# CONNECTICUT
# AGRICULTURAL EXPERIMENT STATION

**NEW HAVEN, CONN.**

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**BULLETIN NO. 2 OF THE TOBACCO SUB-STATION**

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The Connecticut Agricultural Station,
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The Connecticut Valley Tobacco Improvement Association,
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# Wildfire of Tobacco
# in
# 1922

**January, 1923**

Notice to Growers:

If you wish to receive further bulletins regarding tobacco, please send your correct address to the Station at New Haven or to the Association.

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# Wildfire of Tobacco in 1922*


By G. H. CHAPMAN and P. J. ANDERSON.[1]


## INTRODUCTION.

Wildfire is the most serious disease with which the tobacco growers of the Connecticut Valley have ever been confronted. It appeared first in Connecticut in 1919 and was found in three places in Massachusetts in 1920, but its destructiveness was first fully demonstrated during the season of 1921, when the study of this disease was actively undertaken in both states. Owing to its alarming spread in the seed-beds during April and May of that year the writers began a special investigation with the primary object of finding some method or methods of preventing its ravages. A preliminary report of the work was published in September, 1921, as Bulletin 203 of the Massachusetts Agricultural Experiment Station and a detailed study, "Wildfire of Tobacco in Connecticut" (Clinton and McCormick) was issued as Bulletin 239 of the Connecticut Station in May, 1922. Chapman, subsequent to that time, has been located in Windsor at the new Connecticut Tobacco sub-station, but since the wildfire problem is not divided by state lines, the work has been continued in co-operation between the two stations. The most important results of the experiments and observations of the last year are presented in this second bulletin. A number of important publications from other workers along the same line have appeared during the year. These are freely quoted and referred to here in order that the grower may have the advantage of all that has been learned concerning this problem. Just as in 1921, so in 1922, most attention has been given to developing methods of control, and although such methods have not been perfected as yet, nevertheless some improvements have been made, and by means of another season of work we have been able to confirm more fully certain controls which were recommended last year, while others have been found to be of less importance. Some further studies have been made in regard to the life history of the causal organism, especially with reference to overwintering and dissemination.

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*A report of co-operative work carried on at the Tobacco Sub-Station of the Connecticut Agricultural Experiment Station and at the Massachusetts Agricultural Experiment Station. Published with a different introduction as Bulletin 213 of the latter Station.

(1) Dr. Anderson is on the staff of the Mass. Station.

## SYMPTOMS OF WILDFIRE.

Wildfire spots may occur on any part of the plant above ground, but are most abundant and damaging on the leaves. New spots may appear at any stage of development from the emergence of the first leaves in the seed-bed until the plant is harvested. After the plant is cut, however, and during all subsequent operations, no new spots appear and the old ones do not spread. The reader who is not familiar with the disease will learn the symptoms quickly by examining the colored figures on Plate I. In figures 1 and 2 small greenish-yellow spots may be found which show no dead brown tissue at the center. These are the youngest spots,—probably 4 days old. In the same figures may be found other spots, a little older, each of which contains a brown dead area of pinhead size at the center, surrounded by a broad chlorotic band or halo. This broad greenish-yellow halo of definite shape and delimitation is the most reliable character for the diagnosis of wildfire. Spots produced by other diseases may—and usually do—have a certain amount of yellow tissue about them, but it is narrower or of irregular shape or fades away indefinitely into the green of the surrounding leaf. As the wildfire spot becomes mature, however, the central dead brown part becomes larger by the dying of more of the surrounding halo and, especially if the weather is dry, a stage may be reached when there is very little halo left. Such a stage is represented in figure 3 and may be certainly diagnosed as wildfire only by examination of occasional younger spots where the halo is still evident. Figure 2 shows a leaf suffering from the results of two different infection periods, the first one evidenced by large brown dead areas which have been produced by enlargement of the original dead centers or partly by dying of the intervening tissues, the second infection represented by younger spots with broad halos and little or no dead centers. In advanced stages, the dead part of the leaf may become torn or cracked, or parts of it may fall out. Such a stage is represented in figure 4. Severely affected leaves may die, but most of them remain partly alive. When the leaf is cured the spots do not assume the reddish brown color of the healthy leaf, but they become straw-colored or paler to almost white. Consequently they are very noticeable. They are stiff and brittle and easily break, leaving holes in the leaf. Naturally such leaves cannot be used for wrappers and must sell at a lower figure if they can be sold at all.

In the seed-bed the plants in certain definite round areas are usually found to be infected first. Here the seedlings are close-planted with overlapping leaves and the disease spreads rapidly from plant to plant. If the air is very humid, the badly affected leaves in these areas undergo a wet rot and the whole diseased area may become a slimy mass, most of the plants being killed. This wet rot is not confined to the seed-beds. The writers have seen it in the field under very moist conditions, but the seed-bed conditions are most favorable for it. It has not been demonstrated that this wet rot is caused by the wildfire organisms alone. Leaves attacked while they are rapidly expanding become puckered and drawn about the spots. The entire leaf may become distorted and twisted.

## CAUSAL ORGANISM.

Wildfire is produced by the parasitic growth of enormous numbers of bacteria (*Bacterium tabacum* Wolf and Foster) in the leaves. Since various investigators who have published concerning the organism do not agree as to some of the morphological characters, Anderson during the past season has made and studied permanent slides on which the bacteria have been stained by (1) the Duckwell modification of the Pitfield method, (2) the Shunk method* and (3) to a less extent by other methods. The organisms are short cylindrical rods with rounded ends and usually straight sides, but not infrequently individuals will be found which are slightly curved or somewhat dumb-bell shaped. Frequently two or three of them remain end to end in a chain on the slide. Those in chains are shorter, indicating immaturity. Only those which were free from each other were used in measuring. An average size of fifty taken from five slides stained in different ways was 2.3 x .8u. The longest one measured was 3.8u and the shortest 1.4u. Attached to one end there are 1-4 flagella several times as long as the body of the bacterium.



## PREVALENCE AND SPREAD OF THE DISEASE DURING 1922 IN CONNECTICUT.

The first wildfire infection in the seed-beds was found May 7. This date is a little later than that of the first reported infection last year. From May 7 until June 20 many reports of infected seedlings were received, particularly from the Broadleaf section where compartively few infections had been noted in 1921. One hundred and fifty-six seed beds, in which trouble was reported, were examined and in all but eight of these wildfire was found. By June 10 approximately 30 per cent. of the seed-beds showed wildfire. In some instances the infection was very slight and local, in others the entire bed was practically destroyed. During the middle seed-bed period, rain and weather conditions were extremely favorable for wildfire development. It was difficult to air the beds sufficiently to maintain a low humidity under the sash. These factors also to some extent reacted against the application of sprays or dusts as preventive measures. The weather during the latter part of the seed-bed period was unfavorable for the development and spread of wildfire, and such seed-beds as had escaped infection earlier remained free in most instances.

Field infection was quite prevalent shortly after the setting of plants, particularly in cases where plants from slightly infected seedbeds had been used. It was noted that the Broadleaf section developed a much more general field infection than was the case in 1921.

The localities which were most heavily infected last year, however, either due to more careful application of preventive measures or for some other reason, did not show as heavy a general infection as in 1921. Early in July infection spread rapidly, but later in the month when dry warm weather was the rule, the spread of the disease was extremely slow and could scarcely be noted. As in 1921, when the plants matured (and this was true of Havana as well as of Broadleaf) after topping, the infection spread very

*Journ. Bact. 5:181. 1920.

rapidly, and in some instances, particularly in fields which showed a remarkably healthy vigorous growth, it spread to the top of the plant in a very few days. Many of the growers who had a slight *foot-leaf* infection at the time of topping profited by their experience of last year and did not wait for the tobacco to ripen, but cut it "on the green side" and in this way reduced appreciably the damage from wildfire.

On the whole, observations through the state lead to the conclusion that field wildfire infection was much more general than in 1921, but the per cent. of infected fields showing a heavy loss was smaller than in the previous season.

### IN MASSACHUSETTS.

During the early seed-bed period no wildfire was found in this state, although considerable time was spent in visiting the beds of the growers. Since the disease had been found earlier in 1921 it was hoped that we would escape an outbreak this year, but on May 25 a diseased bed was found in Hadley and within the next week it was found in 20 other beds in Hampshire and Franklin Counties. Throughout June and early July continuous and almost unprecedented rains furnished ideal conditions for spread of the disease, and it not only became widespread in the beds, but was found to be prevalent in the fields almost as soon as they were set. The weather almost prevented effective control measures. On July 4 it was estimated that more than 50 per cent. of the fields had more or less wildfire in them and many of them were very seriously affected. The situation looked decidedly worse than last year. The growers were discouraged both by the prevalence of the disease and the poor growing condition of the crop and some of them plowed up their fields. After the first week in July, however, the weather cleared, there were no more long rains and such rains as occurred were followed by hot clear weather. For the next three or four weeks wildfire spread hardly at all and the tobacco grew rapidly, covering the diseased leaves with healthy ones, and many growers felt that the disease had disappeared. Rain storms (frequently and locally accompanied by hail) became more frequent and continued from about the 27th of July, and another outbreak occurred which continued with some slight interruptions throughout August until the crop was harvested. It is probably no exaggeration to say that there was some wildfire in 90 per cent. of the fields. Some were so badly affected that not one disease-free plant could be found in the field. In other fields the infection was so light that the market value was probably not affected at all. Many fields were harvested before mature, with the idea of saving the crop before wildfire became too serious. That there has been a considerable spread of the disease since last year is indicated by the fact that it has now been found in every tobacco-growing town in the state.



### Outside the Connecticut Valley.

During the summer one of the writers had occasion to visit the tobacco regions of New Hampshire and Vermont, where conditions were found to be very similar to those which prevailed in Massachusetts. A serious outbreak occurred in Wisconsin (Pl. Dis. Bul. 6: 40, 139) from which state the disease had not been reported previously. It was also reported for the first time from New York and Georgia (Pl. Dis. Bul. 6: 62, 63). It occurred with more or less severity in Pennsylvania, Maryland, Kentucky (Pl. Dis. Bul. 6: 21) and Ohio. It is rather surprising to find that in North Carolina and Virginia, in which states the disease was first found and where it was very destructive five years ago, there has been no damage from wildfire during 1922. Under date of August 19, Dr. F. D. Fromme, plant pathologist of the Virginia Agricultural Experiment Station, wrote "We have yet to see a case of wildfire in the 1922 crop in Virginia. We have inspected well over 100 fields in counties where it has occurred in the past year. Plant beds were equally free from it this year." Under date of August 21, Dr. F. A. Wolf, plant pathologist of the North Carolina Agricultural Experiment Station, wrote, "I have not received this season a single authentic specimen of tobacco wildfire from this state."

Previous to this year wildfire was not known to occur outside the United States. It has now been reported from South Africa. (2: 366-368)*

## LIFE HISTORY STUDIES.

### Overwintering of the Bacteria.

As a basis for control measures, probably no problem in regard to life history of the causal organism is more important than determination of the method or methods by which the bacteria survive the winter and thus serve as starting points for wildfire of the next year. Certain experiments with the object of solving this problem were conducted during the winter of 1921-22, and though some of the results are not conclusive, progress to date

*The first number in the parenthesis refers to the bibliography on p. 38 of this bulletin, and the numbers after the colon refer to pages of these publications.

will be reported at this time. Other experiments with the same object are now in progress and it is hoped that they will be more satisfactory.

*Effect of freezing the bacteria.* In studying the problem of overwintering, the first point which must be determined is the effect which freezing has on the organisms. If they are not able to withstand the exposure of a New England winter, then the measures of control will be quite different from those which should be tried if they are resistant to cold. Pure cultures of *B. tabacum* on agar were placed out-of-doors at various times during the winter of 1921-22, some of them being frozen solid for months, but in every case when they were brought back into the laboratory and transferred to other media they grew normally. The result was about what one would expect when it is remembered that few species of bacteria are killed by freezing. It is certain from data presented below that freezing does not kill them while in the leaf in the tobacco barn.

*On the seed.* It has been suspected by most workers who have investigated this disease that the bacteria may survive the winter on or with the seed and that early infections in sterilized beds start from the seed. Although this would seem possible, there is as yet no experimental evidence to prove that such is the case in the Connecticut Valley. In Virginia, Fromme and Wingard (3) find conclusive evidence that the organism of blackfire (*Bacterium angulatum*) overwinters in this way. Their evidence for the wildfire organism, however, is not so convincing. A number of experiments were undertaken by the writers for the purpose of determining the possibility of overwintering in the seed. In the interest of brevity these experiments need not be given in detail, but the results may be summarized:

(1) All attempts to islolate the organism directly from suspected seed have failed. (2) Suspected seed has been planted and no wildfire has appeared on the seedlings where other sources of infection have been eliminated. (3) Seed inoculated by soaking in a pure culture of the bacteria and kept in a dry room all winter produced only clean plants in the spring. (4) In another experiment seed was artificially inoculated after it had been sterilized and killed by heat. The seed remained wet from the culture for two weeks. In the spring it was sprinkled on healthy leaves and wildfire resulted, but the conditions are not the same as where seed are kept in a dry room. All the evidence in these experiments was negative and has only the weight of such. The possibility is not precluded that there may be conditions under which the bacteria may winter directly on the seed coat.



There is no evidence that in nature a lesion may come into direct contact with the seed. No one has ever reported seeing a lesion on the seed. It is a well known fact, however, that lesions do occur on the calyx of the flower and on the seed pod. During 1921 in Connecticut, and during the late summer of 1922 in Massachusetts, pod lesions were found on plants being kept for seed. Similar lesions were also produced by artificial inoculation. In threshing out the seed, small broken bits of the pods remain with the seed as chaff and no amount of sifting and cleaning will remove every particle of chaff. If the bacteria overwinter in the seed, it is probably not directly on the seed, but in these fragments of pods, etc., which are with the seed. Since it is known that they survive the winter in leaf lesions, there could hardly be any doubt that they could live over in similar lesions on the pods. Fromme and Wingard (3: 20) present experimental evidence showing that the percentage of wildfire is increased by top-dressing the seed-bed with chaff from infected pods of the previous year. It seems improbable, however, that any considerable proportion of the spring infection in the Connecticut Valley beds starts from the seed, because: (1) Growers now know the disease well enough so that few of them would save seed from infected plants; (2) Many of the growers during the last season used old seed (grown previous to 1920), and yet they did not escape infection; (3) Those who sterilized the seed were apparently no more successful in eliminating the disease from the beds than those who did not*; (4) Even those who advocate most strongly the sterilization of seed do not present convincing data to prove that the disease organism is carried on the seed.

*In the soil.* From the plant, the bacteria may get into the soil in two ways: (1) they may be washed from the plant by the rain during the growing season, and (2) when the leaves or other infected parts are turned into the soil or left to rot on the soil the bacteria probably remain alive for a long time. It is important that we should know how long they remain alive there and capable of infection and whether they may survive the winter in this habitat.

During some control experiments in Whately, it was observed that even when all diseased leaves were removed from the plants, others became infected after rains and almost always on the tips where were beaten down into the soil. It appeared as though the bacteria had been washed from the diseased leaves into the soil and splashed from the soil to the other leaves.

*Records were kept on the beds of 11 growers in Massachusetts who treated their seed with mercuric chloride. Wildfire afterward appeared in 5, while the other 6 had no wildfire in the beds.

In two fields in Hadley and North Hadley which were under constant observation by one of the writers during 1922 the plants became so badly diseased during June that all were pulled and carted from the fields. Both fields were set later with healthy plants, but in both cases there was a very heavy reinfection before the new plants were half grown. The second infection must have come by way of the soil.

Clinton and McCormick (2:404) buried wildfire leaves under healthy plants, and by this means the infection was increased to 63 per cent. as compared with 13 per cent. on adjacent plants not so treated.

The above data furnish very strong evidence that the pathogene may be carried from one plant to another or from one crop to another by means of the soil. The failure to get infection in some of the experiments by planting in infected soil shows, however, that infection will not always result necessarily because the soil was infected.

None of the experiments just quoted furnish evidence of the length of time during which the bacteria may remain alive in the soil or indicate whether they will live through the winter in this habitat. The following experiments and observations throw some light on the latter point:

Experiment 1. In order to see whether the organisms could be carried from one crop to the next through the medium of naturally infected soil, such soil was taken from three beds of diseased plants at different times during the summer of 1921 and seeded with sterilized seed. The plants grown in the soil did not become infected. On the other hand in one of the greenhouse beds which had grown a number of diseased crops, sterile seed was planted in the spring of 1922 and the seedlings became diseased before the plants were an inch high.

Experiment 2. In this experiment one pot of soil was inoculated by spraying a suspension of bacteria over it, while another pot had an equal amount of water sprayed on it. Both were seeded shortly after sprinkling and wildfire developed in the inoculated plot but not in the check.

Experiment 3. On July 1, 1921, Erlenmeyer flasks of soil were sterilized and later inoculated with the bacteria. Part were plugged only with cotton, others were paraffined to prevent drying out. At various times during the winter, soil was taken from these flasks and plated out. Then when bacteria developed about the particles of earth they were shaken in a suspension of water and atomized on healthy plants. The flasks which did not have paraffined plugs became very dry, while the others remained muddy. Heavy infection resulted when inoculations were made, March 10, and others on March 20, 1922, from the dry flasks but none from the tightly closed wet flasks. These flasks were kept in the laboratory and were not frozen. In this case the bacteria were still able to produce infection after 8 months.

In two instances in Connecticut, wildfire was found starting in the edge of the beds in soil which had been outside the pans when the remainder of the beds were steamed. In both cases wildfire was present in the beds in 1921. The fact that the planks were new and the sash had been sterilized with formaldehyde eliminated these as the source of infection.



In a number of cases, in both states, it was found that those parts of the field which were diseased in 1921 showed the heaviest infection in 1922.

On the other hand, fields have been observed which were badly diseased in 1921 and on which the tobacco was free from wildfire in 1922.

On one of the fields at the Connecticut Experiment Station the 1921 crop, which was badly infected with wildfire, was cut late in September and left lying on the ground over winter with a view to getting data on the overwintering under natural conditions. In this case both leaves and stalks were left to weather. In 1922 this field was planted with Havana and Broadleaf wildfire-free seedlings, the stalks and leaves of the 1921 crop having been disked and plowed under two weeks prior to setting. Throughout the season close examinations were made by Slagg and Chapman for wildfire in this field. Wildfire was not found on this particular field during the growing season, but at harvest an occasional infected plant was found, yet nothing to what should have developed if any considerable amount of direct infection occurred as a result of the refuse being left on the field. A careful estimate of the wildfire plants on this plot made at harvesting time showed that plants infected were not more than one-half of one per cent. of the total number, and on all of these the infection was light. This slight infection may have come from plants in the wildfire experimental field, since all the station plots—except for the experimental field—showed about this same percentage of infection late in the season.

Clinton and McCormick (2: 376,419) succeeded in one experiment in infecting tobacco plants in the greenhouse by direct application of wintered-over soil which had been exposed to infection the previous year. Wolf and Moss (4: 30) in North Carolina, and Fromme and Wingard (3: 24) in Virginia present considerable evidence that in the South the organism winters in the soil, but we cannot accept this as conclusive proof of the same condition in New England.

Altogether the weight of laboratory data and field observations indicates that *B. tabacum* is able in some cases to survive the winter in the soil and start new infection from this source in the spring. On the other hand, it is apparently possible under some conditions to raise a clean crop of tobacco on a field that had borne diseased crops during preceding years. The evidence as to soil wintering is, however, not so convincing as it should be and further experiments are now under way which it is hoped will remedy the deficiency.

*In Cured Leaves.* That the bacteria do not die when the diseased leaves are cured in the tobacco barn has been demonstrated in a number of our experiments.

Experiment 4. On March 5, 1922, diseased cured leaves were taken from the Hampshire County warehouse just before they were ready to go into the case. They had been in the tobacco barn under normal conditions all winter. They were ground to a powder in a mortar and the powder sprinkled on wet plants in the greenhouse. After two weeks the plants developed typical lesions of wildfire. Other leaves were ground and the experiment repeated with the same result on March 28. On March 8, some diseased leaves were received from M. H. C. Wells in Deerfield. Some of them were ground and used for inoculation just as the above. Dilution plates were made from the others and the organism thus isolated used for making inoculations. Wildfire developed on the plants inoculated in both ways.

Experiment 5. At Windsor, several times during the winter, wildfire spots from leaves kept in the station shed were brought to the laboratory and the wildfire organism isolated in pure culture. Cultures of wildfire bacteria were obtained from these leaves until the middle of March in this way, and no doubt living bacteria could have been found later than this.

These experiments were conclusive and there can now be no doubt that the wildfire organism can overwinter in cured leaves. It might get back from the cured leaves to the next year's crop in any one of a number of ways: (1) Refuse containing lesions from the shed may be thrown back to the land. (2) Sash and plank are sometimes stored in the tobacco sheds. Bits of broken diseased leaves could easily be carried out on such sash and plank and serve to start infection in the seed-bed. (3) While drawing the tobacco to the warehouse across or near the fields, parts of the diseased leaves might be scattered on the land.

Clinton and McCormick (2: 417) isolated *B. tabacum* from tobacco leaves which had been dried and kept in the herbarium for periods ranging from 198 to 298 days. They were unable, however, to secure the bacteria from other leaves which had been kept for two years.

*In leaves which have been left in the field.* Sometimes leaves when too badly diseased are picked ff and thrown on the ground. At other times the whole diseased plant may be left. The suckers which grow from the old stubs after a diseased crop has been cut are usually infected. These are left on the field all winter. If the bacteria live over in these parts, they might easily start infection the following year. Being subjected to more frequent freezing and thawing and other changes of weather, it is possible that they might not survive in these leaves as they do in cured leaves in the tobacco sheds. We have very little data bearing on this point.



Experiment 6. On April 24, 1922, diseased leaves were collected from plants at Windsor, which had been cut down in the fall and left in the field all winter. These leaves were ground to a powder in a mortar, some of the powder immediately applied to punctured leaves in the greenhouse at Amherst, some of it soaked in water and the wet material applied after 24 hours to other plants. No infection resulted. Similar tests were made with the same material by Chapman and Slagg, but with negative results. This negative evidence should not be considered conclusive. Further experiments are in progress.

Clinton and McCormick (2: 376,419) succeeded in one case in infecting tobacco plants in the greenhouse with tobacco refuse which was wintered out-of-doors.

## Occurrence of Lesions on Stalks.

Wildfier lesions have been reported previously as occurring only on the leaves and occasionally on the pods. During the inspection of a field of tobacco at S. Amherst, some lesions were found on the stalks which were suspected of being wildfire. On further examination it was found that they were not uncommon, but that they were present on a large part of the stalks in this field. Probably they had escaped previous notice because they are inconspicuous and somewhat different in appearance from the lesions on the leaves. They are commonly ⅛-¼ inch in diameter, white or, at most, light brown and sunken. The halo is not distince on most of them, but can be seen about some. A number of them were brought to the laboratory and the typical bacteria isolated from them. Inoculation on leaves with these bacteria produced wildfire spots. In this same field and in various others examined through the summer, it was observed that lesions are common on the "ears" or clasping bases of the leaves. When tobacco is stripped, these bases remain mostly on the stalk. Clinton and McCormick (2: 416) inoculated stalks and produced elongated blackened lesions. The occurrence of lesions on stalks and attached leaf bases may be important in answering the question as to whether land may become infested by throwing tobacco stalks on it. Since the organism overwinters in the leaves, there is no reason why it should not also remain alive in the stalk.

## Occurrence of Lesions on Midribs.

In the process of "stemming" tobacco, the midribs are stripped from the leaf and are sold as fertilizer (incorrectly called tobacco stems). The question has frequently been raised as to whether the land may become infected by the use of "stems" from diseased tobacco. Observations as to the occurrence of lesions on midribs were made at various times in fields during the summer. Frequently lesions were found running along both sides and encroaching on the midrib and often extending directly across the midrib. When the leaf was stripped from the midrib, parts of the lesion remained with the "stem." *B. tabacum* was isolated directly from them. This does not prove that the disease may be carried back to the land by using stems, since it has still to be demonstrated that the bacteria can survive the sweating process, but there can be no doubt that they occur in the midribs and may survive the winter thus in the tobacco shed. Clinton and McCormick (2: 416) produced lesions similar to those described above by inoculating the midribs with pure cultures of the bacteria.

### Relation of Condition of Plant to Infection.

No set of experiments has been planned to determine the relation of the growth and vigor of the plant to susceptibility, but incidental to other experiments a number of observations have been made which indicate that a rapidly growing plant is much more susceptible than one which is growing slowly. During the fall of 1921 two beds were planted in the greenhouse at Amherst, one on very poor soil, one on soil rich in rotted compost. Both were inoculated at various times and the rapidly growing plants of the fertile bed became infected, but all inoculations failed in the other bed until late in the spring, when the plants suddenly began to grow rapidly. In the course of some experiments at the Massachusetts Station during the summer of 1922 numerous unsuccessful attempts were made to inoculate a bed of very slow-growing plants which had received no fertilizer. During the same time other rapidly growing beds in the greenhouse were very readily infected. These experiments are not accurate, but certainly give some strong indications. Also the fact that infection is difficult to secure during the winter months points to the same conclusion. The relation of fertilizers to infection can probably be interpreted by their influence in producing a rapid succulent growth or the reverse. Other investigators of the disease have made similar observations. Clinton and McCormick (2: 390) state that "the use of any fertilizer that favors rapid growth is more likely to help infection * * * than where the fertilization is such that slower or less satisfactory growth takes place." Fromme and Wingard (3: 27) express essentially the same opinion.

### Dissemination.

No experiments directly dealing with dissemination were undertaken during the season of 1922, but observations throughout the year confirm the conclusions of 1921 in most respects. There is one notable exception: The experiments and observations in 1921



led us to believe that all field infection originated from plants which were diseased when taken from the beds. The majority and the worst field infections which we have seen in 1922 did come from that source and could be traced without any question to the seed-bed. On the other hand, a number of cases have come to the writer's attention where the beds were free from disease, (if it is possible at all to tell when they are free) but disease developed in the fields set from these same beds. A few cases may be mentioned:

(1) Anderson inspected the beds of a certain Sunderland grower at intervals of three or four days throughout the season and is positive that they were free from disease. Yet parts of the fields set from these beds were very badly diseased. (2) Tobacco fields owned by a grower in S. Deerfield, but located near Brattleboro, Vt., became badly diseased and were visited by A. V. Osmun and Anderson in June. Most of these fields were set from beds near the fields, but some plants were brought from the beds in S. Deerfield. A most searching examination of the beds at both places failed to reveal a single diseased plant; (3) A field of tobacco on a farm in Whately was isolated from all other tobacco fields and surrounded on all sides by woods. Plants were taken from the *beds* on the same farm. During the spring these beds were repeatedly inspected by C. M. Slagg, a wildfire expert, but he failed to find any infection. Yet wildfire became fairly prevalent in the isolated field; (4) The seed-beds of a grower in North Hadley were frequently inspected by Anderson during the spring, and not a trace of wildfire could be found at any time. During August some diseased plants were found in the middle of his field; (5) Wildfire occurred in a field of the Massachusetts Experiment Station farm which was not being used for wildfire work, but not a trace of it had been seen in the beds at the experiment station where the plants were raised; (6) A certain Windsor grower kept his seed-beds covered at all times with copper lime dust, and frequent inspections by Chapman and Slagg showed no infection. He planted two fields about three miles apart from these beds. One of the fields developed a heavy infection during the growing season; on the other, only a trace of wildfire was found.

Many similar cases were reported to the writers by growers but were not checked up by their personal observations. But the evidence is conclusive that all field infection does not come from the seed-bed. We are now confronted with the problem of determining how such infections did start. Rain could not have brought them from other fields because they were too far removed. There is some probability that in the Sunderland field the bacteria were in the soil over winter, since the worst infection occurred in the same place as last year. In the other cases, however, either no tobacco had been planted during the previous year on these fields or no wildfire had been observed there during 1921. Apparently there is some long distance disseminator which we have not yet found. Those that suggest themselves are (1) workmen, (2) insects and (3) wind. Since many isolated infections were discovered within a week or two after the exceptional wind storm of June 12-13 it is possible that the organisms may have been spread with the dust and sand which was blown in great clouds over the valley at that time. It has been shown above in this report that dry infected soil dusted over healthy plants may produce infection.

All observations of the summer confirm our previous conclusion that the most important short distance disseminator of the disease in the field is the rain, especially when accompanied by wind. It should be noted here, however, that not every rain storm is followed by a new outbreak of wildfire. It was frequently remarked, especially during July, that heavy short rains quickly followed by drying weather resulted in very little spread of the disease. The ideal conditions for spread are (1) long continued rains, (2) rains followed by cloudy weather during which the leaves do not become dry, or (3) periods during which the rains follow each other closely. During June of 1922 we had a long continued combination of all three of the above conditions, which resulted in the worst spread of wildfire which we have ever seen.

## CONTROL MEASURES.

### Sterilization of Seed.

Seed sterilization has been recommended by the writers because it was thought possible that the bacteria might be carried on or with the seed. Fromme and Wingard (3: 20) of the Virginia Experiment Station, in fact, are of the opinion that a large part of the infection is started from the seed. Although there is no conclusive evidence in the Connecticut Valley or elsewhere that such is the case, nevertheless the practice was recommended as a precautionary measure. In 1921, formaldehyde was recommended as the disinfectant (1: 75), but in 1922, mercuric chloride (corrosive sublimate) was recommended because it was found to be just as efficient, and was less likely to cause injury to the seed. Therefore, the following directions for treating tobacco seed were sent out to tobacco growers before planting time:

"Purchase corrosive sublimate tablets at any drug store. Dissolve one tablet in a pint of water to make a 1-1000 solution. Use a glass jar. Place seed in a cheesecloth bag and soak in the solution for exactly fifteen minutes. Poke or stir occasionally with a stick to insure thorough wetting of all the seed. Remove bag of seed and wash thoroughly in water. Spread out seed in a warm room to dry. Store seed where it will not become contaminated. Germination of the seed will not be affected if directions are followed carefully."

Many of the growers in 1922 used the corrosive sublimate treatment for sterilizing their tobacco seed, and at the Windsor laboratory one hundred and twenty lots of seed were sterilized by this method, and the germination before and after sterilization was tested. In no instance in our laboratory tests was there any injury from such seed treatment.



Some of the growers, however, reported that they injured the seed by the corrosive sublimate treatment. Some said that germination was retarded; others that the percentage of germination was lowered; others said that the seed would not germinate at all. It was at first thought that the failure was due to faulty technique, but laboratory tests showed that even a treatment of thirty minutes was not harmful, and some of the growers omitted the washing of the seed after sterilizing without any bad effect. Some reported lack of germination in seed which was sterilized at the tobacco sub-station by Chapman. It was certain then that the injury could not be attributed to faulty technique in all cases. Inquiry among the growers as to the method by which they sprout the seed revealed one difference between their method and that used at the stations; viz., the custom which many growers have of cracking or sprouting the seed in moist cocoanut fibre or apple punk or between sods for a few days before planting. The seed is kept in a warm room of 70-90° F., and from time to time sufficient water is added to keep the fibre or other material slightly moist. It was thought that possibly the fibre might have something to do with the lack of germination, and some of the seed was taken to the laboratory for test, using both unsterilized and sterilized seed of different lots. It was found that the unsterilized seed sprouted in the fibre, and that the sterilized seed did not show any signs of sprouting even after ten days. Other growers brought in samples of seed which they themselves had sterilized and which had failed to sprout in fibre, and these lots were tested also. We tried varying the conditions under which the seed was kept during the sprouting period, and found that under the conditions ordinarily used, it was almost impossible to sprout the sterilized seed, although the same seed in Petri dishes would germinate satisfactorily. It was found finally that in order to germinate sterilized seed, whether in punk or fibre, the pans should be kept at a lower temperature, and also that the moisture content of fibre or punk must be considerably higher than usual. By close attention to these factors it was possible to sprout the different lots of sterilized seed in either punk or fibre almost as well as before sterilization.

Lack of germination of sterilized seed under usual conditions in punk or fibre appears to be due to the fact that the seed coat is hardened by the washing and drying, and there is a much slower softening of the seed coat than is the case with the unsterilized seed. This was tested in the following way:

Experiment 6. Of two lots of seed, one was sterilized for fifteen minutes with a solution of 1-1000 corrosive sublimate, and the other treated for fifteen minutes in pure water without any chemical added. Both lots were taken from the jars and washed and dried in the usual manner. It was found to our surprise that both lots reacted the same, i. e., when placed in punk or fibre under normal conditions the germination was greatly delayed or lacking. This experiment showed that lack of germination was not due to the corrosive sublimate treatment but to another cause, probably the hardening of the seed coat by the washing process or possibly by the rapid drying.

The age of the seed or storage conditions may possibly play a role also, as in many cases growers had no difficulty with their seed. A few cases were brought to our attention where the injury was undoubtedly due to incorrect procedure in the corrosive sublimate method.

Data collected from growers who sterilized their seed during 1922 are not conclusive as to the value of the treatment for preventing wildfire.

As a result of our experience this past year, we are of the opinon that in the Connecticut Valley seed is, at most, a minor source of infection. Nevertheless this is a possibility which should not be lightly overlooked, and growers should not save seed from plants which show wildfire infection. But if this is found necessary, we believe the seed should be treated with corrosive sublimate. To avoid the difficulties discussed above, the beds should be sown with the dry seed. We do not know how long the bacteria will remain on the seed, but it is unlikely that there would be any alive on seed two or three years old. By the use of old seed the chance of infection from this source would be eliminated.

### Sterilization of Soil in the Seed-bed.

Sterilization of the seed-bed soil with either steam or formaldehyde was recommended by the writers (1: 75) because it was thought possible that the organism could live from one season to the next in the soil. Considerable additional evidence that this is one of the ways in which it may pass the winter has been obtained during 1922, and presented in a previous part of this report. It is a common practice for growers to sterilize their beds to kill weed seeds, prevent root-rot and for other reasons, and many beds were sterilized before the 1922 seed was sowed, a few in the fall but the majority in the spring. Careful records were taken on fourteen beds in Massachusetts which had been sterilized this year. Wildfire occurred in seven of them, and the others remained free. No conclusion can be drawn from these data except that soil sterilization alone cannot be depended on to give a clean seed-bed. It is unquestionable that sterilization of soil by either steam or formaldehyde, if properly done, will kill all the wildfire bacteria in the soil treated, but it may not be so easy to eliminate the possibility of getting it contaminated again from infected soil in the walks, surrounding areas, tools, etc. These chances are perhaps greater where soil is sterilized in the autumn. Most growers use steam and consider it cheaper. If steam is used, it should be applied for thirty minutes at 100 pounds pressure. Those who do not have boilers which will produce so high a pressure may determine the proper length of exposure by burying a small potato four or five inches below the surface of the soil under the pan and applying the steam until it is cooked through. Only one of the fourteen mentioned above used formaldehyde. Formaldehyde at a dilution of 1-50 in water is applied at the rate of ½-¾ gallons to the square foot of surface. Some preferred to change the location of the beds rather than sterilize the soil. In Massachusetts, accurate records were kept on eight beds, the location of which had been changed to places where no tobacco was planted last year. Four of them had wildfire this year, four did not. The practice of sterilizing the beds should be continued not only to destroy wildfire bacteria but also to kill other disease organisms and weed seeds.



### Sterilization of Sash and Plank.

The writers (1: 76) in 1921, recommended that old sash and plank be drenched with a 1-50 formaldehyde solution, and this was practiced by a number of growers. Some painted the sash and used new plank.

Data as to the benefits from this practice during 1922 are not very conclusive because in most cases other sources of introduction were not eliminated, but in a few cases under the writers' constant observation clean plants were raised in 1922 under the same sash and with the same sideboards (after sterilizing both) which had been used for badly diseased beds in 1921. Danger of infection from contaminated sash is well illustrated by the following experience of a Connecticut grower: His seed-beds in 1921 were so heavily infected in June with wildfire that the plants were destroyed. The sideboards were destroyed, the beds plowed up and the sash stored over winter in a tobacco barn. The grower in 1922 decided to take no chance of a wildfire infection and contracted with a farmer who did not raise tobacco to grow sufficient plants for his use. The farm on which the plants were grown was remote from any tobacco fields or beds, new land was plowed and fitted and old seed in which there was no possibility of contamination was used. It might be supposed that these precautions would insure freedom from the trouble, but as the farmer growing the plants had no sash, the sash used on the beds in 1921 were taken from the first farm and used on the beds. They were not sterilized, and shortly after the plants were up a very heavy infection occurred on all the beds on which the sash were used. While not absolutely conclusive, the inference is justified that the sash carried the bacteria. Unfortunately no beds without sash were grown on this particular instance, but it might be said that the possibility of contamination from other sources in this case would be slight indeed.

The following laboratory experiment was made with the object of determining how long the bacteria would remain alive on a piece of dry wood such as a side plank or sash:

Experiment 7. Small blocks of pine wood were sterilized and then soaked for eight days in a pure culture of *B. tabacum* in bouillon. Then they were removed to dry sterile tubes where they quickly became dry and were kept so for further tests. The experiment was begun July 1, 1921, and the blocks were kept in the laboratory. At various intervals the blocks were tested for live bacteria by dropping one in sterile bouillon. They were still alive on September 10, but were dead on December 3. Sometime between these dates the last of them died. Apparently, then, they are able to live three month or more on dry wood.

In this laboratory experiment, however, the conditions are not the same as they would be in nature: (1) The wood is dried out more rapidly by the laboratory air than by out-of-doors air. Sash are usually stored in a tobacco shed or barn, while the planks may even be left out in the weather. The conditions in the shed are more favorable than the laboratory for the survival of the pathogene; (2) If sash are kept in the tobacco shed, it is possible for diseased parts of the hanging crop to become lodged on them; (3) If the plank are kept out-of-doors, the moisture conditions would be about the same as for soil. In fact the bacteria might be alive in soil which remains attached to the plank. Since we know that the bacteria can remain alive in the leaves and in the soil over winter, there would seem to be no reason why the sash or plank would not be a source of danger. Wolf and Moss (4: 32), and Fromme and Wingard (3: 22) have presented evidence to show that the germs may be introduced into new beds by the use of old cloth covers which were previously used on infested beds. If such cloth covers or the tent covers used in previous years over wildfire crops are used, they should either be boiled thoroughly in water or soaked in formaldehyde like the sash and planks.

## Spraying and Dusting Sed-beds.

Results of the first experiment on the control of tobacco wildfire by spraying or dusting the seed-bed have been published in Bulletin 203 of the Massachusetts Agricultural Experiment Station. Subsequent to the publication of that bulletin the experiment has been repeated at Amherst four times, using a greenhouse bed 4 x 16 feet for each experiment. The plants were pulled and counted when they were large enough for setting in the field, and then the bed immediately seeded for the next experiment. The soil was not sterilized between experiments. The greenhouse bed was used in preference to an out-of-door bed because in this way a longer season could be secured, and the experiment oftener repeated.



Some of the fungicides used in the first experiment were omitted in later experiments because they were found to cause injury to the plants, viz., sulphur dust, lime-sulphur, and the Pickering Bordeaux. NuRexo was used in the second experiment but omitted in the later ones, not because it failed to give control, but because it was thought best to confine the tests to one commercial copper spray. The copper lime dust for Experiment 1 was kindly furnished by the Riches, Piver & Co.; the dust for the later experiments by the Niagara Sprayer Co.; the Pyrox was furnished for all experiments by the Bowker Insecticide Co. In order that all the data may be compared at a glance, the tables of results are first assembled and presented here all together, and then followed by the general discussion.

### EXPERIMENT 8.

June 6-July 26, 1921, cloth bed, out-of-doors. Two applications at intervals of 1 week. (Bul. 203).

| Fungicide. | Total Number of Plants. | Number of Diseased Plants. | Per Cent. of Diseased Plants | Number of Lesions per 100 Plants. |
|---|---|---|---|---|
| Bordeaux, 4-4-50 (2 plots) | 473 | 6 | 1.25 | 2.5 |
| Copper lime dust, 20-80 (2 plots) | 534 | 3 | .55 | .5 |
| NuRexo (2 plots) | 600 | 3 | .48 | .5 |
| Pyrox, 10-50 (2 plots) | 570 | 23 | 4.1 | 6.5 |
| No fungicide (4 plots) | 1079 | 527 | 48.25 | 178.2 |

### EXPERIMENT 9.

October 10-December 10, 1921. Greenhouse. Three applications at intervals of about a week.

| Fungicide. | Total Number of Plants. | Number of Diseased Plants. | Per Cent. of Diseased Plants | Number of Lesions per 100 Plants. |
|---|---|---|---|---|
| Bordeaux, 4-4-50 | 848 | 0 | 0.0 | 0.0 |
| Copper lime dust, 20-80 | 771 | 3 | .38 | 1.2 |
| NuRexo | 747 | 6 | .8 | 1.2 |
| Pyrox, 12-40 | 863 | 5 | .58 | 1.1 |
| No fungicide | 1092 | 221 | 20.2 | 37.5 |

### EXPERIMENT 10.

March 17-May 10, 1922. Greenhouse. Three applications at intervals of over a week. Some infection started before first application.

| Fungicide. | Total Number of Plants. | Number of Diseased Plants. | Per Cent. of Diseased Plants | Number of Lesions per 100 Plants. |
|---|---|---|---|---|
| Bordeaux 4-4-50 | 1637 | 3 | .2 | .3 |
| Copper lime dust, 20-80 | 1449 | 152* | 10.2 | 30.1 |
| Pyrox, 12-50 | 1375 | 140* | 10.0 | 25.8 |
| No fungicide | 1714 | 1322 | 77.0 | 484.0 |

* The explanation of the high percentage of infection in this experiment is presented on page .

EXPERIMENT 11.

May 17-June 22, 1922. Greenhouse. Five applications at intervals of 3 or 4 days.

| Fungicide. | Total Number of Plants. | Number of Diseased Plants. | Per Cent. of Diseased Plants | Number of Lesions per 100 Plants. |
|---|---|---|---|---|
| Bordeaux, 4-4-50 ...... | 1176 | 2 | .1 | .1 |
| Copper lime dust, 20-80 | 821 | 0 | 0.0 | 0.0 |
| Pyrox, 12-50 .......... | 1005 | 3 | .3 | .5 |
| No fungicide .......... | 883 | 499 | 57.0 | 208.0 |

EXPERIMENT 12.

July 14-August 26, 1922. Greenhouse. Five applications at intervals of 3-5 days.

| Fungicide. | Total Number of Plants. | Number of Diseased Plants. | Per Cent. of Diseased Plants | Number of Lesions per 100 Plants. |
|---|---|---|---|---|
| Bordeaux, 4-4-50 ...... | 1205 | 12 | 1.0 | 1.2 |
| Copper lime dust, 20-80 | 1056 | 3 | .3 | .4 |
| Pyrox, 12-50 .......... | 1276 | 12 | 1.0 | 1.2 |
| No fungicide .......... | 938 | 860 | 92.0 | 487.0 |

Experiment 13. In similar experiments at Windsor, the beds were on soil which had grown a heavily infected crop of tobacco in 1921. The beds were not artificially inoculated as in the preceding experiments. The fungicides used were Sanders Dust, No. 1, Niagara 20-80 copper-lime dust, Dosch, 15-85, copper-lime dust, Orchard Brand Bordeaux-lead and Bordeaux-zinc. Seven application were made at intervals of 3 to 5 days. A natural infection developed on the untreated plot and in one corner of a plot next to it. No other wildfire developed on the treated plots.

## Discussion of the Dusting and Spraying Experiments.

*Frequency of application.* The writers last year recommended (1: 81) that the fungicide be applied once a week. Later experiments indicate, however, that this is not sufficient under the following conditions:

(1) When the plants are watered very frequently. On some soils it is necessary to water the beds heavily every day. Most of the fungicide is washed off before the end of a week. This factor was tested in Experiment 10, where the plants were watered and inoculated every day or two. The percentage of infection was fairly high on the Pyrox plot and the dust plot. (The plants in the Bordeaux plot of this experiment were very small and in poor condition on account of accidental burning by cyanide gas which was used to fumigate the house. The low percentage of infection on this plot is not significant.) In the next experiment (Exp. 11) the plants were watered and inoculated less frequently, and the fungicide was applied oftener. The infection was thus reduced again to less than one per cent.

(2) When the beds are exposed to frequent rains. The first rains wash off the fungicide, and later rains spread the bacteria. Even when the beds are covered during rains there is usually considerable drip through the sash between the glass.



(3) When the plants are growing very rapidly, as they usually are just before setting begins. New leaves are produced so rapidly that many of them will be left unprotected for several days if the application is made only once a week.

No definite interval of time between application can be regarded as safe. There are too many influencing factors. The only safe rule is to *keep all leaves covered at all times with the germicide.* During the very rainy season of 1922 no less than eight or ten applications would have been necessary. Growers have also found it a good practice to dust or spray the beds each time they are pulled over for setting.

*Amount of material to be applied.* In applying the dust or spray the only safe rule for judging whether enough has been applied is to note whether all leaves are covered. The amount of material required to produce a thorough covering will vary somewhat with the type of machine used and the stage of growth of the plant. In the experiments recorded above, in which a small rotary hand duster was used, it was found that no less than a pound of dust for each application was required to cover a square rod of plants when they are of a size suitable for setting. With the compressed air sprayer which was used 1½-2 gallons of spray material were found to be sufficient to cover the same area.

*Relative cost of spraying and dusting.* At the local stores in Amherst and Windsor, lime cost $4.90 per bbl. of 280 lbs., or, since a little more if in smaller quantities, about 2c a pound; copper sulphate, 11c per lb.; Pyrox, 20c per lb., and copper-lime dust 10c per lb. Using the amounts per square rod which are indicated above, the cost of materials for eight applications would be as follows:

Bordeaux 4-4-50 ..................12 cents per sq. rd.
Pyrox 12-50 ......................58 cents per sq. rd.
Copper lime dust .................80 cents per sq. rd.

Thus the cost of a commercial fungicide such as Pyrox is nearly five times as great as that of the home-made Bordeaux, while the cost of the dust is nearly seven times as much. A good compressed air sprayer can be secured on the local market for $7.00 to $10.50, while a suitable dust blower costs $12.50 to $18.50. The advantage which the Bordeaux mixture has in cheapness, however, is counterbalanced by the increased time and labor involved in its preparation. The copper-lime dust is immediately ready for application when received, and the Pyrox or NuRexo has only to be dissolved in water.

*Dust vs. liquid sprays.* The results of the six series of tests detailed above indicate that the percentage of control is about the same for the liquid spray as for the dust. In beds where very frequent watering is necessary there might be some advantage in the liquid sprays because when once dried on the leaves, they adhere much better than the dust. The dust, however, has the advantage that it comes up and covers the lower side of the leaves better than the liquid. The dust can be applied more quickly, but thorough dusting with a rotary hand duster is very hard work if continued for any length of time. The dust is also irritating to the nose, eyes and throat. Cheapness of materials and machines is in favor of the liquid sprays. Altogether, the choice between liquid and dust seems to be a matter of personal taste.

*Home-made vs. commercial copper sprays.* In the control obtained there seems to be very little difference between the results secured by the home-made preparation and the commercial sprays such as Pyrox or NuRexo. Home-made Bordeaux has the advantage of cheapness, while the commercial sprays have the advantage of more rapid preparation for application. If a grower has large beds which require frequent application, certainly it would be more satisfactory to prepare his own fungicide. For small beds the commercial sprays might be more satisfactory. Clinton and McCormick (*2*: 386) after experimenting with Bordeaux mixture, and a number of commercial copper sprays, recommend home-made Bordeaux mixture as being cheaper and more effective than other copper fungicides. They tried dust on only one bed and had no wildfire there on either the treated or untreated plot.

*Best time of day for application.* Dust should be applied preferably in the early morning when the plants are wet or after watering. When the copper sulphate and lime in the dust come in contact with water they unite to form Bordeaux mixture, which dries on the leaf and adheres with at least a part of the tenacity of the liquid Bordeaux. If, however, the dust is applied to the dry plant and water then applied, even when the Bordeaux is formed it is mostly washed from the leaf before it dries. Liquid sprays should be applied when the plants are dry because the spray is thus not diluted with water already on the plants, and because less of it drips from the leaves at that time.

*Absolute vs. partial elimination of wildfire.* It will be noted in the tables given above that in almost all of the sprayed and dusted plots a certain amount of wildfire appeared. Only in a few tests has it been possible to eliminate all infection. In the first five series of tests, however, it should be remembered that sprinkling cans full of water teeming with the parasitic bacteria were sprinkled over all the plants every three or four days. Such a method of inoculation is much more drastic than would occur under natural conditions in the beds of the average tobacco grower.



If the treatment here recommended is faithfully carried out by the grower, we believe that in the large majority of cases no wildfire will be found in his beds. Even if there are occasional infected plants in the bed, the treatment is not a failure. The removal of diseased plants from the field will be much easier if there are only a few of them. Even if they are not all removed the amount of final infection may be expected to be less if there are only a few centers from which it can spread.

*Will clean beds give clean fields?* Clean beds are not an absolute guarantee that no wildfire will appear in the fields planted from such beds. During the season of 1922 in at least six instances, the writers have convinced themselves by thorough and frequent inspection that the seed-beds of certain growers were entirely free from wildfire, but the disease developed later in the fields planted from these same beds. (Read the paragraph above on "Dissemination" for more details). Such cases, however, should not encourage anyone to believe that no benefit is derived from keeping the seed-bed clean. The worst and the most widespread field infections have usually come from the bed. Starting with clean plants in the field is not the whole measure of success, but it is a long start toward it.

*Success by practical growers.* During the season of 1922, the writers made frequent inspections and kept careful records on the seed-beds of a number of growers. Untreated checks were not left in any case, and for this reason the results are not entirely convincing. They were unable to find wildfire in any of these beds where the plants were kept constantly covered with the fungicide. On the other hand, it did appear in the beds of many who dusted or sprayed a few times or started to treat only after the disease became evident or used only a scant amount of material.

*Value of an arsenical in the fungicide.* In the first test some of the fungicides, both the dry and the liquid, contained an arsenical. This arsenical not only was found to be of no value for the control of wildfire, but frequently caused injury to the plants. There seems to be no reason for adding an insecticide.

*Dust burn and spray injury.* Heavy application of dust or copper spray frequently causes some injury to the plants. It has been commonly noted in the experimental beds at Amherst that the plants in the check plots appear healthier (except for the wildfire), and larger than in the treated plots. Growers have frequently called the writers' attention to this condition in their beds. Sometimes it is much more marked than at other times. Frequently it cannot be observed at all. Certain conditions of the plant or its environment must be responsible for this variation, but it is not as yet known just which conditions favor and which prevent such injury.

Dust burn is evidenced on the leaves by small dead spots of one-eighth inch diameter or less, colored white, brown or darker to black, irregular in outline, commonly bordered by indefinite blanching of the immediately surrounding tissue. This border, however, is narrow and inconspicuous and fades away indefinitely into the normal green leaf. It is quite different and easily distinguished from the halo about the wildfire spot. The leaf area about the spot is also commonly distorted or puckered into radiating wrinkles. Where excessive amounts of dust are used, whole leaves or entire plants may exhibit this wrinkled distorted appearance without central dead spots. This results in dwarfing.

Spray injury resulting from the liquid fungicides is indicated by larger dead areas in the leaves on the margins, tips, or other places where the liquid stands in drops.

Injury from either dust or liquid spray has never been serious, and at most has resulted only in slightly slower growth of the plants in the beds. The plants immediately recover after being set in the field. The injury is never of sufficient importance to discourage the application of dust or liquid spray.

*Secondary benefits.* Practical growers have frequently called attention to the absence of flea beetle in the treated beds. One prominent grower has stated that he would spray whether he had wildfire or not, because the beds were free from these insects. Copper lime fungicides are known to repel flea beetles.

Frequently when the plants are thick in the bed and kept damp, they rot off at the base of the stem. It has been commonly noticed that this condition does not occur when the beds are properly treated with a fungicide.

*Conclusion. Any grower who will start when the plants are no larger than a dime, and keep the leaves covered at all times with copper lime dust or any other good copper fungicide, can control wildfire in the seed-bed.* We agree with Clinton and McCormick (2: 386) in the following quotation except that we would include dusting as well as spraying: "We are convinced that spraying of tobacco beds should be made one of the routine practices of tobacco growing as long as there is danger from wildfire. * * * We have evidence that plants thoroughly coated with the spray do not become infected anything like unsprayed plants in the same bed. Spraying to be most effective, however, must start before the appearance of wildfire, and be continued until the end of the transplanting season. We would start with the young plants that have just taken root, and whose largest leaves are about the size of a thumb nail. * * * *Spraying, we believe, is the only remedy that prevents spread of the wildfire in a seed-bed, no matter what the source of its introduction.*"



## Destroying Diseased Areas in the Bed.

It is characteristic of the disease that when it is first found in the beds it does not occur uniformly over the bed, but is usually found in round spots which may be from a few inches to several feet in diameter, depending on the length of time during which the spot has been spreading. If only one of a few spots are found in a bed, it is sometimes possible by prompt action to keep the rest of the bed clean. This may be done by immediately destroying all the plants by drenching them with a 1-10 formaldehyde solution. Not only the spot, but all the plants within a foot or two beyond it must be killed. This treatment was successful in preventing further spread in one bed in Sunderland, in one at Hatfield, and two in Windsor, all of which were under the writers' constant observation during the summer. Glass should be removed from the bed at this time unless it is desired to kill the whole bed or a covered section of it. Plants should not be hoed out or pulled out before treatment, since this only serves to spread the trouble. Plants around the burned-out areas should be watched carefully for further spread. Spraying or dusting should also be started at once if it has not been practiced previously.

## Removing All Plants from a Diseased Field and Resetting with Healthy Plants.

Two fields have been under the careful observation of the writers during 1922 in which this practice was adopted, but in both cases it resulted in failure. In one field in Hadley and one in North Hadley, when the plants were about a foot high, they were found to be practically all infected. All were removed from the field, and after it had been harrowed the field was reset with healthy plants. In both cases before the new plants were ready to harvest they became almost as badly infected as the old ones. Apparently the pathogene remains in the soil and, under favorable conditions, will infect the new crop. The grower can gain by this practice only when the weather changes for the better during the growth of the second crop. The same principle would apply also to the restocking of a field where only a part of the plants were diseased. This was tried on a large scale by a grower of shade tobacco at North Hadley, who removed only the diseased plants (about 10%), and restocked with healthy plants, but he failed to control the disease. The following experiment bearing on this point was tried at the Windsor station:

Experiment 14. In one plot nineteen diseased plants were found ten days after setting. They were all removed and replaced by healthy plants. Eleven out of the nineteen resets developed wildfire later.

During 1921, a number of growers practiced either partial or complete restocking with healthy plants after diseased ones were removed, and little or no wildfire appeared later in the field. The same was true of some Connecticut fields in 1922. This apparent control may have been due to weather conditions which were not favorable for infection of the plants of the second setting. At any rate, the results were contrary to most of our experience of 1922. In view of the latter it seems questionable whether restocking should be recommended.

### Roguing Without Resetting.

When only a few plants in a field are diseased it is probably best to remove them from the field and leave empty the places from which they were taken. This was tried with success by three growers in North Hadley whose fields were under the writers' observation during the present season. Other growers have told the writers that they kept wildfire in check by this method.

Experiment 15. In a plot at the Windsor station where five plants were found to be diseased ten days after setting, they were all removed and the places not filled. The surrounding plants were inspected regularly, and in two cases they became infected later. In a later experiment where the plants were about one and one-half feet high, the diseased ones were removed and not replaced. Before harvesting, however, wildfire had appeared on the adjacent plants and had spread 4-6 plants to the windward and along the row.

It is reasonable to believe that bacteria which came into the soil from the original diseased plant would have less opportunity for further infection if no plant replaced the diseased one which was removed. Certainly the danger of surrounding plants becoming infected is diminished by removal of infected ones from the field. On the whole there is no question but that this practice of roguing will help to a great extent where there is only a light infection in the field, especially if the plants are pulled when small. After plants are half-grown, however, under favorable conditions, the disease may spread in its customary manner and it may be necessary to remove plants or infected leaves from plants for some distance around the original point of infection.

### Picking Off Diseased Leaves.

If the plants are large and infection is light, a certain amount of benefit may be derived from removing all diseased leaves and carrying them from the field. The principle of this measure is the elimination of as many as possible of the centers of spread. Then when the rains come the number of bacteria splashed to the healthy leaves will be greatly reduced. This method was tried by Anderson on a four-acre field in Whately.



Experiment 16. Infection in this field started from about 6-8 rows near the east side which had been planted from a diseased bed. At the time when the experiment was started a majority of the plants in these rows were diseased, and it had spread more or less to plants on adjacent rows. There was practically no infection on the west half. On June 30, all diseased leaves were picked from the east half (48 rows). No attention was paid to the west half. On the badly infected rows mentioned above a large basketful of leaves were taken from each row, some of the plants being left almost without leaves. It was picked again four days later, the weather having been very rainy during the last month. Probably as many leaves were removed the second time as during the first picking. It was picked over at short intervals five times afterward, and with each picking the number of diseased leaves decreased until on July 26 hardly a diseased leaf could be found. After the heavy rains of the last few days of July and the first of August, however, wildfire began to appear again on the picked side of the field, but to a greater extent beyond the forty-eighth row where no picking was done. The field was harvested on August 8. On that date the picked and unpicked sides of the field were inspected by Mr. Arthur Hubbard, W. H. Davis, D. Potter, C. M. Slagg, Dr. James Johnson and the writer, and it was the opinion of all that the unpicked showed much more wildfire than the picked side. Mr. Hubbard was of the opinion that the east half would not have been worth harvesting if the disease had been left to take its natural course. The loss in weight from removal of the diseased leaves was not serious. As previously mentioned in this report there was good evidence that when infection began again during the first few days of August, it came from bacteria which were in the soil. This source of infection cannot be eliminated and will probably prevent this method of control from ever being entirely successful. In view of the fact, however, that the season of 1922 was unusually favorable to the spread of wildfire, the results of the experiment are encouraging.

A similar experiment was conducted on a Round Tip plot at the Windsor station, and with similar results. Growers who tried picking off affected leaved are divided as to their opinion of the practical value of the method. The degree of success varied according to the kind of tobacco and method of harvesting. Chances of success are better in primed tobacco because after harvesting starts the leaves are picked so rapidly that the disease does not have an opportunity to get a good start, and it also becomes increasingly difficult for the germ-laden soil to splash to the first leaves. Field observations on the picking of leaves during 1922 lead to the following conclusion:

On the shade Cuban, favorable results were almost uniformly obtained, and the disease was practically eliminated. On Havana and Round Tip, where diseased leaves were removed, there was a considerable variation in the results with a majority of fields showing decided benefit. In Broadleaf there did not seem to be anything gained by picking off the leaves.

For anyone who contemplates this method of control it is recommended that (1) the first inspection be made as soon as the plants are established in the field; (2) the leaves be picked off twice a week as long as any diseased ones can be found; (3) sand leaves of diseased plants be picked also.

Clinton and McCormick (2: 396) also experimented with removal of diseased leaves, and as a result were somewhat doubtful as to the benefits.

### Dusting the Plants in the Field.

The value of dusting the plants in the field with copper-lime dust was tried by two Massachusetts growers under the writers' supervision during the season.

Experiment 17. Twenty-four acres in Hadley were first dusted with a four-row traction duster which was kindly furnished by the Niagara Sprayer Co., on July 6 when the plants were 12-18 inches high. The infection was bad in parts of the field when the experiment was started. Four rows were left without dust. There were very heavy rains on the 8th, and the second application was made on the 13th and 18th. During July there was very little spread of wildfire in any fields, and the palnts grew enormously. By the first of August the plants had grown until the machine could not be drawn through the field without serious damage to the plants and, therefore, no more applications were made. There was considerable spread of the disease during August and up until it was harvested about the middle of the month. A comparison of the treated and unterated rows at that time showed no difference in the amount of the disease. No accurate counts were made but a cursory examination while walking between the rows did not indicate any benefit from the two applications of dust. It was also noticed that there were dust-burn spots on the treated leaves similar to those which have been previously described as occurring in the beds. The owner feared that if the dusting were continued, the spots might affect the market of the crop.

Experiment 18. Another grower in North Hadley dusted two fields with the machine used in Experiment 17, but more frequent applications were made. Wildfire was not controlled, the results being similar to those of Experiment 17.

Experiment 19. On one of the Windsor station plots Round Tip tobacco which showed a heavy mixed infection of wildfire and angular leafspot on the bottom two or three leaves when the plants were from one to one and one-half feet in height, a copper-lime dust was twice applied to four rows, with a five-day interval between the first and second treatments, no rain falling in the interim. Six rows were left untreated for comparison. For about two weeks after treatment, the spread of the disease in the dusted rows was practically nil, while in the undusted rows it spread steadily but very rapidly. After this time three rainy days ensued, but purposely no more dusting was done. After harvest time it was found that the amount of wildfire on the dusted rows was only fifteen per cent. (estimated from partial count on cured tobacco) less than on the rows which had not been dusted.

No doubt if the leaves in the field could be kept covered with dust all the time the disease could be controlled, but this would require more frequent applications, and when the plants become large it cannot be done without considerable breaking of the leaves. Control by this method is probably possible, but not economically so. Further experiments, however, are planned. It was found that the dust adhered much better if applied early in the morning while the plants were still wet with dew.



### Spraying with Bordeaux Mixture in the Field.

Bordeaux mixture was tried with the idea that it would adhere to the leaves more tenaciously, and hence so many applications would not be necessary as when dust was used.

Experiment 20. A field of twelve acres in North Sunderland was sprayed on July 11 with 4-4-50 Bordeaux. No further applications were made because the owner feared that the material would remain permanently on the leaves and affect its sale. An examination on August 14, when the crop was being harvested, showed that it was present in large enough quantity on many of the leaves to give them a decidedly blue cast. A comparison of the sprayed and unsprayed rows showed no difference in the amount of the disease.

Clinton and McCormick (2: 395) experimented with Bordeaux mixture in a preliminary way, and found that it retarded spread of the disease, but did not consider it practical because of cost and unknown effect of the spray on the quality of the mature leaf.

A few Connecticut growers tried spraying in the field in 1921, and reported good control. This year several growers of sun as well as shade-grown tobacco sprayed plants in the field, from one to six times, until the plants were too large to permit of further treatment, but the results have not been encouraging in the case of sun-grown tobacco. While the treatment seemed to check the disease for a time, later in the season, after the plants had grown too large to continue the treatment, wildfire spread rather rapidly, and at harvesting, little difference could be observed between the sprayed and unsprayed areas in the same field. In the case of one grower who had a rather bad field infection when the plants were small, the use of a Bordeaux mixture applied twice on part of the field when the plants were small checked for a long time any further spread of the disease, and at harvesting time the part of the field sprayed twice showed much less wildfire than the unsprayed part of the field.

Bordeaux mixtures are cheaper and, under field conditions, remain on the leaves a longer time, which is, of course, desirable from the infection standpoint, but a disadvantage when the plants are more than half-grown, as it remains on the leaves, and the blue color would be undesirable after the cure.

Another factor operating against the efficiency of dusts or sprays in the field is that after the plants are about half grown, it is a practical impossibility to operate a duster or sprayer to advantage, and one is obliged to stop the treatment at what might be termed the critical period, as it is well known there is often a heavy wildfire infection just prior to maturity.

It is believed, however, that some benefit might be obtained from dusting or spraying when the plants are small and until they are about a foot high, particularly if spraying or dusting were combined with picking off diseased leaves, and the spraying or dusting repeated at very close intervals, say two or three times a week for a period of two weeks or so.

It is believed that the application of dusts or sprays to tobacco in the field is worthy of further consideration, both by the growers and the station, and next season more detailed experiments along this line will be carried on.

At present, however, the evidence at hand is not very favorable for this method of control.

## The Outlook for 1923.

The question now most frequently asked by the grower is: What can we expect from wildfire in 1923 and in the following years? Will it continue as prevalent and troublesome as it has been in 1922? Will it become worse after our land is thoroughly infested with the germ? Or will it gradually disappear? Frequently tobacco growers have told the writers that they would stop raising tobacco if they thought the disease would continue to be as serious as it has been during 1922. No man can predict its future behavior with certainty or anything which approaches certainty, but we can base some judgment on (1) what we know about its relation to weather conditions, and (2) its behavior in states where it has been present longest.

We know that the disease can spread only when the rains are long continued or follow each other in close succession, i. e., when the water remains for long periods on the leaves. The summers of 1921 and 1922 were, for the most part, ideal in this respect for the spread of the disease. They have not been average summers for the Connecticut Valley. The disease will not be as destructive during an average growing season. We do not believe that wildfire will soon disappear from the valley, but during a dry summer it might not cause any damage. After a succession of unfavorable seasons the sources of infection might be so reduced that it would cause little trouble even with the return of a summer favorable for its spread. The above opinion is supported by the course which the disease has taken in the South. Five years ago it was destructive there. In 1921 the season was very dry, and the injury from wildfire was slight. The season of 1922 is said to have been not unusually dry, but the disease has not returned to any extent. Our advice to the Connecticut Valley grower is to plant as usual, take a chance on the weather, but to omit no precaution recommended against wildfire.



## Condensed Recommendations for Control.

There is no one measure by the use of which a tobacco grower may be assured of raising a clean crop. As long as wildfire is in the valley, he must start before the seed is planted, be ever on the alert and ready to put into practice any part or all of the season's program which may now be briefly summarized:

1. Select seed only from plants known to be free from the disease. If possible, go a step farther and take only from fields known to be disease-free. Protecting the flower heads with bags may be useful. Old seed is less likely to be contaminated.
2. If there is doubt about the seed being sterile, soak it in a cheesecloth bag for fifteen minutes in 1-1000 corrosive sublimate, wash and spread out to dry.
3. If possible, locate seed-beds only on land where there was no wildfire during the previous year and where there has been no opportunity for contamination.
4. Sterilize soil with steam at 100 pounds pressure for thirty minutes, or with formaldehyde 1-50 at the rate of one-half gallon to the square foot. It is safer to sterilize walks also. Spring sterilization is safer than fall sterilization.
5. Drench boards and sash with formaldehyde 1-50. If cloth is used, it should either be new or should be boiled in water or treated like the boards and sash. If sash and plank are new or have never been used for tobacco beds, they need not be sterilized.
6. Keep the plants covered with copper-lime dust or a copper spray such as Bordeaux mixture, at all times, from the stage when they are as large as the finger nail until setting is completed.
7. Remember that the germs can be carried from one bed to another on the hands, tools, sash, etc., and avoid such chances.
8. Adopt a system of bed management which will keep the leaves moist during the shortest length of time compatible with the production of good plants.
9. If the disease appears in certain spots in the bed, these spots along with a broad margin of plants which appear healthy should be killed by drenching with 1-10 formaldehyde.
10. Pull plants for setting only from disease-free beds.
11. Starting as soon as the plants have recovered and begun to grow in the field, make frequent inspections and remove every diseased plant from the field.
12. Do not work in a field where there is any wildfire while the leaves are wet.
13. Removal of diseased leaves at intervals of three or four days where the infection when first found is light, will reduce the

numbers of centers of spread, and may materially reduce the percentage of wildfire in the crop when harvested.

14. Do not topdress fields on which tobacco is to be planted with stalks or refuse from badly infected crops.

15. Rotate tobacco with other crops if practicable.

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