THE APPLE SCAB IN TENNESSEE

By

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The Apple Scab in Tennessee
caused by
Venturia inaequalis (Cooke) Winter.

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Introduction

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Importance of disease: Apple scab is one of the most widely distributed and most important of all apple diseases. The appearance of the scab lesions has given rise to several names such as scurf, silver scab, and black spot, in addition to the more common name scab. The first official record of the disease was made by Fries, from Sweden, over a century ago, 1819 (Wallace, 1913: 547). Since that time it has been reported in every country where apples are grown. In the United States it is one of the major pests in almost every section where apples are grown commercially except in certain irrigated areas of the Northwest. The northern apple sections, where the climate is cool and moist, are most seriously infested (Swingle, 1914: 301 - 302). In Tennessee, the distribution of apple scab is general. There is probably not a commercial orchard in the state where scab does not occur and in many of them it is one of the major pests.

Scab is caused by a fungus, Venturia inaequalis (Cooke) Winter, which attacks the fruits, blossoms, leaves and sometimes the twigs of the apple. A very similar

disease which occurs on pears is caused by a closely related fungus but is entirely distinct and does not occur on the apple (Duggar, 1909: 265 - 266). Losses from apple scab are considerably greater than is realized by most growers because the average orchardist considers only the reduced value of the diseased fruit which results from apple scab. Serious as this loss may be, it is frequently less than that which results from other sources. The infection of the pedicels and calyx cups at blooming time frequently causes them to drop and often results in a serious reduction in the set of fruit. Still another source of loss is the injury which is done to the infected leaves. They are considerably dwarfed and frequently dropped prematurely (Hesler and Whetzel, 1917: 4 - 6). It is obviously impossible to estimate with any degree of accuracy the financial loss which results from these sources. The Plant Disease Survey, United States Department of Agriculture, brings together estimates of the loss due to apple scab from all important producing sections. These reports show clearly that scab is the most important of all apple diseases (Plant Disease Bulletin, Supplement 20, 1922).

Description of disease: The first appearance of scab in the spring is usually a small, indistinct, slightly darkened area on the under side of the young leaves. These spots enlarge to almost a quarter of an inch in diameter

and change to an olive brown or almost black color. On the upper surface of the leaves the diseased areas are more definite, the natural luster of the leaf is lost and the spot may or may not become raised, with a corresponding depression on the lower surface. It is common for the diseased areas to be grouped along the midrib and from there radiate into the healthy portions of the leaf (Anderson, 1920: 17 - 18).

On the fruit, scab first appears as an olive brown spot somewhat darker than the diseased area on the leaf. The margins of these spots are often silvery gray due to the loosened epidermis. This appearance has resulted in the name silver scab, which is often applied to this disease. As the spots enlarge their centers may become brown and corky, leaving only an outer ring of the velvety appearance. Several scab spots may unite until considerable areas are included. The infected portion of the fruit is severely dwarfed and in time it may become deeply cracked. Badly infected fruits are greatly distorted and are rendered entirely unfit for sale.

Twig infections of apple scab are rare except on certain very susceptible varieties such as the "McIntosh." When they do occur the lesions are so very small as to be

scarcely visible although occasionally they may reach an eighth of an inch in diameter. These lesions occur on the current season's growth, are irregularly oblong in shape and yellowish gray in color. Severe infections give the twigs a scurfy appearance but apparently do not reduce the vigor of the shoot (Wallace, 1913: 548; 577 - 578).

The causal relation between the apple scab disease and the fungus, Venturia inaequalis (Cooke) Winter, has been very definitely established. The conidial form of this fungus was first discovered in association with the disease and was given the name Fusicladium dentriticum (Wallr.) Fckl. Later an ascomycetous fungus, Venturia Pomi (Fr.) Wint., was found developing saprophytically in fallen apple leaves. More recently these two forms were found to be the imperfect and perfect stages in the development of the same fungus and the name Venturia inaequalis (Cooke) Wint., was given to the organism (Wallace 1913: 556 - 557). For a detailed discussion of synonomy, see Duggar 264 - 267.

Life history of pathogene: This pathogene passes the winter chiefly in the fallen apple leaves as immature perithecia. During the late winter or early spring the perithecia renew development within the tissues of the leaf.

When fully mature, they are nearly spherical bodies, scarcely visible without the aid of a hand lens, varying from 90 to 160 microns in diameter. The walls of the perithecia are dark olive green and the irregular cells give the walls a checkered appearance. As the perithecia mature the asci develop within them. These asci are oblong, or rather club shaped bodies, with thin transparent walls. Immense numbers of them may be formed within a single perithecium. Eight two-celled ascospores develop within each of these asci. The ascospores are olive-brown in color and the upper cell is somewhat broader than the lower, 11 to 15 by 5 to 7 microns (Duggar, 1909: 267 - 270).

The ascospores constitute the most important inoculum during the very early spring. Experiments, conducted in different sections of the country, indicate that the maturity of the ascospores may vary under different conditions (Wallace, 1913: 557 - 563). Further discussion of the period of inoculation will be given later. When the ascospores are fully mature, the perithecium is ruptured and the ascospores are forcefully ejected. The liberation of these spores is governed by their maturity and by the presence of abundant moisture in the air. Several hours of continuous rain, or a very humid atmosphere, are necessary to cause the dehiscence of the perithecia. The ascospores

are not all mature at the same time and therefore the period of spore ejection may extend for several days. Repeated short rainy periods tend to extend this period and cases are not uncommon where mature spores have been liberated intermittently for more than a month. The work which is presented by Wallace in the above citation and the data which are presented later in this paper support these statements.

At the season of ascospore discharge, the young tender apple leaves and fruits are usually exposed. The primary infection usually occurs on the under side of the leaves or about the calyxes of the young fruits. After the spores are forced from the asci they are buoyed up by the air and some may find lodgment on the young leaves. If sufficient moisture is present, these spores germinate and send out a mycelial thread, called a germ tube, which penetrates the cuticle of the leaf and establishes a food relation with the host. The germ tube makes extensive growth and radiates from the point of inoculation (infection court) resulting in a dense mat of mycelium. The lesion becomes visible to the naked eye after about two weeks and it may continue to enlarge until it reaches an eighth, or even a quarter of an inch, in diameter. The mycelium which

constitutes the body of the fungus is reddish brown or olive colored, closely septate and very irregularly branched. This pathogene secures most of its food from the cuticle but it may penetrate the epidermis and absorb considerable water from the underlying tissues. Soon after the characteristic scab lesions appear, the mycelium changes into a dense cushion, stroma, from which spore-bearing stalks, conidiophores, arise. The summer spores, conidia, are budded off from the ends of these conidio-phores and are blown to other apple leaves or fruits where they cause new scab lesions in the same way as has been described for the ascospores. The conidia are more or less ovate, sometimes with a slight reddish tint and usually are not able to retain their power of germination through long periods of unfavorable conditions. Conidia mature very quickly and under favorable conditions they inoculate new places and repeat the development time after time throughout the summer (Duggar, 1913: 267 - 269).

At the close of the growing season, the leaves drop to the ground and those which are infected with the scab fungus serve to carry it over the winter. When the infected leaves die and drop, the mycelium spreads through-out the leaf and gives rise to perithecia. The development

of the perithecia may begin in the fall or winter and be completed as has been described.

The above discussion gives in a general way the life history of the pathogene causing apple scab. There are several points in this life history which influence very decidedly the necessary control measures. The season at which the perithecia mature, the season and the duration of the ascospore discharge, the conditions governing inoculation and incubation and the possibility of other important sources of inocula are of the greatest importance.

Observations in 1922

Purpose: This study of the development of the apple scab fungus, Venturia inaequalis (Cooke) Winter, was begun January first 1922. The ultimate aim of the work was to study the development of the fungus under Tennessee conditions in order to determine more accurately the best time to spray for the protection of the host against the fungus. Throughout this study especial attention was given to the following points: -

The time at which the first ascospore discharge occurs.
The duration of the ascospore discharge.
Correlation of the weather conditions and the development of the fungus.
The advancement of the apple buds, leaves and fruits during the period of ascospore discharge.

Methods: At the time this work was begun, there had been no similar work done in Tennessee and therefore there were no definite records regarding the severity of apple scab in the vicinity of Knoxville. It was well known that the apple scab was generally serious on the fruit of this section, but no investigation of the development of the fungus on the apple leaves had been made.

The first step which was taken in the investigation was to collect a quantity of apple leaves from the neglected orchards near the city. These leaves were placed on the ground in a wire screen where they would be exposed to weather conditions. During January and February some of these leaves were examined every two weeks. After the first of March, an examination was made each week until the perithecia of Venturia inaequalis (Cooke) Winter, were found and after that date the examinations were made approximately every two days.

Several leaves were carefully examined each time with a hand lens magnifying about 10 X until the perithecia were found. After the first immature perithecia were found, mounts were made and examined by means of a microscope. The mounts were prepared by removing several perithecia from the leaf and mounting them in water under a cover glass. In this manner the developmental stage of the fungus was observed. As soon as the ascospores appeared to be mature, some perithecia were mounted in rain water and placed in a moist chamber where conditions were favorable for their germination. Microscopic examinations were continued until practically all of the asci were empty and the ascospores were scarce.

Phenological data were kept throughout the spring. Observations were made as to time of bud swelling, when they began to show pink and when the fruit began to set. These data were obtained from numerous trees near Knoxville in addition to those from which the leaves were secured.

The weather records were obtained from the Knoxville station of the United States Weather Bureau. More detailed data are presented for the months of March and April which cover the period of greatest ascospore activity. This information is presented in charts and tabular form because

of the convenience with which it can be studied.

So far as was possible observations were made in different parts of the State as to the relative susceptability of the more important apple varieties. In order to supplement this list and make it more complete, several publications from other states were consulted.

Data. Weather Conditions: In presenting the following data an effort has been made to prepare simple charts which will show by curves or outlines the important information. Discussions of the charts are intended to emphasize the essential points and correlate the information in such a way as to shwo its practical application.

Chart No. 1 shows the daily fluctuation of the mean temperature at Knoxville Tennessee during the period from January 1st. to June 30th. 1922. A study of this curve shows that the last half of the winter was very mild. Only four times after the first of the year did the daily mean temperature drop below the freezing point and the lowest temperature of the entire period was reached on January 2nd. when the mercury registered 18 degrees F. The entire spring was warm and vegetation was early. After the first of March, there were only five days when the temperature dropped below 43 degrees F., and at no time did it approach the freezing point. Table No. 1 gives the

mean monthly temperatures for this period.

Table No. 1

Weather Conditions from Jan. 1 to June 30, 1922

Month	Mean Monthly Temperature	Total Monthly Precipitation	Character of days: No. days clear	No. days cloudy	No. days Pt. Cloudy
January	40 degrees	4.58 in.	2	19	10
February	47 "	4.09 "	3	16	9
March	52 "	7.60 "	7	20	4
April	61 "	4.61 "	5	16	9
May	68 "	3.82 "	1	19	11
June	76 "	5.27 "	3	18	9

One of the most noticeable facts concerning the weather conditions during the first half of 1922, is the excessive amount of rain which fell and the amount of cloudy or partly cloudy weather during the late winter and spring. Chart No. 2 shows graphically the daily precipitation during this period. An examination of this chart shows that some rain fell on 112 of the 180 days from January 1 to June 30 inclusive. During this period there was a total precipitation of 29.97 inches.

Daily Mean Temperature Record
Jan. 1st to June 30th 1922
No. 1

Degrees F.
90°
80°
70°
60°
50
40°
30°
20°
10°
0°

Date
Jan. 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 30
Feb. 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Mar. 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Apr. 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 30
May 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 30
June 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 30

(Table No. 1 gives the total precipitation each month during this period and also the number of cloudy or partly cloudy days each month. It is striking to note from this table that from March 17 to May 2 only 7 days were clear, while 21 were cloudy and 10 partly cloudy).

Phenological data: Observations on the development of the apple trees were made in the vicinity of Knoxville. These observations included the trees from which leaves were collected for study of the development of the pathogene. The first swelling of the buds became evident on March 16, as is indicated on chart No. 3. Nine days later, on the 25th, the young leaves were about the size of a squirrel's ears and were too far advanced for the dormant spray. The development of the buds from this time was unusually rapid. A little pink was evident in the blossoms on March 27th, the trees were in full bloom on April 4th and the calyxes were closed by the 16th. Charts No. 3, 4, and 5 follow this development until the first of May. It is evident from these data that only 21 days elapsed from the time the buds first showed a little pink until the petals had dropped and the fruit had set.

Development of Pathogene: A further study of Charts No. 3, 4, and 5 shows that the development of the pathogene was equally as rapid as the advance of the trees.

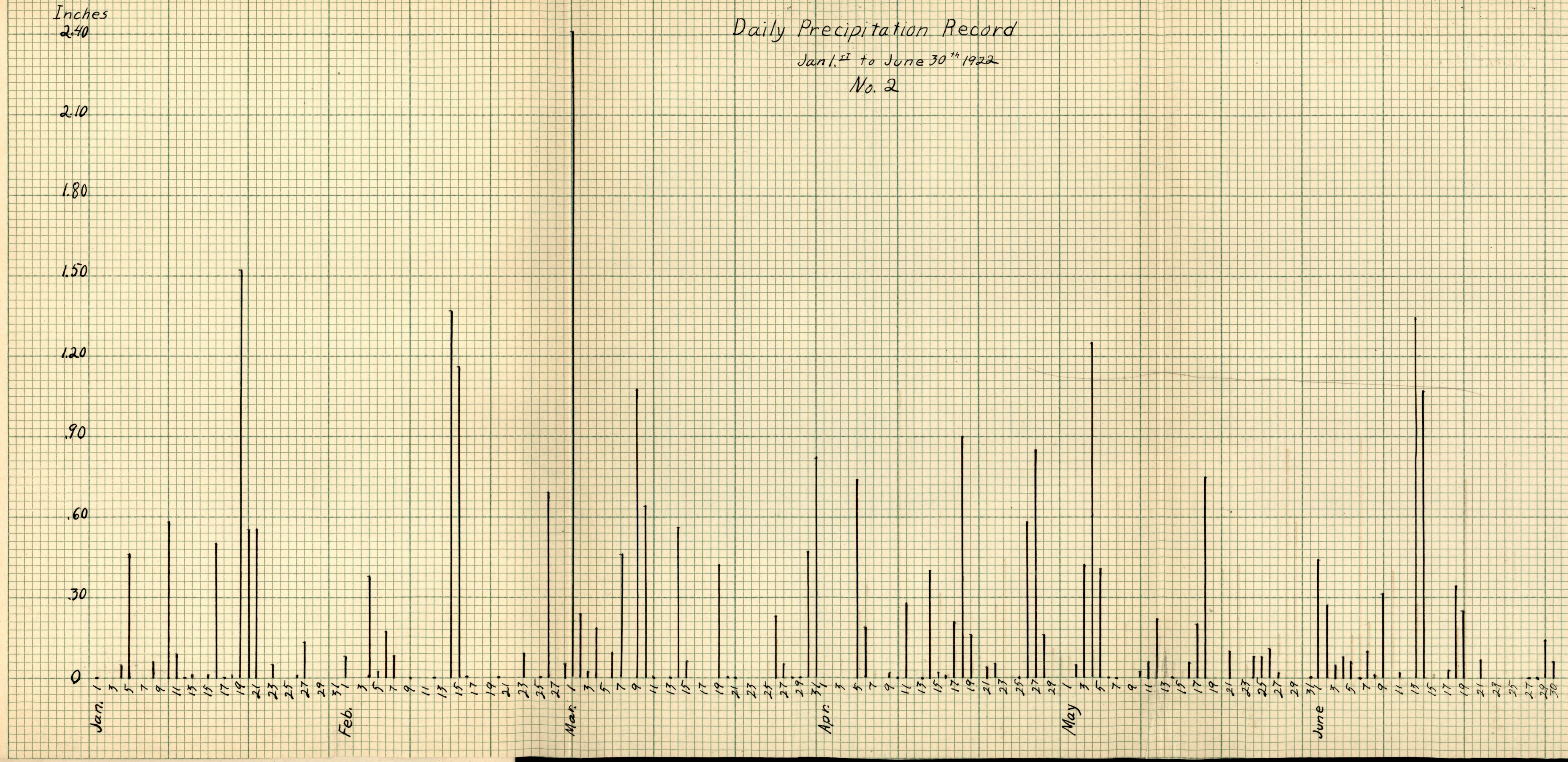
The first immature perithecia of Venturia inaequalis (Cooke) Wint., were found on March 25th, and only eight days later they were mature and the ascospores were ready to be discharged as determined by their appearance. The first ascospores were liberated on April 5th and other discharges occurred intermittently, when conditions were favorable, until April 29th, a period of 24 days. The first infection on the young leaves was found just ten days after the first discharge was observed and the first fruit infection was found five days later. The first appearance of scab on the fruit was in the form of a very small lesion near the calyx of the young apple. Noticeable dwarfing of the young fruit was not observed until several spots developed on the same apple. Dwarfing was noticed on May 1st, which was 25 days after the first ascospores were discharged.

Correlation of Data: All of the data which have been discussed should be considered together in order to be of any value as a guide in the proper application of control measures. Charts No. 3, 4, and 5 have been so arranged that this study may be made conveniently. Going further in the study of these charts there are several facts which are important in this study. The general

Daily Precipitation Record

Jan 1.st to June 30th 1922

No. 2



impression given by the temperature curves and the precipitation records is that weather conditions were favorable for the growth of fungi.

If we consider the phenological data and the development of the fungus together, we find, first of all, that the immature perithecia were not found on the old fallen apple leaves until ten days after the buds first showed a slight swelling and when the young leaves were about one half inch long. By the time the individual buds were separating in the clusters, the time when the pink spray is usually applied, the asci were formed in the perithecia but were not mature. The pathogene developed very rapidly, however, and the ascospores were fully mature and ready to be discharged about two days before the apple trees were in full bloom. The extended rain of April 30th and May 1st occurred before the ascospores were mature. Although the weather was warm and cloudy or partly cloudy after the spores were fully mature, there was no rain until April 5th. There was abundant ascospore discharge during and immediately following this rain, so that the first ascospores were liberated just before the petals began to fall. Whenever conditions were favorable, there was an ascospore discharge from this time until the last of April when practically all of the asci were empty.

Development of Ventricaria maequalis and Accompanying Conditions March 16th to 31st 1922

No. 3

Temperature Variation

80°
60°
40°

Phenological data

Buds begin to swell
Buds swelling
Leaves about ½ inch long
Buds showing little pink
Flower buds are separating; ready for pink spray

Duration of rain

0
0
0

Character of Day

Partly Cloudy
Clear
Clear
Clear
Clear
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy

Ventricaria Development →

Mar. 16 | Noon | Midnight | 17 | Noon | Midnight | 18 | Noon | Midnight | 19 | Noon | Midnight | 20 | Noon | Midnight | 21 | Noon | Midnight | 22 | Noon | Midnight | 23 | Noon | Midnight | 24 | Noon | Midnight | 25 | Noon | Midnight | 26 | Noon | Midnight | 27 | Noon | Midnight | 28 | Noon | Midnight | 29 | Noon | Midnight | 30 | Noon | Midnight | 31 | Noon | Midnight

"Shepherd" CROSS SECTION.
THE FREDERICK POST. CO.

Development of Venturia inaequalis
and
Accompanying Conditions
April 1st to 16th 1922
No. 4

80°
60°
40°
Temperature Variation

Phenological data → 20°

Petals fallen
Full bloom
Petals falling
Blossom buds opening

Duration of rain → 0°

Character of day →

Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight	Noon	Midnight
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
April 1																								
Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Pt. Cloudy	Pt. Cloudy	Pt. Cloudy	Pt. Cloudy	Clear	Clear	Clear	Pt. Cloudy	Pt. Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy

Ascospores fully matured ready to be discharged

Development

Blossom buds opening

Petals falling

Full bloom

Petals fallen

Calyx closing

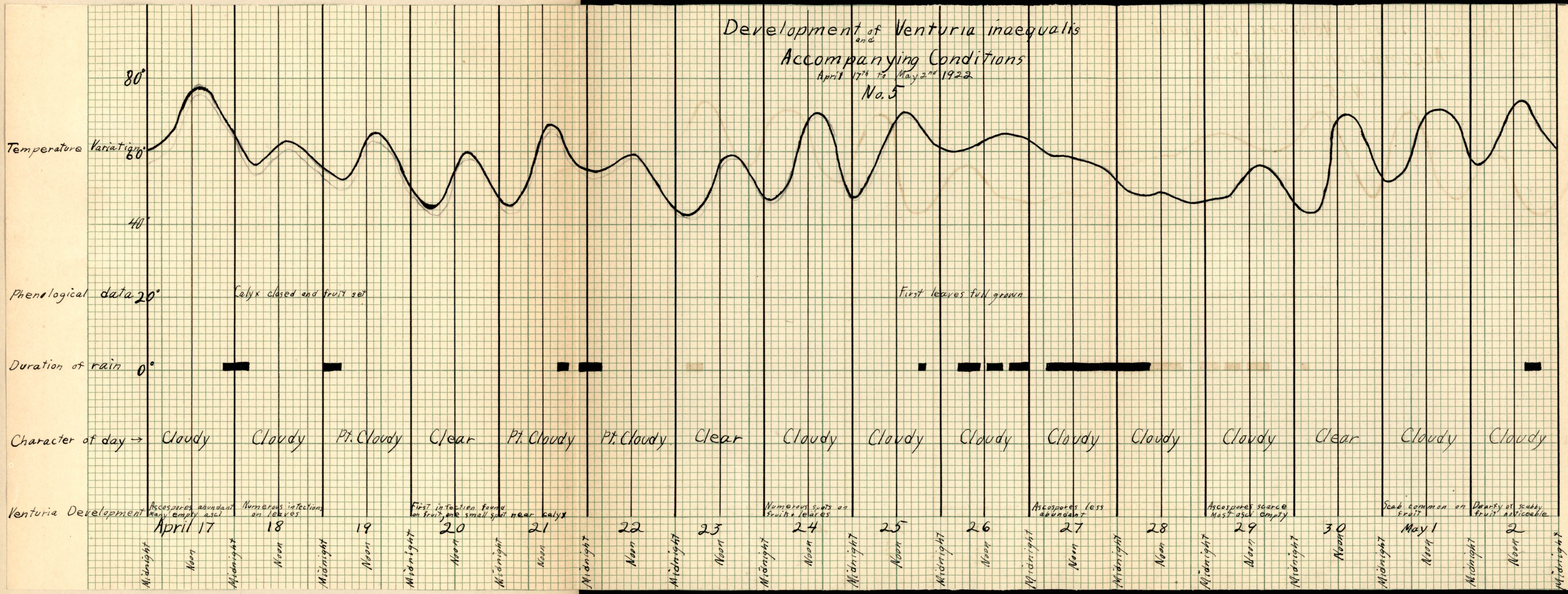
Calyx almost closed

First infection found on underside of leaves

Ascospores very abundant several asci empty

Ascospore discharge continuing, several asci empty

Ascospores being discharged


Development of Venturia inaequalis and Accompanying Conditions
April 17th to May 2nd 1922
No. 5
Temperature Variation
80°
60°
40°
Phenological data
20°
Calyx closed and fruit set
First leaves full grown
Duration of rain
0°
Character of day →
Cloudy
Cloudy
Pt. Cloudy
Clear
Pt. Cloudy
Pt. Cloudy
Clear
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Cloudy
Clear
Cloudy
Cloudy
Venturia Development
Ascospores abundant Many empty asci
Numerous infections on leaves
First infection forms on fruit, one small spot near calyx
Numerous spots on fruits + leaves
Ascospores less abundant
Ascospores scarce Most asci empty
Scab common on fruit
Dearth of scabby fruit noticeable
April 17
18
19
20
21
22
23
24
25
26
27
28
29
30
May 1
2
Midnight
Noon

The period of ascospore activity endured 25 days, from the time the trees were in full bloom until the fruits were almost half an inch in diameter. During this period there were one or more hours of rain on 17 different days which made possible a renewed ascospore discharge on each of these days. Conditions were almost ideal for inoculation and incubation and the ascospores were most abundant just as the petals were falling and the fruits were setting. This period dates from April 7th to 18th, for 1922.

The first infection was found on the under side of the oldest leaves in a cluster before they were full grown. Just ten days after the first ascospore discharge occurred, the first primary infection became visible on the leaves. A very few days later the leaf infections were numerous and frequently more than one scab spot could be found on a single leaf. The injury from these infections was not serious in sprayed orchards and even in the unsprayed, neglected orchards the leaf injury was so far exceeded by the loss of fruit that it was hardly noticed.

The first indication of apple scab on the fruits appeared as small discolored spots very near the calyx, or, as was observed frequently, these lesions first appeared

on the sepals of the calyx itself. During the season of 1922, the first fruit infection was found only four days after the calyx had closed. These first areas enlarged rather rapidly and other lesions appeared on the same fruits so that by the first of May there were some apples in unsprayed orchards which showed a slight dwarfing. Through the summer the fungus spread rapidly and a large percentage of the fruit in unsprayed orchards was rendered unfit for sale.

From the above observations it is evident that there is a very close relation between the weather conditions and the development of the pathogene. There is a similar relation between the development of the trees and the weather although trees are less directly affected by the time and duration of the rainfall than is the fungus.

Observations in 1923

Purpose: The investigation during the spring of 1923 was a continuation of the work which had been started the previous season. In addition to the objects which

have been listed for that work some attention was given to the possibility of conidia causing spring infections after being carried over from one year to the next. In connection with the investigation during 1923, a spraying experiment was conducted for the purpose of determining the relative value of applications at different seasons for the control of apple scab. The source of inocula in the early spring and the methods of preventing the infections which may result from early inoculations are matters of the utmost importance.

Methods: The work was conducted in a manner similar to that of the previous season. The leaves were collected during the fall from trees where scab had been severe during season just closing and were placed under a wire screen where they would be exposed to weather conditions. Observations of these leaves were begun the first of January and were continued until the first of May, 1923.

On December 20th some scabby apples were obtained from the city market and were placed under a screen where they would be exposed to outside conditions. Once each week, after the first of January, an examination was made of material which was scraped from a scab lesion on

one of these apples. The material thus obtained from the surface of a lesion was mounted in distilled water under a cover glass and was placed in a moist chamber where conditions were favorable for spore germination. After two days these slides were examined under a compound microscope in order to determine whether or not the conidia had germinated.

The spray schedule test was conducted on mature apple trees which had received moderately good care for several years. The degree of severity of scab in the orchard was not learned as the owner was not familiar with this disease. The sprays were applied as is indicated in Table No. 2. A Bean triplex power outfit was used for the work. A pressure of 275 pounds was maintained all of the time. The first two sprays were applied with spray guns; extension rods and nozzles were used for the calyx spray. Each tree was sprayed thoroughly using from 5 to 7 gallons of material. The orchard which was available for this work contained a mixture of varieties and therefore it was considered best to duplicate all of the treatments as a check against variety variation. In connection with this work a test of Kayso as a spray spreader was conducted.

One plot of trees was given a complete spray schedule but the Kayso was omitted. All of the plots with this exception were sprayed with a material containing Kayso as is indicated in table No. 2.

Table No. 2.

Apple Spraying Experiment

Plot No	No. of Trees	Applications: Pre-pink	Pink	Calyx	Two weeks	Material used
1	5	*X	--	X	X	L.S.1, Ars.Pb.1# Kayso
2	5	---	X	X	X	" " "
3	5	X	X	---	X	" " "
4	5	X	X	X	---	" " "
5	5	---	X	X	X	" " "
6	5	X	--	X	X	" " "
7	5	X	X	---	X	" " "
8	5	X	X	X	---	" " "
9	5	X	X	X	X	" " "
10	5	X	X	X	X	" " only
11	5	---	--	---	---	Check

X indicates that the spray was applied.
*The arsenate of lead was omitted in the prepink spray on all plots.

Concentrated lime sulphur was used as the fungicide in this test. It was diluted to one degree Baume according to the hydrometer test. The powdered arsenate

of lead was used at the rate of one pound per fifty gallons of material. Kayso, prepared by the California Central Creameries, was used as a spreader at the rate of one pound per one hundred gallons of material. The arsenate of lead and Kayso were made into a smooth paste with a little water and were then poured into the spray tank. It was found necessary to mix the Kayso in this way in order to prevent the formation of gummy balls of the material which do not mix with the water.

Data: The data which have been collected during 1923 are presented in the following charts. Observations extending from January first to May first are included.

Weather conditions: The most striking fact concerning the weather conditions since the first of the year is the extreme fluctuations which occurred in quick succession. Chart No. 6 shows the daily mean temperatures from January 1st to May 1st, and charts 8, 9, and 10 give the daily temperature fluctuations during March and April. During these two months there were 36 days when the temperature changed 20 degrees or more during 24 hours. On thirteen different times there was a change of 30 or more degrees within 24 hours and on March 16th there was a fluctuation of 37 degrees. On eleven different nights

after the sixteenth of March the temperature dropped below 40 degrees F., and on five of these nights the temperature went below the freezing point. Table No. 3 gives the mean monthly temperatures for January, February, March, and April.

Table No. 3

Weather Conditions from Jan. 1 to May 1, 1923

Month	Mean Monthly Temperature	Total Monthly Precipitation	Character of days: No. days clear	No. days cloudy	No. days Pt. Cloudy
January	44 degrees	5.73 in.	3	20	8
February	39 "	4.80 "	8	16	4
March	49 "	6.82 "	9	19	3
April	57.4 "	5.64 "	9	12	9

The precipitation was heavy during the first four months of 1923 as is shown graphically in chart No. 7. There was some rain on 62 of the 120 days from January 1st to May 1st. Table No. 3 gives the total monthly precipitation and a summary of the character of the days during this period. An examination of this table shows that there was very little clear weather during the spring months. Only 18 days were clear dur-

"Hayfevered" CROSS SECTION.
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Daily Mean Temperature Record
Jan. 1st to May 1st 1923
No 6

Degrees
90° 80° 70° 60° 50° 44° 30° 20° 10° 0°

Jan. 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Feb. 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
Mar. 1 3 5 7 9 11 13 15 17 19 21 23 25 27
Apr. 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 30

ing all of March and April while 20 days were cloudy and 9 were partly cloudy.

Phenological data: The unusually slow development of the trees after the buds began to swell is one of the most striking facts shown in charts 8, 9, and 10. The apple buds were swollen noticeably on March 16th but the leaves did not reach one-half inch in length until about the 30th, and the individual flower buds were not separated and showing pink until April 7th. Eleven days elapsed after the buds showed pink before the trees were in full bloom and eleven more days passed before the petals had all fallen. Practically all of the calyxes were closed on May 4th, seven days after the petals had all fallen and 27 days after the buds began to show pink.

Development of pathogene: A further study of charts No. 8, 9, and 10 show that the development of the fungus, Venturia inaequalis (Cooke) Wint., was equally as slow as the development of the trees. The first immature perithecia were found on March 20 but the asci were not mature until about April 9th and the ascospores were not matured until April 17th. Twenty-eight days passed after the first immature perithecia were found before the first ascospores were discharged. After April

17th when the first ascospores were mature, numerous spores were liberated, whenever conditions were favorable until May first, when observations ceased. The first infection on the young leaves was found just nine days after the first ascospores were liberated. These early infections appeared as small discolored areas on the lower side of the oldest leaves. In most cases there were only a few spots on a leaf and they were not evident except on close examination.

Each examination which was made of the lesions on the fruits during January showed an abundance of conidia of Venturia inaequalis (Cooke) Wint. When these conidia were mounted in distilled water a considerable percentage of them germinated. Near the last of January a much smaller percentage of germination resulted than at the first of the month. This gradual decrease was evident throughout February and after March 1st no germination was obtained. The attempt to germinate some conidia in potato agar failed. Conidia became less and less abundant until it was difficult to find any on the slides which were prepared by scrapping the surface of the lesions. By March 18th the apples which had been exposed to outside conditions were almost entirely decayed and it was impossible to find any conidia.

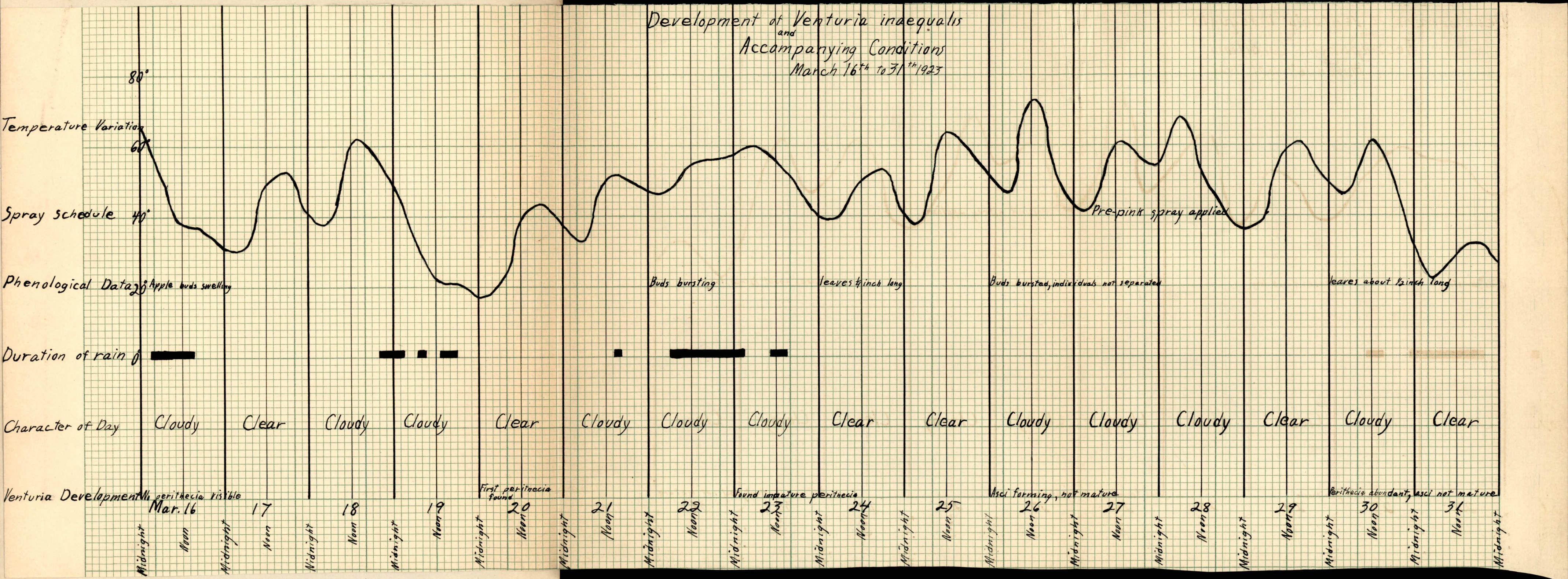
Daily Precipitation Record

Jan. 1st to May 1st 1923

No. 7



Development of Venturia inaequalis and Accompanying Conditions March 16th to 31st 1923



Development of Venturia inaequalis
and
Accompanying Conditions
April 1st to 16th 1923

Spray schedule 40

Temperature Variation
Phenological Data 20

Duration of rain 0

Character of Day

Venturia Development

April. 1 — Conidia(?) did not germinate in agar

2 — Midnight — Noon — Midnight — Clear

3 — Noon — Midnight — Pt. Cloudy

4 — Noon — Midnight — Cloudy

5 — Noon — Midnight — Cloudy

6 — Noon — Midnight — Clear

7 — Noon — Midnight — Clear

8 — Noon — Midnight — Pt. Cloudy

9 — Noon — Midnight — Clear — Asci apparently mature

10 — Noon — Midnight — Pt. Cloudy

11 — Noon — Midnight — Pt. Cloudy

12 — Noon — Midnight — Cloudy

13 — Noon — Midnight — Cloudy

14 — Noon — Midnight — Clear — Asci forming not mature

15 — Noon — Midnight — Pt. Cloudy

16 — Noon — Midnight — Clear — Asci mature Ascospores not mature cross walls formed

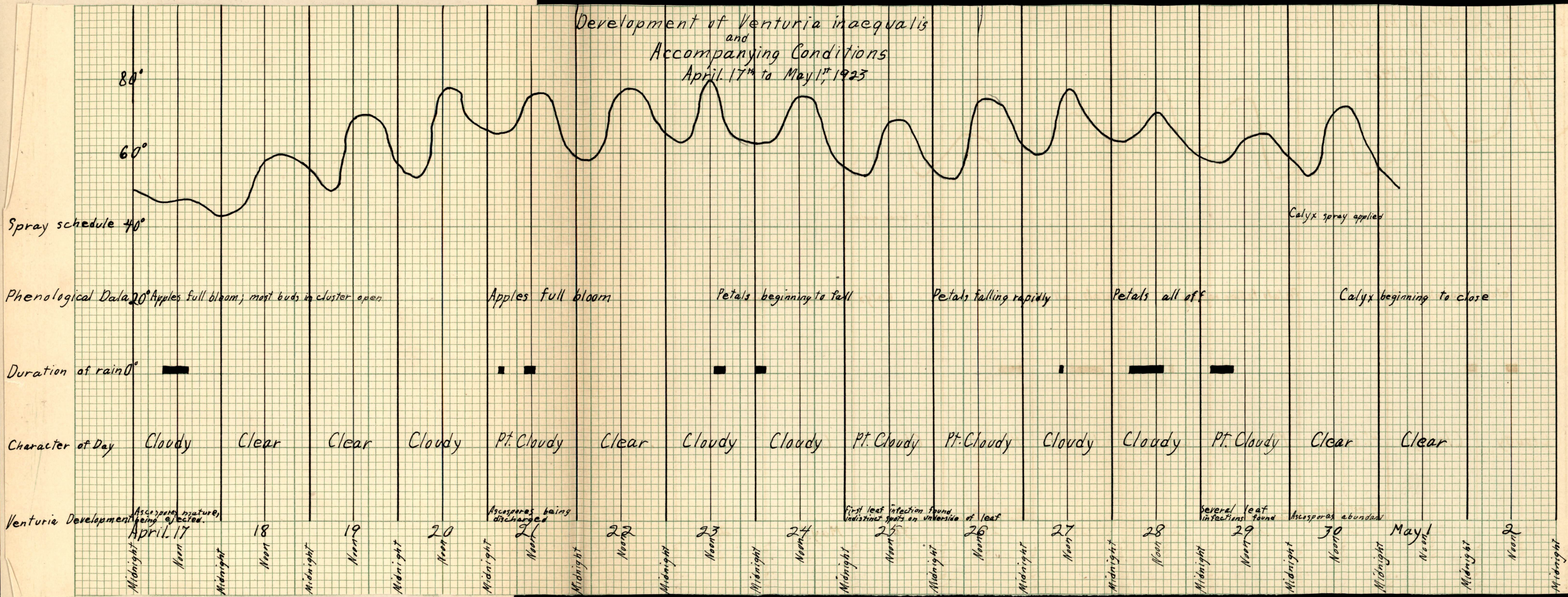
Applied pink spray

Center bud showing pink

Individual buds separating

Buds opening; Center bud open

Development of Venturia inaequalis and Accompanying Conditions April 17th to May 1st, 1923



Spraying data: At the first of May no observations could be made as to the relative value of the different applications for the control of this pathogene. Observations will be continued throughout the summer in order to gather data on this subject. A decidedly more complete covering of the leaves was obtained on the trees where Kayso was included in the spray material. There was a considerable more uniform covering of the leaf surface where Kayso was used; in fact this was so evident that the trees which had not received Kayso could be distinguished at a considerable distance.

Correlation of data: When the data as a whole for 1923 are considered, the most important observation is that the rate of development of the pathogene and the trees seems equally slow. It appears evident that the conditions which retard the development of one, exert a similar influence on the other. Charts No. 8, 9, and 10 show that the first perithecia were found about the time the apple buds were beginning to swell. When the apple buds began to show a pink color the asci were formed, but were not entirely mature. By the time most of the apple blossoms were open the ascospores were mature and a rain which occurred on April 17th made possible the lib-

eration of these ascospores. There were abundant ascospores and conditions were favorable for inoculation during a part of the period of full bloom. Since the first ascospores were liberated there has been some rain on seven days and there has been renewed discharge during and immediately following each of these rains. At the first of May there are abundant ascospores so that the period of spore discharge has not ended. The first leaf infection was found on April 25th when the petals were falling rapidly.

Comparison of data from 1922 and 1923

A comparison of the charts and tables which have been presented shows some very pronounced differences and some marked similarities between the data of 1922 and 1923. More extreme fluctuations in temperature during the late winter and spring of 1923 are very noticeable. The spring of 1923 was considerably colder than that of 1922. After the middle of March 1922 the temperature did not drop to the freezing point while in

1923 there were five nights after that date when the mercury registered below the freezing point. The precipitation during the first half of 1922 and 1923 is not decidedly different. There was an excess of rain during both seasons.

An examination of the phenological data for these two years is very interesting. The first swelling of the apple buds was noticed about the same time each year, but the development was very much more rapid in 1922 than in 1923. Even though the apple buds began to swell about the same time both years, in 1922 they showed pink eleven days earlier, they were in full bloon 13 days earlier, and the calyx was closed 16 days earlier than in 1923. During the season of 1922 there were only 20 days from the time the buds showed pink until the calyx was closed while during 1923 this development occupied 28 days. The calyx was closed in 1922 at approximately the same date that the apples were coming into full bloom in 1923.

A further examination of the data which have been presented shows that the rate of development of the pathogene corresponds very closely to the rate of development of the trees. The difference in development of the fungus during 1922 and 1923 was equally as marked as was

the difference in blooming season of the apples during those years. The first perithecia were found five days earlier in 1923 than in 1922, but the asci were apparently mature 9 days later in 1923, and the ascospores matured 17 days later. In 1922 there were only 11 days from the time the first perithecia were found until the ascospores were liberated, while in 1923 the same development required 28 days. It is evident from these data that weather conditions affect the fungus and the trees in a similar manner.

Application of data to Control: The application of a fungicide for the protection of apples against this fungus is a well established practice. Spraying is a protective measure rather than a cure, and it is therefore necessary for the fungicide to be applied before the inoculum reaches the infection-court which has been used most extensively includes the following applications:- (1) A pink spray which is ordinarily applied when the buds begin to show a decided pink color and the individual buds in a cluster are separating. (2) The second, or calyx, spray is applied at petal-fall before the calyxes have closed. (3) A third application is made about two weeks later, and additional sprays which may be necessary for

the control of other diseases are usually of some value in scab control. An extra application at the beginning of the season just before the buds begin to show pink is being considered by many growers. Such an early application is intended to make sure that the infection courts are covered with a fungicide before the inoculation. It is usually known as a pre-pink spray.

According to the data which have been presented for the season of 1922 a pre-pink application is not necessary provided the pink spray is applied during the very limited time available. The ascospores were not liberated until after the time for the pink spray but they were apparently mature just as the buds were opening and therefore if rain had occurred at that time, April 1st, an ascospore discharge would have occurred. Had these conditions existed the pink spray should have been completed before April 1st. As conditions did exist there were only five days available for the application of the pink spray and there was some rain on two of these days. In order to have been safe in 1922, the pink spray should have been completed before March 31st, because there was rain nearly all of that day and the spores were ready to be discharged by the following day. In order to have completed the spray by that time it would have been necessary

to start before the buds showed a decided pink. In other words, under the conditions of 1922, the first application for scab should have begun during the pre-pink stage unless the orchard could be covered in two or three days.

Charts 4 and 5 show that during 1922 there were ten days during which the calyx spray could be applied. Rain would have interfered with the spraying on three half days of this time so that there were only eight and one-half days available for the work. With sufficient spray equipment to apply the pink and calyx sprays at the proper time the later applications could have been completed according to schedule.

The unusually late spring in 1923 and the slow development of both the apple trees and the fungus gave more ample time for the application of the important sprays. There were ten days after the buds began to show pink before the blossoms were too far advanced for the pink spray. Rain interfered with the spraying on four half days of this time, but there were eight days during which the pink application could have been made. The ascospores were not mature until most of the apple buds were open and therefore during the spring of 1923 a pre-pink application was not necessary. At that sea-

son of the year the young leaves are enlarging so rapidly that the fungicide should be applied very shortly before the spores are liberated in order to protect the tender growth. For that reason a pre-pink spray should not be substituted for the pink application under conditions such as existed in 1923.

Charts 9 and 10 show that in 1923 there were seven days during which the calyx spray could have been applied. The petals were falling rapidly on April 26th and the calyxes were not closed until May 4th, but during this time enough rain occurred on two days to interfere with the work. The warm weather during the last half of April in 1923 hastened the development of the apple blossoms so that there was about the same time for the calyx spray as was available in 1922.

Review of literature: Investigations similar to the one here have been conducted in several other states and it is desirable to review briefly the data from these sources.

New York: Excellent work was done on this subject at Cornell University by Errett Wallace during 1909, 1910, 1911 and is reported in Bulletin 335 of the Cornell Agricultural Experiment Station. In this investigation the perithecia were found to begin to develop during the fall

and winter. The immature perithecia, containing only a mass of protoplasm, were found on February 26, 1909. The perithecia were found most abundantly on the upper surface of the leaves as they lay on the ground. The ascospores matured about the time that the apple blossoms were ready to open. In 1908 the mature spores were found on May 4th, and in 1910 on May 1st, but the apple blossoms were in about the same condition each year. The liberation of the ascospores continued for about one month after it was first observed. Artificial inoculations preformed by Wallace showed the incubation period of this fungus to vary from eight to fifteen days. The first infections on the leaves in the spring could be traced to some period of rain which made the discharge of ascospores possible and he concluded that the ascospores constituted the chief spring inoculum. The blossom buds usually open slightly before the leaf buds and are therefore more exposed to this early inoculation. A serious outbreak of scab is not dependent on a heavy ascospore primary infection because of the abundance of conidia which may be formed from primary infections. As a result of this investigation, Wallace concluded that the first spray for scab should be applied just before

the blossoms open and that an application after the blossoms fall is necessary in order to protect the trees from later attacks. The grower should watch the weather as well as the conditions of the fruit buds and attempt to get the spray on before a rainy spell. Wallace concludes from his work that a dormant spray is of no value for scab control and that spraying the fallen leaves is not successful because neither application can prevent early infections. The spray schedule as recommended by the Cornell Experiment Station includes the pink, calyx and two weeks sprays for the control of scab.

Oregon: Investigations for the control of apple scab were conducted at Hood River, Oregon during 1914, 1915 and 1916. The results of this work are reported by Childs in Bulletin 143, of the Oregon Agricultural Experiment Station. The work during the first two years indicated that only very poor control of apple scab might be obtained when the spray schedule was begun at the time the buds were showing pink. During 1916 studies were made of the life history of the pathogene, Venturia inaequalis (Cooke) Winter. Childs found numerous immature perithecia in all of the orchards which were examined on February 20th, 1916. A microscopic examination of the perithecia showed that the asci had not yet formed. They first became distinguishable on March 7th. The

first ascospore discharge was observed on March 20th, and the last discharge was observed on June 27th, or more than three months later. During this period there were five distinct periods of spore ejection during which the conditions were favorable for general infection. At the time of the first spore discharge the trees were largely dormant and therefore no infection resulted. The second period of ejection began April 10th and at that time the buds were not far enough advanced for the pink spray, but the leaves were large enough for severe infection to occur. The heaviest spore ejection occurred during the first three or four days of a wet spell; gradually this discharge became less towards the end of the rain. Scab infections were first observed on unsprayed trees on May 8th, which lesions probably resulted from inoculations between April 10th and 21st. From his work, Childs concludes that the period of ascospore discharge begins much earlier than had been previously reported and continues for a longer time. His results show clearly that a delayed dormant application is necessary to prevent the early infections, but that none of the later sprays can be safely omitted because of the continued ascospore discharge.

Virginia: During the season of 1922 important experiments were conducted in Virginia on the control of apple scab. The results of these experiments are presented by F. J. Schneiderhan in the proceedings of the Twenty-seventh Annual Meeting of the Virginia State Horticultural Society. This work indicates very clearly that a complete spray schedule is necessary and it emphasizes the importance of thoroughness in all disease control work. Schneiderhan concludes from acutal counts that the relative value of the different sprays for scab control is: - delayed dormant spray 3 per cent, the pink spray 41 per cent, the calyx spray 33 per cent, and the two weeks spray 12 per cent.

Michigan: During the spring of 1922 observations were taken at the Michigan Agricultural Experiment Station on the development of the fungus. The results of these observations were reported by C. W. Bennett in the Quarterly Bulletin, Volume 5 No. 3 of the Experiment Station. These observations showed that the ascospores were mature by April 17th when the apple buds had hardly begun to show green. The first spores were duscharged before the buds were ready for the usual pink spray and in many orchards early infections appeared which were not cared for in a spray schedule beginning with the pink

spray. As a result of this work the Michigan station is recommending a pre-pink spray in addition to the regular schedule.

Illinois: "Discharge of ascospores was noticed on April 20th, but infection on the leaves did not show up until May 14th. The long period of incubation was probably due to the unusually cold weather which prevailed the later part of April and the first week in May, during which time the temperature was always below 65 degrees and was usually below 60 degrees. Discharge was especially vigorous during the middle of May when heavy rains occurred. This resulted in a serious fruit infection in many orchards" (Anderson, H. W. In The Plant Disease Bulletin, Supplement 14, 1921). The above observations referred to the development of the fungus during the spring of 1920. In a recent letter (April 12, 1923) from Dr. Anderson on this subject, he says, in part, "A few ascospores were beginning to form at Urbana on March 24th and a great many were matured by the first of April, yet up to this time there had not been even a swelling of the buds of the apple. Every rain now brings a discharge of the ascospores and yet the buds are just beginning to swell at this date (April 12, 1923)"

Conclusions

It is very evident from the data which are presented in this paper that continued investigations are greatly needed in this state. Especial attention should be given to the time of the first ascospore discharge. Perhaps the microscopic examination of infected leaves should begin earlier in the winter in order to follow more accurately the early development of the perithecia. No explanation is offered as to why in the northern United States an earlier ascospore discharge than is reported in this paper for Tennessee should be found.

The data which are included in this paper indicate very clearly that the weather conditions exert a predominant effect on the development of both the apple blossoms and the fungus. It seems, from the information which is available, that the conditions which are favorable for the rapid development of the one are equally favorable for the other. For this reason it is probable that the maturity of the ascospores will occur each year at about the same stage in the development of the apple blossoms. This was true in the two years which are covered in this investigation.

The precipitation during 1922 and 1923 was very nearly equal and very similarly distributed. The spring of 1923 was much colder than that of 1922 as has been pointed out previously in this paper. These observations, together with the fact that the development of the apple blossoms and the fungus was much slower in 1923, indicate that temperature exerted most influence on their rate of development. The fact that the periods of ascospore discharge correspond exactly with the periods of rainfall which occurred after the spores were mature, indicates that moisture very largely governs the liberation of spores after the perithecia are mature. In other words, temperature affects the rate of development of the fungus but precipitation (duration rather than amount) affects the discharge of the spores from the mature perithecia.

It appears that conidia do not live over winter and that the scab lesions on the twigs do not occur commonly in Tennessee. Therefore ascospores are the important inocula for the first spring infections in this state.

It is vital for the control of scab that a spray be applied just before the first ascospores are discharged in the spring. Both a pre-pink and an pink application seem unnecessary; but if there is danger that the pink

spray may not be completed before the petals begin to open, it is advisable to begin the spray during the pre-pink stage. During early, warm springs there is considerable danger that the apple buds may develop so rapidly as to make the pink spray impracticable and under such conditions the work should be begun before the buds show pink.

P*D.

APPLE SCAB

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