severe Internal Bark Necrosis had been remove

[5]The nature and origin of the rootstock are unknown.

This repeated sampling from the same place made it possible to determine the degree of variation in exchangeable manganese which might be met with at different seasons within the same soil. There was considerable uniformity except for the two samples taken in July and September of the same year which were comparatively high in exchangeable manganese. Temperature and moisture variations could be responsible for this difference. Fujimoto and Sherman (13, 14) studied the effects of drying, heating, and wetting on the level of exchangeable manganese in Hawaiian soils and found that both drying and heating increased the exchangeable manganese, while wetting decreased it. Such changes in climatic conditions may be responsible for the erratic occurrence of Internal Bark Necrosis noted in the field, where the disease is much more serious in some seasons than in others when it may not appear at all. Hot, dry seasons would tend to favor the appearance of Internal Bark Nerosis, while cool, wet seasons would retard its development.

The variation is considerable in both exchangeable and reducible manganese in the five other orchards as is shown in Table 13 but not more so than would be expected from different soil types.

(11) *A uniform highly manganiferous soil was subdivided for treatments with acidifying and neutralizing chemicals and with sodium nitrate to learn the effect of these treatments on the incidence and severity of Internal Bark Necrosis on trees grown in the treated soils (compare Tables 4-8) and upon quantities of exchangeable and easily reducible nanganese to be found in the soils after treatment.*

All the soil was collected from orchard No. 1 in two different years.[6] All samples marked X were collected in 1946 and those marked A in 947. As is shown in Table 14 all treatments involving acidification of he soil caused an increase in Internal Bark Necrosis. All neutralizing reatments produced healthy trees and a relatively high pH. The two heck soils with pH comparatively low happened, in this experiment, to produce healthy trees only, but it is known from a complete study of 30 uch check trees (Table 3) that 46.7 percent of this larger sample of heck trees became diseased. This difference in response is believed to e due to inherent differences in individual trees growing under uniform onditions. The response to treatment with sodium nitrate, which inuced a pH near the border line and a low exchangeable manganese, uises questions which cannot now be satisfactorily answered (see discuson of data presented in Table 10, Page 19). An intricate relation of itrates to the intake of manganese in abundance at a comparatively igh pH contrasts with the simpler effect of the application of ammonium

[6] The Huxham orchard near Huntington in which Internal Bark Necrosis was frequent observed.

Table 13. Quantities of Exchangeable and Easily Reducible Manganese* Found in the Soils of 6 West Virginia Orchards.†

Orchard Number	Sampling Date‡	Source of Soil Sample	Soil pH	Manganese: Exchangeable (ppm)	Manganese: Easily Reducible (ppm)
1	June 9	Abandoned site**	5.19	63.7	416.5
	July 7	Abandoned site	5.52	138.0	313.5
	July 28	Abandoned site	5.33	51.4	258.5
	August 9	Abandoned site	5.49	58.5	446.7
	September 11	Abandoned site	5.33	104.1	404.8
	April 25	Abandoned site	5.31	86.5	363.2
	May 21	Abandoned site	5.28	83.0	478.8
	July 23	Abandoned site	——	85.4	470.3
2	October 2	Healthy Stayman	4.26	12.2	135.4
	October 2	IBN††, Delicious	4.84	5.9	17.6
	October 2	IBN, York‡‡	6.50	4.1	20.8
	September 2	Healthy Delicious	5.83	50.3	112.9
	September 2	IBN, Delicious‡‡	6.40	16.1	231.6
3	June 27	Healthy Delicious	4.41	67.8	222.2
	June 27	IBN, Delicious	4.33	73.7	134.0
	August 14	Healthy Delicious	4.50	80.0	304.7
	August 14	IBN, Delicious	4.46	17.8	11.6
	August 17	IBN, Delicious	4.38	164.0	143.6
4	June 5	IBN, Delicious	4.90	41.6	240.2
	June 5	Healthy Delicious	4.60	15.7	161.2
5	October 21	IBN, Delicious	4.78	19.4	217.6
	October 21	Orchard entrance	——	11.2	80.7
	September 2	IBN, Delicious	4.43	76.6	345.7
6	September 29	Tree with bitter pit	——	69.0	254.4
	September 29	Tree with bitter pit	——	13.2	3.9

* As determined by the method of Sherman, McHargue and Hodgkiss (27).

† Orchard 1 was the Huxham orchard near Huntington in Cabell County. Orchards and 3 were situated in Hampshire and Monongalia Counties, respectively. The locatio of Orchard 4 is now uncertain. Orchards 5 and 6 were situated in Morgan and Maso Counties, respectively.

‡ The sampling period extended from June, 1946 to September, 1947.

** All samples from this orchard taken at different seasons from the same site whic was previously abandoned because of severity of the development of Internal Bark Necrosi in young trees growing there.

†† IBN = Internal Bark Necrosis.

‡‡ It is uncertain if soil around this diseased tree was given a neutralizing treatme after symptoms appeared and before sampling.

sulfate which lowers the pH and in so doing promotes the intake c manganese.

It is unfortunate that the soluble manganese content of the soil was not determined. Presumably, the manganese in the soil solutio would have been more readily available to the trees than the other form of manganese. It may be noted that soil treated with sulfur, sulfuri acid, and manganese sulfate contained greater concentrations of ex changeable manganese than the control soil. All of the trees growing i

TABLE 14. EFFECT OF THE TREATMENT OF A UNIFORM HIGHLY MANGANIFEROUS SOIL WITH ACIDIFYING AND WITH NEUTRALIZING CHEMICALS AND WITH $NaNO_3$ UPON THE EXCHANGEABLE AND REDUCIBLE MANGANESE TO BE FOUND AFTER TREATMENT AND UPON THE INCIDENCE AND SEVERITY OF INTERNAL BARK NECROSIS.*

SOIL TREATMENT ADDED TO 15 LBS. OF SOIL	SOIL SAMPLE NUMBER	SOIL pH AT END OF EXPERIMENT	SYMPTOM SEVERITY	MANGANESE FOUND	
				EXCHANGEABLE	EASILY REDUCIBLE
				(ppm)	(ppm)
$(NH_4)_2SO_4$, 15 gm	A-21	4.52	Slight	61.5	321.1
$(NH_4)_2SO_4$, 15 gm	A-22	4.50	Slight	76.2	321.1
$NaNO_3$, 19.3 gm	A-30	5.04	Slight	4.5	294.8
Sulfur, 1.7 gm	X-2	4.76	Moderate	219.9	365.0
Sulfur, 3.4 gm	X-7	4.74	Severe	278.4	338.1
H_2SO_4, 5.6 ml	X-77	4.58	Severe	260.9	324.0
H_2SO_4, 11.2 ml	X-82	4.45	Severe	372.0	259.7
$MnSO_4$, 384 gm	X-26	5.02	Severe	197.1	507.7
MgO_2, 7.3 gm	A-16	6.44	None	42.1	365.0
Na_2CO_3, 9.7 gm	X-68	7.84	None	73.1	373.2
Mg CO_3, 16.7 gm	A-11	6.38	None	66.7	402.4
$CaCO_3$, 18.4 gm	A-1	6.55	None	11.2	425.8
Ca $(OH)_2$, 6.8 gm	X-15	6.52	None	86.5	428.2
Ca $(OH)_2$, 13.6 gm	X-23	7.13	None	36.2	421.2
Untreated Control	X-42	4.80	None	105.8	270.2
Untreated Control	X-55	4.78	None	135.7	325.2

* All soil was collected from Orchard 1 in two different years. All X - numbered samples were collected in 1946 and A - numbered samples in 1947.

soils receiving these treatments were moderately to severely diseased. The concentration of exchanceable manganese in soils treated with alkalizing agents was less than that of the control soils. None of these trees exhibited symptoms of Internal Bark Necrosis. Soils treated with ammonium sulfate and sodium nitrate contained less exchangeable manganese than the control soils. The trees which grew in the soils treated with either ammonium sulfate or sodium nitrate exhibited slight symptoms of Internal Bark Necrosis, while the trees which grew in the control soils did not. The one certain conclusion which can now be reached, on the basis of the available evidence, is that the symptoms of Internal Bark Necrosis did not appear in trees grown in soils to which lime or other alkalizing agents were added.

Summary

INTERNAL Bark Necrosis is a non-parasitic disease affecting the apple tree. It is of primary importance on the variety Delicious and its sports, although other varieties may be affected.

In the early stages of the disease small elevations are visible on the epidermis and young bark which, if cut open, reveal dead areas within the cortex and inner bark which oftentimes extend into the wood. As the disease develops, the older bark becomes rough and scaly, the affected limbs unthrifty, and death frequently follows.

The disease occurs when susceptible trees, under some conditions, take up manganese from the soil in such quantities that the tissues become poisoned as it accumulates within them. Manganese toxicity resulting in Internal Bark Necrosis develops most commonly on trees growing in soils of high manganese content and which are also usually highly acid.

Manganese is a minor element essential in minute quantities for plant growth. It is insoluble in neutral or alkaline soils, but becomes progressively more soluble as the soil acidity increases beyond the 6.5 pH level. Internal Bark Necrosis never developed on apple under experimental conditions when the soil pH was above 5.3. It is recommended that orchardists maintain the soil pH at or above 5.5 to prevent development of this disease. Consideration should be given to the fact that treatments which acidify the soil tend to increase the quantity of available manganese. The application of sodium nitrate was found also to favor development of the disease without causing any increase in soil acidity such as resulted from the addition of ammonium sulfate. This should be considered before recommending the application of sodium nitrate as a fertilizer to manganiferous soils planted to the variety Delicious. The application of lime and other neutralizing substances reduces the availability of manganese. The incidence and severity of Internal Bark Necrosis usually can be controlled by such soil-neutralizing treatments.

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