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A STUDY OF TRUNK INJURIES AND DISEASES
OF APPLE TREES

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by

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Approved
J. C. Whitten.

PREFACE

Owing to the prevalence of canker diseases in Missouri apple orchards, and the untold damage which they are causing, the growers are asking for information that will enable them to combat these diseases successfully. It was with the idea of obtaining additional information concerning these diseases, that this investigation was undertaken.

The conditions were most favorable for carrying on this investigation. Abundant material has been at all times available in the Experiment Station orchard, and in commercial orchards adjacent to Columbia. These orchards are planted in different types of soils; they represent the extremes of orchard management from practically no attention to the best of care, and include about 150 varieties of apples, ranging from one to twenty-five years of age. The laboratories of Botany and Horticulture are well equipped for mycological work. Much of the inoculation work was carried on in the greenhouse, especially during the winter months.

Careful observations on the appearance and behavior of canker diseases under normal conditions in the orchard formed an important part of this work, throughout the year,

beginning in September. These observations were supplemented by numerous experiments in the field and laboratory.

Some of this investigation has necessarily been a repetition of previous work in other sections of the country. This has seemed necessary in order to corroborate previous investigations, and to determine the behavior of these diseases under Missouri conditions. Several new points have been established, however, and are here reported for the first time.

This investigation has been done under the direction of Dr. J. C. Whitten, to whom I am greatly indebted for valuable suggestions and his untiring enthusiasm, without which much of this work could not have been accomplished. I wish also to acknowledge my indebtedness to Dr. G. M. Reed for suggestions pertaining to the laboratory work.

INTRODUCTION

During the past fifteen years the attention of apple growers in various parts of the country, particularly in the Northern and Middle Western States, has been called repeatedly to the prevalence and destructive nature of certain 'canker' diseases of apple trees. Canker is a general term used to designate injuries to the bark and growing layer on the trunk and branches of apple trees, caused by fungi. Although these injuries have been observed for more than a century, the real cause of the trouble was not known until comparatively recent years. Sunscald was usually held responsible, though not infrequently the cause of the injury was attributed to old age, or unfavorable soils. It is now known that canker is due to fungus attack, and that there are many fungi which cause canker diseases.

The "New York apple tree canker," and the "Illinois canker" or "blister canker", are the two most common and most destructive canker diseases in Missouri. The former of these is caused by the fungus Sphaeropsis malorum Berk., while the latter is due to Nummularia discreta Tul. A bark canker, Myxosporium corticolum, is very widespread, but apparently causes but little or no injury. Recently I found a canker disease caused by a fungus which apparently is new to Botanists. This investigation is concerned primarily with the New York canker and the Illinois canker, together with injuries to apple trees through which infection may take place.

OBJECTS OF THIS INVESTIGATION.

The main objects of this investigation were to study the more common injuries to the trunks and branches of apple trees, with a view of determining how they may be avoided, and the best treatment where the injury already exists. The relation between trunk injuries and subsequent infection has been studied to determine how infection may be avoided.

This investigation on canker diseases of apple trees includes a study of their relative importance, the extent of their injury, the time and manner of infection, the relative susceptibility of the different varieties, the factors influencing fungus growth, and the comparative efficiency of different methods of control. The ultimate aim was to obtain an efficient means of control which would at the same time be practical. With this idea in mind, all of the control measures have been carried on in the orchard.

Appearance of Canker

The New York canker and the Illinois canker are very similar in appearance in their earlier stages. In fact it is impossible for the casual observer to distinguish between them. For that reason, and to avoid needless repetition, both diseases will be first described in so far as they are similar; later emphasizing their points of difference.

The appearance of the cankers varies greatly with age. In their earlier stages these diseases appear as reddish brown spots. The line separating the diseased areas from the healthy bark is clearly pronounced. Later on these spots are usually further marked and made more noticeable by cracks in the bark around their margin.

The fungi grow most rapidly lengthwise of the limb, thus forming long and relatively narrow wounds. It is not at all uncommon to find infections six feet or more in length and only two or three inches wide. Such an infection is shown in Fig. 1. Infected branches are, therefore, seldom girdled until the fungus has progressed several feet along the limb. The growth of the fungus from the point of infection upward is usually more rapid than the growth downward. The growth is also faster in the region of the cambium than it is in the bark. The progress of the disease is marked at frequent intervals by lines in the bark, showing the periodic growth

of the mycelia. Fig.2 These lines may remain more or less distinct for a year or more.

The cankers are most commonly found on the larger branches of mature trees. Occasionally, however, these diseases may be found on the trunks of young trees. Often small limbs of old trees are diseased ^{throughout} their entire length. Small limbs are frequently killed in one season, while a relatively longer time is usually required to girdle the larger branches.

The appearance of these cankers is greatly influenced by the rate of progress which the fungi make in the host tissues. When the growth is slow, the diseased areas are marked by frequent cracking of the bark, due to shrinking of the latter, ^{to} and the enlargement of the adjacent sound tissues. This enlargement tends to check the further advance of the disease. On the other hand, when the disease is advancing rapidly, the cracks in the bark are correspondingly farther apart. Frequently infections attain to four or five feet in length by two or three inches wide before the bark cracks around the margin. Fig.1.

The appearance of older infections is often modified by the growth of saprophytic fungi, the presence of borers, and to a certain extent by sunscald. It is frequently difficult, therefore, to determine the causal fungus in the absence of the fruiting structures.

Appearance of the New York Canker.

The New York canker may often be distinguished from the Illinois canker in their earlier stages from the fact that with the former the bark usually clings tenaciously to the decaying wood. This canker is easily distinguished from the Illinois canker in the later stage of the disease, by the presence of numerous small fruiting bodies scattered over the blackened surface. They are formed beneath the epidermis but soon break through exposing the black pycnidia. These bodies are small, usually about 1 mm. in diameter, but large enough to be seen easily with the unaided eye.

Appearance of the Illinois Canker.

There is no distinguishing feature of the Illinois canker that will hold true in every case in the early stages of the infection. Usually, however, these cankered spots are more nearly the color of the bark at first, and hence less noticeable than Sphaeropsis infections.

As the disease progresses the canker spots may become slightly sunken. More frequently however, they are elevated somewhat above the surrounding tissue, due probably to the growth of saprophytic fungi beneath the bark. The diseased bark usually peels off readily from the wood. On the smaller limbs, particularly, the epidermis frequently becomes detached, forming blisters.

No difficulty will be experienced in distinguishing the Illinois canker in the latter stages of the disease. The canker spots which at first are somewhat inconspicuous, eventually become blackened and the diseased area covered with large blister-like fruiting structures. These patches of black, decaying wood are easily seen from a distance. The fruiting bodies vary in size from $1/8$ to $1/4$ inch or more in diameter. They are attached to the decaying wood and remain there even after the bark has fallen away, thus constituting a diagnostic character of absolute reliability, separating this from all other known cankers. Fig. 2.

Myxosporium corticolum

One of the most common canker diseases is caused by the fungus Myxosporium corticolum. The fungus grows in the outer bark on the trunks of apple trees. Much of the roughened, scaly appearance of the trunks of old trees is due to this fungus. It is confined to the outer layers of the bark and for that reason the damage done is relatively small. In outward appearance the cankered spots resemble those caused by Sphaeropsis malorum. Attention is called to this bark canker, mainly for the purpose of distinguishing it from the New York and other similar cankers of a more serious nature.

The attention of the public was first called to this canker on the trunks and branches of apple trees by Atkinson.⁴ Paddock at first thought that this bark canker was caused by Sphaeropsis malorum. Further study showed that this injury was due

to a different fungus, which he called Macrophoma malorum Pk. Edgerton (35) (1908) reported the results of his investigation of this canker under the name Myxosporium corticolum. He thus describes the appearance of the disease on the trunks of apple trees: "It produces a canker on the old bark and has been frequently confused with Sphaeropsis malorum. They may be distinguished from the fact that the former occurs only in the bark, does not penetrate deeply in the host, the mycelium extending only about one third of the way to the cambium zone. New rings of growth are formed each year. It grows out, during the second year, into the unaffected bark surrounding the canker and this region becomes the spore bearing one for that season. Spore pustules begin to form in the summer and continue through fall, winter, and spring."

The fungus may grow one or two inches in each direction during the season. While this new growth is taking place, the old bark scales off, and in its place new bark is formed which apparently is entirely free from the disease. As a result, the fungus causes but little real damage to the tree.

The spores are borne in acervuli. These pustules are formed under four or five layers of bark cells. They are small, about 1 to 2 mm. in diameter, and slightly raised at the place where the bark is ruptured. The spores are hyaline, cylindrical, very densely granular, and vary in size from 18-32 X 6-9 microns. These spores differ mainly from Sphaeropsis spores in color, the latter being reddish brown.

Although this disease does not injure the tree directly to any great extent, the cracks made in the bark may afford an opportunity for infection by one of the more serious canker diseases. Whitten, who has observed this canker for many years, states that in some instances it paves the way for Sphaeropsis infection. During a severe winter the bark sometimes cracks unusually deep around the cankered areas, and may occasionally be followed by infection by Sphaeropsis.

At the time this investigation was started, and for some time afterwards, I did not recognize this bark canker as being distinct from the New York canker, since the latter is mentioned by Paddock (49)) as producing only a general roughening of the bark in some instances. Again, their fruiting bodies are almost identical in external appearance. The article by Edgerton, noted above, suggested the probability of our bark canker being caused by a fungus other than Sphaeropsis . . . Fruiting specimens were taken to the laboratory and examined microscopically. Careful examination of a large number of slides showed that this fungus agreed in every particular with Myxosporium, etc. in the character of the fruit body and the appearance of the spores. I was, therefore, reasonably certain that they were identical.

Further proof of the identity of this fungus was sought in germination and cultural studies. Spores sown in hanging drops of apple juice, began to germinate after 24 hours, sending out the germ tube from the end of the spore. The germinating spores usually became from one to three septate,

and took on a brownish tinge.

Some of the spores were isolated and pure cultures of the fungus were grown upon dextrose, potato agar, bean agar, and bean pods. The aerial hyphae was at first white, becoming pink with age. The growth was slow in every case, and no spores were produced upon any medium tried.

These cultural and germinating characteristics agree in the main with those described for Myxosporium corticolum, thus substantiating the microscopical diagnosis. There is no doubt that the bark canker occurring on the apple trees in the Horticultural Grounds is caused by the fungus Myxosporium corticolum.

INVESTIGATIONS AND LITERATURE

The diseased condition of the trunk and limbs of apple trees due to Sphaeropsis malorum, had been observed for many years before the real cause of the injury was known. It was commonly thought to be due entirely to sunscald. In 1898 Waite (61) called attention to the probability of this injury being caused by the fungus Schizophyllum commune Fr. In the same year Paddock (49) found Sphaeropsis malorum spores commonly associated with the injury. By a series of inoculation experiments, he proved the disease to be due to Sphaeropsis malorum, the same fungus causing the well known Black Rot of the apple.

As a disease of Pomaceous fruits the fungus has been known for many years. Attention was first called to the Black rot of apples by Peck (53) (1881), who proved that the disease is caused by the fungus Sphaeropsis malorum. Halstead (33) (1892), showed that a similar disease of pear and quince fruits is caused by the same fungus. Paddock's experiments proved that the fungus causing the black rot and the fungus causing the New York canker are identical.

SUSCEPTIBLE AND RESISTANT

VARIETIES

Different varieties of apple trees vary widely in their susceptibility to canker diseases. Some are almost, if not quite immune, others offer a minimum resistance, while between

these two extremes lies a larger number of sorts with varying degrees of resistance. Those sorts which sunscald badly are most likely to be affected with canker later on. The degree of susceptibility of any given variety seems to vary somewhat with the district.

Mc Cready(45)(1909), in his report of the New York canker in Canada, says that the varieties which suffer most severely are Ben Davis, Northern Spy, Stark, Ontario, Salome, Shannon, and King. He mentions as the most resistant varieties, Peewaukee, Cranberry, Pippin, and Talmon Sweet. The most susceptible varieties in New York State, according to Paddock, are Spitzenberg, Twenty Ounce, Baldwin, Wagoner, Greening, and King; given in the order of their susceptibility. Talmon Sweet is the most resistant variety.

Some data are given by Sears(160)(1902), from Nova Scotia, showing the number of trees of different varieties of apples affected by New York canker from which it appears that Ribston Pippin, Nonpareil, and King are especially subject to this disease.

Nothing has been reported previous to this paper, concerning the susceptibility of the different varieties of apple trees to the Illinois canker. In order to determine the relative susceptibility of the different sorts to the Illinois canker and the New York canker, careful observations were made on a large number of varieties as to the number of infections, and the relative virulence of the diseases in different varieties. These observations were made on the

the trees on the Horticultural Grounds. This orchard contains nearly 150 varieties of apple trees, comprising all of the commercial sorts adapted to this section, and many European varieties of more or less promise. Thus an unusual opportunity was afforded of obtaining the relative susceptibility of the different sorts. The trees vary in age from two to seventeen years. In determining the relative susceptibility, only trees of approximately the same age are compared.

The relative susceptibility of the different varieties of apple trees to canker diseases is indicated in the following table:

Table I.

Variety	No. of trees.	Percent of trees infected		Rate of progress
		Sphaeropsis	Nummularia	
Albemarle	1	0.00	0.00	Rapid
Anison	1	1.00	1.00	Rapid
A. Orient	1	0.00	0.00	
Arkansas	1	0.00	0.00	
Ark. Black	1	00.00	0.00	
Ark. Beauty	1	0.00	0.00	
Ashton	1	1.00	0.00	Slow
Autumn Str	1	0.00	0.00	
Bailey Sw.	1	1.00	0.00	Medium
Balagh	1	0.00	0.00	
Baldwin	2	0.50	0.00	Medium
Banana	2	0.00	0.00	
Batullen	2	1.00	0.00	Slow
Battyani	1	1.00	0.00	Rapid
Bayard	2	0.50	0.00	Very slow
Beach	1	0.00	0.00	
Ben Davis	34	0.26	0.24	Medium
Ben Hur	2	0.00	0.00	
Elenheim	1	1.00	0.00	Medium
Bastian	1	0.00	0.00	
Brier Sw	1	0.00	0.00	
Canada Rein		1.00	1.00	Very slow

Table I(Continued.)

Variety	No. of trees	Percent of trees infected.		Rate of progress
		Sphaeropsis	Nummularia	
Champion	2	6.00	0.50	Rapid
Clay	1	1.00	0.00	Rapid
Clark	1	1.00	0.00	Slow
Clayton	1	0.00	1.00	Very rapid
Collins	1	1.00	0.00	Slow
Czar Thorn	1	0.00	1.00	Rapid
Delicious	2	0.00	0.00	
Delaware	1	1.00	0.00	Slow
Devonshire Duke	1	0.00	0.00	
Doctor	1	1.00	0.00	Medium
Dorn	1	1.00	0.00	Medium
Downing Blush	1	1.00	0.00	Medium
Duling	2	0.00	0.00	
Edwards	1.00	1.00	1.00	Rapid
Eper	1	1.00	0.00	Slow
Ewalt	1	0.00	0.00	
Fameuse	4	0.50	0.00	Very slow
Fausts Rome	1	0.00	0.00	
Flory	1	1.00	0.00	Medium
Gano	10	0.54	0.33	Medium
Ginnie	1	0.00	0.00	
Gold Medal	1	1.00	0.00	Slow
Golden Russet	1	0.00	0.00	
Grays Red	1	1.00	0.00	Rapid
Green Win. Pip.	1	0.00	0.00	
Grimes	12	0.17	0.00	Medium
Heidorn	1	0.00	0.00	
Hubbards	1	0.00	0.00	
Huntsman	5	0.20	0.20	Slow
Ingram	2	0.00	0.00	
Jonathan	55	0.20	0.00	Slow
July	1	0.00	1.00	Slow
July Cluster	1	0.00	0.00	
Kartacs	1	1.00	0.00	Medium
King David	2	0.00	0.00	
Kans. Greening	1	1.00	0.00	Medium
Lady	1	1.00	0.00	Medium
Lady Cariner	1	0.00	0.00	
Lady Duchess	1	1.00	0.00	Very Slow
Littus Pippin	1	1.00	0.00	Medium
Liveland Rasb.	4	0.00	0.00	
London	1	0.00	0.00	
Longfield	1	0.00	0.00	
Lou	1	1.00	0.00	Slow
Louise	1	0.00	0.00	
Lowell	1	1.00	0.00	Very rapid

Table I.(Continued)

Variety	No.of trees.	Percent of trees infected		Rate of progress
		Sphaeropsis	Nummularia	
Maggar	2	0.50	0.00	Medium
Maiden Blush	2	1.00	0.00	Medium
Managere	1	0.00	0.00	
Mann	1	0.00	1.00	Slow
Mc.Intosh	1	0.00	0.00	
Melon	1	1.00	0.50	Rapid
Metill	1	1.00	0.00	Slow
Mexander	1	1.00	0.00	Slow
Mihalype	1	1.00	0.00	Medium
Miller Boys	1	1.00	0.00	Rapid
Minnesota	1	0.00	0.00	
Minkler	2	0.00	0.50	Slow
Missouri	4	0.00	0.00	
Moshiers Sweet	1	0.00	0.00	
Nelson Sweet	1	0.00	1.00	Very rapid
Noble Savor	1	0.00	0.00	
Nyari Piros	1	1.00	0.00	Slow
Nyari Vej.	1	0.00	0.00	
Nyack	1	1.00	0.00	Slow
Ohio Beauty	1	0.00	0.00	
Ohio Pippin	1	0.00	0.00	
Olive	1	0.00	0.00	
Oldenberg	1	1.00	1.00	Very Slow
Ontario	1	0.00	0.00	
Panyik	1	0.00	0.00	
Pasman	1	0.00	0.00	
Peach	1	0.00	0.00	
Pickett	1	0.00	0.00	
Primate	1	1.00	1.00	Medium
Pumpkin Russet	1	0.00	0.00	
Pumpkin Sweet	1	0.00	0.00	
Pyros Baccata	1	0.00	0.00	
Rome	4	0.00	0.00	
Rutherford	1	1.00	0.00	Very slow
Seedling	5	0.25	0.00	Very slow
S pitzenberg	1	1.00	1.00	Very rapid
Stanard	1	1.00	0.00	Medium
Sum.Colville	1	1.00	0.00	Rapid
Tetofski	3	0.33	0.00	Rapid
Tudor	1	1.00	0.00	Slow
Wine Sap	7	0.57	0.14	Medium
Wolt River	1	0.00	0.00	
White Pippin	1	1.00	1.00	Slow
York Imperial	4	0.50	0.00	Very slow

Nearly fifty percent of the varieties of apple on the Horticultural Grounds are infected with either the New York canker or the Illinois canker or both, as shown in Table I. The former is the more prevalent. The progress of the diseases varies greatly with the variety. The seasonal growth of the fungi varies from a few inches in some varieties to several feet in the less resistant sorts. The relative rate of progress is indicated in the table by the terms "very slow", "slow", "medium", "fast", "very Fast". In determining the degree of susceptibility of any particular variety, the number of infections is considered, but the final conclusion is based largely upon the subsequent progress of the disease.

Growth of the Mycelium.

The depth to which the mycelia of canker fungi penetrate the host tissues has a direct bearing upon the subsequent treatment of the infections. This point seems never to have been determined experimentally. Paddock did not consider this point of sufficient economical importance to warrant much study. Other investigators seem to have concurred in his opinion which probably accounts for the present lack of experimental data along this line.

A marked discoloration of the wood beneath the affected areas has been uniformly observed in the case of both New York and Illinois canker infections. The extent of this discoloration has been taken by some investigators to indicate the depth of fungus growth. One would hardly

be justified, however, in this assumption without further proof.

In order to determine this point, typical specimens of last season's fungus growth were selected from which to make slides for microscopical study. These specimens included material of the New York and Illinois cankers. After experimenting with several stains without success, I finally tried gentian violet and eosin, at the suggestion of Dr. Durand. With this combination stain, splendid results were obtained; the pink mycelium showing in strong contrast to the violet host tissues.

The best results were obtained by applying the stains successively to the wood sections on a glass slide. The sections were first stained deeply with gentian violet, usually twenty to thirty minutes being required for this stain. The slides were then washed with 95% alcohol until streams of violet ceased to appear. The sections were then stained for about one minute in eosin ($\frac{1}{2}$ % eosin in 95 % alcohol). After the surplus eosin had been wiped from the slide, the sections were cleared in carbol-turpentine clearer, washed in xylol, and mounted in balsam.

The slides were made from free hand sections taken at various depths from the cambium to the center of the infected limbs. When properly stained, the mycelium showed very distinctly in each of these sections. Uniformly good results were obtained from specimens of the two kinds of canker. In the case of each, the presence of their respective

mycelia in the center of infected limbs that were two and a half inches in diameter was thus demonstrated.

As further proof that the mycelia seen in the stained sections were those of Sphaeropsis and Nummularis, and not of some saprophyte, cultures were made. Small portions of diseased wood taken from the center of the limbs were introduced into sterile corn agar slopes, the usual sanitary precautions being observed. Twelve tubes were inoculated from a limb infected with the Illinois canker, and an equal number from a New York canker infection. Colonies were produced from each bit of wood having the characteristics of the respective fungi. All of the Nummularia cultures produced the typical yellow ochre conidia, but in none of the cultures were fruiting structures formed. Inoculations were made in apple twigs with mycelium from these cultures. The fungus grew at all points of inoculation and produced the characteristic lesions in three to four weeks.

Since the New York canker fruited in the cultures it was not thought necessary to further identify the fungus by means of inoculations. These experiments prove beyond a doubt that the Sphaeropsis fungus penetrates to the center of the affected limb. The evidence indicates that the same habit is true of the Illinois canker fungus, but since the fungus did not fruit either in cultures or on the inoculated twigs, the final proof is lacking.

MANNER OF INFECTION.

The fungus causing the New York canker is invariably regarded as a wound parasite. Paddock (49) (1898), says, "The mycelium is unable to penetrate to the cambium through living bark, but those spores that chance to fall and germinate in wounds, produce the cankers."

Salmon (59) (1910^{et}), from his investigation of this canker writes, "These cankers may be formed either by the mycelium in a mummified apple which in drying has become glued to the branch, growing from the diseased apple into the branch, or the mycelium may directly invade the wood from the base of a dead fruit spur which has been killed by the fungus."

It is undoubtedly true that most canker infections occur through wounds made in the bark and wood of trunks and branches, as may be seen from even a casual observation. In most instances the infection can be traced to some sort of previous injury. Occasionally, however, the disease is present in its worst form when no previous injury can be seen. To determine the percentage of infections occurring through wounds, careful observations were made on the diseased trees on the Horticultural Grounds. These results, together with the percentage of infections from each class of wounds, or through lenticels, are given in Table II.

MANNER OF CANKER INFECTION

Table II.

Source of Infection	Kind of canker, Number, and Percent of Infections							
	Sphaeropsis		Nommularia		Myxosporium		An Unknown Canker	
	No.	%	No.	%	No.	%	No.	%
Prune W.	88	37	32	53.0	000.0		10	17.8
Insect Injury	19	8.1	3	5.0	0.0		4	7.0
Sunscald	9	3.8	8	13.3	0.0		3	5.3
Mechanical	15	6.3	5	8.3	1.0	0.6	4	7.0
Fruit spurs	21	8.9	0	0.0	0.0		10	17.8
Lenticels	15	6.5	0	0.0	51.0	28.9	11	19.2
Unclassified	49	20.8	12	20.0	124.0	70.5	15	25.9
Total	236		60		176.0		57	

It will be seen from this table that wounds made in pruning are the most common source of subsequent canker infections. The "unclassified" should in most instances fall under one of the classes of infection resulting from some form of wound. Thus approximately 85% of Sphaeropsis infections, 100% of Nommularia infections, and 35% of the infections from the "Unknown" fungus, occur through some form of injury made in the bark or wood. It appears from this table that the mycelium of the New York canker may directly invade the wood through fruit spurs, or even through lenticels on twigs and small branches. These observations corroborate those of Salmon, and furthermore establish the fact that infections sometimes occur through lenticels. The same habit may be true of the Illinois canker fungus, but my observations do not warrant the assertion.

In order to further determine whether the spores of Sphaeropsis malorum could germinate on the surface of the uninjured bark of apple twigs, and the mycelium penetrate the living bark and into the wood, a series of experiments were carried on in the laboratory, and in the greenhouse. Sphaeropsis spores from pure cultures were sprayed on apple twigs without in any way injuring the bark. These twigs were subsequently kept under bell jars for forty eight hours to maintain a moist condition surrounding the twigs until the spores had had time to germinate, and furthermore, to guard against outside infection.

In two weeks the first infections were observed. Four days later more than fifty percent of the twigs were infected with one to six infections each. In several instances the fungus was fruiting abundantly. Eighty-eight percent of the twigs were found to be infected after thirty days from the time the spores were sprayed onto the twigs. The fungus fruited, eventually, on all of the infected twigs.

Usually the infections were found around the tender, swelling buds, but in several instances the fungus penetrated the smooth, injured bark, and produced the characteristic lesions. In the former case the immediate progress of the fungus was rapid, the mycelium growing into the wood in a comparatively short time. In instances where the germ tube entered the host through a lenticel, the fungus advanced slowly at first. As soon, however, as the mycelium reached the growing layer, the immediate acceleration in the growth and spread of the disease was very marked. These results point

unmistakably to the fact that Sphaeropsis spores are capable of germinating on the surface of the uninjured bark of apple twigs, and invading the bark and wood through buds and lenticels. These results, however, do not agree with the common opinion concerning the infection habits of this fungus.

This seems to be the only experimental work that has been done to determine whether Sphaeropsis infection of apple twigs may not occur through bark which has not been previously injured. For this reason, and because the results obtained in the above experiments, are contrary to a very general opinion among investigators, it was thought best to repeat the experiment with different varieties, under varying conditions of moisture and temperature. Twigs were taken from apple trees of the most resistant and most susceptible sorts and inoculated as before. On April 7, this experiment was begun on sections of twigs from Jonathan, Winesap, Doctor, Kartacs, and Ben Davis varieties. Some of the twigs of each variety were subsequently protected with bell jars as before, and an equal number were left unprotected. Five twigs of each sort were not inoculated to serve as controls. They were covered with bell jars for 24 hours.

The spores were obtained from a pure culture flask of corn meal, which contained an abundance of mature spores. The culture flask was nearly filled with sterile water, then shaken vigorously to set free the spores. The entire contents

of the flask was then filtered through absorbant cotton into another sterile flask. This water containing the spores was sprayed on the twigs with an atomizer.

Table III. shows the results of these experiments. Notes were taken on these experiments at frequent intervals, but only the final results, taken on May 15. are given in the table.

Table III.

Date of Inoculation	Variety	Number of Twigs		Percent of Infections	
		Under bell jar	Not Under bell jar	Under bell jar	Not under bell jar
1914					
Mar. 2	Ben Davis	34	none	88	
Apr. 7	Winesap	25	20	27.6	22.0
Apr. 7	Jonathan	12	12	14	15.5
Apr. 7	Kartacs	13	13	10.4	8.0
Apr. 7	Doctor	10	10	35.7	29.6
Apr. 7	Ben Davis	15	15	27.0	23.4

A higher percentage of the twigs was infected from these kept moist, that is protected with bell jars, with the exception of the Jonathan variety, and even here the difference is not great enough to affect the general average to any great extent. We are justified in saying that a moist atmosphere is favorable for Sphaeropsis infection through the lenticels in the bark. It is probable that similar infections occur in the twigs of apple trees during the warm spring rains, when the relative humidity of the atmosphere is high.

As soon as it was known that Sphaeropsis spores were capable of germinating on uninjured bark and producing cankers, the question arose as to how far the mycelium penetrates into the bark and wood under these conditions. It had previously been shown by means of stained sections of heartwood that the fungus uniformly penetrated the heartwood, where the original infection occurred in wounds extending into the cambium. Now since it was known that the germinating tubes could penetrate the living bark and produce cankers, it remained to be shown whether under such conditions the mycelium could extend down into the heartwood.

Paddock (50) found that where infections took place through slight injuries made in the outer bark, the fungus did not reach even the cambium. His conclusions are questionable, however, since his observations extended over only a few weeks time.

A twig which had recently become infected through a lenticel was examined, and it was found that the fungus was confined to the outer half of the bark as indicated by the brown color. At this time, and for several weeks afterwards, the growth of the fungus was extremely slow. After about two weeks the growth suddenly became very rapid. An examination showed clearly the presence of the mycelium in the cambium zone. Five days later a twig cut through an infection showed the discoloration of the wood past the center. Further proof of the mycelium in the heartwood was obtained by a

microscopical examination of stained sections of wood taken from the center of the twig. The closely septate mycelium was clearly visible in every case.

These results show that this fungus is capable of penetrating living bark and wood of apple twigs under certain conditions. It is quite generally believed that infections in the outer bark may eventually heal over before the fungus reaches the cambium, especially if the tree is of a resistant type and is also vigorous. It is probable, however, that the fungus continues to advance slowly from year to year until the growing layer is reached, when the work of destruction is accelerated.

here X
A large number of inoculations and some cross inoculations have been made by inserting spores or culture material into punctures made in the bark of apple, pear, quince, Japanese plum, and crab apple twigs. Some inoculations have also been in the larger limbs of mature apple trees growing under normal conditions. Several apple trees were transplanted in the greenhouse last fall, upon which inoculation experiments have been subsequently conducted. In addition to the inoculation, other punctures were made but not inoculated to serve as checks. The results of these experiments with Sphaeropsis malorum, are given in table IV.

INOCULATION EXPERIMENTS WITH
SPHAEROPSIS MALORUM.

Table IV.

Date of Inoculation	Host Inoculated	No. of Punctures	Infections %	No. of Checks	Infected Cks. %
1913					
Dec.2	Apple tree	4	100.0	4	00.0
Dec.2	Apple tree	4	100.0	4	00.0
1914					
Jan.24	Apple tree	16	100.0	8	#12.0
Jan.31	Apple fruit	6	100.0	4	00.0
Mar.2	Apple twigs	15	100.0	5	00.0
Mar.11	Apple twigs	20	100.0	10	00.0
Mar.16	Apple twigs	10	100.0	5	00.0
Mar.20	Apple twigs	168	100.0	84	4.0
Mar.22	Pear twigs	160	90.0	40	3.0
Mar.22	Quince twigs	25	100.0	10	00.0
Apr.7	Crab apple	25	72.0	10	00.0

From the above table it will be seen that in the case of apple and quince, the fungus grew at all points of inoculation. In a few instances the check punctures became infected, amounting in one instance to 12% of the total number of checks. It is probable that the infections were carried by the woolly aphids, as they were feeding in all of the check punctures. The fungus fruited on all of the infected twigs in one to four weeks after inoculation. Some of the spores were examined microscopically and identified as Sphaeropsis malorum.

These experiments prove the identity of one of the canker fungi found in the Horticultural orchard, and also show that it is parasitic on pear and quince, thus substantiating Paddock's results and conclusions.

The Illinois canker is universally regarded as a wound parasite. Careful observations are sufficient to convince one that in the main this is true. Hasselbring(39) (1902), who did the pioneer work on this fungus as a parasite on apple, states that, "So far as observations go at present they seem to show that Nummularia discreta, like Lectria and other fungi of similar habits, is a wound parasite. Apparently it is unable to gain entrance to the tree except through a previously existing wound in the bark."

So far as I have been able to find, there has never been an experiment to determine whether infection may not also occur through uninjured bark. It was originally planned to determine this point in the same manner that it was determined for the Sphaeropsis canker. For this purpose pure fruiting cultures was necessary, but the fungus could not be induced to fruit on any of the twenty-five media tried. For that reason the attempt was not made, as the results would have been unreliable unless cultures of pure spores were used for the inoculation.

A number of inoculations were made with culture material of this fungus, or what was taken to be Nummularia, in order to substantiate the cultural diagnosis. It was also desired to study the appearance of the infection in its various stages of growth. Punctures were made through the bark with a flamed scalpel and some of the culture

material introduced with sterile instruments. The final results of these experiments are shown briefly in table V.

INOCULATION EXPERIMENTS
WITH NUMMULARIA DISCRETA.

Table V.

Date of Inoculation	Host Inoculated	No. of Punctures	Infections %	Check Infect. %
1914				
Jan. 4	Apple tree	18	100.0	0.0
Mar. 11	Apple twigs	12	100.0	0.0
Mar. 12	Apple tree	4	93.9	0.0
Mar. 23	Apple twigs	140	100.0	0.0
Apr. 4	Apple twigs	90	100.0	13.3

The inoculation on January 4. was made on a four year old apple tree in the greenhouse. The fungus grew slowly at first, but as soon as the vitality of the tree was lowered from the effects of the disease, the fungus advanced much more rapidly, and soon invaded the entire tree. Fruiting structures of Nummularia began to form on the trunk of the tree about May 1. The fungus grew at all points of inoculation of the apple twigs but failed to fruit, except upon the trunk of the largest tree as previously noted. Nevertheless, I feel justified in asserting that my previous diagnosis of this fungus in cultures, is confirmed in these results.

TIME OF INFECTION

A knowledge of the time when fungus spores are disseminated normally is of value in determining means of control, especially if the disease is to be controlled by spraying. It is known in a general way that Sphaeropsis and Nummularia spores are disseminated in the spring. Very little experimental work has been done along this line, the conclusions of previous investigators being based mainly upon the time when new infections were observed.

In speaking of the New York canker for conditions in New York State Paddock ((50) states that, "Infection takes place in the spring of the year as is shown by the growth that the fungus makes in the bark."

The only experimental data, previous to this investigation, on the time of spore dissemination was obtained by Wolf ((65) (1909-10), at the Nebraska Experimenta Station. For this purpose he used trap cultures consisting of glucose agar plates, which were exposed in the orchard for a short time at intervals of a few days from September to May inclusive. He thus summarizes his results:

"Nummularia discreta, although its spores were mature, did not disseminate its spores until May 2. At no time from September to May inclusive were viable spores of Sphaeropsis malorum present in the atmosphere of the orchard."

On March 1, experiments were started to determine the time when spores of Sphaeropsis malorum, and Mummularia discreta are disseminated normally in the apple orchard on the Horticultural Grounds. Two types of trap cultures were used in these experiments. One was the plate method employed by Wolf, and the other similar to a method recently described by Heald(37)(1913). In view of the fact that Heald's method is new it has seemed best to give it in some detail.

"A brass curtain screw is turned into the bark of the trunk or branch so as to stand at right angles to the surface. A glass object glass is set into a transverse groove in the bark and held by the screw at an angle of about 45 degrees. A more or less compact mass of absorbent cotton is placed between the lower end of the slide and the vertical end of the screw. The trap was always set below a lesion bearing fruiting pustules, in such a position that a part of the rain water flowing over the surface would be conducted down the slide and through the absorbent cotton.

"After each rain the cotton was removed and placed in sterile Petri dishes for transport to the laboratory. A new mass of cotton was put into place to be ready for the next rain.

"The cotton from each trap was introduced by means of sterile forceps into an Erlenmeyer flask containing sterile water. Each flask was then shaken vigorously to

set free the spores."

A drop of water containing spores was taken from the flask with a sterile pipette and placed upon a glass slide for microscopical examination for spores. The viability of the spores was determined in cultures. The colonies suspected of being the ones wanted were marked, and their subsequent development followed to substantiate the diagnosis.

Sphaeropsis spores appeared in the traps for the first time on April 6, following a rain the night before. The spores were mature as was determined by plate cultures. These spores have since continued to appear regularly in the traps, following each rain until May 10.

The spores of Nummularia were first disseminated April 30, in trap cultures. Potato agar plates were exposed in the orchard for one minute, and after three days, colonies of Nummularia were identified in the cultures. Spores of this fungus have not been found in any of the traps fashioned after Heald, but this is probably due to the fact that only one light shower of rain has fallen during the past two weeks. The spores of this fungus are disseminated at Columbia at about the same time of the year that Wolf found they were disseminated at the Nebraska Station. It was thought they might be disseminated somewhat earlier in the season this far south.

It is probable that these diseases can be effectively controlled by spraying at the time spores are being disseminated as stated above. The time of spraying for other fungi does not coincide with the time when canker spores are being disseminated, and hence the latter are not effectually controlled by the regular sprays.

THE RELATION OF SUNSCALD TO
CANKER DISEASES.

Horticulturists have associated canker with sunscald ever since these injuries have been observed. Previous to Paddock's work both injuries were thought to be due to sunscald. This conclusion was not without foundation since canker usually has about the same relative position on the trunks and branches as sunscald. Paddock observed that in some instances cankers occur quite uniformly on the south west side of the trees, thus indicating that they had their origin in injuries produced by sunscald.

While it is now known in a general way that cankers occur more frequently on the south than on the north side of the trunk and branches, yet, so far as I have been able to find there has been, previous to this work, no classified data showing the proportion of infections occurring on each side. To determine this, the positions of about 300 infections with respect to the sun's rays was noted. The data from these observations are shown in table VI.

POSITION OF CANKER INFECTIONS WITH
RESPECT TO THE SUN'S RAYS.

Table VI.

Side of trunk or branch	Kind of canker; Number, and Percent of Infections.					
	Shpaeropsis		Nommularia		"New" Canker fungus	
	No.	%	No.	%	No.	%
North	9	7.5	11	11.7	8	15.4
South	36	30.0	29	30.0	15	28.8
East	14	11.7	10	10.6	9	17.3
West	17	14.2	19	20.1	8	15.4
Southwest	43	35.8	25	27.6	12	23.1
Total	120	99.8	94	100.0	52	100.0

A summary of these results is very convincing. More than 80% of the infections occur on the side of the trunk and branches of apple trees exposed to the sun's rays, and less than 20% are situated on the shady side. The full significance of these facts can probably be best understood when considered in connection with the cause and nature of sunscald.

There is a vast amount of literature on sunscald, but very little of it is based upon experimental data. Still horticulturists have arrived at a pretty clear conception

concerning the nature of this injury.

Green(32)(1895) writes as follows upon this subject for Minnesota conditions: "Sunscald is the trouble that shows itself by the tree becoming rotten in the trunk on the south side, which finally so weakens it that it cannot support its top, and consequently breaks down very likely when loaded with fruit."

Hansen(34)(1897) writes, "Sunscald causes great loss in the northwest prairie states in the apple districts, ...causing the bark to die and decay. Oftentimes the dead, blackened bark separated entirely from the stem. Orchardists now generally recognize the cause of the trouble and prevent it by shading the stem in some way. Low headed trees are best for severe locations. Tall trunks suffer more from sunscald and severe winds."

Whitten(34) has conducted extensive experiments along this line, extending over a period of years, and this seems to be the only experimental work that has ever been carried on in connection with this injury. While the results of these investigations have not yet been published, brief reference to these data have been made from time to time in his writings. The following quotation is from Whitten.

"..Sunscald usually occurs in late winter. The coloring matter in the bark of the apple tree has the power

of absorbing heat from the sun's rays on clear winter days. On the Experiment Station grounds we have found that a thermometer inserted in the growing layer on the north or shady side of an apple tree will stand at about atmospheric temperature day and night. A similar thermometer in the growing layer in the south side of the same apple tree will frequently register 25 to 35 degrees or more above atmospheric temperature when the sun is shining brightly. This alternate heating up of the south side of the trunk or main limbs during the day, and freezing at night during February and March, sometimes injures the growing layer. It is probable that the cells on the south side of the tree tend to become active on sunny days and become tender, so that they cannot stand subsequent cold nights without injury."

This injury to the growing layer in the south side of the trunks and main branches of apple trees, in all probability, lessens the power of the growing tissue to resist the subsequent progress of canker diseases. No other injury is so favorable to their rapid growth. In view of this fact it was thought best to continue the trunk temperature experiments as previously carried on by Whitten. In addition it was proposed to treat tree trunks with lime whitewash to determine its influence in reflecting the sun's rays, and reducing the temperature on the south side during bright sunlight.

Two adjacent apple trees of the same variety, and as nearly similar in every respect as it was possible to find were chosen for this experiment. Trees were chosen that branched high so that the thermometers would be shaded as little as possible. A thermometer was carefully inserted in the growing layer on the south side of the trunk of each tree at height of about three feet from the ground. A similar thermometer was placed in the growing layer on the north side of the trunk of one of the trees, and a third thermometer at the surface of the ground directly under the thermometer on the south side. The other tree was given a heavy coat of lime whitewash. Another thermometer was suspended from a limb to register atmospheric temperatures.

The thermometers were arranged to stand as nearly parallel with the trunk as possible, to allow the greatest bulb surface contact with the cambium tissue. Some difficulty was experienced in fitting the thermometers. It is essential that they fit closely to secure capillary connection with the tree tissues. Holes were finally made with a gimlet somewhat larger than the thermometer bulbs, and in withdrawing the gimlet some of the fine particles of borings were left in the edges of the hole. The thermometers were pressed down so that the tops of the bulbs were below the surface of the bark, then sealed with a few drops of warm grafting wax.

The temperatures were recorded daily, usually at about 2 o'clock, or the time when the thermometer on the south side of the unwhitewashed tree registered highest. Occasionally hourly readings were made for comparing the relative rate of temperature changes. The following table contains the data taken from December 26, 1913 to April 30, 1914 inclusive.

Table VII.

Date 1913-14	Time	Temperatures			Weather
		North	South	Atmospheric	
Dec. 26	2	31.1	34	30.2	Hazy
Dec. 28	2	35.6	33.8	33	Cloudy
Dec. 29	2	35.5	33.5	32	Cloudy
Jan. 7	11	37.4	39.9	40	
Jan. 8	1	58.5	63.8	56	
Jan. 8	5.30	54.3	55.8	48	Sundown
Jan. 8	5.35	54	55.2	48	"
Jan. 9	3	54	37.4	31.5	Cloudy
Jan. 10	3	33.8	32.0	31	Cloudy
Jan. 11	1	35.6	43.7	37.5	
Jan. 11	5	36.6	45.5	37	
Jan. 12	9	17.4	17.6	7	
Jan. 12	2.30	24.3	43.3	46	
Jan. 13	3.30	38.3	54.5	44.5	
Jan. 19	4	65.3	77	64	
Jan. 23	4	52.7	57.7	54.6	Cloudy
Jan. 26	4	49.	70.7	57	
Jan. 28	3	62.6	62.6	60	Cloudy
Jan. 29	4	29.3	28.4	19.4	Cloudy
Jan. 30	11	30.4	31.8	27.	Cloudy
Jan. 30	2	32	32	26	Cloudy
Jan. 31	10	34.7	32	31.5	
Jan. 31	1.30	38.7	44.2	37.2	
Feb. 1	1.15	47.3	57.3	47	
Feb. 2	2	54	58.3	51	Hazy
Feb. 4	2.15	32	59	32	
Feb. 5	1.45	33.8	45.1	32	
Feb. 5	2.10	33.8	50	33	
Feb. 5	2.30	33.8	50.4	33.5	
Feb. 6	10.	27	30.2	26.6	
Feb. 6	3	#	22	14.	
Feb. 6	5.15	#	#	10	Sundown

Note:- # Temperature below 10 degrees Fahr.

Table VII. (Continued)

Date 1914	Time	Unwhitewashed tree			White washed South	Atmos. Temp.	Weather
		North	South	South'			
Feb.7	9.	#	#	8.6	#	0.0	
Feb.7	11.	#	20.9	144.8	8.6	3.0	
Feb.7	11	#	26.5	24.8	14.	9.0	
Feb.7	2.	#	39.	29.3	22.	11.0	
Feb.8	2.	22.1	33.	26.6	23.	20.0	Hazy
Feb.9	2.	34.9	58.	46.2	41.4	44.0	
Feb.10	1.	34.1	62.8	60	39.2	33.5	
Feb.10	2.10	34.	63.	48.2	41.5	33.5	
Feb.10	2.20	36.	67.	50.	46.6	36.0	
Feb.11	2.	29.1	32.5	29.3	25.5	25.0	Cloudy
Feb.12	2.	23.	25.	23.	28.5	23.5	Cloudy
Feb.13	2.	23.	25.	21.	28.5	23.5	Cloudy
Feb.14	1.16	22.9	46.	30.2	24.8	27.0	Cloudy
Feb.14	3.	30.2	29.3	27.5	25.5	24.0	Cloudy
Feb.15	1.50	34.7	40.0	32.	29.3	38.0	
Feb.16	2.30	30.9	52.0	42.	27.5	25.0	
Feb.17	9.30	40.6	46.	32.	38.3	48.0	
Feb.17	22.	51.4	72.5	55.4	52.7	53.5	
Feb.17	2.10	51	73.4	55.	53.6	53.5	
Feb.18	2.	32.	34.	33.8	31.	33.	Cloudy
Feb.19	11.30	28.5	48.	28.4	22.9	22.	
Feb.19	2.	31.5	70.2	44.6	33.4	28.	
Feb.19	5.45	29.3	42.9	31.8	31.	23.	Sundown
Feb.20	2.	31.1	34.7	29.3	30.6	33.0	Cloudy
Feb.21	9.	26.	28.4	25.7	31.	28.	
Feb.21	10.30	32.	37.6	28.4	29.3	35.5	
Feb.21	12.15	35.2	56.3	32.5	34.4	41.	
Feb.21	1.0	37.	52.5	32.9	36.1	43.	
Feb.21	4.	41.	64.4	46.8	44.6	47.	
Feb.23	2	17.6	19.6	19.4	16.7	15.	Cloudy
Feb.24	12.15	28.4	53.6	26.	34.7	21.	
Feb.24	1.	29.8	54.6	28.4	34.7	20.0	
Feb.24	2.	30.2	64.4	32.	43.7	24.	
Feb.24	2.15	30.2	68.6	32.	43.6	24.	
Feb.24	3.	29.8	61.7	33.8	44.5	21.	
Feb.25	11.	28.4	38.3	24.5	29.3	25.	
Feb.25	2.	31.	61.5	39.5	43.	30.	
Feb.26	2.	42.8	68.8	44.6	54.5	47.	
Feb.27	2	55.4	77.	57.5	61.	55.	
Mar.2	2	44.6	61.5	46.4	45.6	39.	
Mar.3	2.	32.5	33.	29.3	32.	33.	Cloudy

Note:- # Below 10 degrees Fahr.

Table VII.(Continued)

Date 1914	Time	Unwhitewashed			White washed South	Atmos. Temp.	Weather
		North	South	South'			
Mar.4	2.	37.9	71.2	46.	55.8	44.	
Mar.5	3.	52.3	77.	55.4	56.	50.	Cloudy
Mar.6	2.	33.	37.3	32.	33.8	33.	Hazy
Mar.7	2.	33.8	38.3	32.	34.2	34.	
Mar.8	2.	37.	40.	31.	36.	40.	Cloudy
Mar.9	12.	38.3	54.5	41.	39.2	40.	Cloudy
Mar.9	1.40	41.4	68.0	52.	42.2	45.	Cloudy
Mar.9	1.55	41.9	68.2	54.5	42.5	45.	
Mar.9	1.59	41.9	64.4	54.5	42.5	45.	
Mar.10	2.	49.6	54.5	44.6	50.0	49.5	
Mar.11	2.	42.	36.5	33.	32.	35.	
Mar.12	2.	42.	61.5	57.8	43.	45.	
Mar.13	2.	60.	79.7	73.4	61.5	60.	
Mar.15	2.15	77.5	97.7	85.6	80.3	77.	
Mar.16	12.	55.	60.3	43.7	56.3	55.	Cloudy
Mar.16	2.	58.	68.8	57.2	59.0	58.	Cloudy
Mar.17	2.	53.6	71.6	60.8	56.3	52.	Cloudy
Mar.18	2.	35.6	41.	37.4	37.2	36.	Cloudy
Mar.19	2.	34.7	53.6	42.	36.5	32.	
Mar.19	2.15	34.7	57.2	43.	36.5	32.	
Mar.20	2.	39.2	65.3	50.4	41.	38.	
Mar.21	2.	34.7	34.7	32.	34.7	34.	Cloudy
Mar.22	2.	39.3	53.7	52.7	40.5	44.	
Mar.23	9.	39.	35.6	34.	35.	40.5	
Mar.23	2.	54.5	76.3	70.	56.	57.	
Mar.24	2.	68.	79.3	68.5	70.2	77.	
Mar.26	2	72.	73.4	64.5	72.5	73.5	Cloudy
Mar.27	2.15	64.7	70.7	62.6	65.5	65.	Cloudy
Mar.28	2.15	74.3	82.	69.	76.	75.	Cloudy
Mar.29	2.	69.2	75.2	64.3	69.5	73.5	Cloudy
Mar.30	2.	55.4	59.	51.6	56.	55.	Cloudy
Mar.31	2.	63.	81.5	73.4	67.	71.	
Apr.1	2.	57.	59.	52.7	57.4	58.	Cloudy
Apr.2	2.	67.	83.	73.4	68.5	65.	
Apr.3	3.	48.2	55.5	51.	48.5	48.	Hazy
Apr.4	2.	58.	71.	65.3	59.	54.	
Apr.5	2.	58.	75.2	70.	59.	59.5	
Apr.7	2.30	45.5	51.	46.5	46.	45.5	
Apr.8	2/	37.8	44.6	41.	38.	36.	Hazy

Note:-Bright sun unless otherwise stated.

Table VII.(COntinued)

Date 1914	Time	Unwhitewashed			White washed South	Atmos. Temp.	Weather.
		N North	South	South'			
Apr.9	2.	46.4	63.5	59.0	47.0	45.0	Cloudy Hazy
Apr.10	2.	45.0	47.5	47.0	45.	45.0	
Apr.11	2.	49.0	61.0	51.0	50.0	47.0	
Apr.12	2.	59.0	80.6	74.3	60.4	57.0	
Apr.13	2.	676.0	78.	66.0	68.0	62.0	
Apr.14	2.	69.0	79.0	66.0	69.0	67.0	Cloudy
Apr.15	2.	68.0	80.0	69.0	72.0	68.9	
Apr.16	1.45	83.3	98.5	78.0	83.0	83.3	
Apr.18	2.0	71.6	74.3	51.5	71.5	71.0	
Apr.19	1.15	45.5	45.5	44.6	43.0	43.0	
Apr.20	2.0	60.0	69.0	---	80.0	85.0	Hazy Cloudy Cloudy
Apr.21	1.45	79.0	90.5	---	80.0	85.0	
Apr.22	2.0	79.0	86.0	---	83.0	86.0	
Apr.23	2.0	63.0	63.7	---	63.5	63.5	
Apr.24	2.0	65.0	68.5	---	67.0	65.0	
Apr.25	2.0	74.3	83.3	---	80.5	82.5	Cloudy
Apr.26	2.0	81.0	88.0	---	85.0	92.0	
Apr.27	2.0	75.2	81.5	---	80.0	82.0	

Table VII. gives the temperature readings of whitewashed and unwhitewashed trunks of apple trees, covering a period of four months. The date and time of day when the records were taken are shown in the first two columns. The column "South'" shows the temperatures in the trunk on the south side of an unwhitewashed tree at the surface of the ground. Under the last column "Weather" the cloudy days are noted; on all other days the sun was shining at the time the thermometers were read.

Table VIII. shows the relative temperatures in the growing layer on the north and south sides of an apple tree trunk, as compared with atmospheric temperature, on bright sunny days.

Table VIII.

Date	Time	Temperatures Fahr.			Atmospheric Temperature
		North	South	Difference	
1914					
Jan.7	11.0	37.4	39.9	2.5	40.0
Jan.8	1.0	58.5	68.5	10.0	56.0
Jan.8	5.30	54.3	55.8	1.5	48.0
Jan.11	1.0	35.6	43.7	8.1	37.5
Jan.11	5.0	36.1	45.5	9.4	37.0
Jan.12	9.0	17.4	17.6	0.2	7.0
Jan.12	2.0	24.3	43.3	19.0	46.0
Jan.13	3.0	28.3	54.5	16.2	44.5
Jan.19	4.0	65.3	77.0	11.7	64.0
Jan.31	10.0	34.7	35.0	0.3	31.5
Jan.31	2.0	38.7	44.2	5.5	37.2
Jan.31	3.0	38.0	43.0	5.0	36.0
Feb.4	2.0	32.0	59.0	27.0	32.0
Feb.5	2.0	33.8	45.1	11.3	32.0
Feb.5	2.30	33.9	50.5	16.6	33.5
Feb.6	10.0	27.5	30.2	3.3	26.5
Feb.8	2.0	34.9	57.0	12.1	44.0
Feb.10	1.0	34.1	62.8	28.7	33.5
Feb.10	2.0	34.0	63.0	29.0	33.6
Feb.10	2.30	36.0	67.1	31.1	36.0
Feb.15	2.0	34.7	40.0	5.3	38.0
Feb.16	2.0	30.9	52.0	21.1	25.0
Feb.17	9.0	40.6	46.0	5.4	48.0
Feb.17	2.0	51.4	72.5	21.1	55.0
Feb.17	2.15	51.4	73.4	22.0	54.5
Feb.19	2.0	31.5	70.2	38.7	28.0
Feb.19	5.45	29.3	42.9	23.6	23.0
Feb.21	9.0	26.0	28.4	2.4	28.0
Feb.21	10.0	32.0	37.6	5.6	35.5
Feb.21	12.0	35.2	56.3	21.1	41.0

Table VIII.(Continued)

Date	Time	Temperatures Fahr.			Atmospheric Temperature
		North	South	Difference	
1914					
Feb.21	1.0	37.0	52.5	15.5	43.0
Feb.21	4.0 m	41.0	64.4	17.4	47.0
Feb.24	12.0	28.4	53.5	25.1	21.0
Feb.24	1.0	29.8	54.5	24.7	20.0
Feb.24	2.0	30.2	68.6	38.4	24.0
Feb.24	3.0	29.8	61.7	31.9	21.0
Feb.25	11.0	28.4	38.3	9.9	25.0
Feb.25	2.0	31.0	61.5	30.5	30.0
Feb.26	2.0	42.8	68.8	26.0	47.0
Feb.27	2.0	55.4	77.0	21.6	55.0
Feb.28.	2.0	44.6	61.5	16.9	39.0
Mar.4	2.0	37.9	71.2	33.3	44.0
Mar.5	3.0	52.0	77.0	25.0	50.0
Mar.9	12.0	38.3	54.4	16.1	40.0
Mar.9	2.0	41.9	68.2	26.3	45.0
Mar.12	2.0	42.0	61.5	19.5	45.0
Mar.13	2.0	60.0	79.7	19.7	60.0
Mar.15	2.0	77.5	97.7	20.2	77.0
Mar.19	2.15	34.7	57.2	22.5	32.0
Mar.20	2.0	39.2	65.3	26.1	38.1
Mar.22	2.0	39.3	52.7	13.4	44.0
Mar.23	2.0	54.5	76.3	21.8	57.0
Mar.24	2.0	68.0	79.3	11.3	77.0
Mar.27	2.0	64.7	70.7	6.0	65.0
Mar.28	2.0	74.3	82.0	7.7	75.0
Mar.31	2.0	63.0	81.5	18.5	71.0
Apr.2	2.0	67.0	83.0	16.0	65.0
Apr.4	2.0	58.0	71.0	13.0	54.0
Apr.5	2.0	58.0	75.2	17.2	59.5
Apr.9	2.0	46.4	63.5	17.0	45.0
Apr.12	2.0	59.0	80.5	21.6	57.0
Apr.13	2.0	67.0	78.0	11.0	62.0
Apr.14	2.0	69.0	79.0	10.0	67.0
Apr.16	2.10	83.3	98.5	15.2	83.0
Apr.20	2.0	60.0	69.0	9.0	66.0
Apr.21	2.0	79.0	90.6	11.6	85.0
Apr.25	2.0	74.3	83.3	9.0	82.5
Apr.26	2.0	81.0	88.0	7.0	92.0

The temperature on the north side remains about the same as atmospheric temperature, on clear and cloudy days, while the temperature of the growing layer on the south side of the same is uniformly higher on clear bright days. The greatest differences in these temperatures occur on days when the sun shines brightly, and the atmospheric temperature is below 32 degrees. This is especially true if the preceding night was extremely cold so that the cell sap is frozen. On February 19, at 2 o'clock, a thermometer in the south side of the trunk registered 70 degrees. This was 38.7 degrees higher than the temperature on the north side of the same trunk, and 42 degrees above atmospheric temperature. The night previous was unusually cold. Similar results were recorded on February 24, following a cold night. Thus it frequently happens that the cells on the south side of the trunk are at growing temperatures, while ice crystals are present in the north side. Undoubtedly, this freezing of the cells in the southside of the trunks of apple trees at night, and heating up during the day, injures the growing layer. These injured cells are less able to resist the progress of canker diseases, which accounts for the greater frequency of these infections on the side of the trunks and main limbs exposed to the direct rays of the sun.

CONDENSED SUMMARY OF DATA FROM TABLE VIII.

Table IX.

Month	Minimum		Maximum		Mean		Mean Difference
	North	South	North	South	North	South	
December	31.1	33.8	35.6	34.0	34.1	34.0	0.0
January	24.3	32.0	65.0	77.0	39.3	48.8	9.5
February	17.6	19.4	55.4	77.2	38.2	57.2	19.0
March	32.5	33.0	77.5	97.7	49.3	62.3	13.0
April	37.8	44.6	83.3	98.5	61.8	70.7	8.9

Table IX gives a brief summary of the temperatures in the growing layer of the trunks of apple trees, December to April inclusive. During sunlight the temperatures averaged uniformly higher in the south side of the trunks for each month, with the exception of December, when there was no difference. The greatest mean difference was obtained in February, the month when the lowest atmospheric temperatures were recorded. From the results shown in the column, "Mean difference" it will be seen that the greatest injury from sunscald occurred in February, and probably some injury during March and January.

The effect of lime whitewash, applied to the trunk of the tree, in reducing the temperature in the growing layer on the south side, is shown in Table X.

COMPARISON OF THE TEMPERATURES OF WHITEWASHED
WITH UNWHITEWASHED TRUNKS OF APPLE
TREES ON SUNNY DAYS.

Table X.

Date	Time	Trunk Temperatures			Temperature Atmospheric
		Unwhitewashed	Whitewashed	Difference	
1914					
Feb.7	11.0	20.9	8.6	12.3	3.0
Feb.7	1.0	26.4	14.1	12.3	9.0
Feb.7	2.0	39.0	22.1	16.9	11.0
Feb.9	2.0	57.0	41.4	15.6	44.0
Feb.10	1.0	62.8	39.2	23.6	33.5
Feb.10	2.30	67.0	46.6	20.4	36.0
Feb.16	2.0	40.0	29.3	10.7	38.0
Feb.15	2.0	52.0	27.5	24.5	25.0
Feb.17	2,10	73.4	53.6	19.8	53.5
Feb.19	2.0	70.2	33.4	36.8	28.0
Feb.21	1.0	52.5	40.0	12.5	43.0
Feb.24	2.15	68.6	43.6	25.0	24.0
Feb.25	2.0	61.5	43.0	28.5	30.0
Feb.26	2.0	68.8	54.5	14.3	47.0
Feb.27	2.0	77.0	61.0	16.0	55.0
Mar.2	2.0	61.5	45.4	16.0	39.0
Mar.5	3.0	77.0	56.0	21.0	50.0
Mar.9	2.0	68.2	42.5	25.7	45.0
Mar.12	2.0	61.5	43.0	18.5	45.5
Mar.13	2.0	79.7	61.5	18.2	60.0
Mar.15	2.15	97.7	80.3	17.3	77.0
Mar.19	2.15	57.2	36.5	20.7	32.0
Mar.20	2.0	65.3	41.0	20.7	38.0
Mar.22	2.0	52.7	40.5	12.2	44.0
Mar.23	2.0	76.3	56.0	20.3	57.0
Mar.24	2.0	79.3	70.2	9.1	77.0
Mar.31	2.0	81.5	67.0	14.5	71.0
Apr.2	2.0	83.0	68.5	14.5	65.0
Apr.4	2.0	71.0	59.0	12.0	54.0
Apr.5	2.0	75.2	59.0	16.2	59.5
Apr.7	2.30	51.0	46.0	5.0	45.5
Apr.9	2.0	63.5	47.0	16.5	45.0
Apr.12	2.0	80.6	60.4	19.2	57.0
Apr.13	2.0	78.0	68.0	10.0	62.0
Apr.14	2.0	79.0	69.0	10.0	67.0
Apr.16	2.0	98.5	84.6	13.9	83.0

The effect of lime whitewash on the temperature in the south side of the trunks of apple trees is shown in Table XX. From this table it will be seen that the temperature of the whitewashed tree varies only a few degrees from atmospheric temperature, but frequently it is 20 to 25 degrees lower than the temperature on the south side of the unwhitewashed tree trunk. The white wash prevents the relatively high temperatures in the trunks on the south side by reflecting the sun's rays. Injury to the trunks and main limbs of apple trees can be prevented by applying lime whitewash or lime sulphur to the trunks and main limbs, to keep them white during February and March.

These results agree with those obtained by Whitten during many years of similar investigations on a larger scale.

THE RELATION OF INSECTS TO
CANKER INFECTION.

There appears to be no data, previous to this work, showing the relation of insects to canker infection. Since, however, infections usually occur through wounds made in the bark, it seemed reasonable to suppose that injuries from borers and other insects of similar habits, might result in canker infection. Of course the percentage of infections resulting from insects depends largely upon the number of insects and the relative amount of injury done by them.

To determine the percentage of infections occurring through insect injuries, observations were made on all of the canker infections in the Experiment Station orchard. The results of these observations, as compared with the percentage of infections occurring from all other sources of wounds, are given in Table II. (Page 21)

The two insects most commonly found associated with canker injuries are the apple tree borers and the woolly aphis. The former bores through the bark and into the wood of the trunk and limbs of apple trees, thus affording a source of canker infection in the cambium, where these fungi grow most rapidly. Again, since the borers work laterally around the trunk and limbs as well as longitudinally, the canker may more readily complete the girdling of the affected parts.

In the older injuries from borers where canker is also present, it is impossible to say which pest is responsible for the original injury, but in the case of newer infections there can be no doubt. Several infections were observed this spring,

of recent canker infection, through injuries by borers. In these instances the canker fungus was growing out radially from the hole made by the borer in entering the host.

The Woolly Aphis is frequently found feeding around the edges of wounds, where it often hinders the healing process. It is probable that these insects, especially the winged forms, may through their migratory habits, be important agents in distributing the cankers from tree to tree. I removed a few of the aphids from a new Sphaeropsis canker infection and transferred them to sterile bean agar slopes, to determine whether they were capable of carrying the infection. Sterile instruments were used to remove the aphids, care being taken to not bring them in contact with the infection. Twelve cultures were made, ten of which developed characteristic Sphaeropsis colonies in one week. To be sure, other fungus and bacterial colonies appeared in most of the cultures, but there was one pure culture. This would seem to indicate that the means of infection were present on the bodies of the aphids at the time they were feeding. Hence, we may conclude that when these insects migrate, they may carry canker spores or other means of infection with them. Further investigation should be made before drawing conclusions as to the relative importance of these insects as distributors of canker diseases.

THE CHARACTER OF THE SOIL IN ITS
RELATION TO CANKER.

Apple tree growing on loess soils are uniformly freer from canker diseases than similar varieties on the heavier clay soils. The trees are much more vigorous, and ordinary wounds in the bark and wood heal readily. Infections occur probably less frequently and the subsequent progress of the disease is relatively slower.

An old Ben Davis orchard on loess soil was badly burned by a fire which swept through the orchard a few years ago. The dead bark and wood on the trunks and limbs offered favorable opportunities for the germination of canker spores, and many infections from the Illinois and New York cankers followed. And now, after three years, comparatively little progress has been made by these diseases. Wherever infected branches have been killed, the greater part of the injury was due to the fire.

Early in December, about fifty infections were treated. So far, these treatments were successful in every case, as may be seen from Table XI. Similar treatments were far less satisfactory on the same variety on the heavy clay soil at Columbia. The character of the soil is an important factor in determining the amount of the injury that may be expected from canker diseases. The character of the soil also influences the efficacy of the treatment.

EFFECT OF TREATMENTS.

Table XI.

Disinfectant	No.of Infections Treated	No.of Infections Progressing	Efficiency %
Copper Sulph.Sol.	30	00	100.0
Mercuric chloride solution	10	00	100.0
Paint alone	10	00	100.0

The above infections were treated on December 8,9, and 10,1913. The last observation was made April 28,1914. At that time there was no indication of further growth of the fungus on any of the treated wounds. It is safe to conclude, therefore,that the New York and Illinois cankers may be effectually checked by either of the treatments above mentioned, provided the trees are growing in loess soil. It is probable that equally satisfactory results might be obtained by the same methods of treatment of trees on any type of soil that favors a vigorous growth of the trees.

CULTURE STUDIES WITH SPHAEROPSIS MALORUM.

The field work was supplemented by microscopical and various cultural studies in the laboratory. The first problem was to obtain pure cultures of the fungus. For this purpose a 2 % dextrose, potato agar was used, and the Petri dish method of isolation employed. No fruiting bodies were to be found on any of the diseased trees in the Experiment Station orchard at the time this work was begun in September. Isolations were, therefore, made by introducing small bits of the diseased material from the inner bark into the agar tubes before the plates were poured. For this purpose a flamed scalpel was used.

Two days after the colonies appeared, transfers were made to potato agar slopes. Since the cultural characteristics of Sphaeropsis were not known, isolations were made from each of the colonies appearing in the plates, for future study. Pure cultures of four fungi were thus obtained.

Careful notes were made every day on the character of the colonies. Within a week three of the fungus colonies were identified, namely, Rhizopus, Aspergillus, and Penicillium. The aerial portion of the unidentified fungus was snow white at first, becoming dark gray with age. The mycelium in the substratum eventually became jet black. The unknown colonies failed to fruit after two months in the laboratory.

On November 1, some cankered apple limbs were found containing mature Sphaeropsis spores, from which pure cultures were obtained. Cultures were also made from pycnospores found in an apple affected with Black Rot. The cultures obtained from these two sources were identical in appearance with the unknown fungus.

To test the pathogeneity of the unknown fungus, inoculations were made on a two-year old apple tree from each series of cultures of the unknown fungus. The infections were made by introducing some of the culture material into punctures made in the bark with a flamed scalpel. The tree was first disinfected with a solution of mercuric chloride (1:1000), and washed with sterile water. There were 24 inoculations made and an equal number of punctures not inoculated to serve as checks. All of the punctures, including the checks, were protected with moist filter paper for 48 hours.

The fungus grew at all points of inoculation and produced, in two weeks, characteristic lesions of the New York canker. None of the checks grew. The fungus fruited in all of the infections by February 6, producing characteristic Sphaeropsis spores, which were found to germinate readily in hanging drops of tap water. The spores were oval, reddish brown, and measured 22-27 X 9-11 microns.

These results prove conclusively that the unknown fungus was Sphaeropsis malorum; the fungus causing one of the canker diseases under investigation.

DEVELOPMENT OF SPHAEROPSIS MALORUM
ON DIFFERENT MEDIA.

In order to gain some knowledge of the food requirements, this fungus was grown on a number of different media. The media were prepared in flasks of 150 cc. capacity. The agar media were made according to a common standard of approximately 50 grams dry weight of material to a litre of distilled water, and 20 grams of agar. The inoculations were made from a pure culture of the fungus. Careful notes were taken three times a week for one month, on the relative growth on the various media. The average of these results are shown in Table XII.

TABLE COMPARING THE GROWTH OF SPHAEROPSIS
ON VARIOUS MEDIA.

Table XII.

Media Used	No. of Cultures	Aver. No. of days before fruiting	Aver. growth of fungus		Av. grow of fun- gus.
			Aerial	In Substratum	
Apple Solution	3	7	Slight	Fair	Fair
Apple agar	5	4	Fair	Fair	Fair
Apple twig Sol.	3	-	Fair	None	Slight
Bean solution	3	-	Fair	None	Slight
Bean agar	3	5	Fair	Fair	Fair

Table XII.(Continued)

Media Used	No.of cultures	Aver.No. days before fruiting	Growth of fungus		Aver. growth of fungus.
			Aerial	In Substratum	
Bean Dex.agar	5	5	Good	Very good	Good
Bread	1	5	V.good	Excellent	Excellent
Bean pods	5	4	Good	Good	Good
Corn agar	5	5	Good	Good	Good
Corn meal	2	7	Good	V.good	V.good
Corn meal and apple twig Sol.	2	4	Good	V.good	V.good
C.M.& prune Sol.	2	5	V.good	Excellent	Excellent
Full nutrient S.	3	None	None	None	None
Potato agar	3	4	V.good	V.good	V.good
Prune Sol.	2	-	Good	Good	Good
Rice steamed	2	7	Good	Good	Good
Rice agar	3	3	Good	Good	Good
Rice Dex. agar	3	4	Good	V.good	V.good
Rice and prune S.	2	10	V.good	Excellent	Excellent
Silage agar	3	3	Good	Good	Good
Silage Dex.agar	3	3	Good	V.good	V.good
Turnip slope	4	3	V.good	Excellent	Excellent
Turnip solution	2	6	Excel.	Good	V.good
Turnip agar	3	4	Fair	Good	Good
Turnip Dex.agar	3	4	Good	V.good	Good

The most striking thing shown in Table XII. is the fact that the fungus is not very particular in its food requirements, but grows well upon most of the media tried. This is to be expected since the fungus has such a wide range of hosts. The fungus failed to make any visible growth on the full nutrient solution, but upon all of the other solutions more or less growth was made. The best growth was made upon coarse media that was well aeriated, showing that a certain amount of oxygen is essential to the best growth of the fungus.

CULTURE STUDIES WITH NUMMULARIA DISCRETA.

Some difficulty was experienced in obtaining cultures of Nummularia discreta. Although the fruiting structures began forming in October, the ascospores were not produced until early in March. In the meantime repeated efforts were made to induce the fungus to grow in artificial cultures, by introducing small pieces of the diseased wood into agar slopes. The fungus could not be induced to grow in this manner on any of the various media tried.

The first ascospores were seen on March 2. These spores were immature as was indicated by their lack of color at this time, and by the fact that they failed to germinate in hanging drops of nutrient solutions. Some of the spores were plated at this time but they failed to germinate. Several days later the effort was repeated, and this time a few weak growing colonies appeared on the plates after five days. Transfers were made to agar slopes of various media, including potato, bean, corn, rice, and silage agar. The fungus grew upon the silage agar and produced yellow conidia, but upon the other media the fungus grew slowly or not at all.

It was determined to grow the fungus on different media to gain some knowledge of its food requirements, but more especially to see if the fungus could be induced to fruit. The media were prepared in flasks of 150 cc. capacity. The

transfers were made from one of the vigorous growing cultures mentioned above.

TABLE COMPARING THE GROWTH OF NUMMULARIA DISCRETA
ON DIFFERENT MEDIA.

Table XIII.

Media Used	No.of cultures	No.days until conidia formed	Germination No.of days- until	Aver.growth of fungus
Apple solution	2	6	1	Good
Bread	2	6	1	Fair
Bean pods	6	8	1	Excellent
Bean Dex.agar	6	7	1	V.good
Corn solution	2	7	1	Good
Corn meal	4	7	1	V.good
Full nutrient Sol.	2	-	2	Slight
Prune solution	3	7	1	Good
Rice & prune Sol.	4	9	1	V.good
Rice agar	4	-	1	None
Rice Dex.agar	4	7	1	Fair
Silage agar	6	7	1	Good
Silage Dex.agar	6	7	1	V.good
Turnip slopes	--	-	-	None
Turnip solution	2	7	2	Good

The above table contains a summary of the data comparing the growth of Nummularia on different media. The best growth occurred usually on coarse media that was well aeriated. The aerial growth was good on most of the solutions, but the growth in the substratum was negligible.

The fungus can be identified fairly well from its appearance in artificial cultures. The aerial portion is a white, loose mass of short hyphae, and the colony is always light brown in the substratum. A few days after forming, the center of the colony becomes yellow in color, due to the production of numerous, minute yellow ochre conidia.

In none of the cultures have the fruiting structures yet formed, but the rice cultures appear to be forming the stromatic rings, preparatory to fruiting. (May 10) These cultures are to be preserved throughout the summer, unless the fungus fruits beforehand.

EXPERIMENTS ON CANKER TREATMENTS.

Investigators differ in their opinions as to the advisability of treating canker diseases after the infection is well established in the host. Satisfactory results have been reported in some instances by cutting out the diseased portion and disinfecting the wound, followed by a protective covering of some sort, such as white lead paint or coal tar. Others have reported negative results or no results at all from similar treatments. This leads us to believe that the efficiency of the treatment depends upon factors such as season, climate, soil, and vigor of trees, and that these factors have not received sufficient recognition in treating these diseases.

McGready⁴⁵ (1910) in his report on the results of investigations in 1909 by Eastman, is quite positive in his assertion that the New York canker can be controlled by cutting out the affected areas, disinfecting with mercuric chloride solution, and painting the surface with coal tar. As preventive measures, he recommends spraying the trees with lime sulphur before the buds begin to swell and with Bordeaux later on.

Paddock recommends a wash made according to the following formula:

Whale oil soap.....1 pint
Slaked lime.....3 pints
Water.....4 gallons
Wood ashes to thicken as desired.

This wash is to be applied to the trunks and limbs as a preventive measure. A thorough spraying with Bordeaux mixture is also recommended. He seems to doubt the feasibility of treating the infections after the disease has become established in the host.

Judging from the nature of the attacks of Nummularia discreta, Hasselbring seems to think there is no method of curing the injury after the parasite has once gained entrance to the limb. The lack of sufficient experimental data on the treatment of New York and Illinois canker diseases is very evident, and until this data is supplied, the work of controlling these diseases cannot be systematized. It is not known which is the best disinfectant to be used in treating canker infections, and there is much doubt in the minds of many as to the value of any disinfectant in checking the progress of the fungus after it has gotten well into the heartwood.

In order to test the relative value of various disinfectants, a large number of infections in different stages of development have been treated. A large number of disinfectants were available, but it was thought best to limit the

number to those most commonly employed by horticulturists. Thus a relatively larger number of trees could be treated with each, and hence more conclusive results obtained. The first trees were treated in September, followed by similar treatments of other diseased trees at short intervals until April 20th. It is planned to continue these periodic treatments during the summer. The object is to determine the relative effect of the season on the efficacy of the treatment.

The method of cutting out the affected areas was the same in every case, only the subsequent treatment being varied. The disinfectants used were mercuric chloride solutions, copper sulphate solution, carbolic acid solution, and formalin. The strength of the disinfectant used was varied. In every case the surface of the treated area was given a protective covering of some sort to prevent the tissues from drying out and cracking, and also to prevent further infection. White lead paint was commonly used for this purpose, but a few infections were covered with Bordeaux mixture, with enough additional lime added to thicken. With some of the injuries, the disinfectant was omitted to serve as checks.

Very soon after the work was begun, several practical problems arose. Should one cut at the visible junction of the diseased with the healthy tissue? How deep into the diseased wood is it advisable to cut, in order to insure the best results? What strength of the disinfectant would likely

prove most efficacious? These were practical problems having a direct bearing upon the successful treatment of these diseases. If, as seemed likely, the mycelia grows out into the healthy tissue beyond the line indicated by the discoloration and cracking of the bark, we could not reasonably hope to control these diseases so long as any of the growing mycelium was left in the host tissue. On the other hand, we did not wish to sacrifice the branches more than was necessary. The same thing might be said regarding the depth that it is necessary to cut out the affected areas in order that the treatment may be effective.

A review of the literature leaves one much in doubt. Investigators differ widely in their opinions concerning these points. Paddock concludes that in some instances, the mycelium of Sphaeropsis malorum penetrates the wood to some extent. Hasselbring thinks it probable that under certain conditions the mycelium of Nummularia penetrates to the heart wood. Faurot in speaking of the Illinois canker says, "This parasitic invasion extends not only into the bark, but also into the wood, even into the heart of the wood." Our later investigations substantiate this statement by Faurot, further discussion of which is given in another part of this work. Apparently these conclusions are drawn entirely from the appearance of the diseased host, the discoloration being accepted as the limit of mycelial growth. At least, this is true of Paddock's and Hasselbring's work, and Faurot does not state how he arrived at his conclusions.

It was determined to investigate this point later on. In the meantime, affected areas of New York and Illinois canker were being cut out at varying depths; for it seemed reasonable to believe that even if further investigation did disclose the fact that the mycelia penetrated to the heartwood, it would not necessarily follow that the fungus was capable of continuing its growth after the surface portion had been removed. It was thought that the disinfectant used might penetrate the wood to a depth sufficient to kill the remaining mycelia.

Again, but little experimental work had been done to determine what strength of the disinfectant to use to obtain the best results. Sturgis¹³¹ found (1893) by a series of laboratory experiments that a 0.03% solution of copper sulphate is fatal to the fungus Sphaeropsis malorum. A moderately weak Bordeaux mixture made of three pounds of copper sulphate, three pounds of lime and fifty gallons of water contains 0.75% copper salts, which is more than twenty-five times the minimum strength required to kill the fungus spores, according to Sturgis. Thus it would seem that ordinary Bordeaux is sufficiently strong to be fatal to the fungus Sphaeropsis malorum.

The disinfectants were used in varying strengths and frequent observations were made to determine whether ^{the} disease was still advancing or not, and also to determine if any deleterious effects were produced upon the host where the

stronger solutions were used.

Most of the treatments were made on the Horticultural Grounds, but about fifty infections of New York and Illinois canker were treated in an old Ben Davis orchard on the loess soil at McBaine, to compare the effect of similar treatments on soils differing widely in character. A total of more than two hundred and fifty infections have been treated.

During the warm days the latter part of November and the first part of December, more or less growth of the fungus was made on some of the treated infections, amounting in some instances to as much as four or five inches. (See Fig. 2-b) Most of these growing areas had been previously treated with formalin. Some of these affected areas were again cut out around the edges and treated as before, some were merely given another coat of paint, while still others were left alone.

Before cutting out an infected area, an effort was made to determine the causal fungus. No difficulty was experienced in doing this, where the fungus was in the fruiting stage. The variations in the appearance of the cankered spots renders the identification of the fungus from a superficial examination of the affected areas somewhat uncertain. It was sometimes necessary, in the absence of fruiting bodies, to grow cultures of the fungus from the diseased wood to further substantiate the previous diagnosis.

In treating the infected areas, the diseased bark and wood was usually removed. To do this, the bark was first cut around the margin of the diseased spot with a sharp knife. The cut was made in the sound tissue one half inch to one inch from the margin of the infection, on the sides, and one half to four inches from each end. The diseased bark and wood was then removed. The tool used for this purpose is a triangular steel plate with sharp ground edges, fastened securely to a bent shank. The wounded surface was then moistened with one of the fungicidal solutions, except where no fungicide was used. This was followed usually with a coat of white lead paint, but in a few cases, Bordeaux was applied instead.

The results obtained so far with the various methods of treating the New York canker on a large number of varieties are given in Table No. XIV. As shown in the table, one hundred eighty infections on thirty eight varieties have been treated in various ways. It is reasonable to suppose that there might be a direct relation between the relative resistance of the different varieties, and the efficacy of the treatment. We would expect the more resistant sorts to respond most readily to the treatment. My observations lead me to believe that this is true.

EXPERIMENTS ON TREATING SPHAEROPSIS MALORUM.

Table XIV.

Date 1913-1914	Variety of Apple trees	Disinfectant used	No. of Infections Treated	Efficiency %
Sept. 26	Gano	Paint	7	100.0
Oct. 6	Jonathan	CuSO ₄ #	4	100.0
Oct. 10	Jonathan	CuSO ₄	3	100.0
Oct. 12	Ingram	CuSO ₄	1	100.0
Oct. 12	Jonathan	CuSO ₄	5	80.0
Oct. 24	Metiff	Carbolic acid	3	100.0
Oct. 24	Selumes	Formalin	3	100.0
Oct. 24	Anison	Formalin	6	00.0
Oct. 24	Primate	Formalin	3	33.0
Oct. 25	Kartacs	Carbolic acid	3	100.0
Nov. 6	Miller Boy	HgCl ₂ ##	9	100.0
Nov. 10	Wild Crab	HgCl ₂	2	100.0
Nov. 10	Nyack	HgCl ₂	3	100.0
Nov. 12	Bailey Sweet	HgCl ₂	6	100.0
Nov. 12	Winesap	HgCl ₂	5	100.0
Nov. 12	Fausta Rome	HgCl ₂	1	100.0
Nov. 12	Wafer	HgCl ₂	2	100.0
Nov. 13	Batullen	HgCl ₂	2	100.0
Nov. 13	Collins	HgCl ₂	1	100.0

#copper sulphate solution.
##mercuric chloride solution.

Table XIV. (Continued)

Date 1913-1914	Variety of Apple tree	Disinfectant used	No. of Infections Treated	Efficiency %
Nov.13	Kans.Greening	HgCl ₂	4	100.0
Nov.12	Ben Hur	Paint	1	100.0
Nov.13	Wine Rubbets	Formalin	7	100.0
Nov.30	Melon	HgCl ₂	1	100.0
Dec.1	Gold Medal	HgCl ₂	1	00.0
Dec.1	July	HgCl ₂	1	100.0
Dec.1	York Stripe	HgCl ₂	6	100.0
Jan.12	Grimes	Paint	6	83.0
Jan.13	Mihalype	HgCl ₂	3	100.0
Jan.13	Jonathan	CuSO ₄	4	100.0
Jan.13	Ben Davis	CuSO ₄	1	100.0
Jan.13	Maiden Blush	Carbolic acid	2	100.0
Jan.14	Maiden Blush	Paint	1	100.0
Jan.14	Stanard	Paint	1	00.0
Jan.14	Battyani	Paint	2	00.0
Jan.14	Summer Colv.	HgCl ₂	3	100.0
Jan.14	Winesap	HgCl ₂	5	100.0
Jan.15	Jonathan	CuSO ₄	6	100.0
Jan.15	Spitzenberg	CuSO ₄	5	00.0
Jan.15	Maggar	CuSO ₄	1	100.0

Table XIV. (Continued)

Date 1913-14	Variety of Apple	Disinfectant used	No. of Infections Treated	Efficiency %
Jan.15	Ashton	CuSO ₄	2	100.0
Jan.15	Wafer	CuSO ₄	2	100.0
Jan.16	Tudor	Carbolic acid	1	00.0
Jan.16	York Imperial	Carbolic acid	1	100.0
Jan.16	Jonathan	Carbolic acid	2	100.0
Jan.16	Sweeting	CuSO ₄	3	100.0
Jan.16	Jonathan	Paint	2	100.0
Jan.17	Jonathan	Paint	3	66.0
Jan.19	Winesap	CuSO ₄	5	20.0
Jan.19	Flory	Carbolic	4	75.0
Jan.19	Jonathan	Carbolic	1	00.0
Apr.12	Jonathan	Bordeaux	1	100.0
Apr.12	Jonathan	Bordeaux	1	100.0
Apr.12	Jonathan	Bordeaux & Pain ^t	1	100.0
Apr.12	Grimes	Bordeaux	1	100.0
Apr.13	Jonathan	Bordeaux	1	100.0
Apr.17	Lit. Pippin	CuSO ₄	2	100.0
Apr.17	Winesap	HgCl ₂	1	100.0
Apr.18	Huntsman	Paint	2	100.0
Apr.18	Spitzenberg	CuSO ₄	1	00.0

EXPERIMENTS ON TREATING NUMMULARIA DISCRETA.

Table XV.

Date 1913-14	Variety of apple	Disinfectant used	No. of Infections Treated	Efficiency %
Nov.10	Nyack	HgCl ₂	2	100.0
Nov.27	Clayton	HgCl ₂	2	00.0
Jan.12	Ben Davis	HgCl ₂	5	100.0
Jan.12	Delaware	HgCl ₂	1	100.0
Jan.14	Ashton	CuSO ₄	1	100.0
Oct.24	Anison	Formalin	2	00.0
Nov.11	M.Sweeting	CuSO ₄	2	100.0
Jan.16	Ben Davis	Carbolic acid	7	82.0
Apr.18	Minkler	Carbolic acid	1	100.0
Apr.	Nelson Sweet	Bordeaux	1	100.0

A few infections which were thought to be due to Sphaeropsis malorum at the time they were treated, have since been proved to be caused by a new fungus. For want of a name, this new fungus is designated as fungus No. 4. The fruiting bodies of this fungus are very similar to those of Sphaeropsis malorum, except that the former are slightly larger when mature.

They are easily distinguished by a microscopical examination. The spores of fungus No.4 are borne in an acervulus. They are cylindrical, straight or slightly curved, hyaline, and sometimes having a greenish tinge. They are about four times as long as wide, measuring from 2-2.5 X 7-9 microns.

A few infections of this canker have been treated in various ways as shown in Table XVI.

EXPERIMENTS ON TREATING THE
CANKER FUNGUS NO. 4

Table XVI.

Date 1913-14	Variety of apple	Disinfectant used	No. of Infections Treated	Efficiency %
Oct.24	Huntsman	Formalin	3	00.0
Nov.11	Grays Red	HgCl ₂	1	00.0
Nov.11	Tetofski	Formalin	2	00.0
Nov.11	Champion	HgCl ₂	4	00.0
Nov.27	Clayton	HgCl ₂	1	00.0

It will be seen from Table XVI. that the treatment failed absolutely in every instance. In some cases the fungus grew out on all sides of the treated areas and fruited, in less than two months after the infections had been treated.

At first a bark canker caused by Myxosporium corticolum, commonly found on the trunks of apple trees, was confused with the New York canker. A few trees were treated before it was learned that this bark canker is not of sufficient importance to warrant an attempt to control it. The varieties treated and the methods used are shown in Table XVII.

EXPERIMENTS ON TREATING MYXOSPORIUM CORTICOLUM.

Table XVII.

Date 1913-14	Variety of apple	Disinfectant used	Number of trees
Sept. 29	Gano	Paint	2
Oct. 1	Jonathan	Paint	1
Oct. 2	Ingram	Copper sulphate solution	2
Oct. 3	Ingram	Paint	1
Oct. 3	Ingram	Copper sulphate solution	1
Oct. 10	Jonathan	Copper sulphate solution	1
Oct. 24	Eper	Formalin	1
Oct. 31	Sekura	Carbolic acid	1
Nov. 6	Nyari	Mercuric chloride Sol.	1
Nov. 10	Jonathan	Mercuric chloride Sol.	1

These treatments were successful in almost every case. There seems to be little, if any difference, in the results

obtained from the different methods of treatment. While in most cases there has been no subsequent progress of the disease, still I am convinced that the results obtained are not worth the effort. This canker appears to be annual in the host. All that the treatment has done, therefore, is to prevent reinfection this spring.

EFFECT OF COPPER SULPHATE SOLUTION IN
CONTROLLING CANKER DISEASES.

Table XVIII.

Kind of Canker	Number of Infections Treated	Number Progressing	Mean Efficiency %
Sphaeropsis	46	6	86.5
Nummularia	3	3	100.0
Fungus No.4	---	---	-----

Table XVIII. shows the relative effect of copper sulphate solution in controlling the New York and the Illinois canker diseases. Apparently the former does not yield so readily to this treatment. This is by no means a just comparison, due to the wide difference in the respective number of infections treated. The data seems to indicate that Nummularia discreta responds more readily to this treatment, but we are hardly justified in drawing this conclusion.

THE EFFECT OF MERCURIC CHLORIDE SOLUTIONS IN CONTROLLING
CANKER DISEASES.

TABLE NO. XIX.

Kind of Canker	Number of Infections Treated	Number Progressing	Mean Efficiency %
Sphaeropsis	56	2	96.4
Nummularia	10	2	80
Canker, No. 4	6	6	00

Table No. XIX. gives a comparison of the value of mercuric chloride solution in checking the progress of three different canker diseases. Sphaeropsis malorum and Nummularia are pretty well controlled by this method, but the progress of the unknown fungus seems not to be affected. It is safe to conclude that the New York and the Illinois canker can be controlled in most instances with mercuric chloride solution.

The results obtained from treating canker diseases with formalin have been very unsatisfactory, as the results in Table No. XX. indicate. The use of formalin is objectionable aside from its failure to give the desired results. Formalin appears to have a bad effect upon the tissues of the tree, killing the adjacent cells, and causing the bark around the treated wound to dry up and crack. I have obtained only negative results from its use. Formalin is an unstable compound in the presence of air and moisture, and it is probable that its fungicidal value is soon lost when applied to the surface of the tree. Again, the deleterious effect upon the cells may render them less resistant to the subsequent advance of canker diseases.

EFFECT OF FORMALIN IN CONTROLLING CANKER
DISEASES.

TABLE NO. XX.

Kind of Canker	Number of infections Treated	Number progressing	Mean Efficiency %
Sphaeropsis	19	8	57.9
Nummularia	2	2	00.0
Unknown Canker No.4	5	5	00.0

THE EFFECT OF CARBOLIC ACID IN CONTROLLING
CANKER DISEASES.

TABLE NO. XXI.

Kind of canker	No. of Infections Treated	Number progressing	Efficiency %
Sphaeropsis	22	2	90.9
Nummularia	8	2	75.0

Carbolic acid is of some value in treating canker diseases as is shown in Table No. XXI. .

EFFECT OF WHITE LEAD PAINT IN CONTROLLING
CANKER DISEASES.

TABLE NO. XXII.

Kind of canker	No. of infections treated	Number progressing	Efficiency %
Sphaeropsis	24	4	83.3
Nummularia	3	1	67.0
Unknown canker	00		

Several infections were cut out and the surface of the wounds painted without being previously disinfected. These treatments serve as a basis upon which to compare the values of the disinfectants. Paint alone is of considerable value, especially where more than one coat is applied. Neither of these treatments had any effect in controlling the unknown canker.

These results warrant the assertion that the New York and Illinois canker can be controlled in a certain measure. In all probability, the final results will be much lower than those shown in the ^{above} table. On the other hand, more satisfactory results would have been obtained if all of the infections had been treated as they would have been in a commercial orchard. Many infections were treated on limbs and some on trunks that were almost girdled by the canker. Seldom has the progress of the disease been checked in such cases, thus reducing the percentage of successful treatments. In a commercial orchard, these limbs would have been pruned below the infection.

SUMMARY OF RESULTS ON TREATING
CANKER INFECTIONS.

Table XXIII.

Disinfectant used	Kind of Canker and the Relative Efficiency of Treatment		
	Sphaeropsis	Mummularia	Fungus No.4
	%	%	
Mercuric chloride Sol.	96.4	80.0	00.0
Copper sulphate Sol.	86.5	100.0	00.0
Carbolic acid	90.9	75.0	None treated
Formalin	57.9	60.0	00.0
Paint	83.3	67.0	None treated

The relative values of the disinfectants on the different canker diseases are shown in Table XXIII. These are the results so far obtained. (May 10.) I expect to continue the observations upon these treatments until September, and it is probable that the results will be quite different then.

Mercuric chloride solution, copper sulphate solution, and carbolic acid each have some fungicidal value on the New York and Illinois cankers, but the fungus No.4 was not checked by any of the treatments used.

GENERAL SUMMARY AND CONCLUSIONS.

Four canker diseases of apple trees have been studied more or less thoroughly in this investigation. The fungi causing three of these cankers have been identified, namely, Sphaeropsis malorum, Nummularia discreta, and Myxosporium corticola. The fungus causing the other canker has not yet been identified. It seems never to have been reported as a parasite on apple trees, previous to this paper. It is probable that it is unknown to botanists.

The relative susceptibility of different varieties of apple trees to the New York and Illinois canker diseases has been worked out from observations on the percent of trees infected, and the relative virulence of the diseases in the different sorts. Some sorts are more resistant than others, but it is probable that no variety is entirely immune. Among the commercial varieties most resistant to the New York canker are Rome Beauty, Ingram, Grimes, Missouri Pippin, Minkler, Jonathan, and Winesap. The most susceptible sorts are Spitzenberg, Ben Davis, Gano, King, and Champion.

The susceptible and resistant varieties to the Illinois canker have not been reported, previous to this paper. Those varieties most resistant to the Illinois canker are Ingram, Grimes, York Imperial, Fameuse, and Gold Medal. Among the most susceptible sorts are Ben Davis, Nelson Sweet, Clayton, Collins,

Champion, and Spitzenberg.

No variety of apple is immune to Myxosporium corticolum.

Old trees are more susceptible to canker diseases than trees that are young.

It was proved from observations and experiments that the mycelia of Sphaeropsis malorum, and Nummularia discreta invade the tissues of infected trunks and branches of apple trees, except in the early stages of infection.

A study was made of the manner of canker infection. It was found that infections of Sphaeropsis malorum, and Nummularia discreta, usually occur through wounds. Approximately fifty percent of infections originate in wounds made in pruning. All wounds made in the bark or wood of apple trees should be immediately disinfected with mercuric chloride solution, or copper sulphate solution, followed by a heavy coat of paint.

Sphaeropsis malorum is not necessarily a wound parasite. Contrary to the opinion of previous investigators, infections may occur through tender buds, fruit spurs, or even lenticels. As a result, infections cannot be prevented merely by avoiding wounds in the trees, as is generally believed.

Infections by the Myxosporium fungus occur almost invariably through lenticels.

The new canker fungus gains entrance to the host

through wounds, fruit spurs, and lenticels.

The time of the year when the spores are disseminated normally in the Experiment Station orchard was determined for Sphaeropsis malorum, and Nummularia discreta. Viable spores of the former began to be disseminated on April 6, or two weeks before the first spray was applied to the trees. It is probable that spraying the trees the first week in April with lime sulphur, or Bordeaux mixture, would be effective in reducing the number of infections. Spores of Nummularia discreta were first disseminated on April 30, and they have continued to appear in the trap cultures up to the time of this writing. (May 10).

The cause of sunscald and its relation to subsequent canker infection has been studied somewhat thoroughly. Eighty percent of canker infections occur on the side of the trunk and limbs exposed to the direct rays of the sun. The progress of canker fungi is much more rapid on the sunny side of the tree. Apple trees are subject to canker diseases in direct proportion to the extent of previous injury from sunscald. Sunscald can be prevented by whitewashing the trunks and main limbs to reflect the sun's rays during February and March.

Two types of insects, borers and aphids, have been found commonly associated with canker diseases. The aphids feed on the tender tissues in the edges of wounds. Some

culture work was done which seemed to indicate that the aphids may carry infection from tree to tree.

The experiments on treating canker infections indicate that the New York canker, and the Illinois canker may be cured in a large percent of cases, even after the fungi are well established in the host, provided the trees are vigorous. Mercuric chloride solution, and copper sulphate solution, were about equally effectual. The use of formalin gave negative results in every case. It appears to have ~~a~~very injurious effect upon the tissues of apple trees.

Canker infections can be largely, but not wholly prevented, by avoiding needless injury to the bark and wood, and protecting wounds made in pruning.

Fig. 1

- 1a Fire blight or body blight on pear.
- 2 Cankered apple tree limb, showing new growth of New York Canker at b, and indicating that the original infection was from a pruning wound at c.
- 3 Illinois canker on an apple tree limb, just beginning to fruit after a rapid growth of the fungus.

Fig. 2

A tree infected with Illinois canker showing the Woolly Aphids feeding in the edge of the wound at a. The characteristic blistering of the epidermis on the newer parts is shown at b.

Fig. 3

Fig. 4

An apple tree badly infected with Illinois Canker is shown in Fig. 3. Infection started where the limb was removed at a, and extended upward several feet and down the trunk to the ground. The Fig. 4 shows the trunk of the same tree properly treated.

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